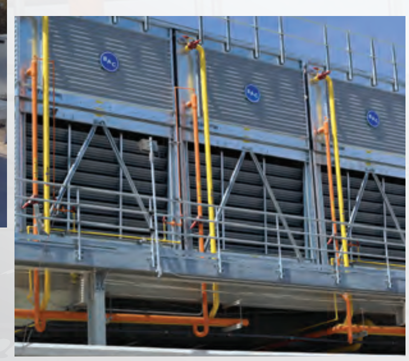
REFRIGERATION HANDBOOK

VOLUME III



BALTIMORE AIRCOIL COMPANY

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BAC Evaporative Condensers

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BAC Evaporative Condensers

Evaporative condensers provide heat rejection for many types of systems, and the application will determine which BAC evaporative condenser is best suited for your project.

CXVT – Models are the largest factory-assembled evaporative condensers available on the market. CXVT benefits include fewer required cells, lower overall fan horsepower, significantly reduced refrigerant charge, and fewer piping connections, lowering both the cost of installation and ownership. CXVT Extreme Efficiency (XE) Models meet or exceed three times ASHRAE Standard 90.1 energy efficiency requirements and two times California Title 24 requirements, reducing operating costs up to 48%.

CXVB – Models deliver efficient performance in an easy-to-maintain package. BAC's Advanced Coil and Combined Flow Technology provides maximum capacity at the lowest refrigerant charge available in the industry by incorporating fill media into the traditional evaporative condenser. In addition, CXVB models are designed to mount directly on existing support steel of both crossflow and counterflow units, making them a direct replacement option for almost any existing model.

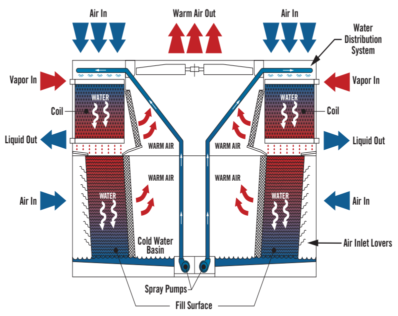
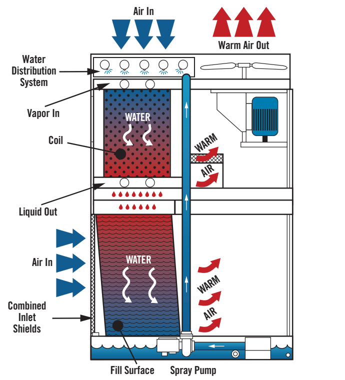
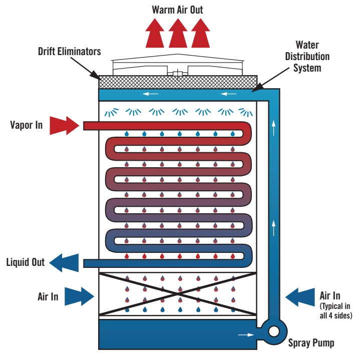
PCC – Models are axial fan, induced draft evaporative condensers that serve as the ideal replacement units, designed to minimize energy consumption and reduce footprint. These units can also be containerized for export, requiring minimal assembly during rigging and offering the lowest ocean freight costs for shipping. The lower section is provided with rigging pins reducing the alignment time to minutes.

VCA – Models are the workhorse of the industry. VCA models are traditional style, forced draft evaporative condensers with axial fans to minimize energy consumption. With motors located at the base of the unit, pre-assembled platform packages, and oversized access doors, the VCA has set itself apart from the competition by being the easiest to service condenser in the industry.

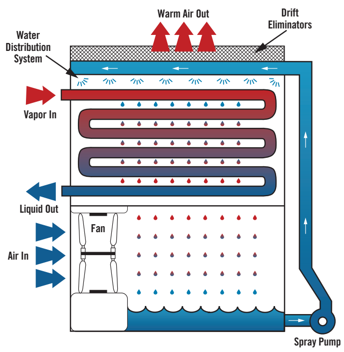
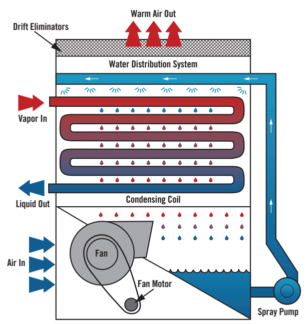
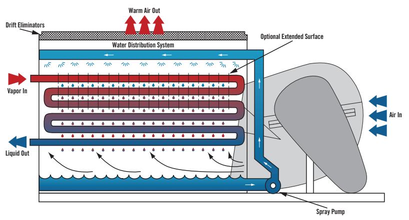
VC1 – Models are traditional style evaporative condensers with centrifugal fans and are suited for applications where external ductwork or other sources of external static pressure exist. These units are also ideal for areas where sound abatement is critical.

VCL – Models are centrifugal fan evaporative condensers that are specifically designed with a low profile. These units fit well into mechanical equipment rooms with low ceilings or are easily hidden behind louvered walls on buildings. Low profile models are available in heights ranging from 5'-3" to 8'-5".

Evaporative Condenser Product Lines

	CXVT	CXVB	PCC
Model			
Flow and Fan System	Combined Flow, Induced Draft, Axial Fan	Combined Flow, Induced Draft, Axial Fan	Counterflow, Induced Draft, Axial Fan
Cataloged Capacity Range	540 - 2,114 Nominal Tons*	75 - 1,287 Nominal Tons*	46 - 2,734 Nominal Tons*
UNIQUE FEATURES	• Extreme Efficiency (XE Models) available • Lower installation cost • Lower operating cost • Fewer piping connections • Layout flexibility	• Lowest refrigerant charge per ton • Fewer piping connections • Layout flexibility • Easy maintenance	• Replacement of existing installations • Redundant fan option on 12' x 18' units • Winter dry operation • Containerized for export

*Nominal Tons (R-717) at 96.3˚F CT, 20˚F SST, 78˚F EWB

<table>
<tr><th>VCA</th><th>VC1</th><th>LOW PROFILE VCL</th><th></th></tr>
<tr><td>
</td><td>
</td><td>
</td><td>Model</td></tr>
<tr><td>Counterflow,
Forced Draft,
Axial Fan</td><td>Counterflow,
Forced Draft,
Centrifugal Fan</td><td>Counterflow,
Forced Draft,
Centrifugal Fan</td><td>Flow and Fan System</td></tr>
<tr><td>87 - 1,433 Nominal Tons*</td><td>7 - 1,140 Nominal Tons*</td><td>11 - 212 Nominal Tons*</td><td>Catalogued Capacity Range</td></tr>
<tr><td>• Easiest motor access
• Independent fan drives
• Pre-assembled platforms
• 24’ long coils for reduced piping</td><td>• Low sound by design
• Indoor and outdoor installations
• Split coils option for multiple compressors or auxiliary cooling
• Copper connections option
• Containerized for export</td><td>• Low sound by design
• Easily hidden
• Indoor and outdoor installations
• Single piece shipping and rigging</td><td>UNIQUE FEATURES</td></tr>
</table>

*Nominal Tons (R-717) at 96.3˚F CT, 20˚F SST, 78˚F EWB

Product Comparison

ITEMS SHADED IN BLUE ARE BAC EXCLUSIVE FEATURES AND OPTIONS

Standard Features	CXVT	CXVB	PCC[4]	VCA	VC1	VC1-C	VCL
Axial Fan	•	•	•	•			
Centrifugal Fan[1]					•	•	•
Large Plenum Area for Access	•	•		•			
R-717 Tons	540 - 2,114	75 - 1,287	46 - 2,734	87 - 1,433	7 - 1,140	153 - 333	11 - 212
R-22 Tons	683 - 2,676	105 - 1,815	65 -3,851	122 - 2,019	10 - 1,608	216 - 469	16 - 299
Premium Efficient Fan Motors	•	•	•	•	•	•	•
Construction Options							
Water-Contact Stainless Steel Basin[3]	•	•	•	•	•	•	•
Water-Contact Stainless Steel Unit		•	•	•	•	•	•
Stainless Steel Construction[3]	•	•		•	•	•	
EVERTOUGH™ Construction	•	•	•	•			
TriArmor® Corrosion Protection System	•	•	•	•			
Coil Options							
Extended Surface Coils		•		•	•	•	•
Stainless Steel Coils	•	•	•	•	•	•	•
ASME U Designator Coils	•	•	•	•	•	•	•
Multiple Circuit Coils	•	•	•	•	•	•	•
Options and Accessories							
Independent Fan Operation		•	•	•			
BALTIGUARD™ Fan System	•	•			•		•
Low Sound Fan	•	•	•				
Whisper Quiet Fans		•	•				
Intake Sound Attenuation	•	•			•		•
Discharge Sound Attenuation	•	•	•		•		•
Handrails with Ladder[2]	•		•	•	•		
External Access Platform with Ladder[2]	•	•	•	•	•		
Internal Ladder	•	•					
Internal Access Platform	•	•					
Gear Drive	•						
Basinless Unit Construction	•						
Indoor Applications					•	•	•
Motor Removal System	•	•	•				
Single Point Wiring		•	•	•			
Redundant Pumps		•		•	•		
SunScreens		•					

NOTES:

1. Centrifugal fan units can overcome ESP imposed by duct work or other restrictions. A larger fan motor may be required. Contact your local BAC Representative with any questions.
2. Safety cages are available on ladders when required by local safety standards.
3. Seams between the panels inside the basin are welded for CXVB, CXVT, PCC, and VCA models. The basin is leak tested at the factory and welded seams are provided with a 5-year, leak-proof warranty.
4. Some materials of construction options and accessories were not available during the time of printing.

Evaporative Condenser Replacements

Replacing an existing unit involves a number of considerations including thermal load, available footprint, environmental considerations, and what specific application the unit will be serving. Below is a starting point for which current products best match previous models. For final selection please consult your local BAC Representative for the expertise your job deserves.

Manufacturer	Fan Type	Air Flow	Model/Product	Current BAC Match
BAC	Centrifugal	Forced Draft Counterflow	CMA	VC1/VCL
BAC	Centrifugal	Forced Draft Counterflow	VNC	VC1
BAC	Centrifugal	Forced Draft Counterflow	VLC	VC1
BAC	Centrifugal	Forced Draft Counterflow	VSC	VC1
BAC	Centrifugal	Forced Draft Counterflow	VXC	VC1
BAC	Centrifugal	Forced Draft Counterflow	C1000	VC1
BAC	Axial	Forced Draft Counterflow	CPA	VCA/VCL
BAC	Axial	Forced Draft Counterflow	VAC	VCA
BAC	Axial	Forced Draft Counterflow	VXMC	VCA
BAC	Axial	Forced Draft Counterflow	C2000	VCA
BAC	Axial	Induced Draft Crossflow	CFT-C	CXVT/CXVB
BAC	Axial	Forced Draft Counterflow	VC2	VCA
Evapco	Centrifugal	Forced Draft Counterflow	LRC	VCL
Evapco	Centrifugal	Forced Draft Counterflow	LSC(A,B,E)	VC1/VCL
Evapco	Axial	Forced Draft Counterflow	PMC(A,B,E,Q)	VCA
Evapco	Axial	Induced Draft Counterflow	ATC(E)	PCC
Evapco	Axial	Induced Draft Counterflow	UBC	PCC
Evapco	Axial	Induced Draft Combined Flow	PHC	CXVB/CXVT
Imeco	Centrifugal	Forced Draft Counterflow	XLC	VC1
Imeco	Axial	Forced Draft Counterflow	XLP	VCA
Imeco	Axial	Induced Draft Counterflow	IDC	PCC
Guntner	Axial	Induced Draft Counterflow	ECOSS	CXVB/PCC

These suggested replacements are a good starting place for replacing old units with a similar current model, however there are many applications where you can switch to a model with different air flow and footprint, while still meeting your refrigeration needs.

PRODUCT SPOTLIGHT:

Retrofit Access Door

Easy access to evaporative cooling equipment has traditionally been a challenge because of the small, round access doors common to most manufacturers' units.

Retrofit Door on Competitor's Unit

This difficulty results in:

- ✓ Units that are serviced less frequently
- ✓ Degradation of performance due to scaling
- ✓ Increased operating costs
- ✓ Restricted egress to service personnel
- ✓ Shortened service life

Based on customer input, BAC is the first to market an engineered, oversized access door for the aftermarket.

- ✓ Improved egress can remove institutional restrictions
- ✓ Easy access for regular service and maintenance
  - 28" by 36" inward swinging, hinged door
  - Big enough to fit an 8' A-frame ladder
  - Up to 3x the current access area of common circular doors
- ✓ Two locking handles assure positive sealing
- ✓ Easily adapts to multiple unit sizes
- ✓ Average install time 8 hours
- ✓ Patented

CXVT Evaporative Condenser

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The CXVT Evaporative Condenser is perfect for applications where size matters. The CXVT provides the added value of reduced operating costs, improved reliability, and a cost effective solution to both the owner and the installing contractor for large projects. Newly redesigned, the CXVT offers XE (Extreme Efficiency) models which are on average 3 times more efficient than the minimum energy requirements in ASHRAE Standard 90.1-2013 and 2 times more efficient than the minimum energy requirements in California Title 24.

TriArmor® Corrosion Protection System

EVERTOUGH™ CONSTRUCTION

XE

BAC's CXVT:
When Size Matters

540 to 2,114 R-717 Tons in a Single Unit

- Lower Installation Cost
- Lower Operating Cost
- Fewer Piping Connections
- Layout Flexibility
- Lowest Refrigerant Charge Per Ton

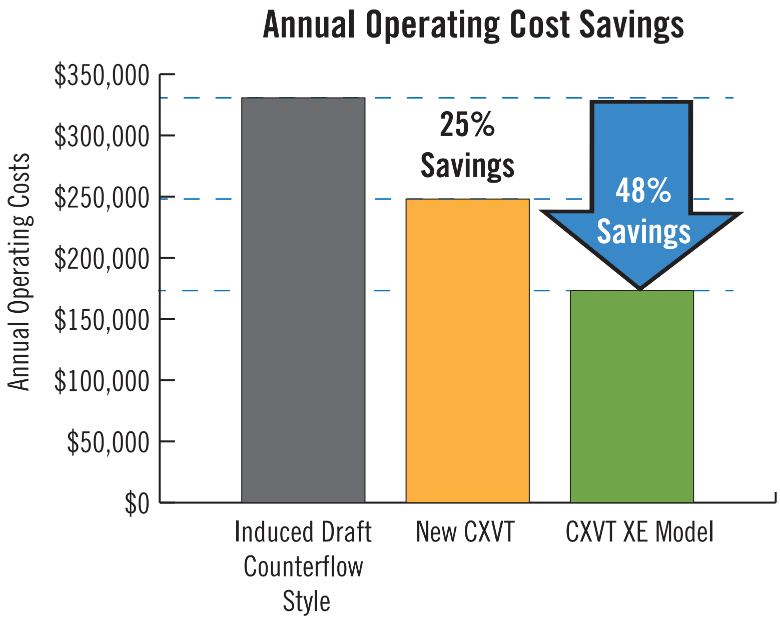
CXVT

The CXVT Evaporative Condenser offers a cost effective solution for both the owner and the installing contractor by reducing operating cost, improving reliability and reducing installation costs. The CXVT Evaporative Condenser is now available with XE (Extreme Efficiency) models to further reduce operating costs. These benefits can best be illustrated in the following example.

Actual Project: Food Processing Facility in the Northwest U.S.
100,732 MBH, 85°F CT, 66.7°F WBT

Solution #1: Reduce Total Cost of Ownership, Best Selection – CXVT XE Models

	Induced Draft Counterflow Style	Old CXVT	New CXVT	XE Model: Best Choice
Number of Units	12	8	7	**8**
Total HP (Fan & Pump)	840	720	630	**440**
Refrigerant Connections (Total)	48	32	28	**32**



New CXVT

- ✓ $1.7M in operating cost savings over the life of the equipment from HP reduction
- ✓ 25% annual operating cost savings

CXVT XE Model

- ✓ $3M in operating cost savings over the life of the equipment from HP reduction
- ✓ 48% annual operating cost savings

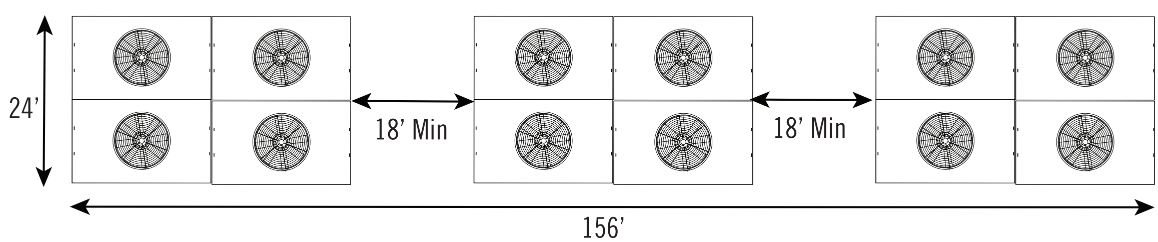
NOTE: Annual operating costs based on fan and pump kW x $0.12kWh x 8760 hours x 50% average load for the year.

Solution #2: Reduce Installation Cost, Best Selection – New CXVT

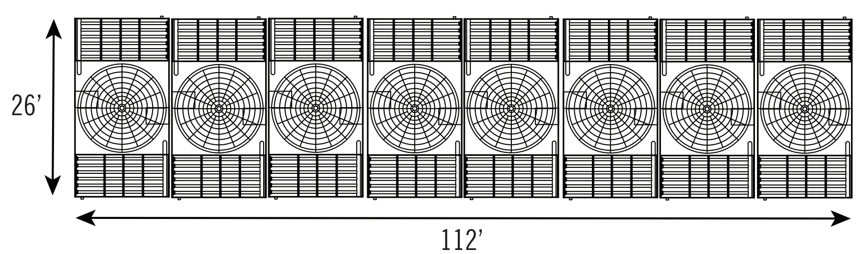
	Induced Draft Counterflow Style	CXVT XE Model	New CXVT: Best Choice
Number of Units	12	8	**7**
Plan Area (ft²)	3,744	2,912	**2,548**
Total HP (Fan & Pump)	840	440	**630**
Refrigerant Connections (Total)	48	32	**28**

Layout Plan Area Required Selection

Induced Draft Counterflow Style



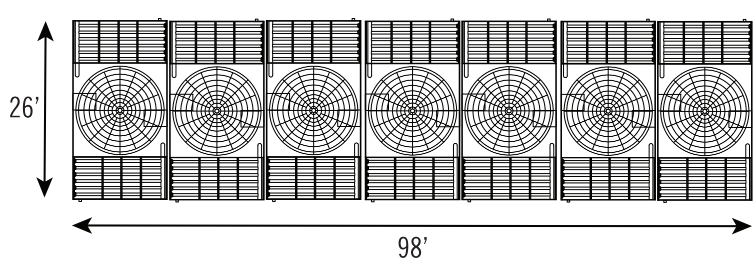
Better Selection for Reducing Installation Cost: CXVT XE Model



8 Cells: Reduced by 4!

32 Refrigerant Connections: Reduced by 16!

Best Selection for Reducing Installation Cost: New CXVT



7 Cells: Reduced by 5!

28 Refrigerant Connections: Reduced by 20!

CXVT Benefits

Reduced Operating Costs

- The highest capacity in the industry in a single unit (540 - 2,114 R-717 tons)
- Combined Flow Technology provides the highest capacity at the lowest refrigerant charge
- Up to 40% reduction of total cost of ownership with the XE Models
- On average, 60% lower refrigerant charge when compared to other evaporative condensers

Multi-Cell CXVT Installation Showing Simplified Piping

Improved Reliability

- Upgraded seismic and wind load capabilities to meet requirements in North America
- Largest standard access doors in the industry (64" x 34")
- Welded, not bolted, Stainless Steel basin reduces potential for leaks and increases the life of the unit (optional)
- Coils fabricated per ASME B31.5 standards
- Coils shipping into Canada are available with CRN
- Scale reducing technology increases system efficiency
- Heavy duty premium efficient motors are standard
- Meets wind and seismic requirements of the International Building Code (IBC)

Now Even Larger Oversized Access Doors

Cost Effective Installation

- Dual air intakes allow for simple steel designs and layout flexibility
- Half the number of coil connections save time and material on piping, welding and valves
- Flexibility of coil connection location simplifies piping
- Lower operating weight reduces steel sizing and lower shipping weight reduces crane sizing
- Single fan and motor reduces wiring and controls
- Built in rigging guides allow for fast rigging
- Factory pre-assembled external platforms reduces installation time (optional)

Standard Rigging Guides

XE Model Benefits

The CXVT XE models are the newest addition to BAC's CXVT Evaporative Condenser portfolio. They are tailored for projects that require extreme efficiency units to minimize operating cost, provide application assurance, and reduce sound levels. The CXVT XE models are on average 3 times more efficient than the minimum energy requirements in ASHRAE Standard 90.1-2013 and 2 times more efficient than the minimum energy requirements in California Title 24.

Lowest Operating Costs

- 40% reduction in operating cost for an 860-Ton system
- Payback of less than 1 year

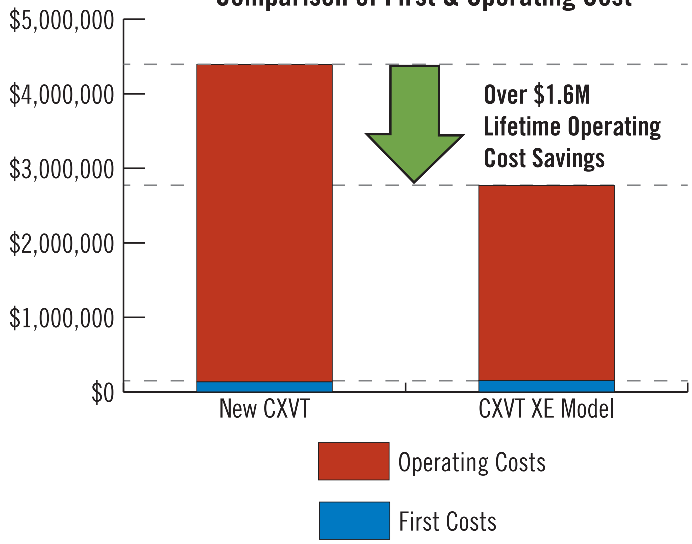
Application Assurance

- On average 3 times more efficient than minimum energy requirements in ASHRAE 90.1-2013
- On average 2 times more efficient than minimum energy requirements in California Title 24
- Extends the life of the mechanical drive components (minimum L_{10} bearing life 190,000 hours, 40% longer than the standard CXVT)

Reduced Sound Levels

- Sound reduction up to 50% (3 dB)
- Fans optimized to minimize sound levels and maximize efficiency
- Additional sound reducing options available

860 Ton Selection CXVT vs. CXVT XE Model Comparison of First & Operating Cost

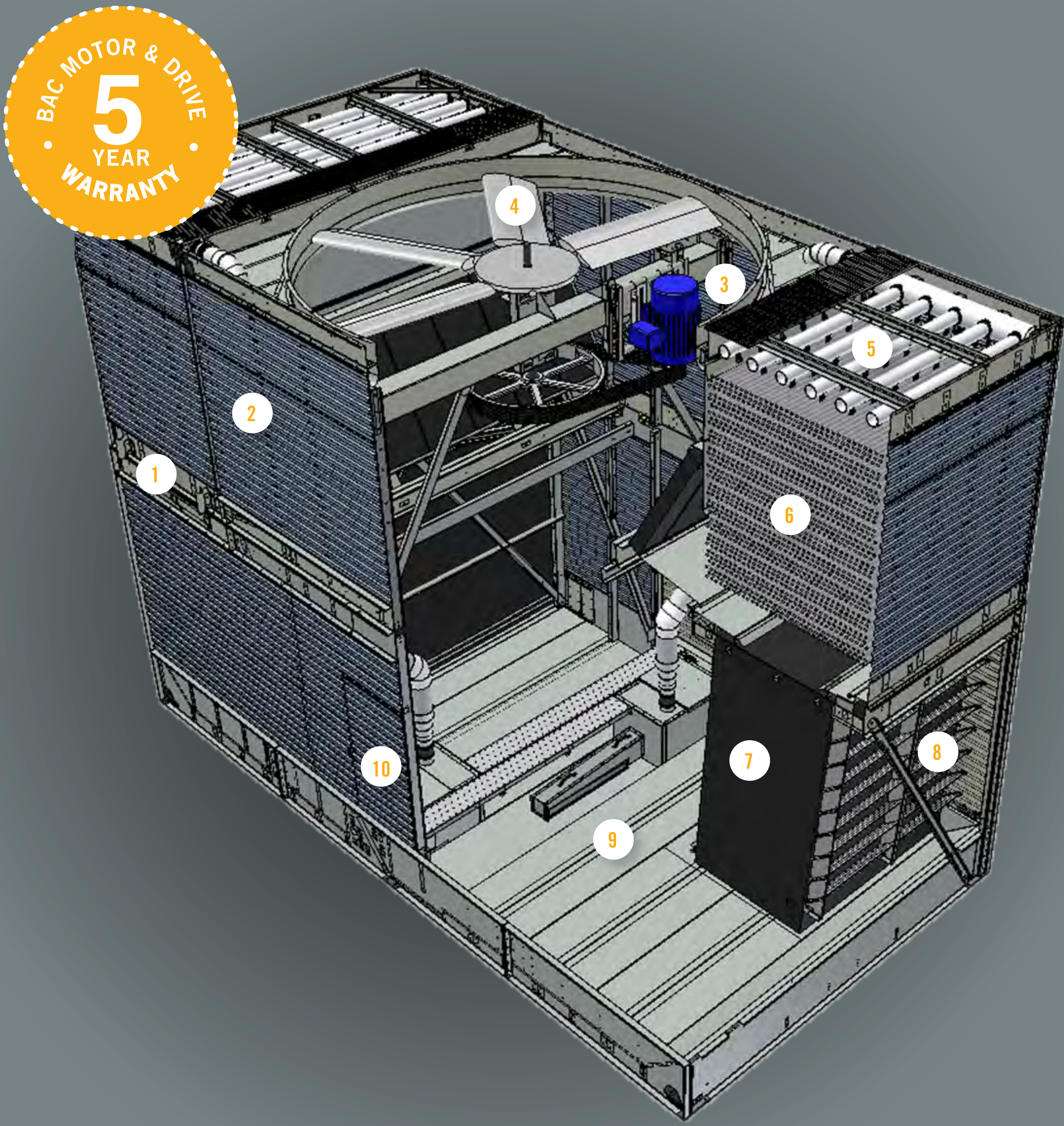


NOTE: Operating costs based on fan and pump kW x $0.12kWh x 8760 hours x 50% average load for the year x 20 years.

Lowest Operating Costs | Application Assurance | Reduced Sounds Levels

COMPARE ❯ SELECT ❯ SPECIFY ❯

CXVT Construction Details



1 Heavy-Duty Construction

- G-235 (Z700 metric) mill galvanized steel is the heaviest galvanizing available ensuring durability
- Meets wind and seismic requirements of the International Building Code (IBC)

2 FRP Casing Panels

- Corrosion resistant, UV resistant finish ensuring long life
- Maintenance free

3 BALTIDRIVE® Power Train

- Premium quality, solid backed, multi-groove belt to ensure reliable operation
- Corrosion resistant cast aluminum sheaves reduce drive maintenance compared to cast iron sheaves
- Heavy-duty bearings with a minimum L_{10} of 80,000 hours (200,000 hour average life) ensures reliable drive operation
- Premium efficient/inverter duty fan motors as standard
- 5-year motor and drive warranty

4 Low HP Axial Fan

- High efficiency fans maximize the capacity for each model
- Quiet operation to minimize sound levels from the discharge of the unit

5 Water Distribution System

- Visible and accessible during operation to increase inspection frequency and reduce maintenance
- Overlapping spray patterns ensure proper water coverage over the coil and reduce scale formation and maintain the thermal efficiency for the life of the unit
- Large orifice, non-clog 360 Spray Nozzles

6 Coil Sections

- Continuous serpentine, steel tubing increases reliability of the coil
- Hot-dip galvanized after fabrication (HDGAF) increases reliability of the coil
- Maximum allowable working pressure is 300 psig (2,068 kPa)
- Sloped tubes allow for free drainage of condensed refrigerant
- Fabricated per ASME B31.5 standards
- Canadian shipments are supplied with CRN

7 BACross® Fill with Integral Drift Eliminators

- High efficiency heat transfer surface optimizes thermal performance and energy efficiency
- Polyvinyl chloride (PVC) is impervious to rot, decay, and biological attack
- Flame spread rating of 5 per ASTM E84
- Elevated off of the water basin to reduce maintenance

8 FRP Air Intake Louvers

- Corrosion resistant, UV resistant finish ensuring long life
- Maintenance free
- Separate from the fill which allows for clear inspection of the fill-air interface which is where scale build up occurs first

9 Basin

- Sloped water basin for easy cleaning
- Suction strainer with anti-vortex hood
- Adjustable water make-up assembly

10 Hinged Access Doors

- Inward hinged door on each end wall allows easy, safe access to the interior of the unit
- Permanently attached to the unit

CXVT
Custom Features & Options

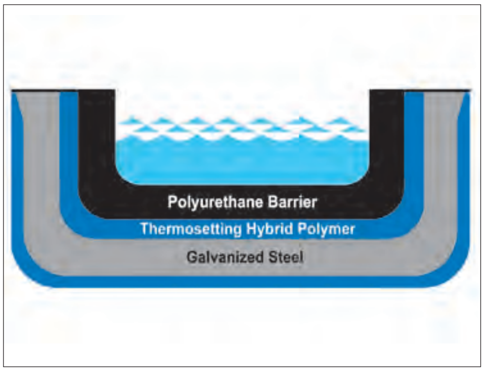
Materials of Construction

Determining the appropriate material of construction for a project depends on several factors, including water quality, climate and environmental conditions, availability of time and manpower for maintenance, unit lifetime requirements, and budget. BAC provides the widest variety of material of construction options in the industry and has the ability to provide a solution to meet all conditions and budgets. Options such as the TriArmor® Corrosion Protection System and EVERTOUGH™ Construction provide superior corrosion resistance and durability at a tremendous value.

Standard Construction Installation

STANDARD CONSTRUCTION

G-235 mill galvanized steel is the heaviest commercially available galvanized steel, universally recognized for its strength and corrosion resistance. To assure long life, a G-235 mill galvanized steel frame with fiberglass reinforced polyester (FRP) casing panels and louvers is used as the standard material of construction. The structural integrity of the unit is provided by its strong steel frame. With proper maintenance and water treatment, G-235 galvanized steel and FRP will provide an excellent service life under the operating conditions normally encountered in refrigeration applications.



TriArmor® Corrosion Protection System Triple Layer Protection of the Basin

Customer Valued

TRIARMOR® CORROSION PROTECTION SYSTEM (OPTION)

The TriArmor® Corrosion Protection System consists of heavy gauge G-235 mill galvanized steel panels fully encapsulated by a thermosetting hybrid polymer and further protected by a polyurethane barrier applied to all submerged surfaces of the cold water basin. The triple layers of protection form a completely seamless cold water basin for the most leak resistant and durable basin in the industry. Other components within the basin, such as the strainer and submerged structural supports, will be constructed of stainless steel. The TriArmor® Corrosion Protection System was specifically designed for evaporative cooling applications and released in 2006 after a decade of extensive R&D and field testing. To date, there are thousands of successful installations in North America. Every basin is leak tested at the factory and warranted against leaks and corrosion for five years.

Application of TriArmor® Corrosion Protection System

EVERTOUGH™ CONSTRUCTION (OPTION)

EVERTOUGH™ Construction combines the most corrosion resistant materials to provide the best value in corrosion protection for most water chemistries. EVERTOUGH™ Construction is backed by a comprehensive 5-year warranty which covers ALL components from the fan to the cold water basin, from louver to louver, including the motor (excluding the coil).

The following materials are used in EVERTOUGH™ Construction:

- The basin is constructed with the TriArmor® Corrosion Protection System. The basin is leak tested at the factory and warranted against leaks and corrosion for 5 years.
- Fiberglass reinforced polyester (FRP) casing panels are corrosion and UV resistant, ensuring long life.
- Designated steel components above the basin are constructed of heavy-gauge G-235 mill galvanized steel and further protected with a thermosetting hybrid polymer.
- The distribution system is non-corrosive Schedule 40 PVC.
- Other components within the basin, such as the strainer and submerged structural supports, will be constructed of stainless steel.

Welded Stainless Steel Basin

THERMOSETTING HYBRID POLYMER (OPTION)

A thermosetting hybrid polymer, used to extend equipment life, is applied to select G-235 mill galvanized steel components of the unit. The polymerized coating is baked onto the G-235 mill galvanized steel and creates a barrier to the already corrosion resistant galvanized steel. The thermosetting hybrid polymer has been tested to withstand 6,000 hours in a 5% salt spray without blistering, chipping, or losing adhesion.

Thermosetting Hybrid Polymer

STAINLESS STEEL (OPTION)

Several stainless steel options are available.

- **WELDED STAINLESS STEEL BASIN**
  A welded stainless steel basin is available. All steel panels and structural members of the basin are constructed from stainless steel. Seams between panels inside the basin are welded, providing an advantage over bolted stainless steel basins for minimizing susceptibility to leaks at basin seams. The basin is leak tested at the factory and welded seams are provided with a

Welded Stainless Steel Basin

CXVT
Custom Features & Options

5-year, leak-proof warranty.

- **ALL STAINLESS STEEL CONSTRUCTION (OPTION)**
  All unit structural elements and the basin are constructed of stainless steel. Seams between panels inside the basin are welded, providing an extreme advantage over bolted basins for minimizing susceptibility to leaks at basin seams. The basin is leak tested at the factory and welded seams are provided with a 5-year, leak-proof warranty. Casing panels and air intake louvers are constructed of corrosion and UV-resistant fiberglass reinforced polyester (FRP).

BASINLESS UNIT CONSTRUCTION (OPTION)

The basinless unit construction option enables CXVT Evaporative Condensers to be directly installed on new or existing basins. This custom feature reduces maintenance costs by eliminating the integral basin from traditional units. It simplifies piping and pumping requirements of multi-cell installations, eliminates concern for basin corrosion, and provides a cost-effective solution for many field-erected replacement projects. BAC is the only leading evaporative cooling equipment manufacturer to provide basinless construction for factory assembled equipment.

Basinless Unit Construction

STANDARD FIBERGLASS REINFORCED POLYESTER (FRP) CASING PANELS

Used with BAC's durable steel frame construction, FRP casing panels offer a more durable corrosion resistant unit. FRP casing panels are a key component due to their corrosion resistant properties.

STEEL CASING PANELS AND LOUVERS (OPTION)

Steel casing panels and louvers are available in G-235 mill galvanized steel, thermosetting hybrid polymer, and stainless steel.

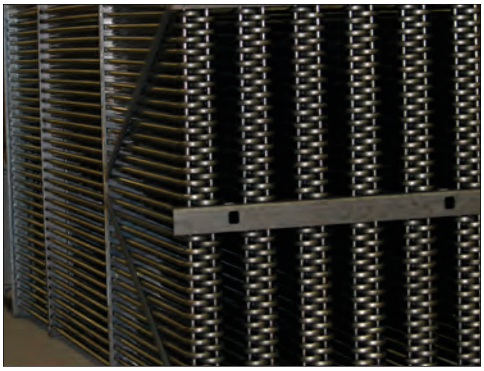
Coil Configurations

BAC offers a large selection of coil configuration options to fulfill any thermal and pressure drop requirements.

Standard Serpentine Coil

STANDARD SERPENTINE COIL

The standard coil is constructed of continuous lengths of all prime surface steel. The coil is hot-dip galvanized after fabrication (HDGAF) to apply a thick, zinc corrosion barrier over the entire exterior surface of the coil. The coil is designed for low pressure drop with sloping tubes for free drainage of fluid. Each coil has a maximum allowable working pressure of 300 psig (2,068 kPa) and is fabricated per ASME B31.5 standards to ensure the highest quality and complete integrity.



Stainless Steel Coil

STAINLESS STEEL COIL (OPTION)

Coils are available in stainless steel for specialized applications. The coil is designed for low pressure drop with sloping tubes for free drainage of fluid. Each coil has a maximum allowable working pressure of 300 psig (2,068 kPa) and is fabricated per ASME B31.5 standards to ensure the highest quality and integrity.

ASME U DESIGNATOR COIL (OPTION)

BAC offers coils that are certified in accordance with the ASME Boiler and Pressure Vessel Code, Section VIII, Division I. ASME U designated coils are available for projects requiring ASME certified pressure vessels and involve 3rd party inspection and certification. Standard ASME U designated coils are rated at 340 psig (2,344 kPa) maximum allowable working pressure, and they are pneumatically tested at 375 psig (2,586 kPa).

Multiple Circuit Coil

MULTIPLE CIRCUIT COILS/AUXILIARY COOLING CIRCUIT (OPTION)

Split coil configurations are available to allow separate process fluid or refrigerant loops through the same unit. Separate loops may be needed for multiple applications requiring different temperature processes or multiple types of process fluids or refrigerants. Multiple refrigerant circuit coils are generally required on halocarbon refrigerant systems, where it is common practice to maintain individual compressor systems. The quantity of circuits, capacity per circuit, and desired connection size and type should be specified when requesting this option.

NOTE: A Canadian Registration Number (CRN) is required for all pressure vessels over 15 psig entering Canada. The CRN identifies that the design of a boiler, pressure vessel, or fitting has been accepted and registered for use in Canada. CRN is available for all BAC Dual and TriCoil configurations in Canada.

COPPER SWEAT FITTINGS (OPTION)

Factory installed copper sweat fittings are available to simplify field piping.

CXVT
Custom Features & Options

Drive System Options

The fan drive system provides the cooling air necessary to reject unwanted heat from the system to the atmosphere. All BAC drive systems use premium efficient cooling tower duty motors and include BAC's comprehensive 5-year motor and drive warranty. Cooling tower duty motors are specially designed for the harsh environment inside an evaporative condenser and have permanently lubricated bearings, drastically decreasing the maintenance requirement of the motor. BAC belt drive systems are the most durable and maintenance friendly drive systems on the market, including single nut adjustment for belt tensioning.

STANDARD BALTIDRIVE® POWER TRAIN

The BALTIDRIVE® Power Train utilizes special corrosion resistant materials of construction and state-of-the-art technology to ensure ease of maintenance and reliable year-round performance. This BAC engineered drive system consists of a specially designed powerband and two cast aluminum sheaves located at minimal shaft centerline distances to maximize belt life. When compared to a gear drive system, this specially engineered belt drive system provides many advantages. The BALTIDRIVE® Power Train requires only periodic inspection of components and belt tensioning, which is simple with a single nut adjustment, and requires less downtime. Only fan bearing lubrication is required for routine maintenance. Belt drive systems also have the added advantage of being suitable for variable frequency drive (VFD) applications without requiring expensive optional accessories.

BALTIDRIVE® Power Train Fan System

GEAR DRIVE SYSTEM, CLOSE-COUPLED MOTOR (OPTION)

A gear drive system is available as a fan drive option on the CXVT. Both the gear drive and couplings are selected with a 2.0 service factor. Gear construction includes a nickel-alloy steel shaft, case hardened gears, self lubrication, and a single piece, gray iron housing. This drive system ships completely installed and aligned.

GEAR DRIVE SYSTEM, EXTERNALLY MOUNTED MOTOR (OPTION)

A gear drive system with a TEFC motor mounted outside the airstream is also available on the CXVT. A non-corrosive carbon-fiber composite drive shaft with stainless steel hubs is selected with a 2.0 service factor. The motor and drive shaft ship separately for easy field installation.

Customer Valued

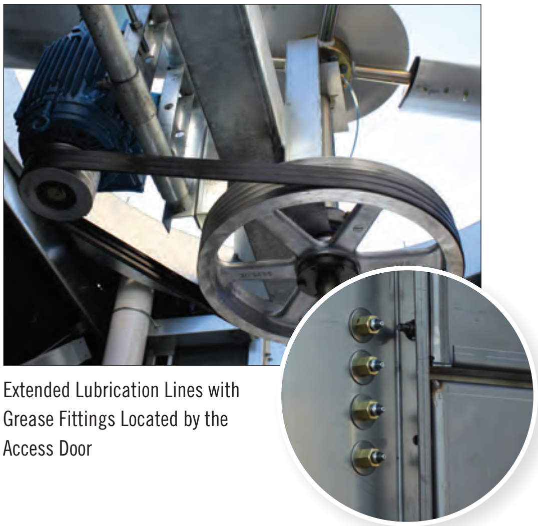
VIBRATION CUTOUT SWITCH (OPTION)

A factory mounted vibration cutout switch is available to effectively protect against rotating equipment failure. BAC can provide either a mechanical or solid-state electronic vibration cutout switch in a NEMA 4 enclosure to ensure reliable protection. Additional contacts can be provided on either switch type to activate an alarm. Remote reset capability is also available on either switch type.

Customer Valued

EXTENDED LUBRICATION LINES (OPTION)

Extended lubrication lines are available for lubrication of the fan shaft bearings. Fittings are located on the exterior casing panel next to the access door.



Extended Lubrication Lines with Grease Fittings Located by the Access Door

Basin

The spray water collects in the basin and then is pumped back over the condensing coil. During operation, the sloped CXVT basin eliminates any stagnant water zones, which are susceptible to biological growth.

STANDARD MECHANICAL WATER LEVEL CONTROL

Mechanical make-up valves must operate continuously in the moist and turbulent environment within evaporative cooling equipment. Due to this environment, the operation of the valve must be simple and the valve must be durable. BAC's high quality mechanical water level control assembly is standard with all units and has been specially designed to provide the most reliable operation while being easy to maintain. This accessory is omitted for remote sump applications.

Mechanical Water Level Control

CXVT
Custom Features & Options

ELECTRIC WATER LEVEL CONTROL (OPTION)

BAC's Electric Water Level Control (EWLC) is a state-of-the-art, conductivity actuated, probe type liquid level control. The hermetically sealed EWLC is engineered and manufactured specifically for use in evaporative cooling systems and is equipped with an error code LED to indicate status, including when the water and/or probes are dirty. The EWLC option replaces the standard mechanical make-up valve, and includes a slow closing, solenoid activated valve in the make-up water line to minimize water hammer. EWLC is recommended when more precise water level control is required and in areas that experience sub-freezing conditions.

BASIN HEATERS (OPTION)

Evaporative cooling equipment exposed to below freezing ambient temperatures require protection to prevent freezing of the water in the basin when the unit is idle. Factory-installed electric immersion heaters, which maintain 40°F (4.4°C) water temperature, are a simple and inexpensive way of providing such protection.


Basin Heater

HEATER kW DATA

	0°F (-17.8°C) Ambient Heaters		-20°F (-28.9°C) Ambient Heaters	
Model Number	Number of Heaters	kW per Heater	Number of Heaters	kW per Heater
CXVT-x-1224-x and XECXVTx-1224-x	2	12	2	15
CXVT-x-1426-x and XECXVTx-1426-x	2	14	2	20
CXVT-x-2424-x and XECXVTx-2424-x	4	12	4	15
CXVT-x-2826-x and XECXVTx-2826-x	4	14	4	20

NOTE: This table is based on 460V/3 phase/60 Hz power.

BASIN SWEEPER PIPING (OPTION)

Basin sweeper piping is an effective method of reducing sediment that may collect in the basin. A complete piping system, including nozzles, is provided in the basin to connect to side stream filtration equipment (provided by others). For more information on filtration systems, consult "Filtration Guide" found on **page J241.**

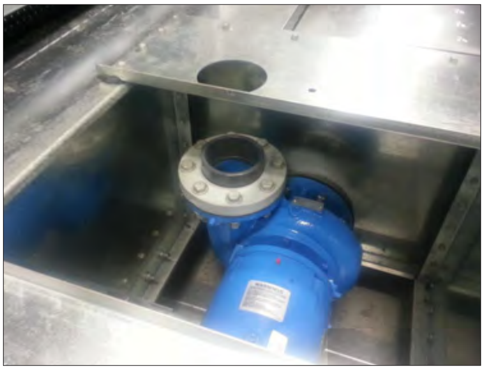
LOW AND HIGH LEVEL ALARM FLOAT SWITCH (OPTION)

Low and high level alarm float switches are available to provide added control to your equipment operation. Level alarms can alert operators to an abnormal operating condition to ensure the highest system efficiency with minimal water usage.

Water Distribution System

STANDARD SPRAY WATER PUMP

The CXVT comes standard with two integral spray water pumps sized to distribute the recirculating water over the coils, maximizing capacity. The patented BAC 360 Spray Nozzles are non-clog, ensure even flow over the coil area, and are simple to remove for maintenance. Parallel flow of air and spray water allow for inspection and access to the top of the coils during operation.



Standard Spray Water Pump

Fill

BACross® Fill, BAC's patented crossflow hanging fill, was developed after years of extensive research. BACross® Fill is made of PVC and is optimized to provide the highest thermal capacity. PVC is virtually impervious to rot, decay, and biological attack. The fill is elevated above the basin floor to facilitate cleaning and maintenance. The integral eliminators effectively strip entrained moisture from the leaving air stream with minimum pressure drop to prevent water loss with negligible impact on efficiency.

STANDARD FILL

Standard fill can be used in applications with spray water temperature up to 130°F (54.4°C). The fill and drift eliminators are formed from self-extinguishing PVC having a flame spread rating of 5 per ASTM E84.

HIGH TEMPERATURE FILL (OPTION)

An optional high temperature fill material is available which increases the maximum allowable spray water temperature to 140°F (60°C). The online selection program automatically determines if high temperature fill is necessary based on the design requirements.

BACross® Fill Manufacturing

CXVT
Custom Features & Options

Shipping and Rigging

BAC units are factory-assembled to ensure uniform quality with minimum field assembly. Each unit has been designed with rigging and assembly in mind and includes features to minimize the number of tools required and installation time.

STANDARD RIGGING GUIDES

Rigging guides allow easy alignment and engagement of the coil sections, the fan (plenum) section, and lower section of units. The guides ensure proper placement of the coil sections to the fan section making rigging much simpler and reducing the time required.

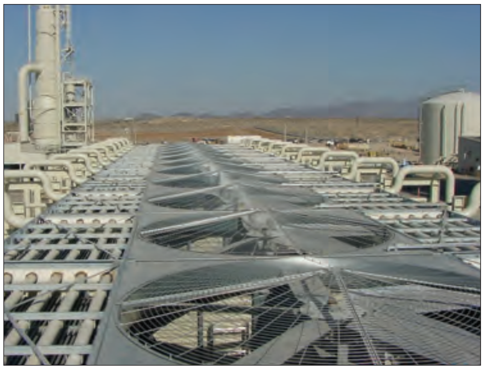
Standard Rigging Guides

KNOCKDOWN UNITS (OPTION)

Knockdown units are available for jobs where access to the evaporative condenser location is limited by elevators, doorways, or similar obstacles, where lifting methods impose very strict weight limits, or where the shipping cost of a fully assembled unit is excessive. All materials of construction and design features are the same as those of a factory assembled unit. Welded stainless steel basins are excluded from knockdown due to the need for in-plant assembly.

Sound Options

Recognition of the importance of sound reduction is growing and can be a very important design criterion for any project. BAC maintains the widest selection of sound mitigating options in the market place and can provide the most cost effective option to meet any requirement.


Low Sound Fans

STANDARD FAN

The fan provided for all CXVT Evaporative Condensers is selected to optimize low sound levels and maximize thermal performance.

LOW SOUND FAN (OPTION)

The Low Sound Fan option reduces sound up to 9 dBA. Adding a high solidity fan decreases fan speeds, which proportionally decreases sound levels.

▶ **SOUND ATTENUATION** (OPTION)

Factory designed, tested, and rated sound attenuation options are available for both the air intake and discharge. Consult your local BAC Representative regarding available options.

Access Options

BAC provides a broad offering of access options. Our evaporative equipment is designed to be easily maintained for sustaining capacity over a longer life.

Standard Internal Walkway

Customer Valued

STANDARD INTERNAL WALKWAY

An internal walkway is standard allowing access to the spacious plenum area for maintenance and inspection of the basin, make-up, fill, and drive system.

▶ **MOTOR REMOVAL SYSTEM** (OPTION)

The removal system includes davit arm(s) to facilitate motor replacement.

Motor Removal System

Customer Valued

EXTERNAL PLATFORM (OPTION)

Every external platform is preassembled and pre-fitted at the factory to ensure that every component will fit and function exactly as described. The platform will ship secured in the basin and attach quickly in the field with minimum fasteners. Safety gates are available for all handrail openings.

NOTE: Platforms, ladders, handrails, safety gates, and safety cages can be added at the time of order or as an aftermarket item.

External Motor Platform, Ladder, Handrails, and Safety Cage

CXVT
Custom Features & Options

ACCESS DOOR PLATFORM AND LADDER PACKAGES (OPTION)

An access door platform is available to allow access to the unit when installed on elevated supports. This option allows for safe access to the unit, as well as a working platform to stage tools for maintenance.

HANDRAIL PACKAGES (OPTION)

Handrail packages are available to provide safe access to the top of the unit for maintenance to the distribution system. Fan deck extensions are available for passage around the fan on units designed with maximized fan diameters or discharge sound attenuation. The specially designed handrail packages are secured for compact shipping in the basin to minimize shipping costs and are ready for field assembly. NOTE: Partial or full grating above the coil air intake is recommended with this option.

INTERNAL SERVICE PLATFORM AND LADDER PACKAGES (OPTION FOR TWO PIECE UNITS)

For access to the motor and drive assemblies, an internal ladder and upper service platform with handrails is available on larger units. Safety gates are available for all handrail openings. An internal walkway is required with this package.

Internal Ladder, Service Platform, and Walkway

CXVB Evaporative Condenser

TABLE OF CONTENTS

The CXVB delivers efficient performance in an easy-to-maintain package. BAC's Advanced Coil and Combined Flow Technology provides maximum capacity at the lowest refrigerant charge available in the industry by incorporating fill media into the traditional evaporative condenser. In addition, CXVB models are designed to mount directly on existing support steel of both crossflow and counterflow units, making them a direct replacement option for almost any existing model.

TriArmor® Corrosion Protection System

EVERTOUGH™ CONSTRUCTION

IBC Compliant

BAC's CXVB:

Maximum Capacity at Lowest Charge

75 to 1,287 R-717 Tons in a Single Unit

- Lowest Refrigerant Charge Per Ton
- Fewest Piping Connections
- Layout Flexibility
- Shake Table Tested to S_{DS} of 2.40g
- Easy Maintenance

iiar® International Institute of Ammonia Refrigeration

RETA® Education • Efficiency • Development

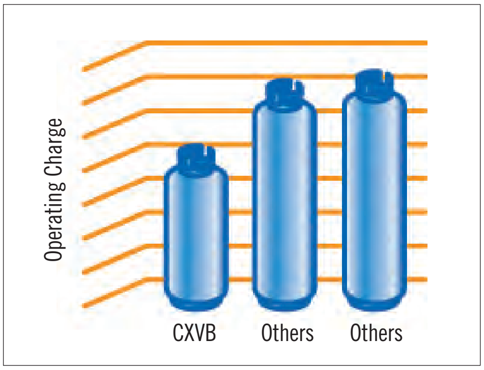
U.S. Green Building Council Member®

IARW® International Association of Refrigerated Warehouses

CXVB Benefits

Technology – Leadership

- Patented Combined Flow Technology provides the highest capacity at the lowest refrigerant charge in the industry
- Air and water flow in a parallel path, therefore eliminating scale-producing "hot spots" on the coil
- Increased heat rejection occurs as the water flows over the fill, therefore lowering spray water temperatures
- Meets wind and seismic requirements of the International Building Code through shake table testing. Rated to withstand a seismic event up to 2.40g and windloads up to 167 psf.
- Premium efficient motors are standard and ready for VFD's now or later



Operating Charge

Installation Efficiency

- Combined Flow Technology lowers installation and operating costs
  - Significantly lower refrigerant charge
  - Fewer coil connections and valves
  - Lower weights mean support steel can be reduced
  - Less overall piping connections and fewer supports
- Pre-assembled platform package reduces installation time (option)
- Single point wiring simplifies field installation (option)

Easily Accessible Spray Water Distribution

Service – Maintenance

- Oversized doors for access to the internal walkway
- Spacious interior provides easy access to the basin, drift eliminators, coils, and drive system
- Extended lubrication lines, internal walkway, and ladder (standard)
- A water distribution system that makes service of the nozzles, spray branches, and headers possible without the need for tools
- Motor davit system to facilitate motor removal (option)

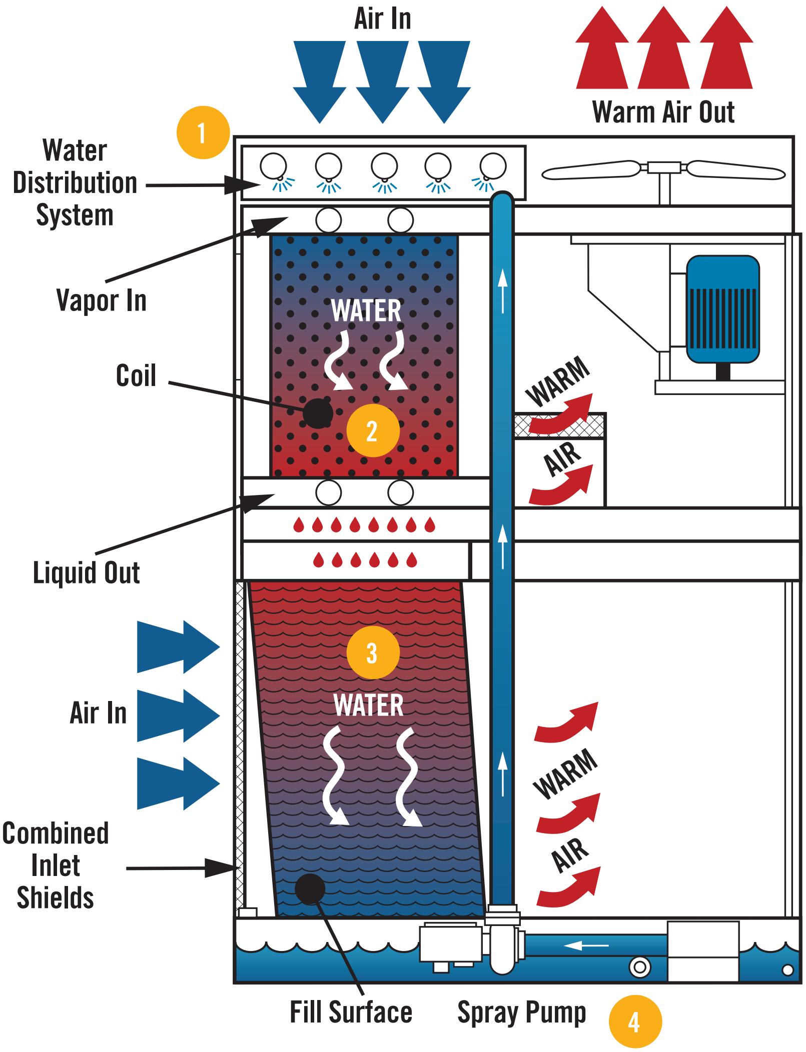
Pre-Assembled Platforms

Industrial Grade Construction

- Materials of construction
  - Mill galvanized (G-235) steel construction (standard)
  - TriArmor® Corrosion Protection System encapsulates the hygienic basin with three barriers of protection (option)
- Fully welded, not bolted, stainless steel basins (option)
- All coils are fabricated to ASME B31.5 standards

Application of TriArmor® Corrosion Protection System

Patented Combined Flow Technology



1. Water is sprayed in parallel with the fresh ambient air flowing over the outside of the condensing coil. Parallel air and water paths minimize scale-producing dry spots that may be found on the bottom of the tubes in other, conventional condensers.
2. The condensing coil rejects heat through both evaporative cooling using the fresh air stream and, more significantly, through sensible cooling of the pre-cooled recirculating spray water. Reducing this evaporative cooling component from the coil section helps to minimize the propensity to form scale on the coil surface.
3. The recirculating spray water falls from the coil to the fill surface section where it is cooled by a second fresh air stream using evaporative heat transfer.
4. Water is pumped over the condensing coil at a rate greater than 10 USGPM/ft^2 of coil plan area to ensure continuous wetting of the primary heat transfer surface, which enhances heat transfer efficiency and minimizes scale formation.

CXVB Construction Details

1 Heavy-Duty Construction

- G-235 (Z700 metric) mill galvanized steel panels
- Meets seismic and wind requirements for International Building Code
- Shake table tested and verified with seismic ratings up to 2.40g and windload ratings up to 167 psf

2 BALTIDRIVE® Power Train

- Premium efficient/inverter duty fan motors are standard
- 5-year motor and drive warranty
- Corrosion resistant cast aluminum sheaves
- Heavy-duty bearings, with minimum L_{10} 80,000 hours
- Extended lubrication lines with grease fittings are standard
- Premium quality, solid-backed, multi-groove belt

3 Low HP Axial Fans

- High efficiency
- Quiet operation
- Corrosion resistant

4 Water Distribution System

- Visible and accessible during operation
- Overlapping spray patterns ensure proper water coverage
- Large orifice, non-clog, 360 Spray Nozzles

5 Coil Section (NOT SHOWN)

- Continuous serpentine, steel tubing
- Hot-dip galvanized after fabrication (HDGAF)
- Maximum allowable working pressure is 300 psig (2,068 kPa)
- Fabricated per ASME B31.5 standards
- Orders shipping into Canada are supplied with a CRN

6 BACross® Fill with Integral Drift Eliminators (NOT SHOWN)

- High efficiency heat transfer surface
- Recyclable Polyvinyl chloride (PVC)
- Impervious to rot, decay, and biological attack
- Flame spread rating of 5 per ASTM E84
- Elevated off the basin

7 Combined Inlet Shields

- Corrosion resistant
- UV-resistant finish
- Maintenance free
- Reduces sunlight and algae growth

8 Basin

- Sloped basin for easy cleaning
- Suction strainer with anti-vortex hood

9 Recirculating Spray Water Pump

- Close coupled, bronze fitted centrifugal pump
- Totally enclosed fan cooled (TEFC) motor
- Bleed line with metering valve installed from pump discharge to overflow

10 Hinged Access Doors

- Inward swinging door on each end wall
- Opening to a standard internal walkway and internal ladder

CXVB
Custom Features & Options

Materials of Construction

Determining the appropriate material of construction for a project depends on several factors, including water quality, climate and environmental conditions, availability of time and manpower for maintenance, unit lifetime requirements, and budget. BAC provides the widest variety of material of construction options in the industry and has the ability to provide a solution to meet all conditions and budgets. Options such as the TriArmor® Corrosion Protection System and EVERTOUGH™ Construction provide superior corrosion resistance and durability at a tremendous value.

Standard Construction Installation

STANDARD CONSTRUCTION

G-235 mill galvanized steel is the heaviest commercially available galvanized steel, universally recognized for its strength and corrosion resistance. To assure long life, G-235 mill galvanized steel panels and structural members are used as the standard material of construction. The standard construction has been seismically verified by shake table testing in an independent laboratory up to an S_{DS} of 2.40g and can withstand wind loads of up to 167 psf, proving its construction is designed for extreme durability. With proper maintenance and water treatment, G-235 galvanized steel will provide an excellent service life under the operating conditions normally encountered in refrigeration applications.

Customer Valued

TRIARMOR® CORROSION PROTECTION SYSTEM (OPTION)

The TriArmor® Corrosion Protection System consists of heavy gauge G-235 mill galvanized steel panels fully encapsulated by a thermosetting hybrid polymer and further protected by a polyurethane barrier applied to all submerged surfaces of the cold water basin. The triple layers of protection form a completely seamless cold water basin for the most leak resistant and durable basin in the industry. Other components within the basin, such as the strainer and submerged structural supports, will be constructed of Stainless Steel. The TriArmor® Corrosion Protection System was specifically designed for evaporative cooling applications and released in 2006 after a decade of extensive R&D and field testing. To date, there are thousands of successful installations in North America. Every basin is leak tested at the factory and warranted against leaks and corrosion for five years.

Application of TriArmor® Corrosion Protection System

EVERTOUGH™ CONSTRUCTION (OPTION)

EVERTOUGH™ Construction combines the most corrosion resistant materials to provide the best value in corrosion protection for most water chemistries. EVERTOUGH™ Construction is backed by a comprehensive 5-year warranty which covers ALL components from the fan to the cold water basin, from louver to louver, including the motor (excluding the coil).

The following materials are used in EVERTOUGH™ Construction:

- The basin is constructed with the TriArmor® Corrosion Protection System. The basin is leak tested at the factory and warranted against leaks and corrosion for 5 years.
- Designated steel components above the basin are constructed of heavy-gauge G-235 galvanized steel and further protected with a thermosetting hybrid polymer.
- The distribution system is non-corrosive Schedule 40 PVC.
- Other components within the basin, such as the strainer and submerged structural supports, will be constructed of stainless steel.

EVERTOUGH™ Construction Installation

THERMOSETTING HYBRID POLYMER (OPTION)

A thermosetting hybrid polymer, used to extend equipment life, is applied to select G-235 mill galvanized steel components of the unit. The polymerized coating is baked onto the G-235 mill galvanized steel and creates a barrier to the already corrosion resistant galvanized steel. The thermosetting hybrid polymer has been tested to withstand 6,000 hours in a 5% salt spray without blistering, chipping, or losing adhesion.

STAINLESS STEEL (OPTION)

Several stainless steel material of construction options are available.

- **WELDED STAINLESS STEEL BASIN**
  All steel panels and structural members of the basin are constructed from stainless steel. Seams between panels inside the basin are welded, providing an advantage over bolted stainless steel basins for minimizing susceptibility to leaks at basin seams. The basin is leak tested at the factory and welded seams are provided with a 5-year, leak-proof warranty.
- **ALL STAINLESS STEEL CONSTRUCTION**
  Steel panels and structural elements are constructed of stainless steel. Seams between panels inside the basin are welded. The basin is leak tested at the factory and welded seams are provided with a 5-year leak-proof warranty.


Welded Stainless Steel Basin

CXVB
Custom Features & Options

Coil Configurations.

BAC offers a large selection of coil configuration options to fulfill any thermal and pressure drop requirements.

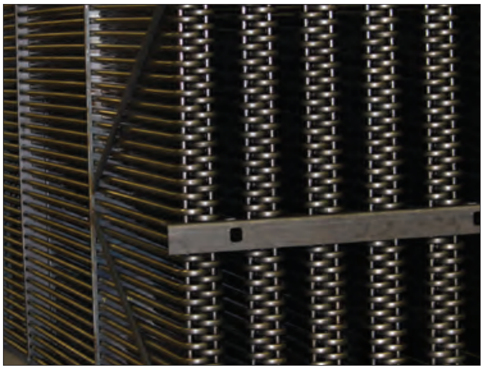
STANDARD SERPENTINE COIL

The standard coil is constructed of continuous lengths of all prime surface steel. The coil is hot-dip galvanized after fabrication (HDGAF) to apply a thick, zinc corrosion barrier over the entire exterior surface of the coil. The coil is designed for low pressure drop with sloping tubes for free drainage of fluid. Each coil has a maximum allowable working pressure of 300 psig (2,068 kPa) and is fabricated per ASME B31.5 standards to ensure the highest quality and integrity.


Standard Serpentine Coil

STAINLESS STEEL COIL (OPTION)

Coils are available in stainless steel for specialized applications. The coil is designed for low pressure drop with sloping tubes for free drainage of fluid. Each coil has a maximum allowable working pressure of 300 psig (2,068 kPa) and is fabricated per ASME B31.5 standards to ensure the highest quality and integrity.


Stainless Steel Coil

ASME U DESIGNATOR COIL (OPTION)

BAC offers coils that are certified in accordance with the ASME Boiler and Pressure Vessel Code, Section VIII, Division I. ASME U designated coils are available for projects requiring ASME certified pressure vessels and involve 3rd party inspection and certification. Standard ASME U designated coils are rated at 340 psig (2,344 kPa) maximum allowable working pressure, and they are pneumatically tested at 375 psig (2,586 kPa).

NOTE: A Canadian Registration Number (CRN) is required for all pressure vessels over 15 psig entering Canada. The CRN identifies that the design of a boiler, pressure vessel, or fitting has been accepted and registered for use in Canada. CRN is available for all BAC Dual and TriCoil configurations shipping into Canada.

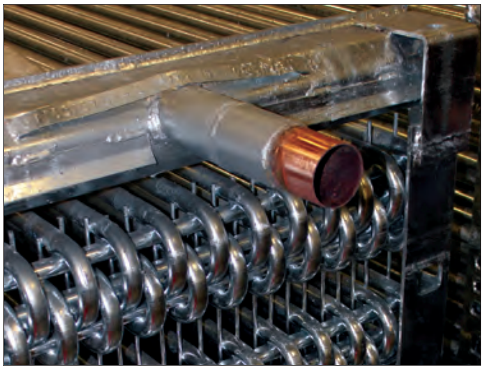
MULTIPLE CIRCUIT COILS/AUXILIARY COOLING CIRCUIT (OPTION)

Split coil configurations are available to allow separate process fluid or refrigerant loops through the same unit. Separate loops may be needed for multiple applications requiring different temperature processes or multiple types of process fluids or refrigerants. Multiple refrigerant circuit coils are generally required on halocarbon refrigerant systems, where it is common practice to maintain individual compressor systems. The quantity of circuits, capacity per circuit, and desired connection size and type should be specified when requesting this option.

Multiple Circuit Coil

COPPER SWEAT FITTINGS (OPTION)

Factory installed copper sweat fittings are available to simplify field piping.



Copper Sweat Fittings

Drive System Options

The fan drive system provides the cooling air necessary to reject unwanted heat from the system to the atmosphere. All BAC drive systems use premium efficient cooling tower duty motors and include BAC's comprehensive 5-year motor and drive warranty. Cooling tower duty motors are specially designed for the harsh environment inside an evaporative condenser and have permanently lubricated bearings, drastically decreasing the maintenance requirement of the motor. BAC belt drive systems are the most durable and maintenance friendly drive systems on the market, including single nut adjustment for belt tensioning to make belt tensioning simple.

CXVB
Custom Features & Options

STANDARD BALTIDRIVE® POWER TRAIN

The BALTIDRIVE® Power Train utilizes special corrosion resistant materials of construction and state-of-the-art technology to ensure ease of maintenance and reliable year-round performance. This BAC engineered drive system consists of a specially designed powerband and two cast aluminum sheaves located at minimal shaft centerline distances to maximize belt life. When compared to a gear drive system, this specially engineered belt drive system provides many advantages. The BALTIDRIVE® Power Train requires only periodic inspection of components and belt tensioning, which is simple with a single nut adjustment and requires less downtime. Only fan bearing lubrication is required for routine maintenance. Belt drive systems also have the added advantage of being suitable for variable frequency drive (VFD) applications without requiring expensive optional accessories.

BALTIDRIVE® Power Train

EXTENDED LUBRICATION LINES

Extended lubrication lines are also provided with the BALTIDRIVE® Power Train for lubrication of the fan shaft bearings. Fittings are located on the exterior casing panel next to the access door.

Extended Lubrication Lines with Grease Fittings Located by the Access Door

Customer Valued

INDEPENDENT FAN OPERATION (OPTION)

Models CXVB-x-0809-x, CXVB-x-0812-x, CXVB-x-1212-x are provided with one motor driving two fans as standard. The CXVB-x-0818-x and CXVB-x-1218-x are provided with two fan motors driving three fans as standard. The independent fan option consists of one fan motor and drive assembly for each fan to allow independent operation, adding an additional step of fan cycling and capacity control. This option ensures redundancy for the fan and motor system.

BALTIGUARD™ FAN SYSTEM (OPTION)

The BALTIGUARD™ Fan System consists of two standard single-speed fan motor and drive assemblies. One drive assembly is sized for full speed and load, and the other is sized for approximately 2/3 speed and consumes only 1/3 the design horsepower. This configuration provides the reserve capability of a standby motor in the event of failure. As a minimum, approximately 70% capacity will be available from the low horsepower motor (pony), even on a design wet-bulb day. Controls and wiring are the same as those required for a two-speed, two-winding motor. Redundant motors are available by increasing the size of the standby fan motor of the BALTIGUARD™ Fan System to the size of the main motor. This provides 100% motor redundancy and the greatest level of reliability.

BAC MOTOR & DRIVE
5
YEAR
WARRANTY

- **BALTIGUARD PLUS™ FAN SYSTEM** (OPTION)

  The BALTIGUARD PLUS™ Fan System builds on the advantages of the BALTIGUARD™ Fan System by adding a variable frequency drive (VFD) to either the pony or the main motor, depending on system requirements. This offers the benefits of additional capacity control and energy savings, along with the redundancy offered by the BALTIGUARD™ Fan System. Alternatively, a VFD can be added to both the pony and main motor for complete capacity control and redundancy under any load.

- **VIBRATION CUTOUT SWITCH** (OPTION)

  A factory mounted vibration cutout switch is available to effectively protect against rotating equipment failure. BAC can provide either a mechanical or solid-state electronic vibration cutout switch in a NEMA 4 enclosure to ensure reliable protection. Additional contacts can be provided on either switch type to activate an alarm. Remote reset capability is also available on either switch type.

BALTIGUARD PLUS™ Fan System Used for VFD Applications

Basin

The spray water collects in the basin which is pumped back over the condensing coil. During operation, the CXVB basin eliminates any stagnant water zones, which are susceptible to biological growth.

- **STANDARD MECHANICAL WATER LEVEL CONTROL**

  Mechanical make-up valves must operate continuously in the moist and turbulent environment within evaporative cooling equipment. Due to this environment, the operation of the valve must be simple and the valve must be durable. BAC's high quality mechanical water level control assembly is standard with all units and has been specially designed to provide the most reliable operation while being easy to maintain. This accessory is omitted for remote sump applications.

Vibration Cutout Switch

CXVB
Custom Features & Options

ELECTRIC WATER LEVEL CONTROL (OPTION)
BAC's Electric Water Level Control (EWLC) is a state-of-the-art, conductivity actuated, probe type liquid level control. The hermetically sealed EWLC is engineered and manufactured specifically for use in evaporative cooling systems and is equipped with an error code LED to indicate status, including when the water and/or probes are dirty. The EWLC option replaces the standard mechanical make-up valve, and includes a slow closing, solenoid activated valve in the make-up water line to minimize water hammer. EWLC is recommended when more precise water level control is required and in areas that experience sub-freezing conditions.


Electric Water Level Control (EWLC)

BASIN HEATERS (OPTION)
Evaporative cooling equipment exposed to below freezing ambient temperatures require protection to prevent freezing of the water in the basin when the unit is idle. Factory-installed electric immersion heaters, which maintain 40°F (4.4°C) water temperature, are a simple and inexpensive way of providing such protection.

HEATER kW DATA

Model Number	0°F (-17.8°C) Ambient Heaters		-20°F (-28.9°C) Ambient Heaters	
	Number of Heaters	kW per Heater	Number of Heaters	kW per Heater
CXVB-x-0806	1	4	1	6
CXVB-x-0809	1	6	1	8
CXVB-x-0812	1	8	1	12
CXVB-x-0818	1	12	1	18
CXVB-x-1212	1	12	1	16
CXVB-x-1218	1	16	1	24

NOTE: This table is based on 460V/3 phase/60 Hz power.

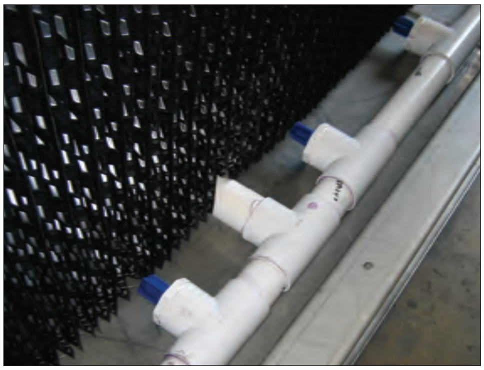

Basin Heater

BASIN SWEEPER PIPING (OPTION)

Basin sweeper piping is an effective method of reducing sediment that may collect in the basin. A complete piping system, including nozzles, is provided in the basin to connect to side stream filtration equipment (provided by others). For more information on filtration systems, consult "Filtration Guide" found on **page J241**.

LOW AND HIGH LEVEL ALARM FLOAT SWITCHES (OPTION)

Low and high level alarm float switches are available to provide added control to your equipment operation. Level alarms can alert operators to an abnormal operating condition to ensure the highest system efficiency with minimal water usage.



Basin Sweeper Piping

Water Distribution System

STANDARD SPRAY WATER PUMP

The CXVB water distribution system comes standard with an integral spray water pump sized to distribute the recirculating water over the coil, maximizing capacity. The patented BAC 360 Spray Nozzles are non-clog, ensure even flow over the coil area, and are simple to remove for maintenance. Parallel flow of air and spray water allow for inspection and access to the top of the coils during operation.

REDUNDANT PUMPS (OPTION)

An optional secondary spray pump is available. A manual valve will be supplied at each pump discharge to allow for manual switch-over for continued equipment operation until maintenance can be performed.

Standard Spray Water Pump

CXVB
Custom Features & Options

Fill

BACross® Fill, BAC's patented crossflow hanging fill, was developed after years of extensive research. BACross® Fill is made of PVC and is optimized to provide the highest thermal capacity. PVC is virtually impervious to rot, decay, and biological attack. The fill is elevated above the basin floor to facilitate cleaning and maintenance. The integral eliminators effectively strip entrained moisture from the leaving air stream with minimum pressure drop to prevent water loss with negligible impact on efficiency.

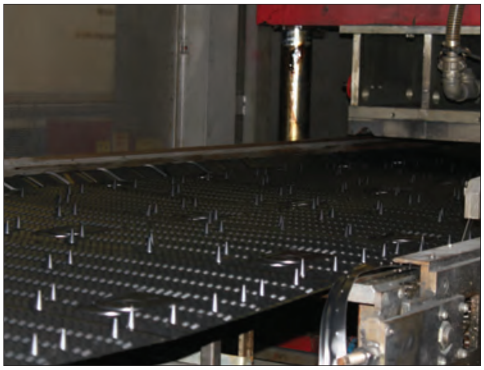
BAC's Combined Flow Technology

STANDARD FILL

Standard fill can be used in applications with spray water temperature up to 130°F (54.4°C). The fill and drift eliminators are formed from self-extinguishing PVC having a flame spread rating of 5 per ASTM E84.

HIGH TEMPERATURE FILL (OPTION)

An optional high temperature fill material is available which increases the maximum allowable spray water temperature to 140°F (60°C). The online selection program automatically determines if high temperature fill is necessary based on the design requirements.



BACross® Fill Manufacturing

Shipping and Rigging

BAC units are factory-assembled to ensure uniform quality with minimum field assembly. Each unit has been designed with rigging and assembly in mind and includes features to minimize the number of tools required and installation time.

KNOCKDOWN UNITS (OPTION)

Knockdown units are available for jobs where access to the condenser location is limited by elevators, doorways, or similar obstacles, where lifting methods impose very strict weight limits, or where the shipping cost of a fully assembled unit is excessive. All materials of construction and design features are the same as those of a factory assembled unit. Welded stainless steel basins and TriArmor® Corrosion Protection System basins are excluded from knockdown due to the need for in-plant assembly.

Sound Options

Recognition of the importance of sound reduction is growing and can be a very important design criterion for any project. BAC maintains the widest selection of sound mitigating options in the market place and can provide the most cost effective option to meet any requirement.

STANDARD FAN

The fan provided for all CXVB Evaporative Condensers is selected to optimize low sound levels and maximize thermal performance.

LOW SOUND FAN (OPTION)

The Low Sound Fan option reduces sound up to 8 dBA. Adding a high solidity fan decreases fan speeds, which proportionally decreases sound levels.

WHISPER QUIET FAN (OPTION)

For the most extreme sound limitations, BAC's Whisper Quiet Fan reduces sound up to 14 dBA.

SOUND ATTENUATION (OPTION)

Factory designed, tested, and rated sound attenuation options are available for both the air intake and discharge. Consult your local BAC Representative regarding available options.

Customer Valued

SINGLE SIDE AIR INTAKE

Single-side air intake units can be placed close to solid walls, reducing the size of enclosures and allowing for more profitable use of premium space. Also, the panel opposite the air intake, called the blankoff panel, is inherently quiet. Positioning the blankoff panel towards the sound sensitive direction insulates sensitive areas from higher sound levels.

Standard Fan

Low Sound Fan

CXVB
Custom Features & Options

Air Intake Options

In an evaporative condenser, airborne debris can be entrained in the water through the unit's air intake. The CXVB has several options for air intake accessories that prevent debris from entering the system and maintain even unobstructed flow through the unit. Reducing the amount of debris that enters the unit lowers maintenance requirements and helps to maintain thermal efficiency.

Single Side Air intake

COMBINED INLET SHIELDS

The Combined Inlet Shields' (CIS) bent flow path blocks sunlight from the basin and fill section and acts as a screen to prevent debris from entering the unit. These benefits result in a significant reduction in algae growth, debris accumulation, and scale build-up. CIS are constructed from corrosion and UV-resistant PVC and are installed in easy to handle sections that are separate from the fill section to facilitate removal, inspection, and replacement. The use of CIS results in lower maintenance costs and ease of maintenance over the life of the unit.

Combined Inlet Shields

Customer Valued

SUNSCREENS (OPTION)

The corrosion resistant SunScreens are mounted above the spray distribution system and help to smooth the airflow into the coils for optimum thermal performance. They also prevent strong winds from carrying spray water out of the unit, and block sunlight in locations previously susceptible to algae growth. SunScreens are constructed in easy to handle sections to facilitate removal, inspection, and replacement.

Access Options

BAC provides a broad offering of access options. Our evaporative equipment is designed to be easily maintained for sustaining capacity over a longer life. All BAC platforms and ladders are OSHA compliant to ensure personnel safety and code compliance.

Internal Walkway

INTERNAL WALKWAY

An internal walkway is provided, allowing access to the spacious plenum area for maintenance and inspection of the basin, make-up, fill, and drive system.

INTERNAL LADDER

For access to the motor and drive assemblies on single air intake models, a movable internal ladder is provided on the CXVB.

MOTOR REMOVAL SYSTEM (OPTION)

The removal system includes davit arm(s) and access panels on the side opposite of the air inlet face, facilitating motor replacement.

Motor Removal System

EXTERNAL PLATFORM (OPTION)

Every external platform is preassembled and pre-fitted at the factory to ensure that every component will fit and function exactly as described. The platform will ship secured in the basin and attach quickly in the field with minimum fasteners. Platforms, ladders, and safety cages can be added at the time of order or as an aftermarket item. Safety gates are available for all handrail openings. All components are designed to meet OSHA requirements.

External Platform

ACCESS DOOR PLATFORM AND LADDER PACKAGES (OPTION)

An access door platform is available to allow access to the unit when installed on elevated supports. This option allows for safe access to the unit, as well as a working platform to stage tools for maintenance.

Customer Valued

INTERNAL SERVICE PLATFORM AND LADDER PACKAGES (OPTION FOR TWO PIECE UNITS)

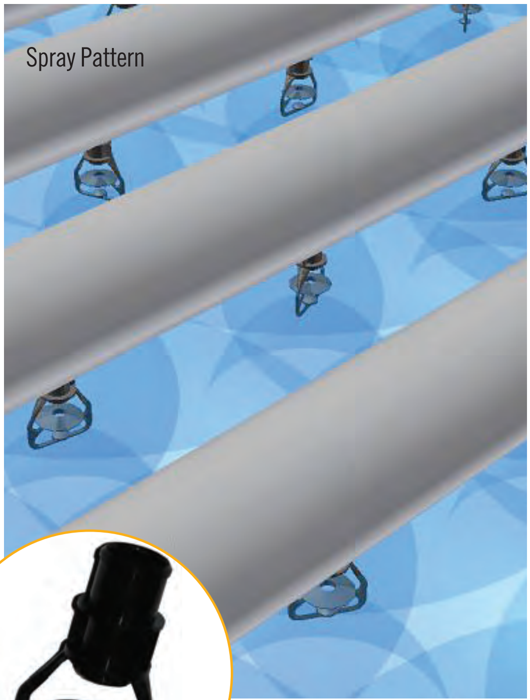
For access to the motor and drive assemblies, an internal ladder and upper service platform with handrails is available on larger units. Safety gates are available for all handrail openings, and all components are designed to meet OSHA requirements.

NOTE: Platforms, ladders, handrails, safety gates, and safety cages can be added at the time of order or as an aftermarket item.

PRODUCT SPOTLIGHT:

BAC 360 Spray Nozzle

Reduce maintenance costs and ensure efficient equipment operation with BAC's non-clog nozzle. The BAC 360 Spray Nozzle combines scatter diffusion technology with large nozzle orifice size, to create the most technologically advanced spray nozzle in the industry!


Spray Pattern


360 Spray Nozzle

Features and Benefits

- Ease of Maintenance
  - Easy snap in/out grommet design
  - Anti-scale design
- Large non-clog orifice
- Robust, durable construction
- Universal alignment
- No moving parts
- Eliminates dry spots inherent in other designs

BAC 360 Spray Nozzles can easily replace nozzles in existing BAC units and other manufacturers' units too!

PCC Evaporative Condenser

TABLE OF CONTENTS

Improving on the PC2 benefits, the PCC lowers installation costs by reducing rigging time. The robust structural frame around the coil casing assures square-ness during rigging and eliminates the need for a shipping skid, thereby eliminating the need for disposal of the skid. The structural frame mates to an enhanced lower section. The lower section is provided with rigging pins reducing the alignment time to minutes. From 46 tons to 2,734 R-717 tons at the lowest condensing temperature, the PCC minimizes the energy consumption of the entire system reducing environmental impact, while saving contractors and owners money.

TriArmor®
Corrosion Protection System

EVERTOUGH™
CONSTRUCTION

BAC®
IBC Compliant

BAC's PCC:
The Ideal Replacement

46 to 2,734 R-717 Tons in a Single Unit

- Increased Capacity with 12' x 20' Units
- Redundant Fan Option on 12' x 18' Units
- Winter Dry Operation
- Seismically Certified up to S_{DS} of 3.10g
- Containerized Units for Exports

iiar® International Institute of Ammonia Refrigeration

RETA® Education • Efficiency • Development

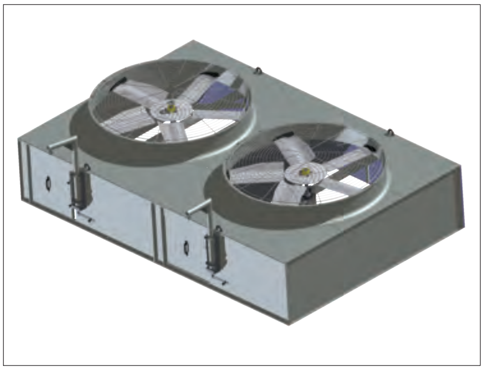
U.S. Green Building Council Member®

IARW® International Association of Refrigerated Warehouses

PCC Benefits

Confidence – Reliability

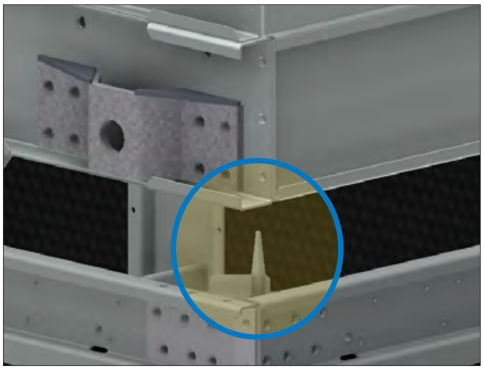
- Meets wind and seismic requirements of the International Building Code
- Bearings selected for a minimum L_{10} life of 100,000 hours
- Premium efficient fan motors are standard and ready for VFD's now or later
- Dual fan option is available on the popular 12' x 18' footprint - **BAC Exclusive!**



Two Fans on 12' x 18' Footprints (Option)

Installation Efficiency

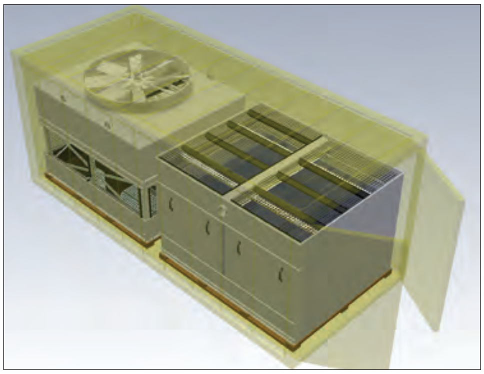
- BAC's new and improved InterLok™ System includes a structural frame to assure square-ness and rigging pins to align the coil casing to the basin reducing rigging time
- Rigging pins on the lower section
  - Align the coil casing and basin in less than 15 minutes per unit
- Pre-assembled IBC and OSHA approved platform packages reduce installation time (option)
- Single piece lift for all units
- Containerized units available for export
- Footprints that mount on most existing steel supports
- Single point wiring simplifies field installation (option)
- 12' x 20' box size increases capacity range reducing the number of cells required for a project



Rigging Pins

Service – Maintenance

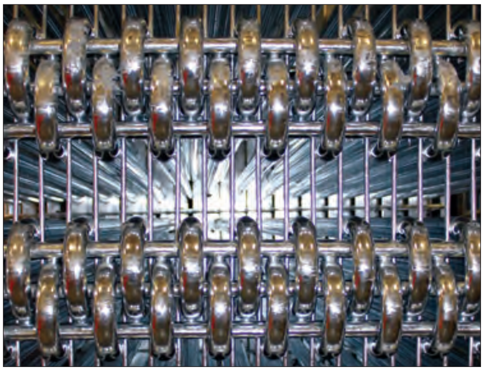
- Air intake louvers are sectioned for easy removal and easy access to all basin components
- External motor adjustment with included wrench
- A water distribution system that makes service of the nozzles, spray branches, and headers possible without the need for tools
- Quick release tool-less strainer



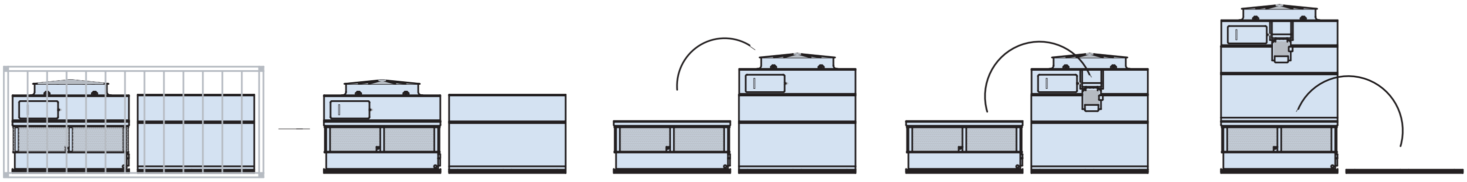
PCC 7.4' (Shown) Can Be Containerized for Export

Industrial Grade Construction

- Durable materials of construction
  - Mill galvanized (G-235) steel construction standard
  - TriArmor® Corrosion Protection System encapsulates the hygienic basin with three barriers of protection (option)
  - EVERTOUGH™ Construction provides the most corrosion resistant materials backed by a 5-year comprehensive, leak and corrosion warranty (option)
- Fully welded, not bolted, stainless steel basins (option)
- All coils are fabricated to ASME B31.5 standards
- Platforms are constructed to the latest IBC and OSHA regulations (option)

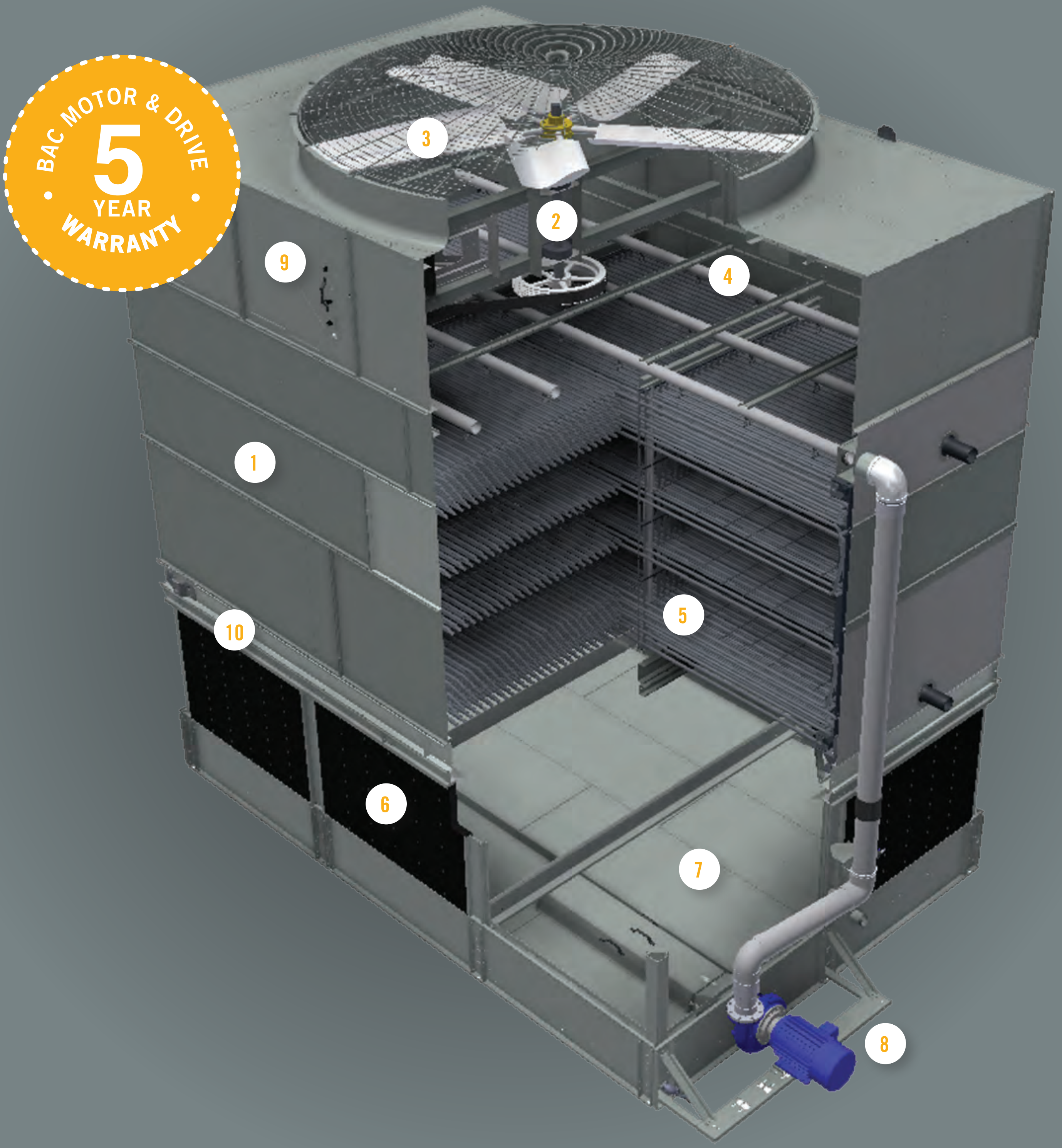


All Coils Are Fabricated to ASME B31.5 Standards



Sequence for Removal and Rigging of a PCC Containerized Unit

PCC Construction Details



1 Heavy-Duty Construction

- G-235 (Z700 metric) mill galvanized steel panels
- Meets wind and seismic requirements of the International Building Code (IBC)
- Certified to withstand up to an S_{DS} of 3.10g
- Robust structural frame assures square-ness

2 BALTIDRIVE® Power Train

- Premium efficient/VFD duty motors are standard
- 5-year motor and drive warranty
- Corrosion resistant cast aluminum sheaves
- Heavy-duty bearings, with minimum L_{10} life of 100,000 hours
- Premium quality, solid backed, multi-groove belt

3 Low HP Axial Fan(s)

- High efficiency
- Quiet operation
- Corrosion resistant aluminum

4 Water Distribution System

- Tool-less removal of spray branches
- Overlapping spray patterns ensure proper water coverage
- Large orifice, non-clog, BAC 360 Spray Nozzles

5 Coil

- Continuous serpentine, steel tubing
- Hot-dip galvanized after fabrication (HDGAF)
- Maximum allowable working pressure is 300 psig (2,068 kPa)
- Sloped tubes for free drainage of fluid
- Fabricated per ASME B31.5 standards
- When required, orders shipping into Canada are supplied with a CRN

6 Combined Inlet Shields

- Corrosion resistant
- Maintenance free
- UV-resistant finish
- Easy to remove sections

7 Basin

- Sloped for easy cleaning
- Suction strainer with removable anti-vortex hood accessible from the louver face
- Adjustable water make-up assembly
- Rigging pins to simplify alignment

8 Recirculating Spray Water Pump

- Close coupled, bronze fitted centrifugal pump
- Totally enclosed fan cooled (TEFC) motor
- Bleed line with metering valve installed from pump discharge to overflow

9 Access Door(s)

- Inward sliding door
- Permanently attached to the unit

10 Rigging Pins (NOT SHOWN)

- Rigging pins on the lower section
- Align the coil casing and the basin in less than 15 minutes per unit

PCC
Custom Features & Options

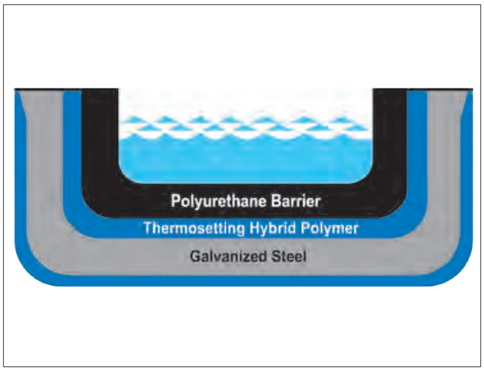
Materials of Construction

Determining the appropriate material of construction for a project depends on several factors, including water quality, climate and environmental conditions, availability of time and manpower for maintenance, unit lifetime requirements, and budget. BAC provides the widest variety of material of construction options in the industry and has the ability to provide a solution to meet all conditions and budgets. Options such as the TriArmor® Corrosion Protection System and EVERTOUGH™ Construction provide superior corrosion resistance and durability at a tremendous value.

Rigging of Standard Construction Installation

STANDARD CONSTRUCTION

G-235 mill galvanized steel is the heaviest commercially available galvanized steel, universally recognized for its strength and corrosion resistance. To assure long life, G-235 mill galvanized steel panels and structural members are used as the standard material of construction. The standard construction has been certified to withstand up to an S_{DS} of 3.10g and can withstand wind loads of up to 140 psf, proving its construction is designed for extreme durability. With proper maintenance and water treatment, G-235 galvanized steel will provide an excellent service life under the operating conditions normally encountered in refrigeration applications.



TriArmor® Corrosion Protection System Triple Layer Protection of the Basin

Customer Valued

TRIARMOR® CORROSION PROTECTION SYSTEM (OPTION)

The TriArmor® Corrosion Protection System consists of heavy gauge G-235 galvanized steel panels fully encapsulated by a thermosetting hybrid polymer and further protected by a polyurethane barrier applied to all submerged surfaces of the cold water basin. The triple layers of protection form a completely seamless cold water basin for the most leak resistant and durable basin in the industry. Other components within the basin, such as the strainer and submerged structural supports, will be constructed of stainless steel. The TriArmor® Corrosion Protection System was specifically designed for evaporative cooling applications and released in 2006 after a decade of extensive R&D and field testing. To date, there are thousands of successful installations in North America. Every basin is leak tested at the factory and warranted against leaks and corrosion for five years.

Application of TriArmor® Corrosion Protection System

EVERTOUGH™ CONSTRUCTION (OPTION)

EVERTOUGH™ Construction combines the most corrosion resistant materials to provide the best value in corrosion protection for most water chemistries. EVERTOUGH™ Construction is backed by a comprehensive 5-year warranty which covers ALL components from the fan to the cold water basin, from louver to louver, including the motor (excluding the coil).

- The basin is constructed with the TriArmor® Corrosion Protection System. The basin is leak tested at the factory and warranted against leaks and corrosion for 5 years.
- Designated steel components above the basin are constructed of heavy-gauge G-235 mill galvanized steel and further protected with a thermosetting hybrid polymer. The thermosetting hybrid polymer has been tested to withstand 6,000 hours in a 5% salt spray without blistering, chipping, or losing adhesion.
- The distribution system is non-corrosive Schedule 40 PVC.
- Other components within the basin, such as the strainer and submerged structural supports, will be constructed of stainless steel.

EVERTOUGH™ Construction Installation

STAINLESS STEEL (OPTION)

Several stainless steel material of construction options are available.

- **WELDED STAINLESS STEEL BASIN**
  All steel panels and structural members of the basin are constructed from stainless steel. Seams between panels inside the basin are welded, providing an advantage over bolted stainless steel basins for minimizing susceptibility to leaks at basin seams. The basin is leak tested at the factory and welded seams are provided with a 5-year, leak-proof warranty.
- **ALL STAINLESS STEEL CONSTRUCTION**
  Steel panels and structural elements are constructed of stainless steel. Seams between panels inside the basin are welded. The basin is leak tested at the factory and welded seams are provided with a 5-year, leak-proof warranty.

Welded Stainless Steel Basin

SEISMIC/WIND UPGRADED STRUCTURE

Select steel panels and structural members are upgraded for higher seismic and wind load applications. An upgraded PCC unit is certified to withstand up to an S_{DS} of 3.10 g and wind loads of up to 140 psf.

PCC
Custom Features & Options

Coil Configurations

BAC offers a large selection of coil configuration options to fulfill any thermal and pressure drop requirements.

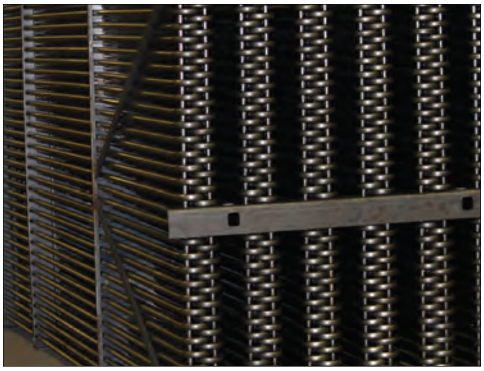
STANDARD SERPENTINE COIL

The standard coil is constructed of continuous lengths of all prime surface steel. The coil is hot-dip galvanized after fabrication (HDGAF) to apply a thick, zinc corrosion barrier over the entire exterior surface of the coil. The coil is designed for low pressure drop. Each coil has a maximum allowable working pressure of 300 psig (2,068 kPa) and is fabricated per ASME B31.5 standards to ensure the highest quality and complete integrity.

Standard Serpentine Coil

STAINLESS STEEL COIL (OPTION)

Coils are available in stainless steel for specialized applications. The coil is designed for low pressure drop with sloping tubes for free drainage of fluid. The coil has a maximum allowable working pressure of 300 psig (2,068 kPa) and is fabricated per ASME B31.5 standards to ensure the highest quality and complete integrity.



Stainless Steel Coil

ASME U DESIGNATOR COIL (OPTION)

BAC offers coils that are certified in accordance with the ASME Boiler and Pressure Vessel Code, Section VIII, Division I. ASME U designated coils are available for projects requiring ASME certified pressure vessels and involve 3rd party inspection and certification. Standard ASME U designated coils are rated at 340 psig (2,344 kPa) maximum allowable working pressure, and they are pneumatically tested at 375 psig (2,586 kPa).

MULTIPLE CIRCUIT COILS/AUXILIARY COOLING CIRCUIT (OPTION)

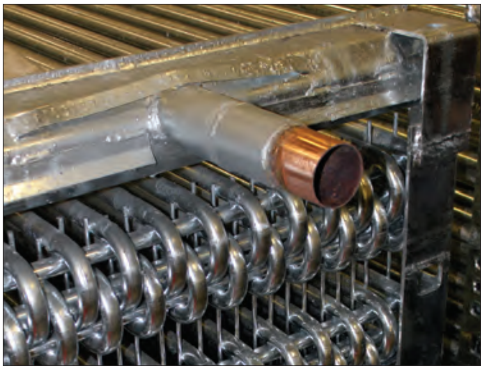
Split coil configurations are available to allow separate process fluid or refrigerant loops through the same unit. Separate loops may be needed for multiple applications requiring different temperature processes or multiple types of process fluids or refrigerants. Multiple refrigerant circuit coils are generally required on halocarbon refrigerant systems, where it is common practice to maintain individual compressor systems. The quantity of circuits, capacity per circuit, and desired connection size and type should be specified when requesting this option.

Multiple Circuit Coil

COPPER SWEAT FITTINGS (OPTION)

Factory installed copper sweat fittings are available to simplify field piping.

NOTE: A Canadian Registration Number (CRN) is required for all pressure vessels over 15 psig entering Canada. The CRN identifies that the design of a boiler, pressure vessel, or fitting has been accepted and registered for use in Canada. CRN is available for all BAC Dual and TriCoil configurations in Canada.



Copper Sweat Fittings

Drive System Options

The fan drive system provides the cooling air necessary to reject unwanted heat from the system to the atmosphere. All BAC drive systems use premium efficient cooling tower duty motors and include BAC's comprehensive 5-year motor and drive warranty. Cooling tower duty motors are specially designed for the harsh environment inside an evaporative condenser and have permanently lubricated bearings, drastically decreasing the maintenance requirement of the motor. BAC belt drive systems are the most durable and maintenance friendly drive systems on the market, including single nut adjustment for belt tensioning.

PCC
Custom Features & Options

STANDARD INDEPENDENT DIRECT DRIVE MOTORS

Standard on PCC-x-0406x and PCC-x-0412x only

The direct drive motor system with TEAO motors is factory mounted, alleviating the need for field installation and includes independent fans and motors for capacity control and redundancy in critical applications. Direct drive systems have the benefit of simplicity by having fewer moving parts, which reduces maintenance requirements and friction loses within the drive system.

STANDARD BALTIDRIVE® POWER TRAIN

The BALTIDRIVE® Power Train utilizes special corrosion resistant materials of construction and state-of-the-art technology to ensure ease of maintenance and reliable year-round performance. This BAC engineered drive system consists of a specially designed powerband and two cast aluminum sheaves located at minimal shaft centerline distances to maximize belt life. When compared to a gear drive system, this specially engineered belt drive system provides many advantages. The BALTIDRIVE® Power Train requires only periodic inspection of components and belt tensioning, which is simple with a single nut adjustment and requires less downtime. Only fan bearing lubrication is required for routine maintenance. Belt drive systems also have the added advantage of being suitable for variable frequency drive (VFD) applications without requiring expensive optional accessories.

BALTIDRIVE® Power Train Used for VFD Applications

INDEPENDENT FAN OPERATION (OPTION)

Two fan 12’ x 18’ PCC models are available with an independent fan. The option consists of one fan motor and drive assembly for each fan to allow independent operation, adding an additional step of fan cycling for capacity control. This option ensures complete redundancy for the fan and motor system.

VIBRATION CUTOUT SWITCH (OPTION)

A factory mounted vibration cutout switch is available to effectively protect against rotating equipment failure. BAC can provide either a mechanical or solid-state electronic vibration cutout switch in a NEMA 4 enclosure to ensure reliable protection. Additional contacts can be provided on either switch type to activate an alarm. Remote reset capability is also available on either switch type.

Maintenance Options

BAC provides maintenance packages to help make maintaining the PCC Evaporative Condenser as easy as possible. Choose the package that will best meet your needs. A properly maintained evaporative condenser will increase its life.

MAINTENANCE PACKAGES

Package Type	Extended Lubrication Lines	Davit Arm With a Mount	Bearing Greaser	Basin Sweeper Piping
Standard	✓			
Enhanced	✓	✓*	✓	
Superior	✓	✓*	✓	✓

Standard Maintenance Package: Extended Lubrication Lines

STANDARD

The Standard maintenance package includes extended lubrication lines to the fan shaft bearings. Fittings are located next to the access door.

*** NOTE:** The Enhanced option comes with a motor removal mount per cell and **one** davit arm. The Superior option comes with a motor removal mount and davit arm **per** cell.

ENHANCED (OPTION)

Customer Valued

The Enhanced maintenance package includes all items in the standard package plus:

- **MOTOR REMOVAL MOUNT** – A motor removal mount per cell with a single arm to facilitate motor replacement is included.
- **AUTOMATIC BEARING GREASER** – Automatic Bearing Greasers come with BAC recommended grease, compatible with all BAC bearings and provide a continuous supply of new grease to eliminate the need for periodic bearing maintenance. Life of the bearing is extended by eliminating under and over greasing problems. Positive displacement pumps allow for mounting up to 30 feet away from the bearing. When the grease pouch is nearly depleted, three months to a year depending on bearing size, simply replace the pouch.

Motor Removal Davit Arm with Motor Removal Mount

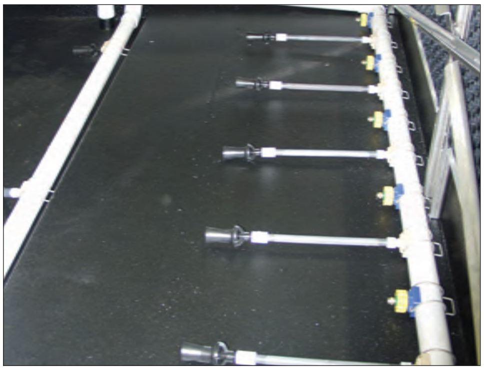
PCC
Custom Features & Options

SUPERIOR (OPTION)

The Superior maintenance package includes extended lubrication lines as described in the standard package as well as:

- **MOTOR REMOVAL SYSTEM** – One motor removal mount and davit arm per cell.
- **AUTOMATIC BEARING GREASER** – Automatic Bearing Greasers come with BAC recommended grease, compatible with all BAC bearings and provide a continuous supply of new grease to eliminate the need for periodic bearing maintenance. Life of the bearing is extended by eliminating under and over greasing problems. Positive displacement pumps allow for mounting up to 30 feet away from the bearing. When the grease pouch is nearly depleted, three months to a year depending on bearing size, simply replace the pouch.
- **BASIN SWEEPER PIPING** – Basin sweeper piping is an effective method of eliminating sediment that may collect in the basin. A complete piping system, including nozzles, is provided in the basin to connect to side stream filtration equipment (provided by others). For more information on filtration systems, consult "Filtration Guide" found on **page J241**.

Automatic Bearing Greaser



Basin Sweeper Piping

Access Options

BAC provides a broad offering of access packages. Our evaporative equipment is designed to be easily maintained for sustaining capacity over a longer life. All BAC platforms and ladders are OSHA and IBC compliant to ensure personnel safety and code compliance.

ACCESS PACKAGES

Package Type	Inclined Ladder	Ladder	Handrails	Platform
Basic	✓			
Basic Plus		✓	✓	
Enhanced		✓		✓

NOTE: Platforms, ladders, handrails, safety gates, and safety cages can be added at the time of order or as an aftermarket item. Safety cages and safety gates are available with the Basic Plus and Enhanced package options.

BASIC (OPTION)

The Basic assess package includes an inclined ladder extending from the base of the unit to the access door, providing safe access with minimal space requirements. All components are designed to meet OSHA requirement.

BASIC PLUS (OPTION)

The Basic Plus access package includes a ladder from the base of the unit to the fan deck and handrails to provide safe access to the top of the unit. The specially designed handrail packages are secured for compact shipping in the cold water basin to minimize shipping costs and are ready for field assembly.

Customer Valued

ENHANCED (OPTION)

The Enhanced access package includes an access door platform and ladder to allow access to the unit when installed on elevated supports. This option allows for safe access to the unit, as well as a working platform to stage tools for maintenance. The platform is pre-assembled and pre-fitted at the factory to ensure that every component will fit and function exactly as described. The platform is rigged easily in the field with minimum fasteners and drastically reduces the time required for rigging external access platforms.

Enhanced Access Package

PCC
Custom Features & Options

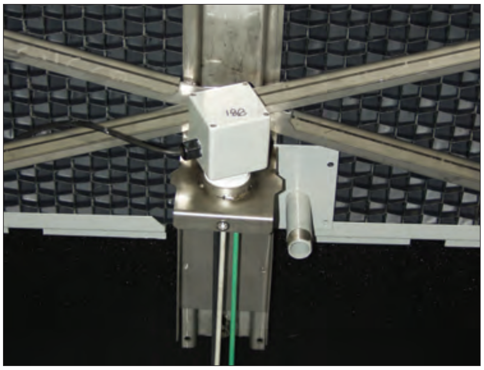
Basin

The spray water collects in the basin and is then pumped back over the condensing coil. During operation, the PCC basin eliminates any stagnant water zones, which are susceptible to biological growth.

Mechanical Water Level Control

STANDARD MECHANICAL WATER LEVEL CONTROL

Mechanical make-up valves must operate continuously in the moist and turbulent environment within evaporative cooling equipment. Due to this environment, the operation of the valve must be simple and the valve must be durable. BAC's high quality mechanical water level control assembly is standard with all units and has been specially designed to provide the most reliable operation while being easy to maintain. This accessory is omitted for remote sump applications.



Electric Water Level Control

ELECTRIC WATER LEVEL CONTROL (OPTION)

BAC's Electric Water Level Control (EWLC) is a state-of-the-art, conductivity actuated, probe type liquid level control. The hermetically sealed EWLC is engineered and manufactured specifically for use in evaporative cooling systems and is equipped with an error code LED to indicate status, including when the water and/or probes are dirty. The EWLC option replaces the standard mechanical make-up valve, and includes a slow closing, solenoid activated valve in the make-up water line to minimize water hammer. EWLC is recommended when more precise water level control is required and in areas that experience sub-freezing conditions.

LOW AND HIGH LEVEL ALARM FLOAT SWITCHES (OPTION)

Low and high level alarm float switches are available to provide added control to your equipment operation. Level alarms can alert operators to an abnormal operating condition to ensure the highest system efficiency with minimal water usage.

BASIN HEATERS (OPTION)

Evaporative cooling equipment exposed to below freezing ambient temperatures require protection to prevent freezing of the water in the basin when the unit is idle. Factory-installed electric immersion heaters, which maintain 40°F (4.4°C) water temperature, are a simple and inexpensive way of providing such protection.

Basin Heater

HEATER kW DATA

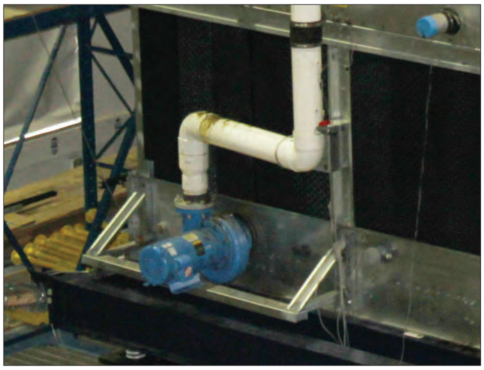
Model Number	-20°F (-28.9°C) Ambient Heaters		Model Number	-20°F (-28.9°C) Ambient Heaters	
	Number of Heaters	kW per Heater		Number of Heaters	kW per Heater
PCC-x-0406x	1	3	PCC-x-2418x	2	24
PCC-x-0412x	1	6	PCC-x-2420x	2	24
PCC-x-7409x	1	8	PCC-x-1024x	2	14
PCC-x-7418x	1	15	PCC-x-1224x	2	16
PCC-x-1012x	1	14	PCC-x-1236x	2	24
PCC-x-1212x	1	16	PCC-x-1240x	2	24
PCC-x-1218x	1	24	PCC-x-2424x	4	16
PCC-x-1220x	1	24	PCC-x-2436x	4	24
PCC-x-2012x	2	24	PCC-x-2440x	4	24
PCC-x-2412x	2	16			

NOTE: This table is based on 460V/3 phase/60 Hz power.

Water Distribution System

STANDARD SPRAY WATER PUMP

The PCC water distribution system comes standard with an integral spray water pump sized to distribute the recirculating water over the coil maximizing capacity. The patented BAC 360 Spray Nozzles are non-clog, ensure even flow over the coil area, and are simple to remove for maintenance.



Standard Spray Water Pump

Shipping and Rigging

BAC units are factory-assembled to ensure uniform quality with minimum field assembly. Each unit has been designed with rigging and assembly in mind and includes features to minimize the number of tools required and installation time.

PCC
Custom Features & Options

INTERLOK™ SYSTEM

The InterLok™ System is a self-aligning casing/basin joint that makes assembly easier. The alignment of the casing and basin joint determines the leak resistance of the joint. With the InterLok™ System, the joint is now inside the unit, therefore eliminating the possibility of water leakage at these seams.

RIGGING GUIDES

The PCC is designed with a robust structural frame around the coil casing to assure square-ness during shipping and rigging. The lower section is equipped with field installed rigging pins that reduces alignment time to less than 15 minutes.

InterLok™ System

KNOCKDOWN UNITS (OPTION)

Knockdown units are available for jobs where access to the evaporative condenser location is limited by elevators, doorways, or similar obstacles, where lifting methods impose very strict weight limits, or where the shipping cost of a fully assembled unit is excessive. All materials of construction and design features are the same as those of a factory assembled unit. Welded stainless steel basins and TriArmor® Corrosion Protection System basins are excluded due to the need for in-plant assembly.

CONTAINERIZED UNITS (OPTION)

The PCC 4’x6’, 4’x12’, 7.4’x9’, and 7.4’x18’ can be containerized in a standard shipping container for easy export, allowing for the lowest transportation cost possible when providing high quality BAC units to all parts of the world. Up to 500 nominal R-22 tons in a single 40’ shipping container.

PCC-x-0406x, PCC-x-0412x, PCC-x-0709x, and PCC-x-0718x Can Be Containerized

Sound Options

Recognition of the importance of sound restriction is growing and can be a very important design criterion for any project. BAC maintains the widest selection of sound mitigating options in the market and can provide the most cost effective option to meet any requirement.

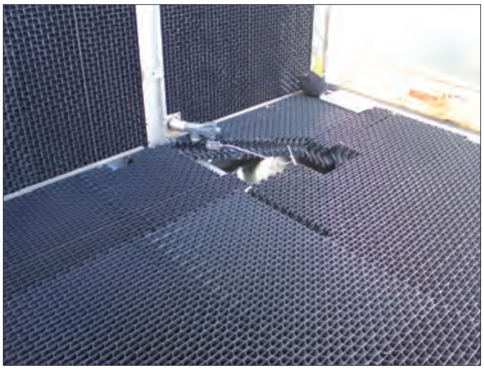
- **STANDARD FAN**
  The fan provided for all PCC Evaporative Condensers is selected to optimize low sound levels and maximize thermal performance.

- **LOW SOUND FAN** (OPTION)
  The Low Sound Fan option reduces sound up to 8 dBA. Adding a high solidity fan allows for decreased fan speed, which proportionally decreases sound levels.

- **WHISPER QUIET FAN** (OPTION)
  The Whisper Quiet Fan reduces sound up to 15 dBA. This single piece, high solidity fan is made from chemical resistant fiber reinforced polyester (FRP) and comes standard with blade leading protection. As a single piece fan, the non-corrosive blades are permanently pitched and require minimal maintenance.

- **WATER SILENCERS** (OPTION)
  Water silencers are available to reduce the sound of falling water inherent in induced draft counterflow evaporative condensers. When utilized with one of BAC's Low Sound Fans, the sound contribution due to water noise can be reduced to negligible levels.

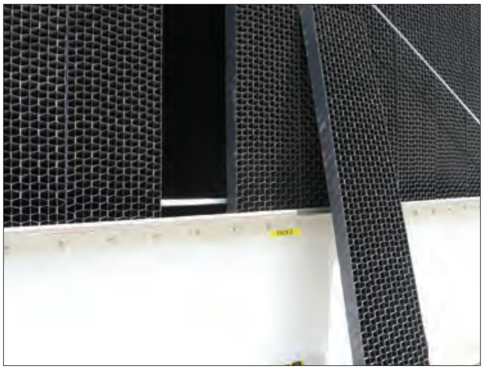

Low Sound Fan


Water Silencers

Air Intake

In an evaporative condenser, airborne debris can be entrained in the water through the unit's air intake. Reducing the amount of debris that enters the condenser lowers maintenance requirements and helps to maintain thermal efficiency.

- **COMBINED INLET SHIELDS**
  The Combined Inlet Shields' (CIS) bent flow path blocks sunlight from the basin and acts as a screen to prevent debris from entering the unit. These benefits result in a significant reduction in algae growth, debris accumulation, and scale build-up. CIS are constructed from corrosion and UV resistant PVC and are installed in easy to handle sections to facilitate removal, inspection, and replacement. The use of CIS results in lower maintenance costs and ease of maintenance over the life of the unit.


Combined Inlet Shields

PRODUCT SPOTLIGHT:

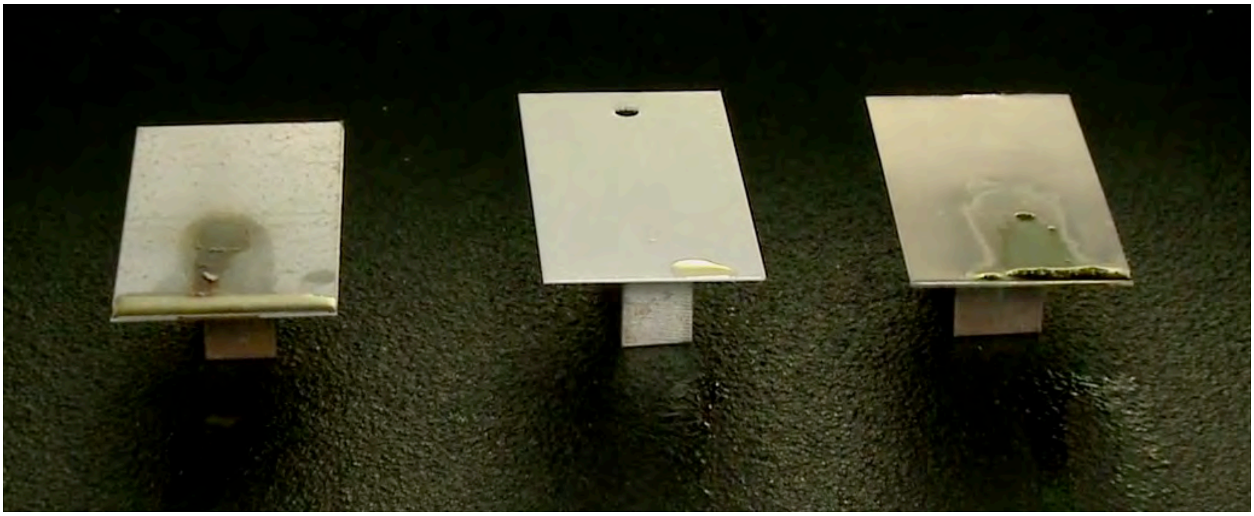
Using a TriArmor Basin to Scrub Emergency Exhaust

Does your local code official insist on having an ammonia scrubber in case of emergency release through the exhaust fans in the engine room? Are you replacing an existing condenser or cooling tower that is also used to scrub the emergency exhaust?

If so, did you know that a basin protected with the TriArmor® Corrosion Protection System can be used to scrub engine room exhaust or an emergency ammonia release?

TriArmor® Corrosion Protection System is impervious to corrosive chemicals. Check out the BAC TriArmor® Corrosion Protection System video at: www.BaltimoreAircoil.com/TriArmor. When ammonia reacts with water the result is ammonium hydroxide which normally strips the zinc from a G-235 basin. As seen in the image captured below, the TriArmor basin can withstand a hydrochloric acid attack, which is equally as corrosive. The TriArmor basin will safely contain the ammonium hydroxide until disposed.

NOTE: Please follow your local, state and federal guidelines to dispose of the ammonium hydroxide.



G-235 Galvanized Steel, Thermosetting Hybrid Polymer, Stainless Steel and the TriArmor® Corrosion Protection System Hydrochloric Acid Testing

Work with your local code official, design engineer, and BAC Representative to determine if you have the proper conditions for this time and money saving scenario.

For more information on TriArmor® Corrosion Protection System, see **page J257**.

VCA Evaporative Condenser

TABLE OF CONTENTS

When your application calls for a workhorse, turn to the VCA. From BAC's InterLok™ System to align the coil casing and basin to the pre-assembled platform packages and unrestricted access to the motors, bearings, and fan, the VCA incorporates features which benefit the installer, operator, end-user, and owner. A tonnage range of 87 - 1,433 R-717 tons and compliance with the wind and seismic requirements of the International Building Code gives added peace of mind and makes the VCA the industry leader in the forced draft, axial fan category.

TriArmor® Corrosion Protection System

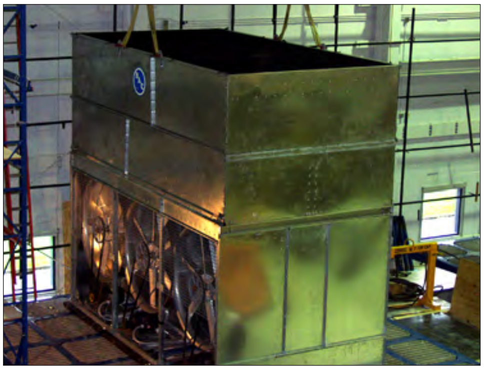
EVERTOUGH™ CONSTRUCTION

BAC® IBC Compliant

VCA Benefits

Peace of Mind – Flexibility

- Independent fan motors are standard
  - Provide redundancy and options for capacity control
  - For replacement opportunities where existing wiring must remain, the VCA can be supplied with a dual motor option
- Meets wind and seismic requirements of the International Building Code through shake table testing
- Bearings selected for a minimum L_{10} life of 94,000 hours
- Premium efficient motors are standard and ready for VFD's now or later



Shake Table Tested VCA

Installation Efficiency

- BAC's InterLok™ System aligns the coil casing and the basin to expedite rigging
- Pre-assembled platform package reduces installation time (option)
- Single point wiring simplifies field installation (option)

BAC's InterLok™ System

Industrial Grade Construction

- Enhanced longevity with a variety of durable materials of construction (see **page E76** for details)
- Fully welded, not bolted, stainless steel basins (option)
- All coils are fabricated to ASME B31.5 standards

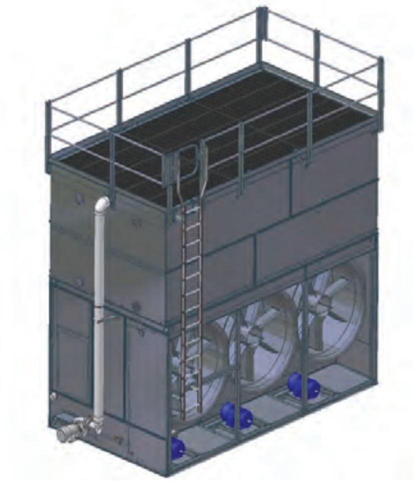
Serviceability

- Two large access doors are standard with every side blow VCA, one included on end blow units
- A hinged, internal partition door is standard
- Entire drive system is located at the base of the unit for easy and unrestricted access to the motors, bearings, and fans
- Extended lubrication lines standard
- A water distribution system that makes service of the nozzles, spray branches and headers possible without the need for tools
- Multiple access options to meet your service and site requirements (all OSHA compliant)

Large Access Door for Easy Maintenance

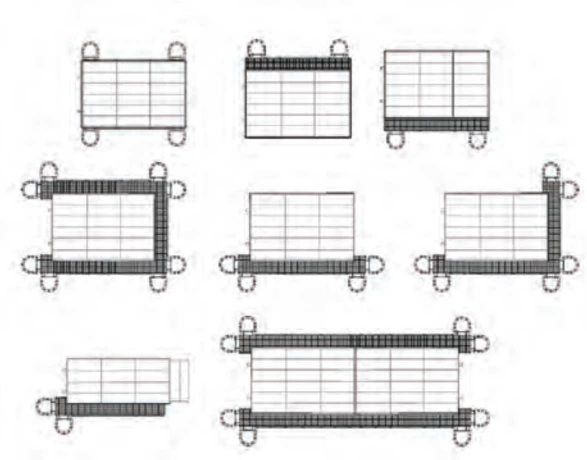
Variety of Access Options

- The VCA has the most access options available in the industry
- Preassembled modular external access packages
- Widest variety of external access packages
  - Perimeter handrails only
  - Flush platform
  - Offset platform
- Assembled at the manufacturing plant to verify fit
- Eliminates potential for missing parts and reduces installation time
- All BAC platforms are available with safety gates and safety cages and are OSHA compliant



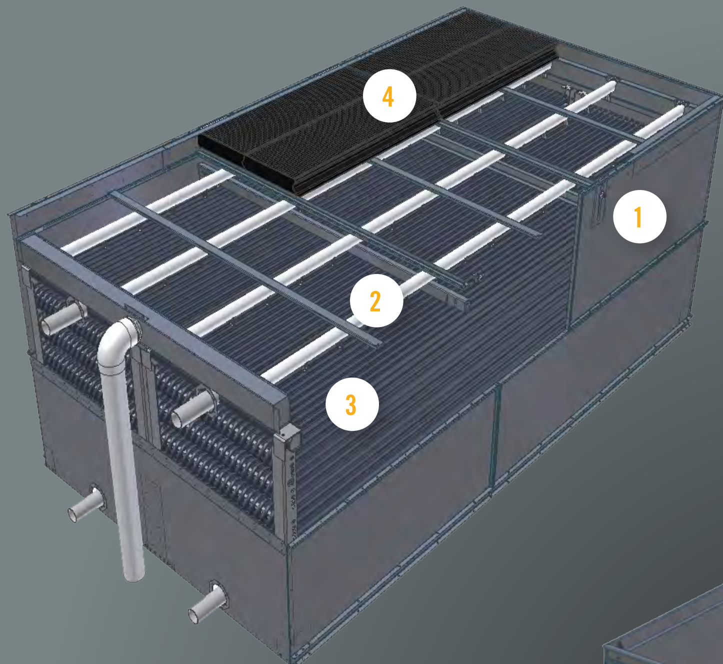
Perimeter Handrails Only

Flush Platform

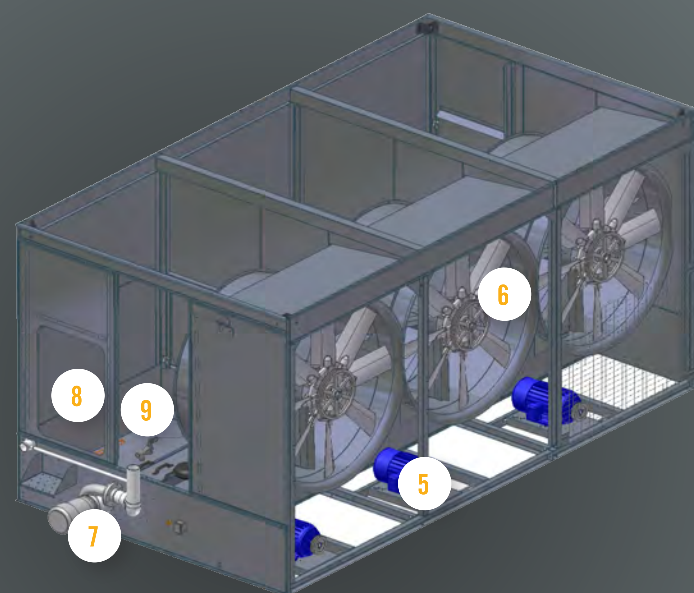


Access Ladder & Platform Options

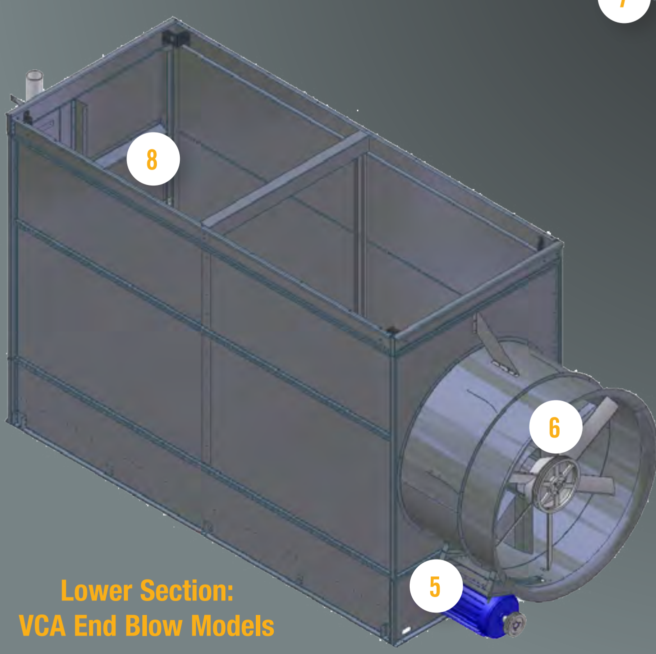
VCA Construction Details



Upper Section



Lower Section:
VCA Side Blow Models



Lower Section:
VCA End Blow Models

1 Heavy-Duty Construction

- G-235 (Z700 metric) mill galvanized steel panels

2 Water Distribution System

- Schedule 40 PVC spray branches
- Large orifice, non-clog, 360 Spray Nozzles
- Nozzle and spray branches grommeted for easy maintenance

3 Coil

- Continuous serpentine, steel tubing
- Hot-dip galvanized after fabrication (HDGAF)
- Maximum allowable working pressure is 300 psig (2,068 kPa)
- Fabricated per ASME B31.5 standards
- Orders shipping into Canada are supplied with a CRN

4 Drift Eliminators

- Recyclable polyvinyl chloride (PVC)
- Impervious to rot, decay, and biological attack
- Flame spread rating of 5 per ASTM E84
- Assembled in easy to handle sections

5 Independent Fan Drive System

- Premium efficient/VFD duty fan motors are standard
- 5-year motor and drive warranty
- Heavy duty bearings, with minimum L_{10} 94,000 hours
- Extended lubrication lines
- Premium quality, solid-backed, multi-groove belt

6 Low Horsepower Axial Fan(s)

- Corrosion resistant

7 Recirculating Spray Water Pump

- Close coupled, bronze fitted centrifugal pump
- Totally enclosed fan cooled (TEFC) motor
- Bleed line with metering valve installed from pump discharge to overflow

8 Access Doors

- Interior of unit is easily accessible
- Two 30” x 44” access doors are standard on side blow units
- One 30” x 44” access door is standard on end blow units

9 Strainer (NOT SHOWN)

- Anti-vortexing design to prevent air entrainment

VCA
Custom Features & Options

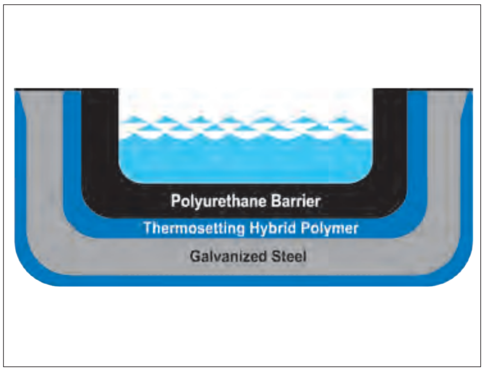
Materials of Construction

Determining the appropriate material of construction for a project depends on several factors, including water quality, climate and environmental conditions, availability of time and manpower for maintenance, unit lifetime requirements, and budget. BAC provides the widest variety of material of construction options in the industry and has the ability to provide a solution to meet all conditions and budgets.

Standard Construction Installation

STANDARD CONSTRUCTION

G-235 mill galvanized steel is the heaviest commercially available galvanized steel, universally recognized for its strength and corrosion resistance. To assure long life, G-235 mill galvanized steel panels and structural members are used as the standard material of construction. The standard construction has been seismically verified by shake table testing in an independent laboratory up to an S_{DS} of 1.60g and can withstand wind loads of up to 90 psf, proving its construction is designed for extreme durability. With proper maintenance and water treatment, G-235 galvanized steel will provide an excellent service life under the operating conditions normally encountered in refrigeration and industrial applications.



TriArmor® Corrosion Protection System Triple Layer Protection of the Basin

Customer Valued

TRIARMOR® CORROSION PROTECTION SYSTEM (OPTION)

The TriArmor® Corrosion Protection System consists of heavy gauge G-235 mill galvanized steel panels fully encapsulated by a thermosetting hybrid polymer and further protected by a polyurethane barrier applied to all submerged surfaces of the cold water basin. The triple layers of protection form a completely seamless cold water basin for the most leak resistant and durable basin in the industry. Other components within the basin, such as the strainer and submerged structural supports, will be constructed of stainless steel. The TriArmor® Corrosion Protection System was specifically designed for evaporative cooling applications and released in 2006 after a decade of extensive R&D and field testing. To date, there are thousands of successful installations in North America. Every basin is leak tested at the factory and warranted against leaks and corrosion for 5 years.

Application of TriArmor® Corrosion Protection System

EVERTOUGH™ CONSTRUCTION (OPTION)

EVERTOUGH™ Construction combines the most corrosion resistant materials to provide the best value in corrosion protection for most water chemistries. EVERTOUGH™ Construction is backed by a comprehensive 5-year warranty which covers ALL components from the fan to the cold water basin, from louver to louver, including the motor (excluding the coil).

Specifically, the following materials are used in EVERTOUGH™ Construction:

- The basin is constructed with the TriArmor® Corrosion Protection System. The basin is leak tested at the factory and warranted against leaks and corrosion for 5 years.
- Designated steel components above the basin are constructed of heavy-gauge G-235 mill galvanized steel and further protected with a thermosetting hybrid polymer.
- The distribution system is non-corrosive Schedule 40 PVC.
- Other components within the basin, such as the strainer and submerged structural supports, will be constructed of stainless steel.

EVERTOUGH™ Construction Installation

THERMOSETTING HYBRID POLYMER (OPTION)

A thermosetting hybrid polymer, used to extend equipment life, is applied to select G-235 mill galvanized steel components of the unit. The polymerized coating is baked onto the G-235 mill galvanized steel and creates a barrier to the already corrosion resistant galvanized steel. The thermosetting hybrid polymer has been tested to withstand 6,000 hours in a 5% salt spray without blistering, chipping, or losing adhesion.

STAINLESS STEEL (OPTION)

Several stainless steel material of construction options are available.

- **WELDED STAINLESS STEEL BASIN**
  All steel panels and structural members of the basin are constructed from stainless steel. Seams between panels inside the basin are welded, providing an advantage over bolted stainless steel basins for minimizing susceptibility to leaks at basin seams. The basin is leak tested at the factory and welded seams are provided with a 5-year, leak-proof warranty.
- **ALL STAINLESS STEEL CONSTRUCTION**
  Steel panels and structural elements are constructed of stainless steel. Seams between panels inside the basin are welded. The basin is leak tested at the factory and welded seams are provided with a 5-year leak-proof warranty.

Welded Stainless Steel Basin

VCA
Custom Features & Options

Coil Configurations

BAC offers a large selection of coil configuration options to fulfill any thermal and pressure drop requirements.

STANDARD SERPENTINE COIL

The standard cooling coil is constructed of continuous lengths of all prime surface steel. The coil is hot-dip galvanized after fabrication (HDGAF) to apply a thick, zinc corrosion barrier over the entire exterior surface of the coil. The coil is designed for low pressure drop with sloping tubes for free drainage of fluid. Each coil has a maximum allowable working pressure of 300 psig (2,068 kPa) and is fabricated per ASME B31.5 standards to ensure the highest quality and integrity.

Standard Serpentine Coil

STAINLESS STEEL COIL (OPTION)

Coils are available in stainless steel for specialized applications. The coil is designed for low pressure drop with sloping tubes for free drainage of fluid. Each coil has a maximum allowable working pressure of 300 psig (2,068 kPa) and is fabricated per ASME B31.5 standards to ensure the highest quality and integrity.

ASME U DESIGNATOR COIL (OPTION)

BAC offers coils that are certified in accordance with the ASME Boiler and Pressure Vessel Code, Section VIII, Division I. ASME U designated coils are available for projects requiring ASME certified pressure vessels and involve 3rd party inspection and certification. Standard ASME U designated coils are rated at 340 psig (2,344 kPa) maximum allowable working pressure, and they are pneumatically tested at 375 psig (2,586 kPa).

Standard Serpentine Coil

NOTE: A Canadian Registration number (CRN) is required for all pressure vessels over 15 psig entering Canada. The CRN identifies that he design of a boiler, or fitting has been accepted and registered for use in Canada. CRN is available for all standard coil configurations shipping into Canada.

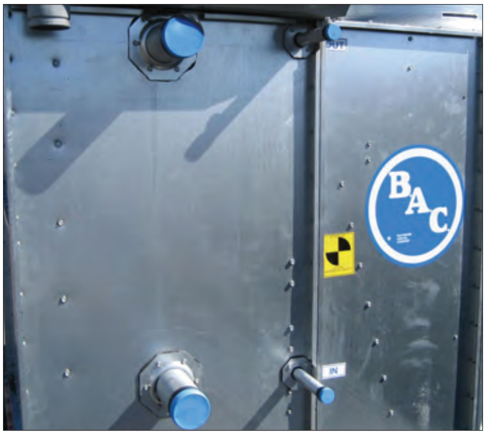
EXTENDED SURFACE COIL (OPTION)

Coils are available with up to all rows finned at 5 fins per inch for seasonal wet/dry operation. The fins increase the surface area of the coil, therefore increasing the condensing capability. The coil is hot-dip galvanized after fabrication (HDGAF) to apply a thick, zinc corrosion barrier over the entire exterior surface of the coil and fins. BAC coils are designed for low pressure drops and to be completely drainable with sloping tubes for free drainage of fluid. Each coil has a maximum allowable working pressure of 300 psig (2,068 kPa) and is fabricated per ASME B31.5 standards to ensure the highest quality and integrity.

Extended Surface Coil

MULTIPLE CIRCUIT COILS/AUXILIARY COOLING CIRCUIT (OPTION)

Split coil configurations are available to allow separate process fluid or refrigerant loops through the same unit. Separate loops may be needed for multiple applications requiring different temperature processes or multiple types of process fluids or refrigerants. Multiple refrigerant circuit coils are generally required on halocarbon refrigerant systems, where it is common practice to maintain individual compressor systems. The quantity of circuits, capacity per circuit, and desired connection size and type should be specified when requesting this option.



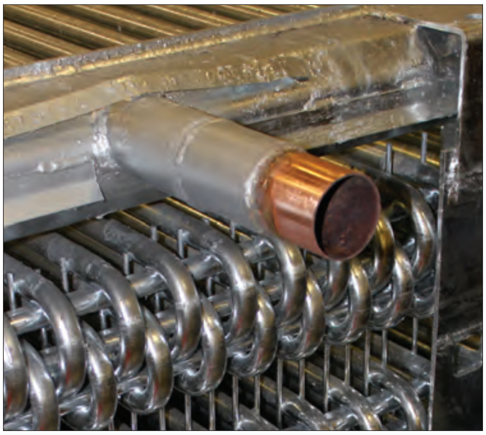
Multiple Circuit Coil

SUBCOOLING COILS (OPTION)

Subcooling coils are available for those halocarbon refrigerant installations where subcooled refrigerant is specified, or where the pressure drop or a vertical rise in the liquid line is great enough to cause excessive flashing. Standard subcooling coil sections provide approximately 10ºF (5.6ºC) of subcooling at standard conditions. Subcooling sections are approximately 7” high and are mounted between the coil and basin sections. Coils are hot-dip galvanized after fabrication and have a maximum allowable working pressure of 300 psig (2,068 kPa).

COPPER SWEAT FITTINGS (OPTION)

Factory installed copper sweat fittings are available to simplify field piping.



Copper Sweat Fitting

VCA
Custom Features & Options

Drive System Options

The fan drive system provides the cooling air necessary to reject unwanted heat from the system to the atmosphere. All BAC drive systems use premium efficient cooling tower duty motors and include BAC's comprehensive 5-year motor and drive warranty. Cooling tower duty motors are specially designed for use in evaporative condenser applications and have permanently lubricated bearings, drastically decreasing the maintenance requirement of the motor. BAC belt drive systems are the most durable and maintenance friendly drive systems on the market, including single nut adjustment for belt tensioning to make belt tensioning simple.

INDEPENDENT FAN DRIVES

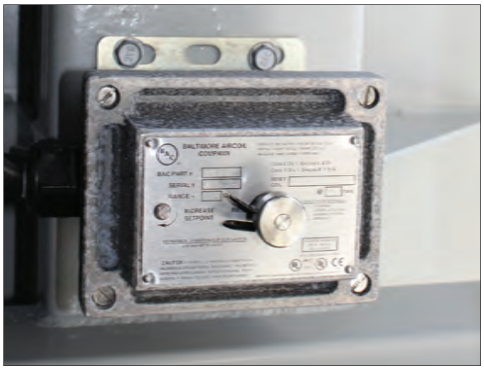
Independent fan motors are standard on every VCA model providing redundancy and options for capacity control. The fans, motors, and drive system of the VCA are located outside the discharge air stream of the unit, protecting them from moisture, condensation, and icing while facilitating maintenance. The fan drive system consists of a specially designed belts, taper lock sheaves, minimum L_{10} bearing life of 94,000 hours and dedicated premium efficient cooling tower duty motor to provide maximum performance. Extended lubrication lines are standard for lubrication of the fan shaft bearings.


Independent Fan Drives

Customer Valued

VIBRATION CUTOUT SWITCH (OPTION)

A factory mounted vibration cutout switch is available to effectively protect against rotating equipment failure. BAC can provide either a mechanical or solid-state electronic vibration cutout switch in a NEMA 4 enclosure to ensure reliable protection. Additional contacts can be provided on either switch type to activate an alarm. Remote reset capability is also available on either switch type.


Vibration Cutout Switch

Basin

The spray water collects in the basin which is pumped back over the condensing coil. The hygienic basin is sloped toward the pump suction. During operation, this design eliminates any stagnant water zones, which are susceptible to biological growth.


Mechanical Water Level Control

STANDARD MECHANICAL WATER LEVEL CONTROL

Mechanical make-up valves must operate continuously in the moist and turbulent environment existing within evaporative cooling equipment. Due to this environment, the operation of the valve must be simple, and the valve must be durable. BAC's high quality mechanical water level control assembly is standard with all units, and has been specially designed to provide the most reliable operation while being easy to maintain. This accessory is omitted for remote sump applications.

ELECTRIC WATER LEVEL CONTROL (OPTION)

BAC's Electric Water Level Control (EWLC) is a state-of-the-art, conductivity actuated, probe type liquid level control. The hermetically sealed EWLC is engineered and manufactured specifically for use in evaporative cooling systems and is equipped with an error code LED to indicate status, including when the water and/or probes are dirty. The EWLC option replaces the standard mechanical make-up valve, and includes a slow closing, solenoid activated valve in the make-up water line to minimize water hammer. EWLC is recommended when more precise water level control is required and in areas that experience sub-freezing conditions.


Electric Water Level Control

Customer Valued

BASIN SWEEPER PIPING (OPTION)

Basin sweeper piping is an effective method of reducing sediment that may collect in the basin of the unit. A complete piping system, including nozzles, is provided in the basin to connect to side stream filtration equipment (provided by others). For more information on filtration systems, consult "Filtration Guide" found on **page J241.**

VCA
Custom Features & Options

BASIN HEATERS (OPTION)

Evaporative cooling equipment exposed to below freezing ambient temperatures require protection to prevent freezing of the water in the basin when the unit is idle. Factory-installed electric immersion heaters, which maintain 40°F (4.4°C) water temperature, are a simple and inexpensive way of providing such protection.

HEATER kW DATA

Model Number	0°F (-17.8°C) Ambient Heaters		-20°F (-28.9°C) Ambient Heaters	
	Number of Heaters	kW per Heater	Number of Heaters	kW per Heater
VCA-122A to VCA-191A	1	6	1	8
VCA-174A to VCA-259A	1	8	1	10
VCA-261A to VCA-322A	1	8	1	12
VCA-323A to VCA-466A	1	12	1	18
VCA-300A to VCA-512A	1	8	1	10
VCA-460A to VCA-779A	1	12	1	15
VCA-662A to VCA-1024A	2	8	2	10
VCA-S700 to VCA-S884A	2	8	2	10
VCA-920A to VCA-1558A	2	12	2	15
VCA-302A to VCA-661A	1	10	1	15
VCA-526A to VCA-1010A	1	15	1	18
VCA-605A to VCA-1321A	2	10	4	20
VCA-S870A to VCA-S1204A	2	10	2	15
VCA-930A to VCA-2019AA	2	15	2	18

Basin Heater

NOTE: This table is based on 460V/3 phase/60 Hz power.

LOW AND HIGH LEVEL ALARMS (OPTION)

Low and high level alarm float switches are available to provide added control to your equipment operation. Level alarms can alert operators to an abnormal operating condition to ensure the highest system efficiency with minimal water usage.

Water Distribution System

STANDARD SPRAY WATER PUMP

The VCA water distribution system comes standard with an integral spray water pump sized to distribute the recirculating water over the coil, maximizing capacity. The patented BAC 360 Spray Nozzles are non-clog, ensure even flow over the coil area, and are simple to remove for maintenance.

REDUNDANT PUMPS (OPTION)

An optional secondary spray pump is available. This pump can be switched easily and maintained while the unit remains in operation.

Spray Water Distribution System

Shipping and Rigging

BAC units are factory-assembled to ensure uniform quality with minimum field assembly. Each unit has been designed with rigging and assembly in mind and includes features to minimize the number of tools required and installation time.

Customer Valued

INTERLOK™ SYSTEM

The coil section self aligns with the basin section. This feature significantly reduces the time required to rig the VCA.

KNOCKDOWN UNITS (OPTION)

Knockdown units are available for jobs where access to the evaporative condenser location is limited by elevators, doorways, or similar obstacles, where lifting methods impose very strict weight limits, or where the shipping cost of a fully assembled condenser is excessive. All materials of construction and design features are the same as those of a factory assembled unit. Welded stainless steel basins and TriArmor® Corrosion Protection System basins are excluded due to the need for in-plant assembly.

InterLok™ System

VCA
Custom Features & Options

Air Intake Options

In an evaporative condenser, airborne debris can be trapped in the water through the unit's air intake. The VCA has several options for air intake accessories that prevent debris from entering the system and maintain even unobstructed flow through the unit. Reducing the amount of debris that enters the unit lowers maintenance requirements and helps to maintain thermal efficiency.

AIR INTAKE SCREENS

Standard 1" x 1" wire mesh screen is factory-installed over the air intake to prevent debris from entering the unit

SOLID BOTTOM PANELS (OPTION)

Factory-installed bottom panels are required when intake air is ducted to the unit.

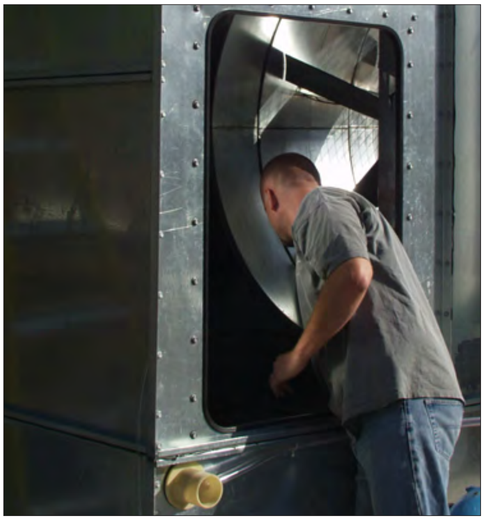
Air Intake Screen

Access Options

BAC's evaporative equipment is designed to be easily maintained for sustaining capacity over a longer life. All access options are meet OSHA requirements to ensure personnel safety and code compliance.

OVERSIZED ACCESS DOOR(S)

Oversized access door(s) are standard on the VCA. Each measures 30" x 44" and a step for easier access is provided for each door.



Oversized Access Door

Customer Valued

PRE-ASSEMBLED EXTERNAL PLATFORM, LADDER, AND SAFETY CAGE (OPTION)

Every external platform module is pre-assembled at the factory to ensure that every component will fit and function exactly as described. The platform will attach quickly in the field with minimal fasteners. Platforms can be added at the time of order or as an aftermarket item. All components are designed to meet OSHA requirements. Platforms, ladders, and safety cages can be added at the time of order or as an aftermarket item.

Pre-Assembled External Platform

Series V Evaporative Condenser

TABLE OF CONTENTS

The VC1, VCL, and VC1-C combine to complete BAC's Series V product line. Together, they provide solutions to some of the most difficult evaporative cooling scenarios. With both indoor and outdoor applications possible the VCL also accommodates low height restrictions. The VC1-C is ideal for exporting, as it fits into standard shipping containers.

iiar®
International Institute of Ammonia Refrigeration

RETA® EDUCATION • EFFICIENCY • DEVELOPMENT

BAC's Series V: Confidence & Reliability

7 to 1,140 R-717 Tons in a Single Unit

- Low Sound by Design
- Indoor & Outdoor Installations; Easily Hidden
- Split Coils for Multiple Compressors
- Export Units
- Single Piece Shipping & Rigging

Series V Benefits

Easy Maintenance

- BAC 360™ Spray Nozzles are non-clogging, reducing maintenance costs, and ensuring efficient equipment operation
- Fans, motors, and drive system are located outside of the moist discharge air stream, protecting them from moisture, condensation, and icing while facilitating maintenance
- All moving parts are located near the base of the unit, within easy reach for cleaning, lubrication, or adjustments

Flexible Installation

- Low profile VCL fits well into mechanical equipment rooms with low ceilings and are easily hidden behind louvered walls on buildings
- Series V models have centrifugal fans, suitable for applications where external duct work and other sources of external static pressure exist
- VC1, VCL, and VC1-C can accommodate indoor applications

Economical Export

- VC1-C models are sized specifically to fit into standard dry van containers, minimizing ocean freight costs for export shipments

BAC 360 Spray Nozzles

Moving Parts Located Near Base of Unit

VC1-C Models Are Sized for Export

Redundancy and Reliability

- Premium efficient/inverter duty motors are standard
- BALTIGUARD™ Fan System provides redundancy and energy savings by providing a pony motor (option)

Centrifugal Fans with Inherently Low Sound Characteristics

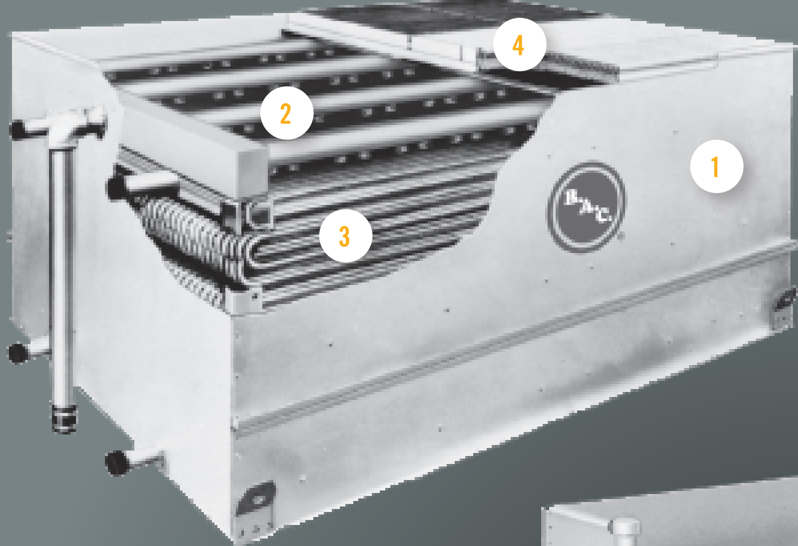
Low Sound

- Centrifugal fans have inherently low sound characteristics
- Factory designed sound attenuation is available for both the air intake and discharge
- Particularly sound sensitive areas can be accommodated by facing the blankoff panel to the sound sensitive direction

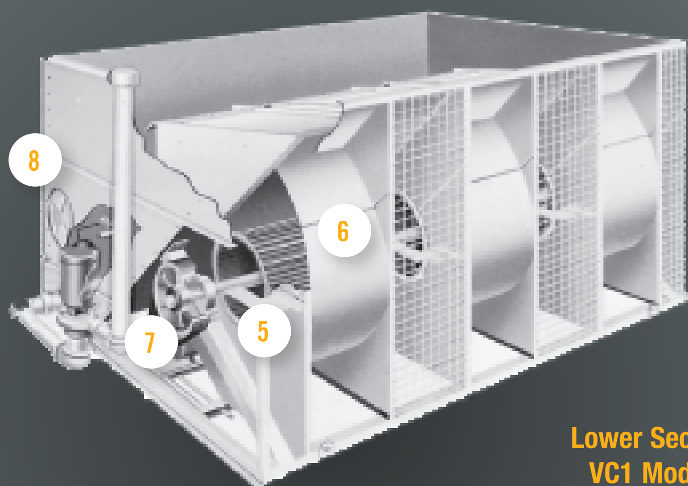
Sound Attenuation

Series V Construction Details

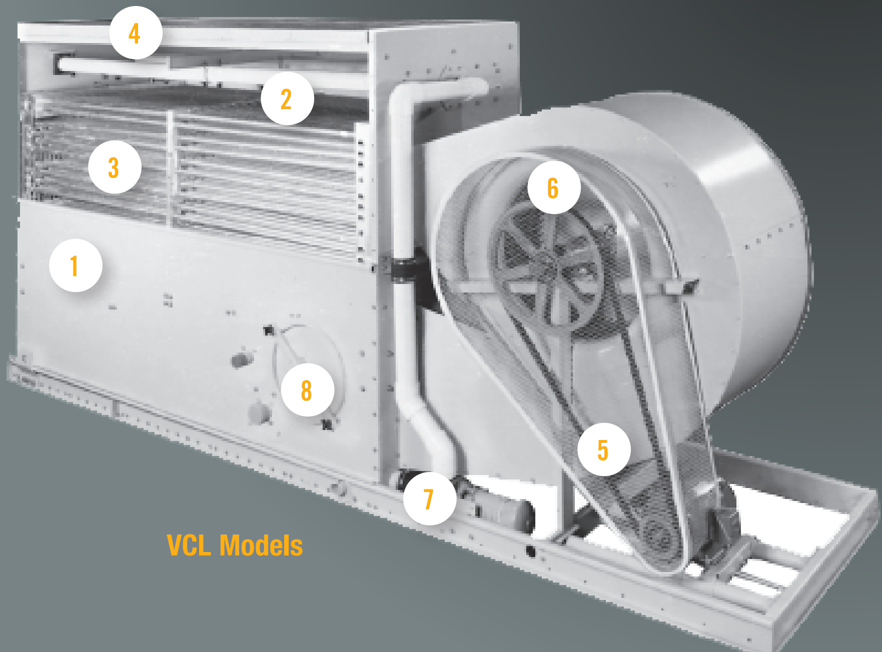
BAC MOTOR & DRIVE 5 YEAR WARRANTY



Upper Section:
VC1 Models



Lower Section:
VC1 Models



VCL Models

1 Heavy-Duty Construction

- G-235 (Z700 metric) mill galvanized steel panels

2 Water Distribution System

- Schedule 40 PVC spray branches
- Large orifice, 360 Spray Nozzles are non-clog
- Nozzles are grommeted for easy maintenance

3 Coil

- Continuous serpentine, steel tubing
- Hot-dip galvanized after fabrication (HDGAF)
- Maximum allowable working pressure is 300 psig (2,068 kPa)
- Sloped tubes for free drainage of fluid
- Fabricated per ASME B31.5 standards
- Orders shipping into Canada are supplied with a CRN

4 Drift Eliminators

- Recycled polyvinyl chloride (PVC)
- Impervious to rot, decay, and biological attack
- Flame spread rating of 5 per ASTM E84
- Assembled in easy to handle sections

5 Fan Drive System

- V-belt
- Heavy duty bearings, with minimum L_{10} 40,000 hours
- Premium efficient/VFD duty fan motors are standard
- 5-year motor and drive warranty

6 Low Sound Centrifugal Fan(s)

- Quiet operation
- Overcome static pressure

7 Recirculating External Spray Pump

- Close coupled, bronze fitted centrifugal pump
- Totally enclosed fan cooled (TEFC) motor
- Bleed line with metering valve installed from pump discharge to overflow

8 Access Doors

- Interior of unit is easily accessible

9 Strainer (NOT SHOWN)

- Anti-vortexing design to prevent air entrainment

Series V Custom Features & Options

Materials of Construction

Determining the appropriate material of construction for a project depends on several factors, including water quality, climate and environmental conditions, availability of time and manpower for maintenance, unit lifetime requirements, and budget. BAC provides the widest variety of material of construction options in the industry and has the ability to provide a solution to meet all conditions and budgets.

Standard VCL Construction Installation

STANDARD CONSTRUCTION

G-235 mill galvanized steel is the heaviest commercially available galvanized steel, universally recognized for its strength and corrosion resistance. To assure long life, G-235 mill galvanized steel is used as the standard material of construction for all units. All exposed cut edges are protected with a thick, zinc coating after fabrication to ensure the zinc rich corrosion barrier is maintained for all over protection.

NOTE: With proper maintenance and water treatment, G-235 galvanized steel products will provide an excellent service life under the operating conditions normally encountered in refrigeration and industrial applications.

THERMOSETTING HYBRID POLYMER (OPTION)

A thermosetting hybrid polymer, used to extend equipment life, is applied to select G-235 mill galvanized steel components of the unit. The polymerized coating is baked onto the G-235 mill galvanized steel and creates a barrier to the already corrosion resistant galvanized steel. The thermosetting hybrid polymer has been tested to withstand 6,000 hours in a 5% salt spray without blistering, chipping, or losing adhesion.

STAINLESS STEEL (OPTION)

For applications where the most severe corrosive conditions exist or where long equipment life is required, several material of construction options utilizing stainless steel are available.

- **WATER CONTACT STAINLESS STEEL BASIN**
  The basin components below the overflow level are constructed of stainless steel.
- **WATER CONTACT STAINLESS STEEL UNIT**
  The basin and water-contacted components below the overflow level in the basin are constructed of stainless steel. All principal steel components in the casing section will be constructed of galvanized steel as standard.
- **ALL STAINLESS STEEL CONSTRUCTION**
  Steel panels and structural elements are constructed of stainless steel. *Available on VC1 and VC1-C units.*

Stainless Steel Basin

Coil Configuration

BAC offers a large selection of coil configuration options to fulfill any thermal and pressure drop requirements.

STANDARD SERPENTINE COIL

The standard cooling coil is constructed of continuous lengths of all prime surface steel. The coil is hot-dip galvanized after fabrication (HDGAF) to apply a thick, zinc corrosion barrier over the entire exterior surface of the coil. The coil is designed for low pressure drop with sloping tubes for free drainage of fluid. Each coil has a maximum allowable working pressure of 300 psig (2,068 kPa) and is fabricated per ASME B31.5 standards to ensure the highest quality and integrity.

Standard Serpentine Coil

STAINLESS STEEL COIL (OPTION)

Coils are available in stainless steel for specialized applications. The coil is designed for low pressure drop with sloping tubes for free drainage of fluid. Each coil has a maximum allowable working pressure of 300 psig (2,068 kPa) and is fabricated per ASME B31.5 standards to ensure the highest quality and integrity.

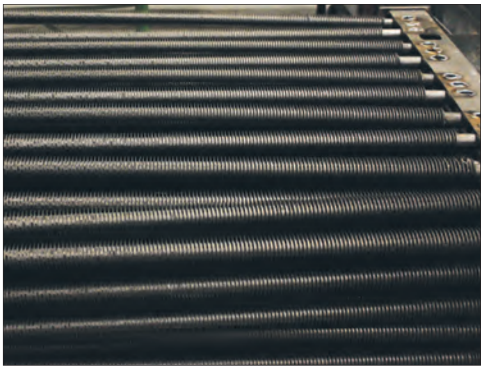
Stainless Steel Coil

ASME U DESIGNATOR COIL (OPTION)

BAC offers coils that are certified in accordance with the ASME Boiler and Pressure Vessel Code, Section VIII, Division I. ASME U designated coils are available for projects requiring ASME certified pressure vessels and involve 3rd party inspection and certification. Standard ASME U designated coils are rated at 340 psig (2,344 kPa) maximum allowable working pressure, and they are pneumatically tested at 375 psig (2,586 kPa).

EXTENDED SURFACE (FINNED) COIL (OPTION)

Coils are available with up to all rows finned at 5 fins per inch for seasonal wet/dry operation. The fins increase the surface area of the coil, therefore increasing the condensing capability. The coil is hot-dip galvanized after fabrication (HDGAF) to apply a thick, zinc corrosion barrier over the entire exterior surface of the coil and fins. BAC coils are designed for low pressure drops and to be completely drainable with sloping tubes for free drainage of fluid. Each coil has a maximum allowable working pressure of 300 psig (2,068 kPa) and is fabricated per ASME B31.5 standards to ensure the highest quality and integrity.



Extended Surface Coil

Series V
Custom Features & Options

MULTIPLE CIRCUIT COILS/AUXILIARY COOLING CIRCUIT (OPTION)

Split coil configurations are available to allow separate process fluid (or refrigerant) loops through the same unit. Separate loops may be needed for multiple applications requiring different temperature processes or multiple types of process fluids (or refrigerants). Multiple refrigerant circuit coils are generally required on halocarbon refrigerant systems, where it is common practice to maintain individual compressor systems. The quantity of circuits, capacity per circuit, and desired connection size and type should be specified when requesting this option.


Multiple Circuit Coil Connections

DESUPERHEATER COILS (OPTION)

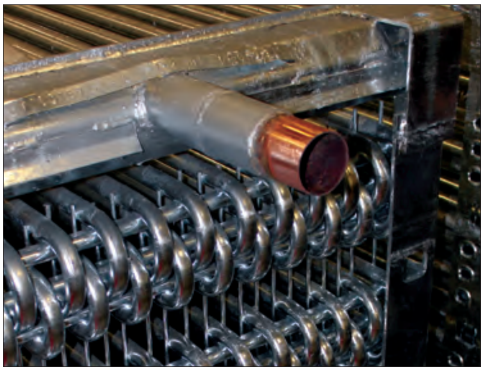
The addition of a desuperheater coil can sometimes permit the use of a unit with a smaller plan area. The desuperheater section is mounted on top of the condenser in the discharge air stream. Coils are hot-dip galvanized after fabrication and have a maximum allowable working pressure of at 300 psig (2,068 kPa). Piping between the desuperheater coil and the condenser coil is not included.

SUBCOOLING COILS (OPTION)

Subcooling coils are available for those halocarbon refrigerant installations where subcooled refrigerant is specified, or where the pressure drop or a vertical rise in the liquid line is great enough to cause excessive flashing. Standard subcooling coil sections provide approximately 10ºF (5.6ºC) of subcooling at standard conditions. Subcooling sections are approximately 7" high and are mounted between the coil and basin sections. Coils are hot-dip galvanized after fabrication and have a maximum allowable working pressure of 300 psig (2,068 kPa).

COPPER SWEAT FITTINGS (OPTION)

Factory installed copper sweat fittings are available to simplify field piping.


Copper Sweat Fitting

NOTE: A Canadian Registration number (CRN) is required for all pressure vessels over 15 psig entering Canada. The CRN identifies that he design of a boiler, or fitting has been accepted and registered for use in Canada. CRN is available for all standard coil configurations shipping into Canada.

Drive System Options

The fan drive system provides the cooling air necessary to reject unwanted heat from the system to the atmosphere. All BAC drive systems use premium efficient cooling tower duty motors and include BAC's comprehensive 5-year motor and drive warranty. Cooling tower duty motors are specially designed for the harsh environment inside a condenser and have permanently lubricated bearings, drastically decreasing the maintenance requirement of the motor. BAC belt drive systems are the most durable and maintenance friendly drive systems on the market, including single nut adjustment for belt tensioning to make belt tensioning simple.

EXTERNAL V-BELT DRIVE

This BAC engineered external drive consists of centrifugal fan(s), motor(s), and drive system(s) located outside of the moist discharge airstream, protecting them from moisture, condensation and icing. The drive system consists of a specially designed belts, taper lock sheaves, and premium efficient cooling tower duty motor to provide maximum performance.

External V-Belt Drive

Customer Valued

BALTIGUARD™ FAN SYSTEM (OPTION)

The BALTIGUARD™ Fan System consists of two standard single-speed fan motor and drive assemblies. One drive assembly is sized for full speed and load, and the other is sized for approximately 2/3 speed and consumes only 1/3 the design horsepower. This configuration allows the reserve capacity of a standby motor in the event of failure. As a minimum, approximately 70% capacity will be available from the low horsepower motor (pony), even on a design wet-bulb day. Controls and wiring are the same as those required for a two-speed, two-winding motor. Redundant motors are available by increasing the size of the standby fan motor of the BALTIGUARD™ Fan System to the size of the main motor, providing 100% motor redundancy (Applicability dependant on motor size and model. Contact your local BAC Representative for more information).

BALTIGUARD™ Fan System

BALTIGUARD PLUS™ FAN SYSTEM (OPTION)

The BALTIGUARD PLUS™ Fan System builds on the advantages of the BALTIGUARD™ Fan System by adding a VFD to either the pony or the main motor, depending on system requirements. This offers the benefits of additional capacity control and energy savings, along with the redundancy offered by the BALTIGUARD™ Fan System. Alternatively, a VFD can be added to BOTH the pony and main motor, for complete capacity control and redundancy under any load.

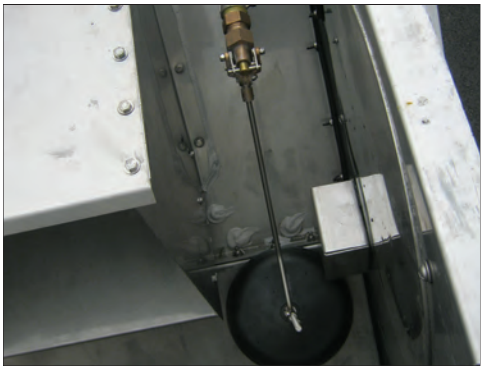
Series V
Custom Features & Options

VIBRATION CUTOUT SWITCH (OPTION)

A factory mounted vibration cutout switch is available to effectively protect against rotating equipment failure. BAC can provide either a mechanical or solid-state electronic vibration cutout switch in a NEMA 4 enclosure to ensure reliable protection. Additional contacts can be provided on either switch type to activate an alarm. Remote reset capability is also available on either switch type.

EXTENDED LUBRICATION LINES (OPTION)

Extended lubrication lines are available for lubrication of the fan shaft bearings. Fittings are located on the exterior casing panel next to the access door.



Mechanical Water Level Control Inspection

Basin

The spray water collects in the basin which is pumped back over the condensing coil. The Series V basin includes the "V" sloped basin design. During operation, this design eliminates any stagnant water zones, which are susceptible to biological growth.

STANDARD MECHANICAL WATER LEVEL CONTROL

Mechanical make-up valves must operate continuously in the moist and turbulent environment within evaporative cooling equipment. Due to this environment, the operation of the valve must be simple and the valve must be durable. BAC's high quality mechanical water level control assembly is standard with all units and has been specially designed to provide the most reliable operation while being easy to maintain. This accessory is omitted for remote sump applications.

Electric Water Level Control

ELECTRIC WATER LEVEL CONTROL (OPTION)

BAC's Electric Water Level Control (EWLC) is a state-of-the-art, conductivity actuated, probe type liquid level control. The hermetically sealed EWLC is engineered and manufactured specifically for use in evaporative cooling systems and is equipped with an error code LED to indicate status, including when the water and/or probes are dirty. The EWLC option replaces the standard mechanical make-up valve and includes a slow closing, solenoid activated valve in the make-up water line to minimize water hammer. EWLC is recommended when more precise water level control is required and in areas that experience sub-freezing conditions.

Customer Valued

BASIN SWEEPER PIPING (OPTION)

Basin sweeper piping is an effective method of reducing sediment that may collect in the basin. A complete piping system, including nozzles, is provided in the basin to connect to side stream filtration equipment (provided by others). For more information on filtration systems, consult "Filtration Guide" found on **page J241.**

LOW AND HIGH LEVEL ALARM FLOAT SWITCHES (OPTION)

Low and high level alarm float switches are available to provide added control to your equipment operation. Level alarms can alert operators to an abnormal operating condition to ensure the highest system efficiency with minimal water usage.

Basin Heater

BASIN HEATERS (OPTION)

Evaporative cooling equipment exposed to below freezing ambient temperatures require protection to prevent freezing of the water in the basin when the unit is idle. Factory-installed electric immersion heaters, which maintain 40°F (4.4°C) water temperature, are a simple and inexpensive way of providing such protection.

HEATER kW DATA

Model Number	0°F (-17.8°C) Ambient Heaters		-20°F (-28.9°C) Ambient Heaters	
	Number of Heaters	kW per Heater	Number of Heaters	kW per Heater
VC1-10 to VC1-25	1	2	1	2
VC1-30 to VC1-65	1	2	1	2
VC1-72 to VC1-90	1	2	1	3
VC1-100 to VC1-135	1	3	1	5
VC1-150 to VC1-205	1	3	1	5
VC1-N208 to VCA-N230	1	5	1	7.5
VC1-N243 to VC1-N315	1	5	1	7.5
VC1-C216 to VC1-C230	1	5	1	7.5
VC1-N338 to VC1-N470	1	7	1	10
VC1-C339 to VC1-C469	1	5	1	7.5
VC1-386 to VC1-516	1	8	1	10
VC1-540 to VC1-804	1	12	1	16
VC1-772 to VC1-1032	2	8	2	10
VCL-016 to VCL-035	1	2	1	2
VCL-038 to VCL-079	1	3	1	4
VCL-087 to VCL-120	1	4	1	5
VCL-134 to VCL-155	1	5	1	7
VCL-167 to VCL-234	1	7	1	9
VCL-257 to VCL-299	1	9	1	12

NOTE: This table is based on 460V/3 phase/60 Hz power.

Series V
Custom Features & Options

Water Distribution System

STANDARD SPRAY WATER PUMP

The Series V water distribution system comes standard with an integral spray water pump sized to distribute the recirculating water over the coil maximizing capacity. The patented BAC 360 non-clog nozzles ensure even flow over the coil area and are simple to remove for maintenance. Parallel flow of air and spray water to allow for inspection and access to the top of the coils during full operation.

Customer Valued

REDUNDANT PUMPS (OPTION)

An optional secondary spray pump is available for critical applications.

Spray Water Pump

Shipping and Rigging

BAC units are factory-assembled to ensure uniform quality with minimal field assembly. Each unit has been designed with rigging and assembly in mind and includes features to minimize the number of tools required and installation time.

All low profile VCL Evaporative Condensers ship completely assembled, minimizing installation time and cost. There are no motors to mount, no sheaves to align, no belts to install, and no make-up system to assemble.

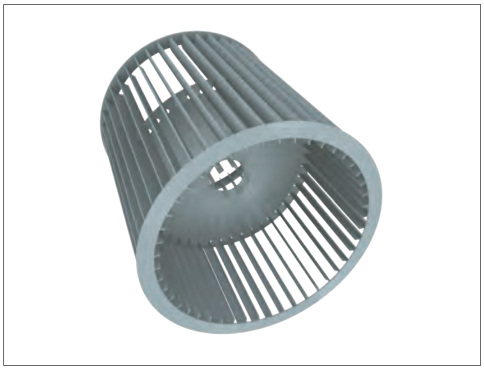
Non-clog Nozzles Ensure Even Flow Over Coil Area

KNOCKDOWN UNITS (OPTION)

Knockdown units are available for jobs where access to the condenser location is limited by elevators, doorways, or similar obstacles, where lifting methods impose very strict weight limits, or where the shipping cost of a fully assembled unit is excessive. All materials of construction and design features are the same as those of a factory assembled unit.

Sound Options

The low sound levels generated by Series V Evaporative Condensers make them suitable for most installations. The panel opposite the air intake, called the blankoff panel, is inherently quiet. Positioning the blankoff panel towards the sound sensitive direction insulates sensitive areas from higher sound levels.



Standard Centrifugal Fan

STANDARD FAN

The standard centrifugal fan provided on Series V Evaporative Condensers is inherently quiet and is selected to optimize low sound levels.

SOUND ATTENUATION (OPTION)

For extremely sound sensitive installations, factory designed, tested, and rated sound attenuation options are available for both the air intake and discharge. Consult your local BAC Representative regarding available options.

Intake and Discharge Sound Attenuation

SINGLE-SIDE AIR INTAKE

Single-side air intake units can be placed close to solid walls, reducing the size of enclosures and allowing for more profitable use of premium space. Also, the panel opposite the air intake, called the blankoff panel, is inherently quiet. Positioning the blankoff panel towards the sound sensitive direction insulates sensitive areas from higher sound levels.

Air Discharge Options

BAC offers a full line of standard discharge hoods that are built, tested, and rated specifically for all Series V Evaporative Condensers.

Discharge Hoods

DISCHARGE HOODS (OPTION)

BAC offers a full line of standard discharge hoods with and without positive closure dampers that are built, tested, and rated specifically for all Series V Evaporative Condensers. The tapered hoods are designed to increase the discharge air velocity to avoid recirculation in extremely tight enclosures. Straight or tapered hoods can be used to elevate the unit discharge above adjacent walls. A larger fan motor may be necessary when this option is provided.

Series V
Custom Features & Options

Air Intake Options

In an evaporative condenser, airborne debris can be entrained in the water through the unit's air intake. The Series V has several options for air intake accessories that prevent debris from entering the system and maintain even unobstructed flow through the unit. Reducing the amount of debris that enters the condenser lowers maintenance requirements and helps to maintain thermal efficiency.

AIR INTAKE SCREENS

Standard 1" x 1" wire mesh screen is factory-installed over the air intake to prevent debris from entering the unit.

Air Intake Screens

BOTTOM INTAKE SCREENS (OPTION)

Series V Evaporative Condensers are available with factory-installed wire mesh screens over the bottom openings to prevent unauthorized access.

SOLID BOTTOM PANELS (OPTION)

Factory-installed bottom panels are required when intake air is ducted to the unit.

Access Options

BAC's evaporative equipment is designed to be easily maintained for sustaining capacity over a longer life. All access options are OSHA compliant to ensure personnel safety and code compliance.

Handrails Packages and Ladders

HANDRAIL PACKAGES AND LADDERS (OPTION)

Handrail packages and ladders are available to provide safe access to the top of the unit for maintenance to the distribution system.

NOTE: Access options can be added at the time of order or as an aftermarket item.

ENGINEERING DATA

Evaporative Condensers

contents

Selection

The heat rejection method is BAC's recommended selection method. The selection can be made via BAC's free product selection software available at www.BaltimoreAircoil.com or manually as described below.

Contact your local BAC Representative for assistance with alternate refrigerant selections.

Heat Rejection Method

In a mechanical refrigeration system, the function of an evaporative condenser is to reject heat to the environment. The heat to be rejected is the sum of the heat input at the evaporator and the energy input at the compressor. For a given set of operating conditions, the energy input through the compression process can vary. Therefore, in order to accurately determine the proper evaporative condenser required, it is necessary to establish the compressor energy input as well as the heat absorbed in the evaporator.

Selection Procedure

The Base Heat Rejection of evaporative condensers are shown in **Tables 1** through **5**. **Tables 6** through **8** present the capacity factors to be applied to the system heat rejection for various condensing temperatures, entering wet-bulbs, and refrigerants.

- ✓ Establish total heat rejection required in thousands of BTU per hour (MBH):
  Total heat rejection = compressor evaporator capacity (MBH) + compressor BHP x 2.545.
- ✓ Determine the refrigerant and design conditions for condensing temperature and entering wet-bulb temperature.
- ✓ Using the appropriate table for the system refrigerant and model (**Tables 6** through **8**), determine the capacity factor for the design condensing temperature and entering wet-bulb temperature.
- ✓ Multiply the total heat rejection by the capacity factor determined in the previous step.
- ✓ From **Tables 1** through **5**, select the evaporative condenser whose Base Heat Rejection equals or exceeds the corrected heat rejection calculated in the previous step.

Selection Example

GIVEN:

R-717 refrigerant

Compressor evaporator capacity = 550 tons

Compressor BHP = 600 HP

Condensing temperature = 95°F

Entering wet-bulb temperature = 76°F

Solution

- ✓ Determine the total heat rejection:
  - Compressor evaporator capacity =
    550 TR x 12 MBH/TR = 6,600 MBH
  - Compressor BHP input =
    600 BHP x 2.545 MBH/BHP = 1,527 MBH
  - Total heat rejection = 8,127 MBH
- ✓ From **Table 6**, the heat rejection capacity factor for R-717 at 95°F condensing temperature and 76°F entering wet-bulb temperature is 1.35.
- ✓ Multiply: 8,127 MBH x 1.35 = 10,972 MBH
- ✓ From **Tables 1** through **5** select a unit with a Base Heat Rejection equal to or greater than 10,972 MBH: Model CXVB-545-1218-30.

TABLE 1: CXVT AND CXVB BASE HEAT REJECTION

Model Number	Base Heat Rejection (MBH)	Model Number	Base Heat Rejection (MBH)	Model Number	Base Heat Rejection (MBH)	Model Number	Base Heat Rejection (MBH)	Model Number	Base Heat Rejection (MBH)
CXVT-617-1224-15	12,783	CXVT-2114-2826-150	43,816	CXVB-113-0809-3	2,336	CXVB-299-1212-10	6,181	CXVB-567-1218-37.5	11,721
CXVT-650-1224-20	13,463	XECXVT540-1224-10	11,190	CXVB-117-0806-5	2,419	CXVB-302-1212-20	6,243	CXVB-571-1224-30	11,804
CXVT-676-1224-25	14,014	XECXVT605-1224-10	12,539	CXVB-123-0806-10	2,543	CXVB-306-1212-10	6,326	CXVB-581-1218-37.5	12,010
CXVT-700-1224-40	14,503	XECXVT629-1426-10	13,030	CXVB-124-0809-5	2,563	CXVB-310-0818-15	6,408	CXVB-595-1224-20	12,300
CXVT-712-1426-20	14,761	XECXVT636-1224-10	13,186	CXVB-126-0809-3	2,605	CXVB-314-1212-15	6,491	CXVB-598-1224-20	12,362
CXVT-731-1224-50	15,159	XECXVT684-1224-15	14,184	CXVB-134-0809-7.5	2,770	CXVB-315-1212-10	6,512	CXVB-601-1218-45	12,424
CXVT-741-1426-25	15,366	XECXVT698-1426-10	14,474	CXVB-137-0806-15	2,832	CXVB-321-0818-15	6,636	CXVB-604-1224-40	12,486
CXVT-754-1224-60	15,624	XECXVT721-1224-20	14,938	CXVB-138-0809-3	2,853	CXVB-327-0818-15	6,760	CXVB-612-1224-20	12,651
CXVT-766-1426-30	15,879	XECXVT734-1426-10	15,221	CXVB-138-0809-5	2,853	CXVB-327-1212-15	6,760	CXVB-628-1218-60	12,982
CXVT-778-1224-50	16,131	XECXVT750-1224-25	15,550	CXVB-141-0809-3	2,915	CXVB-329-0818-22.5	6,801	CXVB-629-1224-30	13,003
CXVT-807-1426-40	16,723	XECXVT775-1224-30	16,069	CXVB-144-0809-7.5	2,977	CXVB-341-1212-20	7,049	CXVB-630-1224-20	13,023
CXVT-813-1224-50	16,843	XECXVT790-1426-15	16,373	CXVB-152-0809-5	3,142	CXVB-341-1212-15	7,049	CXVB-643-1218-60	13,292
CXVT-843-1224-60	17,483	XECXVT832-1426-20	17,244	CXVB-158-0809-5	3,266	CXVB-342-0818-15	7,070	CXVB-655-1224-30	13,540
CXVT-844-1426-50	17,484	XECXVT866-1426-25	17,950	CXVB-163-0809-7.5	3,370	CXVB-345-0818-30	7,132	CXVB-682-1224-30	14,098
CXVT-887-1224-60	18,386	XECXVT895-1426-30	18,549	CXVB-172-0812-7.5	3,556	CXVB-355-1212-25	7,339	CXVB-682-1224-40	14,098
CXVT-894-1426-50	18,520	XECXVT942-1426-40	19,535	CXVB-190-0809-15	3,928	CXVB-357-0818-22.5	7,380	CXVB-711-1224-50	14,698
CXVT-933-1426-50	19,337	XECXVT1080-2424-20	22,385	CXVB-195-0812-10	4,031	CXVB-360-1218-15	7,442	CXVB-719-1236-30	14,863
CXVT-965-1426-60	19,999	XECXVT1210-2424-20	25,079	CXVB-204-0812-7.5	4,217	CXVB-370-1212-25	7,649	CXVB-739-1224-50	15,277
CXVT-1005-1426-75	20,838	XECXVT1258-2826-20	26,074	CXVB-207-0809-20	4,279	CXVB-373-0818-30	7,711	CXVB-762-1224-60	15,752
CXVT-1057-1426-75	21,914	XECXVT1272-2424-20	26,364	CXVB-207-0812-15	4,279	CXVB-381-1212-30	7,876	CXVB-786-1224-60	16,248
CXVT-1234-2424-30	25,577	XECXVT1368-2424-30	28,354	CXVB-216-0812-7.5	4,465	CXVB-387-0818-30	8,000	CXVB-806-1236-30	16,662
CXVT-1300-2424-40	26,945	XECXVT1396-2826-20	28,935	CXVB-217-0812-15	4,486	CXVB-393-1212-30	8,124	CXVB-821-1224-80	16,972
CXVT-1352-2424-50	28,023	XECXVT1442-2424-40	29,888	CXVB-221-0812-7.5	4,569	CXVB-403-1218-15	8,331	CXVB-875-1236-45	18,088
CXVT-1400-2424-80	29,017	XECXVT1468-2826-20	30,427	CXVB-226-0812-7.5	4,672	CXVB-409-0818-45	8,455	CXVB-888-1236-30	18,357
CXVT-1424-2826-40	29,515	XECXVT1500-2424-50	31,090	CXVB-227-0812-20	4,693	CXVB-411-1212-40	8,496	CXVB-914-1236-30	18,894
CXVT-1462-2424-100	30,302	XECXVT1550-2424-60	32,126	CXVB-237-0812-10	4,899	CXVB-437-1218-22.5	9,034	CXVB-918-1236-30	18,977
CXVT-1482-2826-50	30,717	XECXVT1580-2826-30	32,748	CXVB-237-1212-10	4,899	CXVB-444-1218-15	9,178	CXVB-933-1236-30	19,287
CXVT-1508-2424-120	31,256	XECXVT1664-2826-40	34,489	CXVB-238-0812-15	4,920	CXVB-457-1218-15	9,447	CXVB-964-1236-45	19,928
CXVT-1532-2826-60	31,753	XECXVT1732-2826-50	35,899	CXVB-241-0812-10	4,982	CXVB-459-1218-15	9,488	CXVB-966-1236-30	19,969
CXVT-1556-2424-100	32,251	XECXVT1790-2826-60	37,101	CXVB-248-0818-15	5,127	CXVB-467-1218-15	9,654	CXVB-1027-1236-45	21,230
CXVT-1614-2826-80	33,453	XECXVT1884-2826-80	39,049	CXVB-259-0812-20	5,354	CXVB-473-1224-20	9,778	CXVB-1049-1236-45	21,685
CXVT-1626-2424-100	33,702	CXVB-75-0806-3	1,550	CXVB-264-1212-10	5,457	CXVB-482-1218-22.5	9,964	CXVB-1049-1236-60	21,685
CXVT-1686-2424-120	34,945	CXVB-87-0806-3	1,798	CXVB-268-0818-15	5,540	CXVB-483-1218-15	9,985	CXVB-1089-1236-60	22,512
CXVT-1688-2826-100	34,987	CXVB-94-0806-3	1,943	CXVB-270-0812-25	5,581	CXVB-513-1218-22.5	10,605	CXVB-1134-1236-75	23,442
CXVT-1774-2424-120	36,769	CXVB-95-0806-5	1,964	CXVB-281-0818-15	5,809	CXVB-525-1218-22.5	10,853	CXVB-1161-1236-75	24,000
CXVT-1788-2826-100	37,059	CXVB-102-0806-7.5	2,109	CXVB-284-0812-30	5,871	CXVB-525-1218-30	10,853	CXVB-1202-1236-90	24,848
CXVT-1866-2826-100	38,676	CXVB-106-0806-3	2,191	CXVB-285-1212-15	5,892	CXVB-528-1224-20	10,915	CXVB-1257-1236-120	25,985
CXVT-1930-2826-120	40,002	CXVB-111-0806-10	2,295	CXVB-297-1212-10	6,140	CXVB-545-1218-30	11,266	CXVB-1287-1236-120	26,605
CXVT-2010-2826-150	41,661								

Selection

TABLE 2: PCC BASE HEAT REJECTION

Model Number	Base Heat Rejection (MBH)	Model Number	Base Heat Rejection (MBH)	Model Number	Base Heat Rejection (MBH)	Model Number	Base Heat Rejection (MBH)	Model Number	Base Heat Rejection (MBH)
PCC-0046-0406N003	953	PCC-0330-1212N025	6,840	PCC-0586-1224N030	12,146	PCC-0938-2418N040	19,441	PCC-1268-1236N120	26,278
PCC-0048-0406N005	995	PCC-0346-1212N025	7,171	PCC-0590-1218N050	12,229	PCC-0974-1240N040	20,192	PCC-1270-1240N100	26,319
PCC-0057-0406N005	1,181	PCC-0349-0718N020	7,234	PCC-0590-2012N060	12,229	PCC-0980-1236N080	20,315	PCC-1278-2418N120	26,488
PCC-0067-0406N7.5	1,389	PCC-0355-1212N025	7,358	PCC-0590-1024N060	12,229	PCC-0982-2420N040	20,353	PCC-1280-2420N100	26,530
PCC-0078-0412N006	1,617	PCC-0365-1212N030	7,565	PCC-0591-1220N040	12,249	PCC-0988-2418N080	20,478	PCC-1308-1240N100	27,100
PCC-0090-0412N010	1,865	PCC-0375-1212N030	7,772	PCC-0609-1218N050	12,622	PCC-0996-2424N040	20,643	PCC-1318-2420N100	27,317
PCC-0106-0412N010	2,197	PCC-0381-1218N015	7,897	PCC-0614-1220N050	12,726	PCC-1026-1236N060	21,261	PCC-1320-2424N100	27,359
PCC-0113-0709N010	2,342	PCC-0395-1212N040	8,187	PCC-0618-2412N040	12,809	PCC-1030-1240N040	21,343	PCC-1367-1240N120	28,334
PCC-0117-0709N7.5	2,425	PCC-0396-1212N040	8,208	PCC-0618-1224N040	12,809	PCC-1034-2418N060	21,431	PCC-1378-2420N120	28,561
PCC-0118-0412N010	2,446	PCC-0406-1212N040	8,415	PCC-0622-1220N040	12,892	PCC-1038-2420N040	21,514	PCC-1384-2424N100	28,685
PCC-0122-0412N015	2,529	PCC-0416-2012N020	8,622	PCC-0630-2012N080	13,058	PCC-1054-1236N080	21,837	PCC-1420-2424N100	29,431
PCC-0122-0709N7.5	2,529	PCC-0416-1024N020	8,622	PCC-0630-1024N080	13,058	PCC-1060-2424N060	21,970	PCC-1460-2424N120	30,261
PCC-0128-0412N015	2,653	PCC-0431-1220N015	8,933	PCC-0639-1218N060	13,244	PCC-1062-2418N080	22,011	PCC-1500-2424N120	31,090
PCC-0130-0709N7.5	2,694	PCC-0441-1218N020	9,140	PCC-0640-1220N050	13,265	PCC-1071-1240N060	22,207	PCC-1501-2436N060	31,118
PCC-0134-0412N015	2,777	PCC-0466-2012N030	9,659	PCC-0646-2012N060	13,389	PCC-1073-1236N080	22,248	PCC-1580-2424N160	32,748
PCC-0142-0709N015	2,943	PCC-0466-1024N030	9,659	PCC-0646-1024N060	13,389	PCC-1079-1240N080	22,371	PCC-1584-2424N160	32,831
PCC-0154-0709N015	3,192	PCC-0469-1218N020	9,721	PCC-0656-2012N060	13,597	PCC-1080-2420N060	22,385	PCC-1624-2424N160	33,660
PCC-0160-0709N020	3,316	PCC-0491-1220N020	10,177	PCC-0656-1024N060	13,597	PCC-1082-2418N080	22,426	PCC-1710-2440N060	35,449
PCC-0163-0709N015	3,378	PCC-0492-2012N020	10,197	PCC-0659-1220N050	13,659	PCC-1088-2420N080	22,550	PCC-1738-2436N080	36,019
PCC-0166-0709N020	3,441	PCC-0492-1024N020	10,197	PCC-0660-2412N050	13,679	PCC-1105-1240N050	22,906	PCC-1848-2436N080	38,306
PCC-0175-0709N020	3,627	PCC-0494-1218N040	10,239	PCC-0660-1224N050	13,679	PCC-1114-2420N050	23,089	PCC-1947-2436N160	40,348
PCC-0177-0718N010	3,669	PCC-0498-2412N020	10,322	PCC-0689-1220N060	14,280	PCC-1119-1236N100	23,194	PCC-1948-2440N080	40,383
PCC-0184-0709N020	3,814	PCC-0498-1224N020	10,322	PCC-0692-2412N050	14,343	PCC-1125-1240N060	23,317	PCC-2037-2436N120	42,226
PCC-0208-1012N010	4,311	PCC-0517-1218N030	10,716	PCC-0692-1224N050	14,343	PCC-1128-2418N100	23,379	PCC-2060-2440N080	42,686
PCC-0214-0718N020	4,435	PCC-0519-1220N020	10,757	PCC-0710-2412N050	14,716	PCC-1134-2420N060	23,504	PCC-2092-2436N160	43,370
PCC-0222-0718N015	4,601	PCC-0530-2412N030	10,985	PCC-0710-1224N050	14,716	PCC-1135-1236N080	23,523	PCC-2132-2436N160	44,187
PCC-0232-0718N015	4,809	PCC-0530-1224N030	10,985	PCC-0730-2412N060	15,130	PCC-1144-2418N080	23,711	PCC-2143-2440N120	44,413
PCC-0233-1012N015	4,829	PCC-0531-1218N040	11,006	PCC-0730-1224N060	15,130	PCC-1151-1240N060	23,852	PCC-2159-2440N160	44,742
PCC-0246-1012N010	5,099	PCC-0538-2012N060	11,151	PCC-0750-2412N060	15,545	PCC-1153-1240N080	23,893	PCC-2210-2440N100	45,812
PCC-0249-1212N010	5,161	PCC-0538-1024N060	11,151	PCC-0750-1224N060	15,545	PCC-1160-2420N060	24,043	PCC-2223-2436N200	46,065
PCC-0265-1212N015	5,492	PCC-0540-1220N030	11,192	PCC-0756-1236N030	15,668	PCC-1162-2420N080	24,084	PCC-2250-2440N120	46,634
PCC-0267-0718N030	5,534	PCC-0541-1218N040	11,213	PCC-0762-2418N030	15,794	PCC-1171-1236N100	24,263	PCC-2254-2436N160	46,719
PCC-0269-1012N030	5,575	PCC-0544-2012N040	11,275	PCC-0790-2412N080	16,374	PCC-1172-2424N060	24,291	PCC-2302-2440N120	47,703
PCC-0272-1012N020	5,638	PCC-0544-1024N040	11,275	PCC-0790-1224N080	16,374	PCC-1173-1240N080	24,304	PCC-2306-2440N160	47,786
PCC-0278-0718N030	5,762	PCC-0544-1220N040	11,275	PCC-0792-2412N080	16,415	PCC-1180-2418N100	24,457	PCC-2325-2436N200	48,189
PCC-0281-1012N025	5,824	PCC-0557-1220N025	11,545	PCC-0792-1224N080	16,415	PCC-1182-2420N080	24,499	PCC-2345-2440N160	48,608
PCC-0293-1212N015	6,073	PCC-0562-2012N050	11,648	PCC-0812-2412N080	16,830	PCC-1208-1236N100	25,044	PCC-2400-2436N200	49,741
PCC-0295-1012N030	6,114	PCC-0562-1024N050	11,648	PCC-0812-1224N080	16,830	PCC-1218-2418N100	25,245	PCC-2436-2440N200	50,500
PCC-0300-0718N040	6,218	PCC-0564-1218N050	11,690	PCC-0855-1240N030	17,724	PCC-1218-1240N100	25,250	PCC-2468-2440N160	51,158
PCC-0309-1212N020	6,404	PCC-0567-1220N030	11,752	PCC-0862-2420N030	17,866	PCC-1228-2420N100	25,452	PCC-2518-2436N240	52,191
PCC-0315-1012N040	6,529	PCC-0572-1218N040	11,856	PCC-0875-1236N040	18,135	PCC-1234-1240N080	25,579	PCC-2540-2440N200	52,638
PCC-0323-1012N030	6,695	PCC-0580-1220N030	12,021	PCC-0882-2418N040	18,281	PCC-1236-2424N080	25,618	PCC-2615-2440N200	54,201
PCC-0324-0718N020	6,715	PCC-0581-1220N040	12,042	PCC-0931-1236N040	19,287	PCC-1244-2420N080	25,784	PCC-2734-2440N240	56,668
PCC-0328-1012N030	6,798	PCC-0586-2412N030	12,146						

TABLE 3: VCA BASE HEAT REJECTION

Model Number	Base Heat Rejection (MBH)	Model Number	Base Heat Rejection (MBH)	Model Number	Base Heat Rejection (MBH)
VCA-122A	1,793	VCA-491A	7,218	VCA-887A	13,039
VCA-138A	2,029	VCA-507A	7,453	VCA-895A	13,157
VCA-150A	2,205	VCA-510A	7,497	VCA-902A	13,259
VCA-154A	2,264	VCA-512A	7,526	VCA-920A	13,524
VCA-161A	2,367	VCA-513A	7,541	VCA-928A	13,642
VCA-170A	2,499	VCA-526A	7,732	VCA-930A	13,671
VCA-174A	2,558	VCA-537A	7,894	VCA-S932A	13,700
VCA-178A	2,617	VCA-541A	7,953	VCA-942A	13,847
VCA-182A	2,675	VCA-543A	7,982	VCA-946A	13,906
VCA-191A	2,808	VCA-560A	8,232	VCA-957A	14,068
VCA-192A	2,822	VCA-580A	8,526	VCA-S972A	14,288
VCA-195A	2,867	VCA-581A	8,541	VCA-982A	14,435
VCA-206A	3,028	VCA-582A	8,555	VCA-1010A	14,847
VCA-215A	3,161	VCA-585A	8,600	VCA-S1019A	14,979
VCA-227A	3,337	VCA-584A	8,600	VCA-1020A	14,994
VCA-235A	3,455	VCA-600A	8,820	VCA-1024A	15,053
VCA-259A	3,807	VCA-602A	8,849	VCA-1026A	15,082
VCA-261A	3,837	VCA-605A	8,894	VCA-1052A	15,464
VCA-273A	4,013	VCA-609A	8,952	VCA-1062A	15,611
VCA-288A	4,234	VCA-620A	9,114	VCA-S1071A	15,744
VCA-300A	4,410	VCA-623A	9,158	VCA-1075A	15,803
VCA-301A	4,425	VCA-626A	9,202	VCA-1082A	15,905
VCA-302A	4,439	VCA-642A	9,437	VCA-1086A	15,964
VCA-308A	4,528	VCA-653A	9,599	VCA-1120A	16,464
VCA-322A	4,733	VCA-661A	9,717	VCA-S1124A	16,523
VCA-323A	4,748	VCA-662A	9,731	VCA-1160A	17,052
VCA-331A	4,866	VCA-664A	9,761	VCA-1162A	17,081
VCA-340A	4,998	VCA-680A	9,996	VCA-1169A	17,199
VCA-342A	5,027	VCA-684A	10,055	VCA-1170A	17,199
VCA-356A	5,233	VCA-688A	10,114	VCA-1200A	17,640
VCA-375A	5,513	VCA-S700A	10,296	VCA-S1204A	17,699
VCA-377A	5,542	VCA-707A	10,393	VCA-1204A	17,699
VCA-382A	5,601	VCA-711A	10,452	VCA-1218A	17,905
VCA-381A	5,601	VCA-750A	11,025	VCA-1240A	18,228
VCA-393A	5,777	VCA-751A	11,025	VCA-1246A	18,316
VCA-396A	5,821	VCA-754A	11,084	VCA-1252A	18,404
VCA-401A	5,895	VCA-760A	11,172	VCA-1284A	18,875
VCA-402A	5,909	VCA-762A	11,201	VCA-1306A	19,198
VCA-404A	5,939	VCA-779A	11,451	VCA-1321A	19,419
VCA-407A	5,983	VCA-785A	11,540	VCA-1327A	19,507
VCA-416A	6,115	VCA-804A	11,819	VCA-1376A	20,227
VCA-420A	6,174	VCA-808A	11,878	VCA-1414A	20,786
VCA-424A	6,233	VCA-814A	11,966	VCA-1422A	20,903
VCA-429A	6,306	VCA-827A	12,157	VCA-1501A	22,065
VCA-433A	6,365	VCA-S828A	12,173	VCA-1558A	22,903
VCA-446A	6,556	VCA-S838A	12,325	VCA-1570A	23,079
VCA-451A	6,630	VCA-840A	12,348	VCA-1654A	24,314
VCA-460A	6,762	VCA-858A	12,613	VCA-1774A	26,078
VCA-464A	6,821	VCA-866A	12,730	VCA-1790A	26,313
VCA-471A	6,924	VCA-S870A	12,789	VCA-1914A	28,136
VCA-473A	6,953	VCA-879A	12,921	VCA-2019A	29,679
VCA-488A	7,174	VCA-S884A	12,991		

TABLE 4: VC1 AND VC1-C BASE HEAT REJECTION

Model Number	Base Heat Rejection (MBH	Model Number	Base Heat Rejection (MBH)	Model Number	Base Heat Rejection (MBH)
VC1-10	147	VC1-N275	4,043	VC1-908	13,348
VC1-15	221	VC1-N301	4,425	VC1-974	14,318
VC1-20	294	VC1-N315	4,631	VC1-1032	15,170
VC1-25	368	VC1-N338	4,969	VC1-1158	17,023
VC1-30	441	VC1-N357	5,248	VC1-1224	17,993
VC1-38	559	VC1-N373	5,483	VC1-1366	20,080
VC1-46	676	VC1-N417	6,130	VC1-1430	21,021
VC1-52	764	VC1-N470	6,909	VC1-1496	21,991
VC1-58	853	VC1-386	5,674	VC1-1608	23,638
VC1-65	956	VC1-436	6,409	VC1-C216	3,175
VC1-72	1,058	VC1-454	6,674	VC1-C231	3,396
VC1-80	1,176	VC1-467	6,865	VC1-C242	3,557
VC1-90	1,323	VC1-487	7,159	VC1-C260	3,822
VC1-100	1,470	VC1-516	7,585	VC1-C274	4,028
VC1-110	1,617	VC1-540	7,938	VC1-C286	4,204
VC1-125	1,838	VC1-579	8,511	VC1-C299	4,395
VC1-135	1,985	VC1-612	8,996	VC1-C320	4,704
VC1-150	2,205	VC1-646	9,496	VC1-C339	4,983
VC1-165	2,426	VC1-683	10,040	VC1-C354	5,204
VC1-185	2,720	VC1-715	10,511	VC1-C380	5,586
VC1-205	3,014	VC1-748	10,996	VC1-C396	5,821
VC1-N208	3,058	VC1-804	11,819	VC1-C424	6,233
VC1-N230	3,381	VC1-772	11,348	VC1-C445	6,542
VC1-N243	3,572	VC1-872	12,818	VC1-C469	6,894
VC1-N257	3,778	VC1-934	13,730		

TABLE 5: VCL BASE HEAT REJECTION

Model Number	Base Heat Rejection (MBH)	Model Number	Base Heat Rejection (MBH)
VCL-016	235	VCL-108	1,588
VCL-019	279	VCL-115	1,691
VCL-024	353	VCL-120	1,764
VCL-029	426	VCL-134	1,970
VCL-035	515	VCL-148	2,176
VCL-038	559	VCL-155	2,279
VCL-044	647	VCL-167	2,455
VCL-048	706	VCL-185	2,720
VCL-054	794	VCL-209	3,072
VCL-058	853	VCL-223	3,278
VCL-065	956	VCL-234	3,440
VCL-073	1,073	VCL-257	3,778
VCL-079	1,161	VCL-271	3,984
VCL-087	1,279	VCL-286	4,204
VCL-096	1,411	VCL-299	4,395
VCL-102	1,499		

Selection

TABLE 6: HEAT REJECTION CAPACITY FACTORS – R-717 AMMONIA (ALL PRODUCTS)

Condensing Pressure (psig)	Condensing Temp (°F)	Entering Wet-Bulb Temperature (°F)																
R-717		50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82
151.3	85	0.97	1.01	1.06	1.11	1.17	1.25	1.33	1.43	1.55	1.70	1.89	2.14	2.47	2.97	3.73	—	—
154.1	86	0.94	0.98	1.02	1.07	1.13	1.19	1.27	1.36	1.46	1.60	1.76	1.97	2.26	2.66	3.26	4.25	—
156.9	87	0.91	0.95	0.99	1.03	1.08	1.14	1.21	1.29	1.39	1.51	1.65	1.83	2.08	2.40	2.88	3.63	—
159.8	88	0.88	0.91	0.95	0.99	1.04	1.10	1.16	1.23	1.32	1.42	1.55	1.71	1.92	2.20	2.58	3.16	4.13
162.6	89	0.85	0.89	0.92	0.96	1.00	1.05	1.11	1.18	1.26	1.35	1.46	1.60	1.78	2.02	2.34	2.80	3.53
165.5	90	0.83	0.86	0.89	0.93	0.97	1.01	1.07	1.13	1.20	1.28	1.38	1.51	1.67	1.87	2.13	2.51	3.08
168.5	91	0.80	0.83	0.86	0.90	0.93	0.98	1.02	1.08	1.14	1.22	1.31	1.42	1.56	1.73	1.96	2.27	2.72
171.5	92	0.78	0.81	0.83	0.87	0.90	0.94	0.99	1.04	1.10	1.17	1.25	1.35	1.47	1.62	1.82	2.08	2.44
174.5	93	0.76	0.78	0.81	0.84	0.87	0.91	0.95	1.00	1.05	1.11	1.19	1.28	1.38	1.52	1.69	1.91	2.21
177.6	94	0.74	0.76	0.79	0.81	0.84	0.88	0.92	0.96	1.01	1.07	1.13	1.21	1.31	1.43	1.58	1.77	2.02
180.7	95	0.72	0.74	0.76	0.79	0.82	0.85	0.88	0.92	0.97	1.02	1.08	1.16	1.24	1.35	1.48	1.64	1.86
185.0	96.3	0.69	0.71	0.73	0.76	0.78	0.81	0.84	0.88	0.92	0.97	1.02	1.09	1.16	1.25	1.36	1.51	1.68
187.0	97	0.68	0.70	0.72	0.74	0.77	0.79	0.83	0.86	0.90	0.94	0.99	1.05	1.13	1.21	1.31	1.44	1.60
190.2	98	0.66	0.68	0.70	0.72	0.74	0.77	0.80	0.83	0.87	0.91	0.96	1.01	1.07	1.15	1.24	1.35	1.49
193.4	99	0.65	0.66	0.68	0.70	0.72	0.75	0.77	0.80	0.84	0.87	0.92	0.97	1.03	1.10	1.18	1.28	1.40
196.7	100	0.63	0.65	0.66	0.68	0.70	0.72	0.75	0.78	0.81	0.84	0.88	0.93	0.98	1.05	1.12	1.21	1.32
231.7	105	0.56	0.57	0.58	0.60	0.61	0.63	0.65	0.67	0.69	0.71	0.74	0.77	0.81	0.85	0.89	0.95	1.01
231.8	110	0.50	0.51	0.52	0.53	0.54	0.55	0.57	0.58	0.60	0.62	0.64	0.66	0.68	0.71	0.74	0.78	0.82

TABLE 7: HEAT REJECTION CAPACITY FACTORS – R-22, R-134A (CXVB AND CXVT ONLY)

Condensing Pressure (psig)		Condensing Temp (°F)	Entering Wet-Bulb Temperature (°F)																
R-22	R-134a		50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82
155.7	95.2	85	1.16	1.21	1.27	1.33	1.41	1.50	1.60	1.72	1.87	2.05	2.29	2.59	3.01	3.61	4.56	—	—
158.2	97.1	86	1.13	1.17	1.23	1.29	1.36	1.44	1.53	1.64	1.77	1.94	2.14	2.40	2.75	3.24	3.98	5.21	—
160.7	98.9	87	1.09	1.14	1.19	1.24	1.31	1.38	1.46	1.56	1.68	1.83	2.01	2.23	2.53	2.94	3.53	4.46	—
163.2	100.7	88	1.06	1.10	1.15	1.20	1.26	1.32	1.40	1.49	1.14	1.23	1.89	2.09	2.34	2.69	3.17	3.89	5.09
165.8	102.6	89	1.03	1.07	1.11	1.16	1.21	1.27	1.34	1.43	1.53	1.64	1.78	1.96	2.18	2.47	2.87	3.45	4.35
168.4	104.3	90	0.99	1.03	1.07	1.12	1.16	1.22	1.29	1.36	1.45	1.56	1.68	1.84	2.03	2.29	2.62	3.09	3.79
171.0	106.2	91	0.97	1.00	1.04	1.08	1.13	1.18	1.24	1.31	1.39	1.49	1.60	1.74	1.91	2.13	2.41	2.80	3.36
173.7	108.1	92	0.94	0.97	1.01	1.04	1.09	1.14	1.19	1.26	1.33	1.42	1.52	1.65	1.80	1.99	2.23	2.56	3.02
176.4	110.0	93	0.91	0.94	0.98	1.01	1.05	1.10	1.15	1.21	1.28	1.36	1.45	1.56	1.70	1.86	2.08	2.35	2.73
179.1	111.9	94	0.89	0.92	0.95	0.98	1.02	1.06	1.11	1.17	1.23	1.30	1.39	1.49	1.61	1.76	1.94	2.18	2.50
181.8	113.9	95	0.87	0.89	0.92	0.95	0.99	1.03	1.07	1.12	1.18	1.25	1.33	1.42	1.53	1.66	1.82	2.03	2.30
184.6	115.9	96	0.84	0.87	0.90	0.93	0.96	1.00	1.04	1.09	1.14	1.20	1.27	1.35	1.45	1.57	1.71	1.90	2.13
187.4	117.5	97	0.82	0.85	0.87	0.90	0.93	0.97	1.01	1.05	1.10	1.15	1.22	1.30	1.38	1.49	1.62	1.78	1.98
190.2	119.9	98	0.80	0.82	0.85	0.88	0.91	0.94	0.97	1.01	1.06	1.11	1.17	1.24	1.32	1.42	1.53	1.68	1.85
193.0	122.1	99	0.78	0.80	0.83	0.85	0.88	0.91	0.94	0.98	1.03	1.07	1.13	1.19	1.27	1.35	1.46	1.58	1.74
195.9	124.1	100	0.76	0.78	0.81	0.83	0.86	0.88	0.92	0.95	0.99	1.04	1.09	1.14	1.21	1.29	1.39	1.50	1.64
210.7	149.6	105	0.68	0.70	0.71	0.73	0.75	0.77	0.80	0.82	0.85	0.88	0.92	0.96	1.00	1.05	1.11	1.18	1.26
226.4	146.4	110	0.61	0.62	0.64	0.65	0.67	0.68	0.70	0.72	0.74	0.76	0.79	0.82	0.85	0.89	0.93	0.97	1.03

TABLE 8: HEAT REJECTION CAPACITY FACTORS – R-22, R-134A (PCC, VCA, VC1, AND VCL ONLY)

Condensing Pressure (psig)		Condensing Temp (°F)	Entering Wet-Bulb Temperature (°F)																
R-22	R-134a		50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82
155.7	95.2	85	1.09	1.14	1.19	1.25	1.32	1.40	1.49	1.60	1.74	1.91	2.12	2.40	2.78	3.33	—	—	—
158.2	97.1	86	1.06	1.10	1.15	1.20	1.27	1.34	1.42	1.52	1.64	1.79	1.98	2.22	2.54	2.98	3.66	4.78	—
160.7	98.9	87	1.02	1.06	1.11	1.16	1.22	1.28	1.36	1.45	1.56	1.69	1.85	2.06	2.33	2.70	3.24	4.08	—
163.2	100.7	88	0.99	1.03	1.07	1.12	1.17	1.23	1.30	1.38	1.48	1.60	1.74	1.92	2.16	2.47	2.90	3.56	4.65
165.8	102.6	89	0.96	0.99	1.03	1.08	1.13	1.18	1.25	1.32	1.41	1.52	1.64	1.8	2.00	2.27	2.63	3.15	3.97
168.4	104.3	90	0.93	0.96	1.00	1.04	1.09	1.14	1.20	1.27	1.35	1.44	1.56	1.70	1.87	2.10	2.40	2.82	3.46
171	106.2	91	0.90	0.93	0.97	1.01	1.05	1.10	1.15	1.21	1.29	1.37	1.47	1.60	1.75	1.95	2.20	2.55	3.06
173.7	108.1	92	0.88	0.91	0.94	0.97	1.01	1.06	1.11	1.16	1.23	1.31	1.40	1.51	1.65	1.82	2.04	2.33	2.74
176.4	110	93	0.85	0.88	0.91	0.94	0.98	1.02	1.07	1.12	1.18	1.25	1.33	1.43	1.56	1.71	1.90	2.14	2.49
179.1	111.9	94	0.83	0.85	0.88	0.91	0.95	0.98	1.03	1.08	1.13	1.20	1.27	1.35	1.47	1.6	1.77	1.98	2.27
181.8	113.9	95	0.81	0.83	0.86	0.88	0.92	0.95	0.99	1.04	1.09	1.15	1.22	1.30	1.40	1.51	1.66	1.84	2.09
184.6	115.9	96	0.79	0.81	0.83	0.86	0.89	0.92	0.96	1.00	1.05	1.10	1.17	1.24	1.33	1.43	1.56	1.72	1.93
187.4	117.5	97	0.76	0.79	0.81	0.83	0.86	0.89	0.93	0.97	1.01	1.06	1.12	1.18	1.26	1.36	1.47	1.61	1.80
190.2	119.9	98	0.75	0.76	0.79	0.81	0.84	0.86	0.90	0.93	0.97	1.02	1.07	1.13	1.21	1.29	1.39	1.52	1.68
193	122.1	99	0.73	0.74	0.77	0.79	0.81	0.84	0.87	0.90	0.94	0.98	1.03	1.09	1.15	1.23	1.32	1.43	1.57
195.9	124.1	100	0.71	0.73	0.74	0.77	0.79	0.81	0.84	0.87	0.91	0.95	0.99	1.04	1.10	1.17	1.26	1.36	1.48
210.7	149.6	105	0.63	0.64	0.66	0.67	0.69	0.71	0.73	0.75	0.77	0.8	0.83	0.87	0.91	0.95	1.00	1.07	1.14
226.4	146.4	110	0.56	0.57	0.58	0.60	0.61	0.62	0.64	0.65	0.67	0.69	0.71	0.74	0.77	0.85	0.83	0.87	0.92

NOTE: Consult your local BAC Representative for evaporative condenser selections for systems utilizing the following:

✓ Hydrocarbon refrigerants such as propane, butane, or propylene

✓ Centrifugal compressors

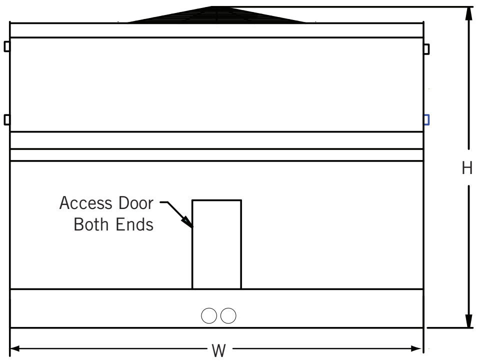
✓ Rotary screw compressors with water-cooled oil coolers

✓ Ammonia evaporative condensers with desuperheaters

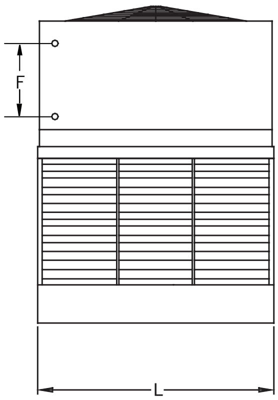
✓ Halocarbon evaporative condensers with subcooling

Sign up for free selection software at www.BaltimoreAircoil.com.

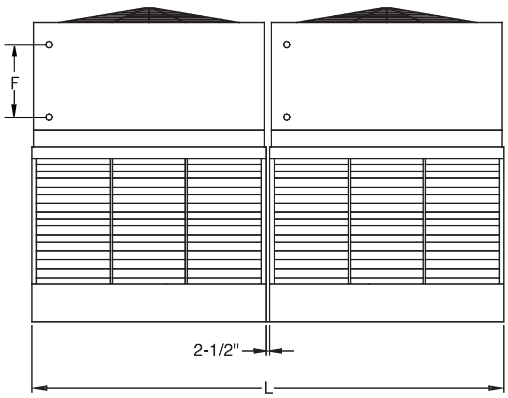
CXVT Engineering Data



End Elevation:
CXVT Units



Side Elevation:
CXVT-x-1224-x and CXVT-x-1426-x



Side Elevation:
CXVT-x-2424-x and CXVT-x-2826-x

NOTES:

1. Model number denotes R-717 capacity in evaporator tons at a 96.3°F condensing temperature, a 20°F suction temperature, and a 78°F entering wet-bulb temperature.
2. R-22 tons are at a 105°F condensing temperature, a 40°F suction temperature, and a 78°F entering wet-bulb temperature.
3. Operating weight is for the unit with the water level at the overflow level and with the coil charged with R-717.
4. The R-22 operating charge is 1.93 times the R-717 charge; R-134a is 1.98 times.
5. Drain size is based on a bottom connection.
6. Coil connections also available on the end. For other refrigerants, contact your local BAC Representative for the coil connection quantity.
7. Coil inlet and outlet connections are beveled for welding.
8. Standard make-up, drain, and overflow connections are located on the bottom of the unit. Make-up connection is 1-1/2" MPT standpipe, drain is 2" FPT and overflow is 3" FPT.
9. Models shipped with an optional gear drive or low sound fan may have heights up to 10.5" greater than shown.

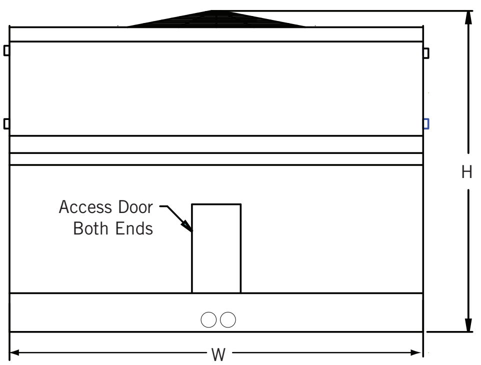
Do not use for construction. Refer to factory certified dimensions. This catalog includes data current at the time of publication, which should be reconfirmed at the time of purchase.

NOTE: Up-to-date engineering data, free product selection software, and more can be found at **www.BaltimoreAircoil.com**.

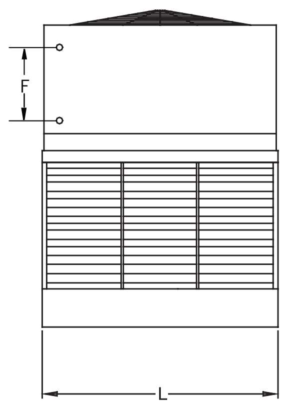
Nom. Box Size	Model Number[1]	Base Heat Rejection (MBH)	R-22 Tons[2]	Fan Motor (HP)	Airflow Rate (CFM)	Pump Motor (HP)	Spray Flow Rate (GPM)	Approximate Weight (lbs): Ship Weight	Approximate Weight (lbs): Heaviest Section	Approximate Weight (lbs): Oper. Weight[3]	R-717 Operating Charge[4] (lbs)	Internal Coil Volume (ft^3)	Remote Sump: Drain Size[5] (in)	Remote Sump: Volume Req. (gal)	Remote Sump: Approx. Oper. Weight (lbs)	W	L	F	H
12' x 24'	CXVT-617-1224-15	12,783	781	15	130,551	(2) 7.5	1,900	37,521	13,072	62,285	843	91	12	1,625	58,409	24'-1"	11'-11"	4'-4"	18'-11"
	CXVT-650-1224-20	13,463	822	20	143,690			37,521	13,072	62,285	843	91			58,409			4'-4"	18'-11"
	CXVT-676-1224-25	14,014	856	25	154,785			37,521	13,072	62,285	843	91			58,409			4'-4"	18'-11"
	CXVT-700-1224-40	14,503	886	40	182,224			34,749	13,072	59,208	704	76			55,331			3'-7"	18'-11"
	CXVT-731-1224-50	15,159	926	50	196,295			34,749	13,072	59,208	704	76			55,331			3'-7"	18'-11"
	CXVT-754-1224-60	15,624	954	60	208,594			34,749	13,072	59,208	704	76			55,331			3'-7"	18'-11"
	CXVT-778-1224-50	16,131	985	50	195,017			37,521	13,072	62,285	843	91			58,409			4'-4"	18'-11"
	CXVT-813-1224-50	16,843	1,029	50	195,580			38,779	13,072	63,544	843	91			59,667			3'-10"	18'-11"
	CXVT-843-1224-60	17,483	1,068	60	207,834			38,779	13,072	63,544	843	91			59,667			3'-10"	18'-11"
	CXVT-887-1224-60	18,386	1,123	60	203,260			47,845	14,257	73,889	1,259	136			69,912			6'-1"	20'-7"
14' x 26'	CXVT-712-1426-20	14,761	901	20	157,445	(2) 7.5	1,900	39,107	14,610	69,079	824	89	12	2,000	64,307	26'-4"	13'-11"	3'-7"	19'-1"
	CXVT-741-1426-25	15,366	938	25	169,602			39,107	14,610	69,079	824	89			64,307			3'-7"	19'-1"
	CXVT-766-1426-30	15,879	970	30	180,229			39,107	14,610	69,079	824	89			64,307			3'-7"	19'-1"
	CXVT-807-1426-40	16,723	1,021	40	198,368			39,107	14,610	69,079	824	89			64,307			3'-7"	19'-1"
	CXVT-844-1426-50	17,484	1,068	50	213,686			39,107	14,610	69,079	824	89			64,307			3'-7"	19'-1"
	CXVT-894-1426-50	18,520	1,131	50	212,485			42,385	14,610	72,724	991	107			67,953			4'-4"	19'-1"
	CXVT-933-1426-50	19,337	1,181	50	212,610			43,798	14,610	74,137	991	107			69,365			3'-10"	19'-1"
	CXVT-965-1426-60	19,999	1,221	60	225,932			43,798	14,610	74,137	991	107			69,365			3'-10"	19'-7"
	CXVT-1005-1426-75	20,838	1,273	75	243,378			43,798	14,610	74,137	991	107			69,365			3'-10"	19'-7"
	CXVT-1057-1426-75	21,914	1,338	75	238,794			54,230	16,500	86,062	1,482	160			81,189			6'-1"	21'-3"
24' x 24'	CXVT-1234-2424-30	25,577	1,562	(2) 15	261,102	(4) 7.5	3,800	75,042	13,072	124,570	1,685	182	(2) 12	3,250	116,818	24'-1"	24'-1"	4'-4"	18'-11"
	CXVT-1300-2424-40	26,945	1,644	(2) 20	287,380			75,042	13,072	124,570	1,685	182			116,818			4'-4"	18'-11"
	CXVT-1352-2424-50	28,023	1,712	(2) 25	309,571			75,042	13,072	124,570	1,685	182			116,818			4'-4"	18'-11"
	CXVT-1400-2424-80	29,017	1,772	(2) 40	364,448			69,498	13,072	118,416	1,408	152			110,662			3'-7"	18'-11"
	CXVT-1462-2424-100	30,302	1,852	(2) 50	392,590			69,498	13,072	118,416	1,408	152			110,662			3'-7"	18'-11"
	CXVT-1508-2424-120	31,256	1,908	(2) 60	417,189			69,498	13,072	118,416	1,408	152			110,662			3'-7"	18'-11"
	CXVT-1556-2424-100	32,251	1,970	(2) 50	390,035			75,042	13,072	124,570	1,685	182			116,818			4'-4"	18'-11"
	CXVT-1626-2424-100	33,702	2,058	(2) 50	391,159			77,558	13,072	127,088	1,685	182			119,334			3'-10"	18'-11"
	CXVT-1686-2424-120	34,945	2,136	(2) 60	415,669			77,558	13,072	127,088	1,685	182			119,334			3'-10"	18'-11"
	CXVT-1774-2424-120	36,769	2,246	(2) 60	406,520			95,690	14,257	147,778	2,519	272			139,824			6'-1"	20'-7"
28' x 26'	CXVT-1424-2826-40	29,515	1,802	(2) 20	314,890	(4) 7.5	3,800	78,214	14,610	138,158	1,648	178	(2) 12	4,000	128,614	26'-4"	28'-1"	3'-7"	19'-1"
	CXVT-1482-2826-50	30,717	1,876	(2) 25	339,205			78,214	14,610	138,158	1,648	178			128,614			3'-7"	19'-1"
	CXVT-1532-2826-60	31,753	1,940	(2) 30	360,459			78,214	14,610	138,158	1,648	178			128,614			3'-7"	19'-1"
	CXVT-1614-2826-80	33,453	2,042	(2) 40	396,736			78,214	14,610	138,158	1,648	178			128,614			3'-7"	19'-1"
	CXVT-1688-2826-100	34,987	2,136	(2) 50	427,371			78,214	14,610	138,158	1,648	178			128,614			3'-7"	19'-1"
	CXVT-1788-2826-100	37,059	2,262	(2) 50	424,971			84,770	14,610	145,448	1,982	214			135,906			4'-4"	19'-1"
	CXVT-1866-2826-100	38,676	2,362	(2) 50	425,221			87,596	14,610	148,274	1,982	214			138,730			3'-10"	19'-1"
	CXVT-1930-2826-120	40,002	2,442	(2) 60	451,865			87,596	14,610	148,274	1,982	214			138,730			3'-10"	19'-7"
	CXVT-2010-2826-150	41,661	2,546	(2) 75	486,756			87,596	14,610	148,274	1,982	214			138,730			3'-10"	19'-7"
	CXVT-2114-2826-150	43,816	2,676	(2) 75	477,587			108,460	16,500	172,124	2,963	320			162,378			6'-1"	21'-3"

CXVT Engineering Data

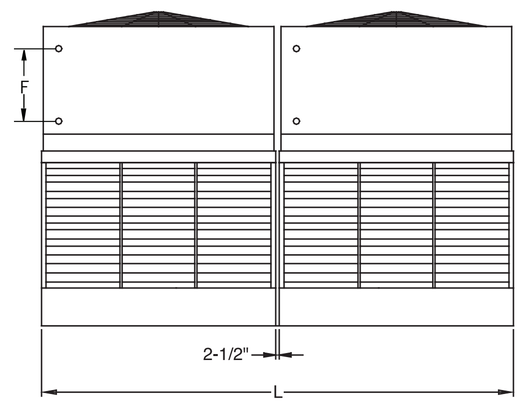
XE Models



End Elevation:
XECXVT Units



Side Elevation:
XECXVTx-1224-x and XECXVTx-1426-x



Side Elevation:
XECXVTx-2424-x and XECXVTx-2826-x

NOTES:

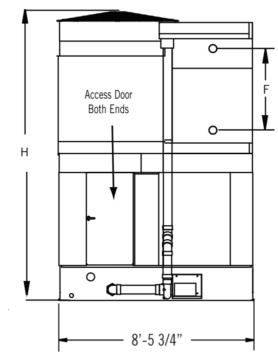
1. Model number denotes R-717 capacity in evaporator tons at a 96.3°F condensing temperature, a 20°F suction temperature, and a 78°F entering wet-bulb temperature.
2. R-22 tons are at a 105°F condensing temperature, a 40°F suction temperature, and a 78°F entering wet-bulb temperature.
3. Operating weight is for the unit with the water level at the overflow level and with the coil charged with R-717.
4. The R-22 operating charge is 1.93 times the R-717 charge; R-134a is 1.98 times.
5. Drain size is based on a bottom connection.
6. Coil connections also available on the end. For other refrigerants, contact your local BAC Representative for the coil connection quantity.
7. Coil inlet and outlet connections are beveled for welding.
8. Standard make-up, drain, and overflow connections are located on the bottom of the unit. Make-up connection is 1-1/2" MPT standpipe, drain is 2" FPT and overflow is 3" FPT.
9. Models shipped with an optional gear drive or low sound fan may have heights up to 10.5" greater than shown.

Do not use for construction. Refer to factory certified dimensions. This catalog includes data current at the time of publication, which should be reconfirmed at the time of purchase.

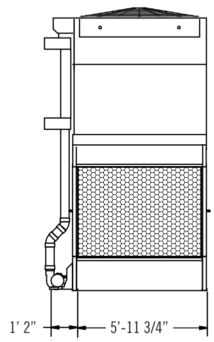
NOTE: Up-to-date engineering data, free product selection software, and more can be found at **www.BaltimoreAircoil.com**.

Nom. Box Size	Model Number[1]	Base Heat Rejection (MBH)	R-22 Tons[2]	Fan Motor (HP)	Airflow Rate (CFM)	Pump Motor (HP)	Spray Flow Rate (GPM)	Approximate Weight (lbs) Ship Weight	Approximate Weight (lbs) Heaviest Section	Approximate Weight (lbs) Oper. Weight[3]	R-717 Operating Charge[4] (lbs)	Internal Coil Volume (ft^3)	Remote Sump Drain Size[5] (in)	Remote Sump Volume Req. (gal)	Remote Sump Approx. Oper. Weight (lbs)	W	L	F	H
12' x 24'	XECXVT540-1224-10	11,190	683	10	114,794	(2) 7.5	1,900	34,749	13,072	59,208	704	76	12	1,625	55,331	24'-1"	11'-11"	3'-7"	18'-11"
	XECXVT605-1224-10	12,539	766	10	114,376			38,779	13,072	63,544	843	91			59,667			3'-10"	18'-11"
	XECXVT636-1224-10	13,186	805	10	111,858			47,845	14,257	73,889	1,259	136			69,912			6'-1"	20'-7"
	XECXVT684-1224-15	14,184	866	15	128,046			47,845	14,257	73,889	1,259	136			69,912			6'-1"	20'-7"
	XECXVT721-1224-20	14,938	912	20	140,933			47,845	14,257	73,889	1,259	136			69,912			6'-1"	20'-7"
	XECXVT750-1224-25	15,550	950	25	151,815			47,845	14,257	73,889	1,259	136			69,912			6'-1"	20'-7"
	XECXVT775-1224-30	16,069	981	30	161,328			47,845	14,257	73,889	1,259	136			69,912			6'-1"	20'-7"
14' x 26'	XECXVT629-1426-10	13,030	796	10	124,964	(2) 7.5	1,900	39,107	14,610	69,079	824	89	12	2,000	64,307	26'-4"	13'-11"	3'-7”	19'-1"
	XECXVT698-1426-10	14,474	884	10	124,335			43,798	14,610	74,137	991	107			69,365			3'-10"	19'-1"
	XECXVT734-1426-10	15,221	930	10	121,993			54,230	16,500	86,062	1,482	160			81,189			6'-1"	20'-9"
	XECXVT790-1426-15	16,373	1,000	15	139,647			54,230	16,500	86,062	1,482	160			81,189			6'-1"	20'-9"
	XECXVT832-1426-20	17,244	1,053	20	153,702			54,230	16,500	86,062	1,482	160			81,189			6'-1"	20'-9"
	XECXVT866-1426-25	17,950	1,096	25	165,570			54,230	16,500	86,062	1,482	160			81,189			6'-1"	20'-9"
	XECXVT895-1426-30	18,549	1,133	30	175,945			54,230	16,500	86,062	1,482	160			81,189			6'-1"	20'-9"
	XECXVT942-1426-40	19,535	1,193	40	193,652			54,230	16,500	86,062	1,482	160			81,189			6'-1"	20'-9"
24' x 24'	XECXVT1080-2424-20	22,385	1,366	(2) 10	229,588	(4) 7.5	3,800	69,498	13,072	118,416	1,408	152	(2) 12	3,250	110,662	24'-1"	24'-1"	3'-7"	18'-11"
	XECXVT1210-2424-20	25,079	1,532	(2) 10	228,751			77,558	13,072	127,088	1,685	182			119,334			3'-10"	18'-11"
	XECXVT1272-2424-20	26,364	1,610	(2) 10	223,717			95,690	14,257	147,778	2,519	272			139,824			6'-1"	20'-7"
	XECXVT1368-2424-30	28,354	1,732	(2) 15	256,092			95,690	14,257	147,778	2,519	272			139,824			6'-1"	20'-7"
	XECXVT1442-2424-40	29,888	1,824	(2) 20	281,865			95,690	14,257	147,778	2,519	272			139,824			6'-1"	20'-7"
	XECXVT1500-2424-50	31,090	1,900	(2) 25	303,630			95,690	14,257	147,778	2,519	272			139,824			6'-1"	20'-7"
	XECXVT1550-2424-60	32,126	1,962	(2) 30	322,655			95,690	14,257	147,778	2,519	272			139,824			6'-1"	20'-7"
28' x 26'	XECXVT1258-2826-20	26,074	1,592	(2) 10	249,928	(4) 7.5	3,800	78,214	14,610	138,158	1,648	178	(2) 12	4,000	128,614	26'-4"	28'-1"	3'-7”	19'-1"
	XECXVT1396-2826-20	28,935	1,768	(2) 10	248,671			87,596	14,610	148,274	1,982	214			138,730			3'-10"	19'-1"
	XECXVT1468-2826-20	30,427	1,860	(2) 10	243,986			108,460	16,500	172,124	2,963	320			162,378			6'-1"	20'-9"
	XECXVT1580-2826-30	32,748	2,000	(2) 15	279,295			108,460	16,500	172,124	2,963	320			162,378			6'-1"	20'-9"
	XECXVT1664-2826-40	34,489	2,106	(2) 20	307,403			108,460	16,500	172,124	2,963	320			162,378			6'-1"	20'-9"
	XECXVT1732-2826-50	35,899	2,192	(2) 25	331,140			108,460	16,500	172,124	2,963	320			162,378			6'-1"	20'-9"
	XECXVT1790-2826-60	37,101	2,266	(2) 30	351,889			108,460	16,500	172,124	2,963	320			162,378			6'-1"	20'-9"
	XECXVT1884-2826-80	39,049	2,386	(2) 40	387,304			108,460	16,500	172,124	2,963	320			162,378			6'-1"	20'-9"

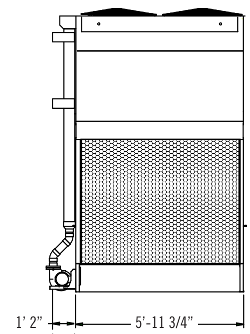
CXVB Engineering Data



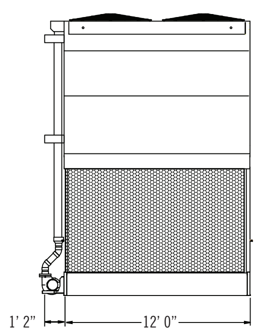
Connection Side:
CXVB 8' x 6', 8' x 9', 8' x 12' and 8' x 18' Units



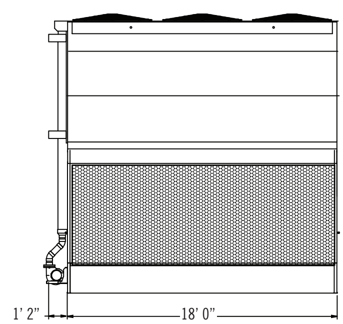
Air Inlet End:
CXVB 8' x 6' Units



Air Inlet End:
CXVB 8' x 9' Units



Air Inlet End:
CXVB 8' x 12' Units



Air Inlet End:
CXVB 8' x 18' Units

NOTES:

1. Model number denotes R-717 capacity in evaporator tons at a 96.3°F condensing temperature, a 20°F suction temperature, and a 78°F entering wet-bulb temperature.
2. R-22 tons are at a 105°F condensing temperature, a 40°F suction temperature, and a 78°F entering wet-bulb temperature.
3. Operating weight is for the unit with the water level at the overflow level and with the coil charged with R-717.
4. The R-22 operating charge is 1.93 times the R-717 charge; R-134a is 1.98 times.
5. Drain size is based on a bottom connection.
6. For R-22 and R-134a, the coil connection quantity may double.
7. Standard make-up, drain, and overflow connections are MPT.
8. Coil inlet and outlet connections are beveled for welding.

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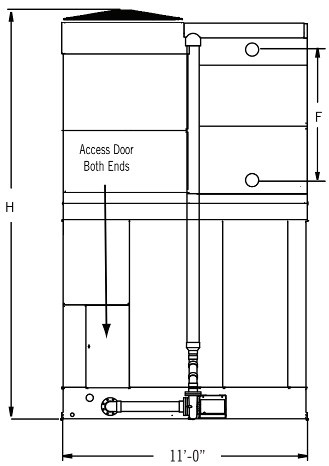
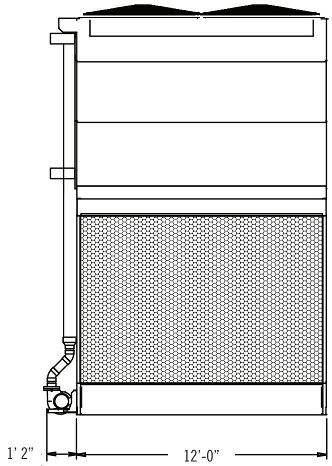
NOTE: Up-to-date engineering data, free product selection software, and more can be found at **www.BaltimoreAircoil.com**.

								Approximate Weight (lbs)					Remote Sump				
Nom. Box Size	Model Number[1]	Base Heat Rejection (MBH)	R-22 Tons[2]	Fan Motor (HP)	Airflow Rate (CFM)	Pump Motor (HP)	Spray Flow Rate (GPM)	Ship Weight	Heaviest Section	Oper. Weight[3]	R-717 Operating Charge[4] (lbs)	Internal Coil Volume (ft^3)	Drain Size[5] (in)	Volume Req. (gal)	Approx. Oper. Weight (lbs)	F	H
8' x 6'	CXVB-75-0806-3	1,550	95	3	22,200	2	290	4,830	2,870	7,410	54	6	6	290	7,300	3'-7"	12'-7"
	CXVB-87-0806-3	1,798	110	3	24,300			5,590	3,160	8,190	71	8			8,070	3'-7"	15'-3"
	CXVB-94-0806-3	1,943	119	3	20,400			7,120	5,050	9,810	161	18			9,700	6'-4"	15'-5"
	CXVB-95-0806-5	1,964	120	5	28,800			5,600	3,170	8,200	71	8			8,080	3'-7"	15'-3"
	CXVB-102-0806-7.5	2,109	129	7.5	32,900			5,630	3,200	8,230	71	8			8,120	3'-7"	15'-3"
	CXVB-106-0806-3	2,191	134	3	23,400			7,580	5,050	10,270	161	18			10,150	6'-4"	18'-1"
	CXVB-111-0806-10	2,295	141	10	35,900			5,950	3,500	8,570	89	10			8,450	3'-7"	15'-3"
	CXVB-117-0806-5	2,419	148	5	27,700			7,590	5,060	10,280	161	18			10,160	6'-4"	18'-1"
	CXVB-123-0806-10	2,543	156	10	35,500			6,660	4,180	9,290	107	12			9,180	6'-6"	18'-1"
	CXVB-137-0806-15	2,832	173	15	39,900			7,650	5,120	10,330	161	18			10,220	6'-6"	18'-1"
8' x 9'	CXVB-113-0809-3	2,336	143	3	31,200	5	500	7,040	3,760	11,010	80	9	8	550	10,790	3'-7"	15'-1"
	CXVB-124-0809-5	2,563	157	5	37,000			7,060	3,770	11,020	80	9			10,800	3'-7"	15'-2"
	CXVB-126-0809-3	2,605	159	3	26,700			9,150	6,310	13,240	214	24			13,030	6'-6"	15'-5"
	CXVB-134-0809-7.5	2,770	170	7.5	42,300			7,090	3,800	11,050	80	9			10,840	3'-7"	15'-3"
	CXVB-138-0809-3	2,853	175	3	30,200			9,270	5,880	13,340	188	21			13,130	6'-6"	17'-11"
	CXVB-138-0809-5	2,853	175	5	36,200			7,950	4,620	11,960	134	15			11,750	3'-7"	15'-2"
	CXVB-141-0809-3	2,915	178	3	29,800			10,170	6,730	14,290	241	27			14,080	6'-6"	18'-1"
	CXVB-144-0809-7.5	2,977	182	7.5	41,900			7,540	4,230	11,530	107	12			11,310	3'-7"	15'-1"
	CXVB-152-0809-5	3,142	192	5	35,700			9,290	5,890	13,350	188	21			13,140	6'-6"	17'-11"
	CXVB-158-0809-5	3,266	200	5	35,300			10,180	6,750	14,300	241	27			14,090	6'-6"	17'-11"
	CXVB-163-0809-7.5	3,370	206	7.5	41,200			8,870	5,500	12,910	161	18			12,700	6'-6"	17'-11"
	CXVB-190-0809-15	3,928	241	15	51,500			9,410	6,010	13,480	188	21			13,270	6'-6"	17'-11"
	CXVB-207-0809-20	4,279	262	20	56,000			10,330	6,890	14,450	241	27			14,240	6'-6"	17'-11"
8' x 12'	CXVB-172-0812-7.5	3,556	218	7.5	53,500	5	719	8,570	4,570	13,910	107	12	10	600	13,700	3'-7"	15'-3"
	CXVB-195-0812-10	4,031	247	10	58,000			9,170	5,150	14,550	143	16			14,340	3'-7"	15'-3"
	CXVB-204-0812-7.5	4,217	258	7.5	44,500			12,030	8,500	17,590	322	36			17,370	6'-4"	15'-5"
	CXVB-207-0812-15	4,279	262	15	66,400			9,250	5,220	14,630	143	16			14,420	3'-7"	15'-3"
	CXVB-216-0812-7.5	4,465	273	7.5	51,700			10,920	6,810	16,370	214	24			16,150	6'-4"	18'-1"
	CXVB-217-0812-15	4,486	275	15	65,700			9,850	5,790	15,260	179	20			15,050	3'-7"	15'-3"
	CXVB-221-0812-7.5	4,569	280	7.5	51,100			11,810	7,650	17,310	268	30			17,090	6'-4"	18'-1"
	CXVB-226-0812-7.5	4,672	286	7.5	50,800			12,690	8,500	18,250	322	36			18,030	6'-4"	18'-1"
	CXVB-227-0812-20	4,693	287	20	72,300			9,870	5,810	15,280	179	20			15,070	3'-7"	15'-3"
	CXVB-237-0812-10	4,899	300	10	56,300			11,820	7,670	17,320	268	30			17,110	6'-4"	18'-1"
	CXVB-238-0812-15	4,920	301	15	65,200			10,910	6,810	16,360	214	24			16,150	6'-6"	18'-1"
	CXVB-241-0812-10	4,982	305	10	55,900			12,700	8,510	18,260	322	36			18,050	6'-4"	18'-1"
	CXVB-259-0812-20	5,354	328	20	71,200			11,530	7,390	17,010	250	28			16,800	6'-6"	18'-1"
	CXVB-270-0812-25	5,581	342	25	76,100			12,180	8,010	17,700	286	32			17,480	6'-6"	18'-1"
	CXVB-284-0812-30	5,871	359	30	80,600			12,790	8,600	18,350	322	36			18,140	6'-6"	18'-1"
8' x 18'	CXVB-248-0818-15	5,127	314	(1) 10 & (1) 5	89,700	7.5	859	12,400	6,660	20,500	161	18	10	750	20,240	3'-7"	15'-9"
	CXVB-268-0818-15	5,540	339	(1) 10 & (1) 5	88,400			13,350	7,570	21,500	214	24			21,240	3'-7"	15'-9"
	CXVB-281-0818-15	5,809	356	(1) 10 & (1) 5	87,600			14,300	8,470	22,500	268	30			22,240	3'-7"	15'-9"
	CXVB-310-0818-15	6,408	392	(1) 10 & (1) 5	86,900			15,830	9,930	24,090	322	36			23,830	6'-6"	18'-7"
	CXVB-321-0818-15	6,636	406	(1) 10 & (1) 5	86,900			15,940	10,030	24,200	322	36			23,940	6'-4"	18'-7"
	CXVB-327-0818-15	6,760	414	(1) 10 & (1) 5	85,200			18,680	12,640	27,100	483	53			26,840	6'-6"	18'-7"
	CXVB-329-0818-22.5	6,801	416	(1) 15 & (1)7. 5	99,500			15,950	10,040	24,210	322	36			23,950	6'-6"	18'-7"
	CXVB-342-0818-15	7,070	433	(1) 10 & (1) 5	85,200			18,780	12,740	27,200	483	53			26,940	6'-4"	18'-7"
	CXVB-345-0818-30	7,132	437	(1) 20 & (1) 10	109,500			15,980	10,070	24,240	322	36			23,980	6'-6"	18'-7"
	CXVB-357-0818-22.5	7,380	452	(1) 15 & (1) 7. 5	98,400			17,470	11,490	25,820	402	44			25,550	6'-4"	18'-7"
	CXVB-373-0818-30	7,711	472	(1) 20 & (1) 10	108,300			17,510	11,530	25,850	402	44			25,590	6'-4"	18'-7"
	CXVB-387-0818-30	8,000	490	(1) 20 & (1) 10	107,300			18,930	12,880	27,350	483	53			27,090	6'-4"	18'-7"
	CXVB-409-0818-45	8,455	518	(1) 30 & (1) 15	122,800			19,090	13,030	27,510	483	53			27,250	6'-4"	18'-7"

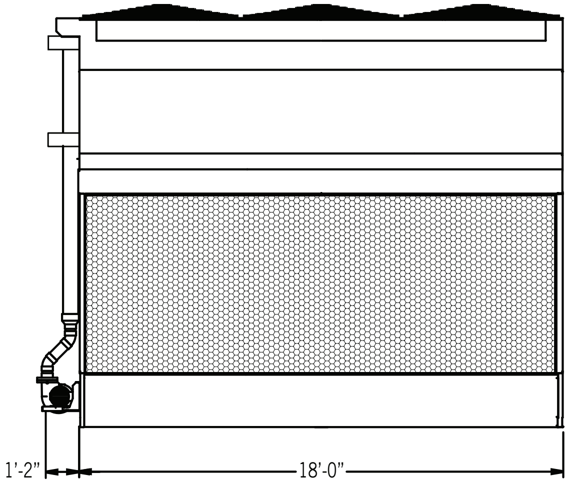
CXVB Engineering Data



Connection Side:
CXVB 12' x 12' and 12' x 18' Units



Air Inlet End:
CXVB 12' x 12' Units



Air Inlet End:
CXVB 12' x 18' Units

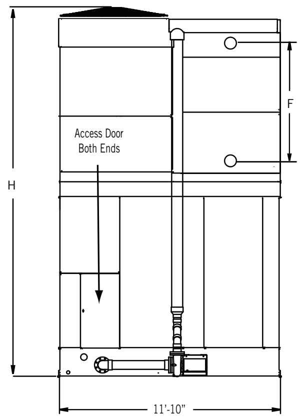
NOTES:

1. Model number denotes R-717 capacity in evaporator tons at a 96.3°F condensing temperature, a 20°F suction temperature, and a 78°F entering wet-bulb temperature.
2. R-22 tons are at a 105°F condensing temperature, a 40°F suction temperature, and a 78°F entering wet-bulb temperature.
3. Operating weight is for the unit with the water level at the overflow level and with the coil charged with R-717.
4. The R-22 operating charge is 1.93 times the R-717 charge; R-134a is 1.98 times.
5. Drain size is based on a bottom connection.
6. For R-22 and R-134a, the coil connection quantity may double.
7. Standard make-up, drain, and overflow connections are MPT.
8. Coil inlet and outlet connections are beveled for welding.

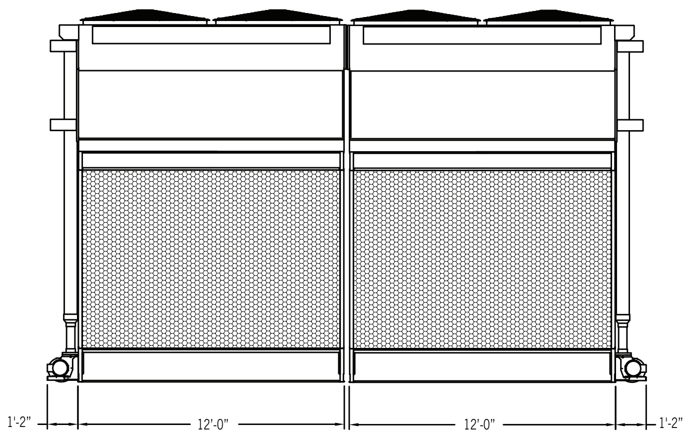
Do not use for construction. Refer to factory certified dimensions. This catalog includes data current at the time of publication, which should be reconfirmed at the time of purchase.

Nom. Box Size	Model Number[1]	Base Heat Rejection (MBH)	R-22 Tons[2]	Fan Motor (HP)	Airflow Rate (CFM)	Pump Motor (HP)	Spray Flow Rate (GPM)	Approximate Weight (lbs)			R-717 Operating Charge[4] (lbs)	Internal Coil Volume (ft^3)	Remote Sump			F	H
								Ship Weight	Heaviest Section	Oper. Weight[3]			Drain Size[5] (in)	Volume Req. (gal)	Approx. Oper. Weight (lbs)		
	CXVB-237-1212-10	4,899	300	10	71,900			10,830	6,110	18,570	177	20			18,310	3'-7"	16'-7"
	CXVB-264-1212-10	5,457	334	10	70,400			12,780	7,960	20,640	294	33			20,380	3'-7"	16'-7"
	CXVB-285-1212-15	5,892	361	15	80,600			12,860	8,040	20,720	294	33			20,460	3'-7"	16'-7"
	CXVB-297-1212-10	6,140	376	10	69,800			14,370	9,480	22,290	353	39			22,030	6'-4"	19'-6"
	CXVB-299-1212-10	6,181	378	10	68,800			16,250	11,260	24,280	471	52			24,020	6'-6"	19'-6"
	CXVB-302-1212-20	6,243	382	20	88,700			12,880	8,060	20,750	294	33			20,480	3'-7"	16'-7"
	CXVB-306-1212-10	6,326	387	10	69,000			15,830	10,870	23,840	442	49			23,580	6'-4"	19'-6"
	CXVB-314-1212-15	6,491	397	15	79,900			14,380	9,490	22,300	353	39			22,030	6'-6"	19'-6"
12' x 12'	CXVB-315-1212-10	6,512	399	10	68,300	7.5	859	17,290	12,260	25,390	530	58	10	750	25,120	6'-4"	19'-6"
	CXVB-327-1212-15	6,760	414	15	78,700			16,330	11,340	24,360	471	52			24,100	6'-6"	19'-6"
	CXVB-341-1212-20	7,049	432	20	87,300			15,380	10,440	23,350	412	45			23,090	6'-6"	19'-6"
	CXVB-341-1212-15	7,049	432	15	78,200			17,370	12,340	25,470	530	58			25,200	6'-4"	19'-6"
	CXVB-355-1212-25	7,339	449	25	94,100			15,430	10,490	23,410	412	45			23,150	6'-6"	19'-6"
	CXVB-370-1212-25	7,649	468	25	93,600			15,990	11,020	24,000	442	49			23,740	6'-4"	19'-6"
	CXVB-381-1212-30	7,876	482	30	98,500			17,400	12,370	25,500	530	58			25,240	6'-6"	19'-6"
	CXVB-393-1212-30	8,124	497	30	98,500			17,470	12,430	25,570	530	58			25,310	6'-4"	19'-6"
	CXVB-411-1212-40	8,496	520	40	109,500			16,320	11,330	24,320	442	49			24,060	6'-4"	19'-6"
	CXVB-360-1218-15	7,442	456	(1) 10 & (1) 5	108,600			15,940	8,990	27,690	265	29			27,200	3'-7"	17'-1"
	CXVB-403-1218-15	8,331	510	(1) 10 & (1) 5	108,100			19,130	12,020	31,050	442	49			30,570	3'-7"	17'-1"
	CXVB-437-1218-22.5	9,034	553	(1) 15 & (1) 7.5	123,800			19,250	12,130	31,170	442	49			30,680	3'-7"	17'-1"
	CXVB-444-1218-15	9,178	562	(1) 10 & (1) 5	105,200			21,280	14,070	33,290	530	58			32,800	6'-6"	20'-0"
	CXVB-457-1218-15	9,447	578	(1) 10 & (1) 5	105,200			21,430	14,210	33,440	530	58			32,950	6'-4"	20'-0"
	CXVB-459-1218-15	9,488	581	(1) 10 & (1) 5	103,800			24,470	17,110	36,660	706	78			36,170	6'-6"	20'-0"
	CXVB-467-1218-15	9,654	591	(1) 10 & (1) 5	103,000			25,960	18,530	38,240	795	87			37,750	6'-6"	20'-0"
	CXVB-482-1218-22.5	9,964	610	(1) 15 & (1) 7.5	120,400			21,460	14,240	33,470	530	58			32,990	6'-6"	20'-0"
12' x 18'	CXVB-483-1218-15	9,985	611	(1) 10 & (1) 5	103,000	10	1,300	26,110	18,660	38,380	795	87	12	1,085	37,890	6'-4"	20'-0"
	CXVB-513-1218-22.5	10,605	649	(1) 15 & (1) 7.5	119,200			23,880	16,550	36,030	662	73			35,540	6'-4"	20'-0"
	CXVB-525-1218-22.5	10,853	665	(1) 15 & (1) 7.5	117,900			26,220	18,770	38,500	795	87			38,010	6'-4"	20'-0"
	CXVB-525-1218-30	10,853	665	(1) 20 & (1) 10	132,600			21,580	14,350	33,590	530	58			33,100	6'-4"	20'-0"
	CXVB-545-1218-30	11,266	690	(1) 20 & (1) 10	131,200			23,920	16,580	36,060	662	73			35,570	6'-4"	20'-0"
	CXVB-567-1218-37.5	11,721	718	(1) 25 & (1) 15	141,300			23,980	16,640	36,120	662	73			35,630	6'-4"	20'-0"
	CXVB-581-1218-37.5	12,010	735	(1) 25 & (1) 15	139,800			26,310	18,860	38,590	795	87			38,100	6'-4"	20'-0"
	CXVB-601-1218-45	12,424	761	(1) 30 & (1) 15	148,500			26,420	18,960	38,690	795	87			38,200	6'-4"	20'-0"
	CXVB-628-1218-60	12,982	795	(1) 40 & (1) 20	165,300			24,400	17,040	36,550	662	73			36,060	6'-4"	20'-0"
	CXVB-643-1218-60	13,292	814	(1) 40 & (1) 20	163,500			26,740	19,270	39,020	795	87			38,530	6'-4"	20'-0"

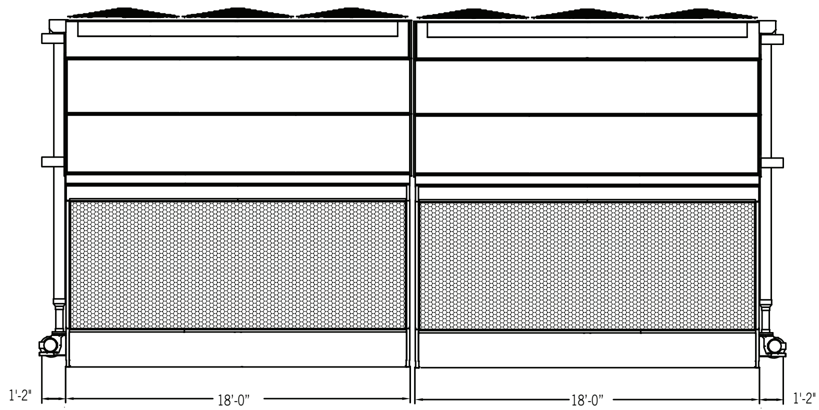
CXVB Engineering Data



Connection Side:
CXVB 12' x 24' and 12' x 36' Units



Air Inlet End:
CXVB 12' x 24' Units



Air Inlet End:
CXVB 12' x 36' Units

NOTES:

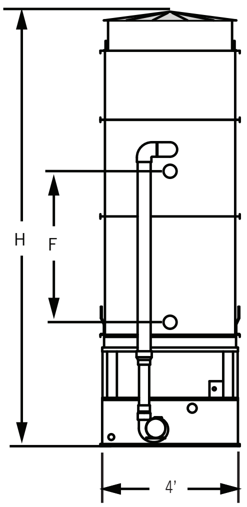
1. Model number denotes R-717 capacity in evaporator tons at a 96.3°F condensing temperature, a 20°F suction temperature, and a 78°F entering wet-bulb temperature.
2. R-22 tons are at a 105°F condensing temperature, a 40°F suction temperature, and a 78°F entering wet-bulb temperature.
3. Operating weight is for the unit with the water level at the overflow level and with the coil charged with R-717.
4. The R-22 operating charge is 1.93 times the R-717 charge; R-134a is 1.98 times.
5. Drain size is based on a bottom connection.
6. For R-22 and R-134a, the coil connection quantity may double.
7. Standard make-up, drain, and overflow connections are MPT.
8. Coil inlet and outlet connections are beveled for welding.

Do not use for construction. Refer to factory certified dimensions. This catalog includes data current at the time of publication, which should be reconfirmed at the time of purchase.

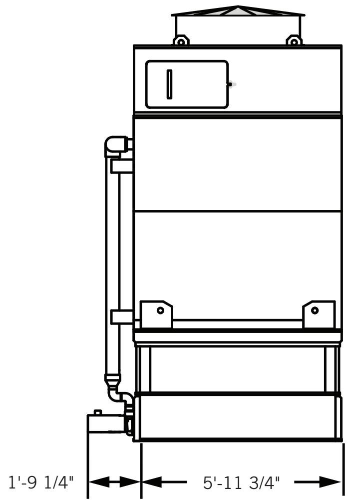
Nom. Box Size	Model Number[1]	Base Heat Rejection (MBH)	R-22 Tons[2]	Fan Motor (HP)	Airflow Rate (CFM)	Pump Motor (HP)	Spray Flow Rate (GPM)	Approximate Weight (lbs)			R-717 Operating Charge[4] (lbs)	Internal Coil Volume (ft³)	Remote Sump			F	H
								Ship Weight	Heaviest Section	Oper. Weight[3]			Drain Size[5] (in)	Volume Req. (gal)	Approx. Oper. Weight (lbs)		
	CXVB-473-1224-20	9,778	599	(2) 10	143,700			21,660	6,110	37,160	354	40			36,620	3'-7"	16'-7"
	CXVB-528-1224-20	10,915	668	(2) 10	140,700			25,560	7,960	41,280	588	66			40,750	3'-7"	16'-7"
	CXVB-571-1224-30	11,804	723	(2) 15	161,100			25,720	8,040	41,440	588	66			40,910	3'-7"	16'-7"
	CXVB-595-1224-20	12,300	753	(2) 10	139,500			28,740	9,480	44,580	706	78			44,050	6'-4"	19'-6"
	CXVB-598-1224-20	12,362	757	(2) 10	137,500			32,490	11,260	48,560	942	104			48,040	6'-6"	19'-6"
	CXVB-604-1224-40	12,486	765	(2) 20	177,300			25,760	8,060	41,500	588	66			40,960	3'-7"	16'-7"
	CXVB-612-1224-20	12,651	775	(2) 10	138,000			31,660	10,870	47,680	884	98			47,150	6'-4"	19'-6"
	CXVB-629-1224-30	13,003	796	(2) 15	159,700			28,750	9,490	44,600	706	78			44,060	6'-6"	19'-6"
12' x 24'	CXVB-630-1224-20	13,023	797	(2) 10	136,600	(2) 7.5	1,718	34,570	12,260	50,780	1,060	116	(2) 10	1,500	50,240	6'-4"	19'-6"
	CXVB-655-1224-30	13,540	829	(2) 15	157,400			32,650	11,340	48,720	942	104			48,200	6'-6"	19'-6"
	CXVB-682-1224-30	14,098	863	(2) 15	156,400			34,730	12,340	50,940	1,060	116			50,400	6'-6"	19'-6"
	CXVB-682-1224-40	14,098	863	(2) 20	174,600			30,750	10,440	46,700	824	90			46,180	6'-4"	19'-6"
	CXVB-711-1224-50	14,698	900	(2) 25	188,100			30,860	10,490	46,820	824	90			46,290	6'-6"	19'-6"
	CXVB-739-1224-50	15,277	935	(2) 25	187,200			31,980	11,020	48,000	884	98			47,470	6'-4"	19'-6"
	CXVB-762-1224-60	15,752	965	(2) 30	197,000			34,800	12,370	51,000	1,060	116			50,470	6'-6"	19'-6"
	CXVB-786-1224-60	16,248	995	(2) 30	197,000			34,940	12,430	51,140	1,060	116			50,610	6'-4"	19'-6"
	CXVB-821-1224-80	16,972	1,039	(2) 40	219,000			32,630	11,330	48,640	884	98			48,120	6'-4"	19'-6"
	CXVB-719-1236-30	14,863	910	(2) 10 & (2) 5	217,200			31,880	8,990	55,380	530	58			54,390	3'-7"	17'-1"
	CXVB-806-1236-30	16,662	1,020	(2) 10 & (2) 5	216,200			38,260	12,020	62,100	884	98			61,130	3'-7"	17'-1"
	CXVB-875-1236-45	18,088	1,108	(2) 15 & (2) 7.5	247,500			38,490	12,130	62,340	884	98			61,360	3'-7"	17'-1"
	CXVB-888-1236-30	18,357	1,124	(2) 10 & (2) 5	210,400			42,560	14,070	66,580	1,060	116			65,600	6'-6"	20'-0"
	CXVB-914-1236-30	18,894	1,157	(2) 10 & (2) 5	210,400			42,860	14,210	66,880	1,060	116			65,900	6'-4"	20'-0"
	CXVB-918-1236-30	18,977	1,162	(2) 10 & (2) 5	207,600			48,940	17,110	73,320	1,412	156			72,330	6'-6"	20'-0"
	CXVB-933-1236-30	19,287	1,181	(2) 10 & (2) 5	206,000			51,920	18,530	76,480	1,590	174			75,500	6'-6"	20'-0"
	CXVB-964-1236-45	19,928	1,220	(2) 15 & (2) 7.5	240,800			42,920	14,240	66,940	1,060	116			65,970	6'-6"	20'-0"
12' x 36'	CXVB-966-1236-30	19,969	1,223	(2) 10 & (2) 5	206,000			52,210	18,660	76,760	1,590	174			75,780	6'-4"	20'-0"
	CXVB-1027-1236-45	21,230	1,300	(2) 15 & (2) 7.5	238,400	(2) 10	2,600	47,760	16,550	72,060	1,324	146	(2) 12	2,170	71,070	6'-4"	20'-0"
	CXVB-1049-1236-45	21,685	1,328	(2) 15 & (2) 7.5	235,800			52,440	18,770	77,000	1,590	174			76,010	6'-4"	20'-0"
	CXVB-1049-1236-60	21,685	1,328	(2) 20 & (2) 10	265,100			43,160	14,350	67,180	1,060	116			66,200	6'-4"	20'-0"
	CXVB-1089-1236-60	22,512	1,378	(2) 20 & (2) 10	262,400			47,830	16,580	72,120	1,324	146			71,140	6'-4"	20'-0"
	CXVB-1134-1236-75	23,442	1,435	(2) 25 & (2) 15	282,600			47,950	16,640	72,240	1,324	146			71,260	6'-4"	20'-0"
	CXVB-1161-1236-75	24,000	1,470	(2) 25 & (2) 15	279,500			52,620	18,860	77,180	1,590	174			76,200	6'-4"	20'-0"
	CXVB-1202-1236-90	24,848	1,522	(2) 30 & (2) 15	297,000			52,830	18,960	77,380	1,590	174			76,400	6'-4"	20'-0"
	CXVB-1257-1236-120	25,985	1,591	(2) 40 & (2) 20	330,500			48,800	17,040	73,100	1,324	146			72,110	6'-4"	20'-0"
	CXVB-1287-1236-120	26,605	1,629	(2) 40 & (2) 20	326,900			53,480	19,270	78,040	1,590	174			77,050	6'-4"	20'-0"

PCC Engineering Data

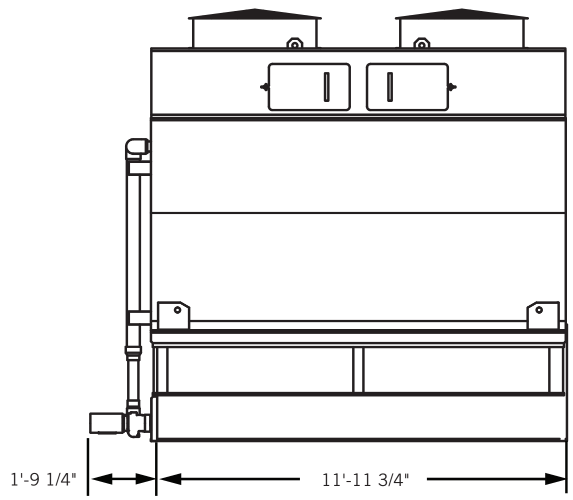
NOTE: Up-to-date engineering data, free product selection software, and more can be found at **www.BaltimoreAircoil.com**.



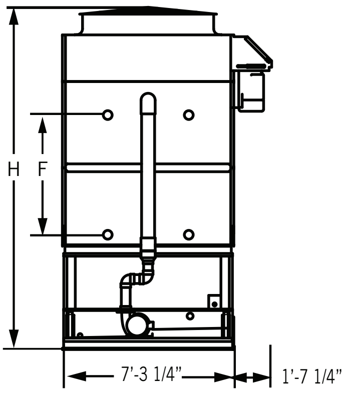
Face A:
PCC 4' x 6' and 4' x 12' Units



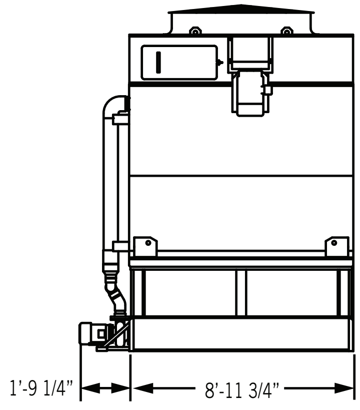
Face D:
PCC 4' x 6' Units



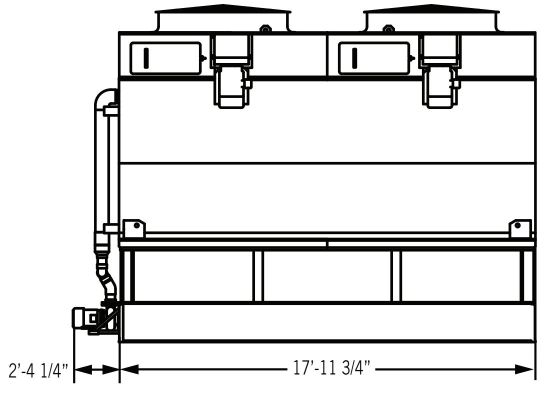
Face D:
PCC 4' x 12' Units



Face A:
PCC 7.4' x 9' and 7.4' x 18' Units



Face D:
PCC 7.4' x 9' Units



Face D:
PCC 7.4' x 18' Units

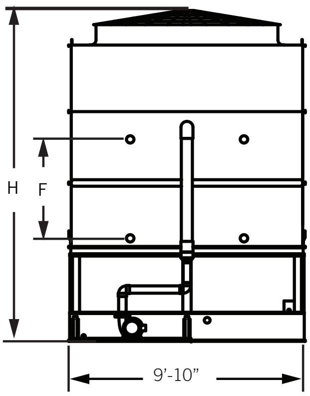
Nom. Box Size	Model Number[1]	Base Heat Rejection (MBH)	R-22 Tons[2]	Fan Motor (HP)	Airflow Rate (CFM)	Pump Motor (HP)	Spray Flow Rate (GPM)	Approximate Weight (lbs) Ship Weight	Heaviest Section	Oper. Weight[3]	R-717 Operating Charge[4] (lbs)	Internal Coil Volume (ft^3)	Remote Sump Drain Size[5] (in)	Vol. Req. (gal)	Approx. Oper. Weight (lbs)	F	H
4' x 6'	PCC-0048-0406N005	995	68	5	16,830	1	97	3,270	2,580	4,440	63	7	4	122	3,739	4'-1"	12'-9"
	PCC-0046-0406N003	953	65	3	13,300			3,430	2,740	4,610	74	8			3,909	4'-1"	12'-9"
	PCC-0057-0406N005	1,181	81	5	14,300			3,870	3,180	5,070	95	10			4,369	4'-9"	13'-4"
	PCC-0067-0406N7.5	1,389	95	7.5	15,080			4,610	3,910	5,830	118	13			5,129	6'-6"	15'-2"
4' x 12'	PCC-0078-0412N006	1,617	110	(2) 3	28,690	1.5	197	5,340	4,230	7,640	96	10	6	184	6,194	4'-1"	12'-9"
	PCC-0090-0412N010	1,865	127	(2) 5	33,520			5,380	4,270	7,680	96	10			6,234	4'-1"	12'-9"
	PCC-0106-0412N010	2,197	150	2) 5	30,600			6,040	4,930	8,380	138	15			6,934	4'-1"	12'-9"
	PCC-0122-0412N015	2,529	173	(2) 7.5	33,330			6,810	5,700	9,180	164	18			7,734	4'-9"	13'-4"
	PCC-0128-0412N015	2,653	181	(2) 7.5	32,190			7,090	5,980	9,480	181	20			8,034	4'-9"	13'-4"
	PCC-0118-0412N010	2,446	167	2) 5	27,950			7,580	6,460	9,990	205	22			8,544	6'-6"	15'-2"
	PCC-0134-0412N015	2,777	189	(2) 7.5	30,380			7,880	6,770	10,310	224	24			8,864	5'-4"	14'-0"
7.4' x 9'	PCC-0113-0709N010	2,342	160	10	41,230	2	275	6,890	5,550	10,260	134	14	6	254	8,519	4'-1"	14'-4"
	PCC-0117-0709N7.5	2,425	165	7.5	35,780			7,550	6,210	10,970	177	19			9,229	4'-1"	14'-4"
	PCC-0142-0709N015	2,943	201	15	44,090			7,550	6,210	10,970	177	19			9,229	4'-1"	14'-4"
	PCC-0122-0709N7.5	2,529	173	7.5	34,100			7,790	6,450	11,220	191	21			9,479	4'-1"	14'-4"
	PCC-0154-0709N015	3,192	218	15	40,930			8,710	7,370	12,190	229	25			10,449	4'-9"	14'-11"
	PCC-0160-0709N020	3,316	226	20	47,190			8,450	7,110	11,910	210	23			10,169	4'-9"	14'-11"
	PCC-0166-0709N020	3,441	235	20	50,630			8,770	7,430	12,250	229	25			10,509	4'-9"	14'-11"
	PCC-0175-0709N020	3,627	247	20	42,360			9,500	8,150	12,990	252	27			11,249	6'-0"	16'-2"
	PCC-0130-0709N7.5	2,694	184	7.5	33,140			9,140	7,800	12,640	258	28			10,899	5'-4"	15'-7"
	PCC-0184-0709N020	3,814	260	20	37,830			11,220	9,870	14,820	363	39			13,079	6'-0"	16'-2"
7.4' x 18'	PCC-0177-0718N010	3,669	250	(2) 5	67,270	5	560	12,260	9,550	19,130	252	27	10	366	15,567	4'-1"	15'-0"
	PCC-0214-0718N020	4,435	302	(2) 10	82,950			12,460	9,740	19,330	252	27			15,767	4'-1"	15'-0"
	PCC-0222-0718N015	4,601	314	(2) 7.5	72,150			13,670	10,960	20,630	340	37			17,067	4'-1"	15'-0"
	PCC-0267-0718N030	5,534	377	(2) 15	89,060			14,020	11,300	20,970	340	37			17,407	4'-1"	15'-0"
	PCC-0232-0718N015	4,809	328	(2) 7.5	68,880			14,140	11,430	21,130	369	40			17,567	4'-1"	15'-0"
	PCC-0278-0718N030	5,762	392	(2) 15	87,370			14,960	12,240	21,980	409	44			18,417	4'-9"	15'-8"
	PCC-0300-0718N040	6,218	423	(2) 20	95,370			15,300	12,580	22,320	409	44			18,757	4'-9"	15'-8"
	PCC-0324-0718N020	6,715	457	(2) 10	85,670			16,190	13,470	23,280	485	52			19,717	4'-9"	15'-8"
	PCC-0349-0718N020	7,234	493	(2) 10	62,290			20,370	17,640	27,700	719	78			24,137	6'-0"	16'-11"

NOTES:

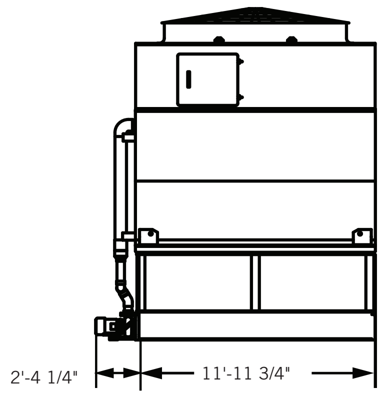
1. Model number denotes R-717 capacity in evaporator tons at a 96.3°F condensing temperature, a 20°F suction temperature, and a 78°F entering wet-bulb temperature.
2. R-22 tons are at a 105°F condensing temperature, a 40°F suction temperature, and a 78°F entering wet-bulb temperature.
3. Operating weight is for the unit with the water level at the overflow level and with the coil charged with R-717.
4. The R-22 operating charge is 1.93 times the R-717 charge; R-134a is 1.98 times.
5. Drain size is based on a bottom connection.
6. For R-22 and R-134a, the coil connection quantity may double.
7. Standard make-up, drain, and overflow connections are MPT.
8. Coil inlet and outlet connections are beveled for welding.

Do not use for construction. Refer to factory certified dimensions. This catalog includes data current at the time of publication, which should be reconfirmed at the time of purchase.

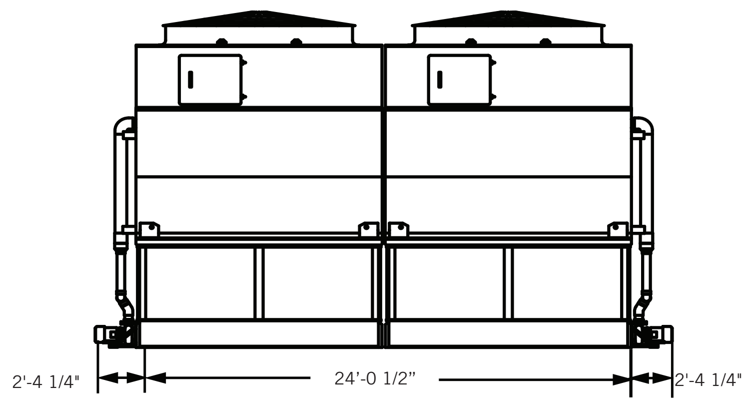
PCC Engineering Data



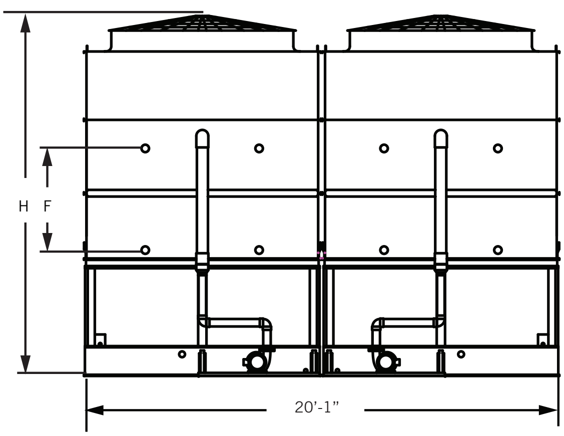
Face A:
PCC 10' x 12' and 10' x 24' Units



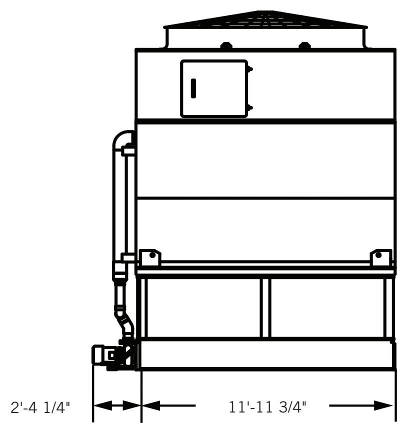
Face D:
PCC 10' x 12' Units



Face D:
PCC 10' x 24' Units



Face A:
PCC 20' x 12' Units



Face D:
PCC 20' x 12' Units

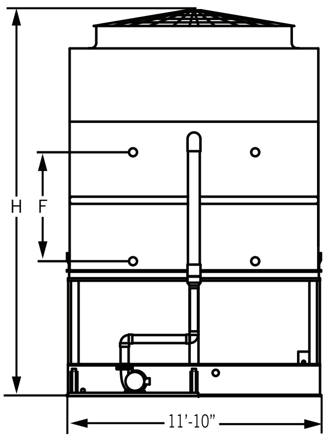
NOTES:

1. Model number denotes R-717 capacity in evaporator tons at a 96.3°F condensing temperature, a 20°F suction temperature, and a 78°F entering wet-bulb temperature.
2. R-22 tons are at a 105°F condensing temperature, a 40°F suction temperature, and a 78°F entering wet-bulb temperature.
3. Operating weight is for the unit with the water level at the overflow level and with the coil charged with R-717.
4. The R-22 operating charge is 1.93 times the R-717 charge; R-134a is 1.98 times.
5. Drain size is based on a bottom connection.
6. For R-22 and R-134a, the coil connection quantity may double.
7. Standard make-up, drain, and overflow connections are MPT.
8. Coil inlet and outlet connections are beveled for welding.

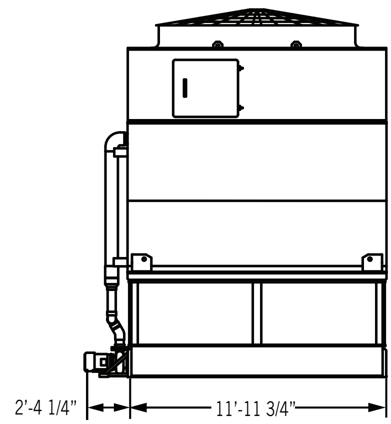
Do not use for construction. Refer to factory certified dimensions. This catalog includes data current at the time of publication, which should be reconfirmed at the time of purchase.

Nom. Box Size	Model Number[1]	Base Heat Rejection (MBH)	R-22 Tons[2]	Fan Motor (HP)	Airflow Rate (CFM)	Pump Motor (HP)	Spray Flow Rate (GPM)	Approximate Weight (lbs)			R-717 Operating Charge[4] (lbs)	Internal Coil Volume (ft^3)	Remote Sump			F	H
								Ship Weight	Heaviest Section	Oper. Weight[3]			Drain Size[5] (in)	Vol. Req. (gal)	Approx. Oper. Weight (lbs)		
10' x 12'	PCC-0269-1012N030	5,575	380	30	84,730	5	504	12,600	10,430	18,550	326	35	8	397	15,760	4'-1"	16'-1"
	PCC-0208-1012N010	4,311	294	10	57,960			12,730	10,560	18,710	351	38			15,920	4'-1"	16'-1"
	PCC-0233-1012N015	4,829	329	15	65,370			12,860	10,690	18,840	351	38			16,050	4'-1"	16'-1"
	PCC-0272-1012N020	5,638	384	20	69,900			14,770	12,600	20,830	431	47			18,040	6'-0"	18'-0"
	PCC-0281-1012N025	5,824	397	25	74,850			14,310	12,140	20,370	426	46			17,580	4'-9"	16'-9"
	PCC-0295-1012N030	6,114	416	30	79,010			14,360	12,190	20,420	426	46			17,630	4'-9"	16'-9"
	PCC-0315-1012N040	6,529	445	40	92,880			15,070	12,900	21,160	460	50			18,370	4'-9"	16'-9"
	PCC-0323-1012N030	6,695	456	30	71,050			17,890	15,710	24,140	626	68			21,350	6'-0"	18'-0"
	PCC-0246-1012N010	5,099	347	10	48,420			18,400	16,220	24,700	677	73			21,910	6'-0"	18'-0"
	PCC-0328-1012N030	6,798	463	30	67,200			18,690	16,510	24,990	677	73			22,200	6'-0"	18'-0"
10' x 24'	PCC-0538-1024N060	11,151	759	60	169,460	(2) 5	1,008	25,320	10,430	37,230	652	70	(2) 8	794	34,440	4'-1"	17'-1"
	PCC-0416-1024N020	8,622	587	20	115,920			25,590	10,560	37,550	703	76			34,760	4'-1"	17'-1"
	PCC-0466-1024N030	9,659	658	30	130,740			25,840	10,690	37,800	703	76			35,010	4'-1"	17'-1"
	PCC-0544-1024N040	11,275	768	40	139,790			29,670	12,600	41,790	862	93			39,000	6'-0"	19'-0"
	PCC-0562-1024N050	11,648	793	50	149,690			28,740	12,140	40,860	852	92			38,070	4'-9"	17'-9"
	PCC-0590-1024N060	12,229	832	60	158,020			28,840	12,190	40,960	852	92			38,170	4'-9"	17'-9"
	PCC-0630-1024N080	13,058	889	80	185,750			30,260	12,900	42,440	920	99			39,650	4'-9"	17'-9"
	PCC-0646-1024N060	13,389	911	60	142,100			35,890	15,710	48,400	1,252	135			45,610	6'-0"	19'-0"
	PCC-0492-1024N020	10,197	694	20	96,830			36,920	16,220	49,530	1,353	146			46,740	6'-0"	19'-0"
	PCC-0656-1024N060	13,597	925	60	134,400			37,490	16,510	50,110	1,353	146			47,320	6'-0"	19'-0"
20' x 12'	PCC-0538-2012N060	11,151	759	60	169,460	(2) 5	1,008	25,320	10,430	37,230	652	70	(2) 8	794	34,440	4'-1"	17'-1"
	PCC-0416-2012N020	8,622	587	20	115,920			25,590	10,560	37,550	703	76			34,760	4'-1"	17'-1"
	PCC-0466-2012N030	9,659	658	30	130,740			25,840	10,690	37,800	703	76			35,010	4'-1"	17'-1"
	PCC-0544-2012N040	11,275	768	40	139,790			29,670	12,600	41,790	862	93			39,000	6'-0"	19'-0"
	PCC-0562-2012N050	11,648	793	50	149,690			28,740	12,140	40,860	852	92			38,070	4'-9"	17'-9"
	PCC-0590-2012N060	12,229	832	60	158,020			28,840	12,190	40,960	852	92			38,170	4'-9"	17'-9"
	PCC-0630-2012N080	13,058	889	80	185,750			30,260	12,900	42,440	920	99			39,650	4'-9"	17'-9"
	PCC-0646-2012N060	13,389	911	60	142,100			35,890	15,710	48,400	1,252	135			45,610	6'-0"	19'-0"
	PCC-0492-2012N020	10,197	694	20	96,830			36,920	16,220	49,530	1,353	146			46,740	6'-0"	19'-0"
	PCC-0656-2012N060	13,597	925	60	134,400			37,490	16,510	50,110	1,353	146			47,320	6'-0"	19'-0"

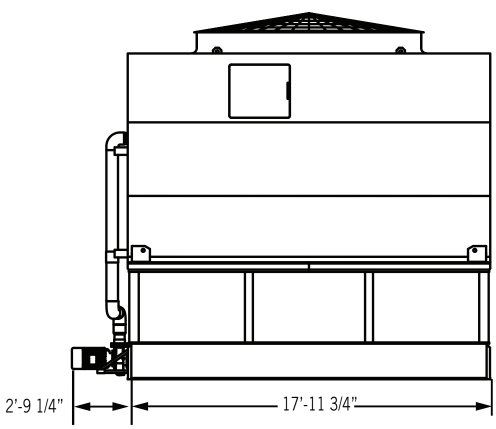
PCC Engineering Data



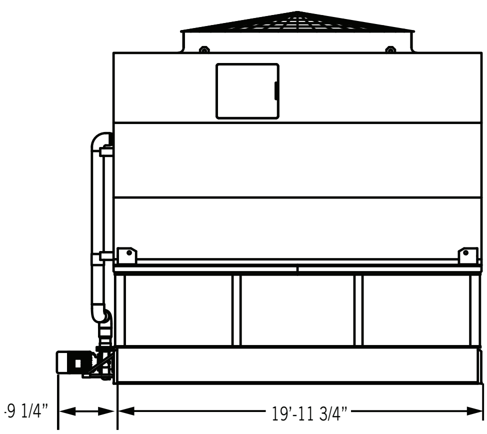
Face A:
PCC 12' x 12', 12' x 18',
and 12' x 20' Units



Face D:
PCC 12' x 12' Units



Face D:
PCC 12' x 18' Units



Face D:
PCC 12' x 20' Units

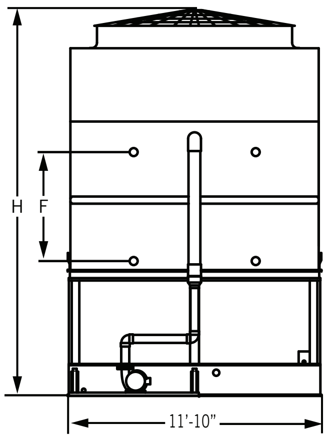
NOTES:

1. Model number denotes R-717 capacity in evaporator tons at a 96.3°F condensing temperature, a 20°F suction temperature, and a 78°F entering wet-bulb temperature.
2. R-22 tons are at a 105°F condensing temperature, a 40°F suction temperature, and a 78°F entering wet-bulb temperature.
3. Operating weight is for the unit with the water level at the overflow level and with the coil charged with R-717.
4. The R-22 operating charge is 1.93 times the R-717 charge; R-134a is 1.98 times.
5. Drain size is based on a bottom connection.
6. For R-22 and R-134a, the coil connection quantity may double.
7. Standard make-up, drain, and overflow connections are MPT.
8. Coil inlet and outlet connections are beveled for welding.

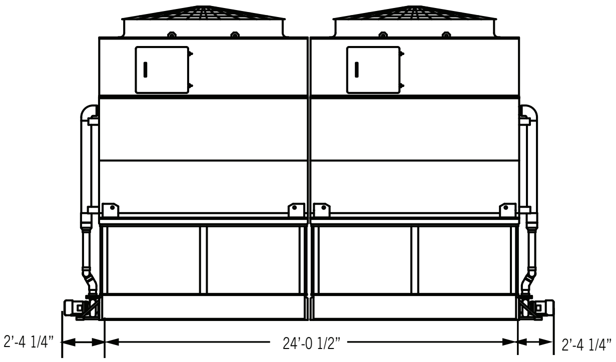
Do not use for construction. Refer to factory certified dimensions. This catalog includes data current at the time of publication, which should be reconfirmed at the time of purchase.

Nom. Box Size	Model Number[1]	Base Heat Rejection (MBH)	R-22 Tons[2]	Fan Motor (HP)	Airflow Rate (CFM)	Pump Motor (HP)	Spray Flow Rate (GPM)	Approximate Weight (lbs)			R-717 Operating Charge[4] (lbs)	Internal Coil Volume (ft^3)	Remote Sump			F	H
								Ship Weight	Heaviest Section	Oper. Weight[3]			Drain Size[5] (in)	Vol. Req. (gal)	Approx. Oper. Weight (lbs)		
12' x 12'	PCC-0249-1212N010	5,161	352	10	64,050	5	610	16,780	13,930	23,950	515	56	10	370	20,873	4'-9"	17'-6"
	PCC-0265-1212N015	5,492	374	15	74,840			15,420	12,570	22,510	432	47			19,433	4'-1"	16'-10"
	PCC-0293-1212N015	6,073	414	15	68,750			19,010	16,150	26,300	636	69			23,223	5'-4"	18'-1"
	PCC-0309-1212N020	6,404	436	20	76,340			17,780	14,930	25,000	566	61			21,923	4'-9"	17'-6"
	PCC-0330-1212N025	6,840	466	25	81,540			17,810	14,960	25,030	566	61			21,953	4'-9"	17'-6"
	PCC-0346-1212N025	7,171	488	25	77,040			20,110	17,250	27,460	699	75			24,383	5'-4"	18'-1"
	PCC-0365-1212N030	7,565	515	30	81,470			20,160	17,300	27,510	699	75			24,433	5'-4"	18'-1"
	PCC-0396-1212N040	8,208	559	40	88,740			20,340	17,490	27,700	699	75			24,623	5'-4"	18'-1"
	PCC-0355-1212N025	7,358	501	25	73,440			21,200	18,350	28,670	819	88			25,593	4'-1"	16'-10"
	PCC-0375-1212N030	7,772	529	30	77,630			21,250	18,400	28,720	819	88			25,643	4'-1"	16'-10"
	PCC-0395-1212N040	8,187	557	40	87,990			20,270	17,420	27,670	744	80			24,593	4'-1"	16'-10"
	PCC-0406-1212N040	8,415	573	40	84,480			21,440	18,590	28,910	819	88			25,833	4'-1"	16'-10"
12' x 18'	PCC-0494-1218N040	10,239	697	40	137,590	7.5	921	23,050	18,730	33,750	637	69	12	548	28,558	4'-1"	17'-8"
	PCC-0381-1218N015	7,897	538	15	104,230			23,790	19,470	34,550	699	75			29,358	4'-9"	18'-3"
	PCC-0441-1218N020	9,140	622	20	104,180			26,080	21,760	36,980	839	91			31,788	4'-9"	18'-3"
	PCC-0531-1218N040	11,006	749	40	128,040			26,450	22,130	37,350	839	91			32,158	4'-9"	18'-3"
	PCC-0564-1218N050	11,690	796	50	136,960			26,550	22,240	37,460	839	91			32,268	4'-9"	18'-3"
	PCC-0469-1218N020	9,721	662	20	97,360			29,680	25,360	40,860	1,116	121			35,668	4'-1"	17'-8"
	PCC-0517-1218N030	10,716	729	30	110,020			29,930	25,610	41,110	1,116	121			35,918	4'-1"	17'-8"
	PCC-0541-1218N040	11,213	763	40	127,310			28,570	24,250	39,660	1,022	110			34,468	4'-1"	17'-8"
	PCC-0572-1218N040	11,856	807	40	114,950			31,820	27,500	43,110	1,229	133			37,918	4'-1"	17'-8"
	PCC-0590-1218N050	12,229	832	50	128,050			30,150	25,840	41,330	1,116	121			36,138	4'-1"	17'-8"
	PCC-0609-1218N050	12,622	859	50	122,820			31,920	27,610	43,220	1,229	133			38,028	4'-1"	17'-8"
	PCC-0639-1218N060	13,244	901	60	129,710			32,020	27,710	43,320	1,229	133			38,128	4'-1"	17'-8"
12' x 20'	PCC-0544-1220N040	11,275	766	40	146,578	7.5	1,025	23,837	19,273	35,730	705	76	12	567	24,792	4'-1”	18'-0”
	PCC-0431-1220N015	8,933	607	15	110,836			24,739	20,173	36,700	774	84			25,760	4'-9”	18'-7”
	PCC-0491-1220N020	10,177	692	20	110,257			27,299	22,733	39,420	929	100			28,480	4'-9”	18'-7”
	PCC-0540-1220N030	11,192	761	30	124,950			27,379	22,813	39,500	929	100			28,560	4'-9”	18'-7”
	PCC-0581-1220N040	12,042	818	40	136,270			27,599	23,033	39,720	929	100			28,780	4'-9”	18'-7”
	PCC-0614-1220N050	12,726	865	50	145,849			27,624	23,058	39,740	929	100			28,800	4'-9”	18'-7”
	PCC-0519-1220N020	10,757	731	20	103,393			31,367	26,803	43,800	1,239	134			32,862	4'-1”	18'-0”
	PCC-0557-1220N025	11,545	784	25	105,902			33,367	28,803	45,920	1,365	147			34,982	4'-1”	18'-0”
	PCC-0567-1220N030	11,752	799	30	116,752			31,447	26,883	43,880	1,239	134			32,942	4'-1”	18'-0”
	PCC-0580-1220N030	12,021	817	30	111,884			33,417	28,853	45,970	1,365	147			35,032	4'-1”	18'-0”
	PCC-0591-1220N040	12,249	832	40	135,139			30,027	25,463	42,350	1,134	122			31,412	4'-1”	18'-0”
	PCC-0622-1220N040	12,892	876	40	121,985			33,637	29,073	46,190	1,365	147			35,252	4'-1”	18'-0”
	PCC-0640-1220N050	13,265	901	50	136,206			31,692	27,128	44,120	1,239	134			33,182	4'-1”	18'-0”
	PCC-0659-1220N050	13,659	928	50	130,515			33,662	29,098	46,220	1,365	147			35,282	4'-1”	18'-0”
	PCC-0689-1220N060	14,280	970	60	137,785			33,913	29,349	46,470	1,365	147			35,532	4'-1”	18'-0”

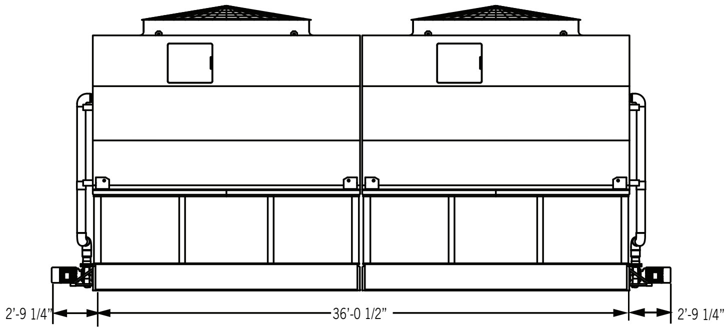
PCC Engineering Data



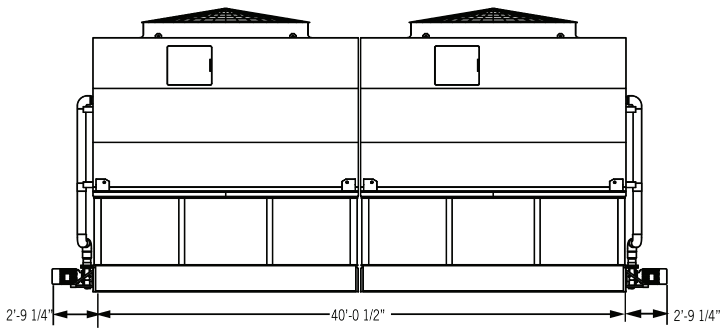
Face A:
PCC 12' x 24', 12' x 36',
and 12' x 40' Units



Face D:
PCC 12' x 24' Units



Face D:
PCC 12' x 36' Units



Face D:
PCC 12' x 40' Units

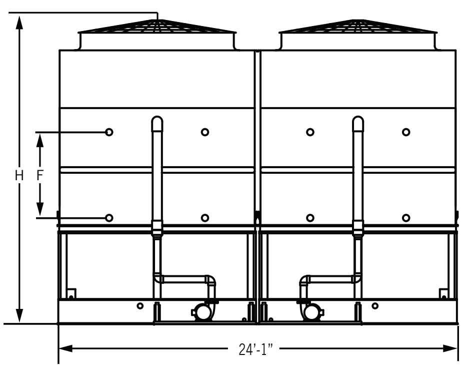
NOTES:

1. Model number denotes R-717 capacity in evaporator tons at a 96.3°F condensing temperature, a 20°F suction temperature, and a 78°F entering wet-bulb temperature.
2. R-22 tons are at a 105°F condensing temperature, a 40°F suction temperature, and a 78°F entering wet-bulb temperature.
3. Operating weight is for the unit with the water level at the overflow level and with the coil charged with R-717.
4. The R-22 operating charge is 1.93 times the R-717 charge; R-134a is 1.98 times.
5. Drain size is based on a bottom connection.
6. For R-22 and R-134a, the coil connection quantity may double.
7. Standard make-up, drain, and overflow connections are MPT.
8. Coil inlet and outlet connections are beveled for welding.

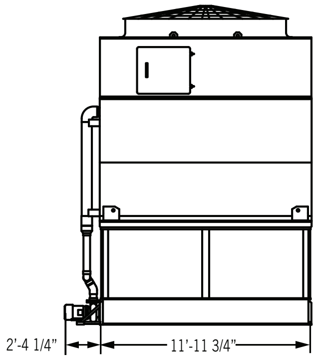
Do not use for construction. Refer to factory certified dimensions. This catalog includes data current at the time of publication, which should be reconfirmed at the time of purchase.

								Approximate Weight (lbs)					Remote Sump				
Nom. Box Size	Model Number[1]	Base Heat Rejection (MBH)	R-22 Tons[2]	Fan Motor (HP)	Airflow Rate (CFM)	Pump Motor (HP)	Spray Flow Rate (GPM)	Ship Weight	Heaviest Section	Oper. Weight[3]	R-717 Operating Charge[4] (lbs)	Internal Coil Volume (ft^3)	Drain Size[5] (in)	Vol. Req. (gal)	Approx. Oper. Weight (lbs)	F	H
12' x 24'	**PCC-0498-1224N020**	10,322	703	20	128,090	(2) 5	610	33,680	13,930	48,020	1,030	111	(2) 10	740	44,943	4'-9"	18'-6"
	PCC-0530-1224N030	10,985	748	30	149,670			30,960	12,570	45,140	864	93			42,063	4'-1"	17'-10"
	PCC-0586-1224N030	12,146	827	30	137,500			38,130	16,150	52,710	1,271	137			49,633	5'-4"	19'-1"
	PCC-0618-1224N040	12,809	872	40	152,680			35,690	14,930	50,130	1,131	122			47,053	4'-9"	18'-6"
	PCC-0660-1224N050	13,679	931	50	163,070			35,750	14,960	50,190	1,131	122			47,113	4'-9"	18'-6"
	PCC-0692-1224N050	14,343	976	50	154,070			40,330	17,250	55,040	1,398	151			51,963	5'-4"	19'-1"
	PCC-0730-1224N060	15,130	1,030	60	162,940			40,430	17,300	55,140	1,398	151			52,063	5'-4"	19'-1"
	PCC-0792-1224N080	16,415	1,117	80	177,470			40,810	17,490	55,520	1,398	151			52,443	5'-4"	19'-1"
	PCC-0710-1224N050	14,716	1,002	50	146,880			42,520	18,350	57,470	1,638	177			54,393	4'-1"	17'-10"
	PCC-0750-1224N060	15,545	1,058	60	155,250			42,620	18,400	57,570	1,638	177			54,493	4'-1"	17'-10"
	PCC-0790-1224N080	16,374	1,114	80	175,980			40,660	17,420	55,460	1,489	161			52,383	4'-1"	17'-10"
	PCC-0812-1224N080	16,830	1,145	80	168,960			43,000	18,590	57,950	1,638	177			54,873	4'-1"	17'-10"
12' x 36'	**PCC-0980-1236N080**	20,315	1,383	80	275,170	(2) 7.5	921	46,250	18,730	67,660	1,274	138	(2) 12	1,096	62,468	4'-1"	18'-8"
	PCC-0756-1236N030	15,668	1,066	30	208,450			47,730	19,470	69,270	1,397	151			64,078	4'-9"	19'-3"
	PCC-0875-1236N040	18,135	1,234	40	208,360			52,310	21,760	74,130	1,678	181			68,938	4'-9"	19'-3"
	PCC-1054-1236N080	21,837	1,486	80	256,070			53,050	22,130	74,870	1,678	181			69,678	4'-9"	19'-3"
	PCC-1119-1236N100	23,194	1,578	100	273,910			53,260	22,240	75,080	1,678	181			69,888	4'-9"	19'-3"
	PCC-0931-1236N040	19,287	1,313	40	194,720			59,510	25,360	81,880	2,232	241			76,688	4'-1"	18'-8"
	PCC-1026-1236N060	21,261	1,447	60	220,030			60,010	25,610	82,380	2,232	241			77,188	4'-1"	18'-8"
	PCC-1073-1236N080	22,248	1,514	80	254,620			57,290	24,250	79,470	2,043	221			74,278	4'-1"	18'-8"
	PCC-1135-1236N080	23,523	1,601	80	229,890			63,790	27,500	86,390	2,458	265			81,198	4'-1"	18'-8"
	PCC-1171-1236N100	24,263	1,651	100	256,100			60,460	25,840	82,830	2,232	241			77,638	4'-1"	18'-8"
	PCC-1208-1236N100	25,044	1,704	100	245,640			64,000	27,610	86,600	2,458	265			81,408	4'-1"	18'-8"
	PCC-1268-1236N120	26,278	1,788	120	259,410			64,200	27,710	86,800	2,458	265			81,608	4'-1"	18'-8"
12' x 40'	**PCC-1079-1240N080**	22,371	1,520	80	293,156	(2) 7.5	2,050	47,856	19,273	71,650	1,410	152	(2) 12	1,096	49,767	4'-1"	19'-0"
	PCC-0855-1240N030	17,724	1,204	30	221,672			49,660	20,173	73,590	1,548	167			51,703	4'-9"	19'-7"
	PCC-0974-1240N040	20,192	1,372	40	220,514			54,780	22,733	79,020	1,859	201			57,133	4'-9"	19'-7"
	PCC-1071-1240N060	22,207	1,509	60	249,900			54,940	22,813	79,180	1,859	201			57,293	4'-9"	19'-7"
	PCC-1153-1240N080	23,893	1,624	80	272,540			55,380	23,033	79,620	1,859	201			57,733	4'-9"	19'-7"
	PCC-1218-1240N100	25,250	1,716	100	291,697			55,430	23,058	79,670	1,859	201			57,783	4'-9"	19'-7"
	PCC-1030-1240N040	21,343	1,450	40	206,787			62,916	26,803	87,780	2,478	268			65,897	4'-1"	19'-0"
	PCC-1105-1240N050	22,906	1,556	50	211,805			66,916	28,803	92,030	2,730	295			70,147	4'-1"	19'-0"
	PCC-1125-1240N060	23,317	1,584	60	233,504			63,076	26,883	87,940	2,478	268			66,057	4'-1"	19'-0"
	PCC-1151-1240N060	23,852	1,621	60	223,768			67,016	28,853	92,130	2,730	295			70,247	4'-1"	19'-0"
	PCC-1173-1240N080	24,304	1,652	80	270,279			60,236	25,463	84,890	2,269	245			63,007	4'-1"	19'-0"
	PCC-1234-1240N080	25,579	1,738	80	243,971			67,456	29,073	92,570	2,730	295			70,687	4'-1"	19'-0"
	PCC-1270-1240N100	26,319	1,788	100	272,412			63,566	27,128	88,430	2,478	268			66,547	4'-1"	19'-0"
	PCC-1308-1240N100	27,100	1,842	100	261,031			67,506	29,098	92,620	2,730	295			70,737	4'-1"	19'-0"
	PCC-1367-1240N120	28,334	1,925	120	275,570			68,008	29,349	93,120	2,730	295			71,237	4'-1"	19'-0"

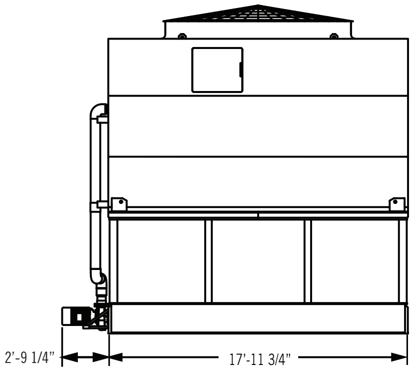
PCC Engineering Data



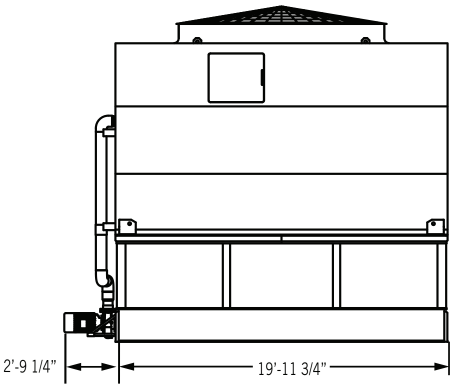
Face A:
PCC 24' x 12, 24' x 18', and 24' x 20' Units



Face D:
PCC 24' x 12' Units



Face D:
PCC 24' x 18' Units



Face D:
PCC 24' x 20' Units

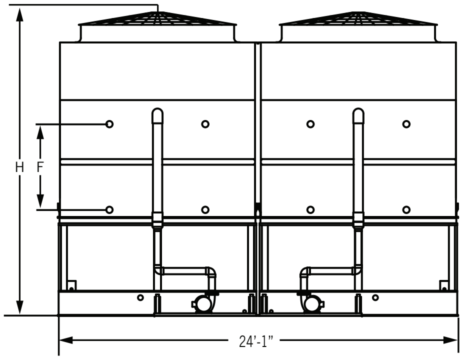
NOTES:

1. Model number denotes R-717 capacity in evaporator tons at a 96.3°F condensing temperature, a 20°F suction temperature, and a 78°F entering wet-bulb temperature.
2. R-22 tons are at a 105°F condensing temperature, a 40°F suction temperature, and a 78°F entering wet-bulb temperature.
3. Operating weight is for the unit with the water level at the overflow level and with the coil charged with R-717.
4. The R-22 operating charge is 1.93 times the R-717 charge; R-134a is 1.98 times.
5. Drain size is based on a bottom connection.
6. For R-22 and R-134a, the coil connection quantity may double.
7. Standard make-up, drain, and overflow connections are MPT.
8. Coil inlet and outlet connections are beveled for welding.

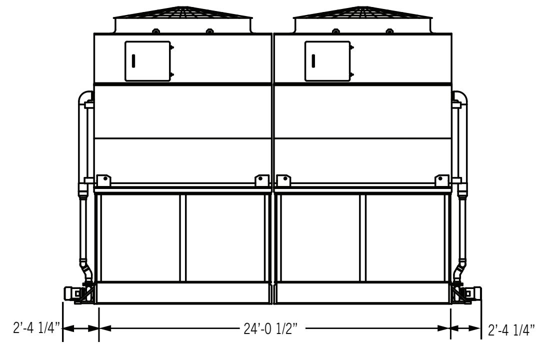
Do not use for construction. Refer to factory certified dimensions. This catalog includes data current at the time of publication, which should be reconfirmed at the time of purchase.

Nom. Box Size	Model Number[1]	Base Heat Rejection (MBH)	R-22 Tons[2]	Fan Motor (HP)	Airflow Rate (CFM)	Pump Motor (HP)	Spray Flow Rate (GPM)	Approximate Weight (lbs)			R-717 Operating Charge[4] (lbs)	Internal Coil Volume (ft^3)	Remote Sump			F	H
								Ship Weight	Heaviest Section	Oper. Weight[3]			Drain Size[5] (in)	Vol. Req. (gal)	Approx. Oper. Weight (lbs)		
24' x 12'	PCC-0498-2412N020	10,322	703	20	128,090	(2) 5	610	33,680	13,930	48,020	1,030	111	(2) 10	740	44,943	4'-9"	18'-6"
	PCC-0530-2412N030	10,985	748	30	149,670			30,960	12,570	45,140	864	93			42,063	4'-1"	17'-10"
	PCC-0586-2412N030	12,146	827	30	137,500			38,130	16,150	52,710	1,271	137			49,633	5'-4"	19'-1"
	PCC-0618-2412N040	12,809	872	40	152,680			35,690	14,930	50,130	1,131	122			47,053	4'-9"	18'-6"
	PCC-0660-2412N050	13,679	931	50	163,070			35,750	14,960	50,190	1,131	122			47,113	4'-9"	18'-6"
	PCC-0692-2412N050	14,343	976	50	154,070			40,330	17,250	55,040	1,398	151			51,963	5'-4"	19'-1"
	PCC-0730-2412N060	15,130	1,030	60	162,940			40,430	17,300	55,140	1,398	151			52,063	5'-4"	19'-1"
	PCC-0792-2412N080	16,415	1,117	80	177,470			40,810	17,490	55,520	1,398	151			52,443	5'-4"	19'-1"
	PCC-0710-2412N050	14,716	1,002	50	146,880			42,520	18,350	57,470	1,638	177			54,393	4'-1"	17'-10"
	PCC-0750-2412N060	15,545	1,058	60	155,250			42,620	18,400	57,570	1,638	177			54,493	4'-1"	17'-10"
	PCC-0790-2412N080	16,374	1,114	80	175,980			40,660	17,420	55,460	1,489	161			52,383	4'-1"	17'-10"
	PCC-0812-2412N080	16,830	1,145	80	168,960			43,000	18,590	57,950	1,638	177			54,873	4'-1"	17'-10"
24' x 18'	PCC-0988-2418N080	20,478	1,394	80	275,170	(2) 7.5	921	46,310	18,730	67,720	1,274	138	(2) 12	1,096	62,528	4'-1"	19'-2"
	PCC-0762-2418N030	15,794	1,075	30	208,450			47,790	19,470	69,330	1,397	151			64,138	4'-9"	19'-9"
	PCC-0882-2418N040	18,281	1,244	40	208,360			52,370	21,760	74,190	1,678	181			68,998	4'-9"	19'-9"
	PCC-1062-2418N080	22,011	1,498	80	256,070			53,110	22,130	74,930	1,678	181			69,738	4'-9"	19'-9"
	PCC-1128-2418N100	23,379	1,591	100	273,910			53,320	22,240	75,130	1,678	181			69,938	4'-9"	19'-9"
	PCC-0938-2418N040	19,441	1,323	40	194,720			59,570	25,360	81,940	2,232	241			76,748	4'-1"	19'-2"
	PCC-1034-2418N060	21,431	1,458	60	220,030			60,070	25,610	82,440	2,232	241			77,248	4'-1"	19'-2"
	PCC-1082-2418N080	22,426	1,526	80	254,620			57,350	24,250	79,530	2,043	221			74,338	4'-1"	19'-2"
	PCC-1144-2418N080	23,711	1,614	80	229,890			63,850	27,500	86,440	2,458	265			81,248	4'-1"	19'-2"
	PCC-1180-2418N100	24,457	1,664	100	256,100			60,510	25,840	82,880	2,232	241			77,688	4'-1"	19'-2"
	PCC-1218-2418N100	25,245	1,718	100	245,640			64,050	27,610	86,650	2,458	265			81,458	4'-1"	19'-2"
	PCC-1278-2418N120	26,488	1,802	120	259,410			64,250	27,710	86,850	2,458	265			81,658	4'-1"	19'-2"
24' x 20'	PCC-1088-2420N080	22,550	1,532	80	293,156	(2) 7.5	2,050	47,897	19,273	71,690	1,410	152	(2)12	1,134	49,804	4'-1"	19'-6"
	PCC-0862-2420N030	17,866	1,214	30	221,672			49,701	20,173	73,630	1,548	167			51,740	4'-9"	20'-1"
	PCC-0982-2420N040	20,353	1,383	40	220,514			54,821	22,733	79,060	1,859	201			57,170	4'-9"	20'-1"
	PCC-1080-2420N060	22,385	1,521	60	249,900			54,981	22,813	79,220	1,859	201			57,330	4'-9"	20'-1"
	PCC-1162-2420N080	24,084	1,637	80	272,540			55,421	23,033	79,660	1,859	201			57,770	4'-9"	20'-1"
	PCC-1228-2420N100	25,452	1,730	100	291,697			55,471	23,058	79,710	1,859	201			57,820	4'-9"	20'-1"
	PCC-1038-2420N040	21,514	1,462	40	206,787			62,957	26,803	87,820	2,478	268			65,934	4'-1"	19'-6"
	PCC-1114-2420N050	23,089	1,569	50	211,805			66,957	28,803	92,070	2,730	295			70,184	4'-1"	19'-6"
	PCC-1134-2420N060	23,504	1,597	60	233,504			63,117	26,883	87,980	2,478	268			66,094	4'-1"	19'-6"
	PCC-1160-2420N060	24,043	1,634	60	223,768			67,057	28,853	92,170	2,730	295			70,284	4'-1"	19'-6"
	PCC-1182-2420N080	24,499	1,665	80	270,279			60,277	25,463	84,930	2,269	245			63,044	4'-1"	19'-6"
	PCC-1244-2420N080	25,784	1,752	80	243,971			67,497	29,073	92,610	2,730	295			70,724	4'-1"	19'-6"
	PCC-1280-2420N100	26,530	1,803	100	272,412			63,607	27,128	88,470	2,478	268			66,584	4'-1"	19'-6"
	PCC-1318-2420N100	27,317	1,856	100	261,031			67,547	29,098	92,660	2,730	295			70,774	4'-1"	19'-6"
	PCC-1378-2420N120	28,561	1,941	120	275,570			68,049	29,349	93,160	2,730	295			71,274	4'-1"	19'-6"

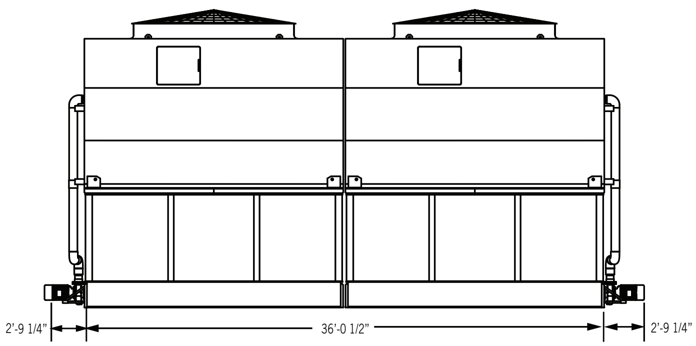
PCC Engineering Data



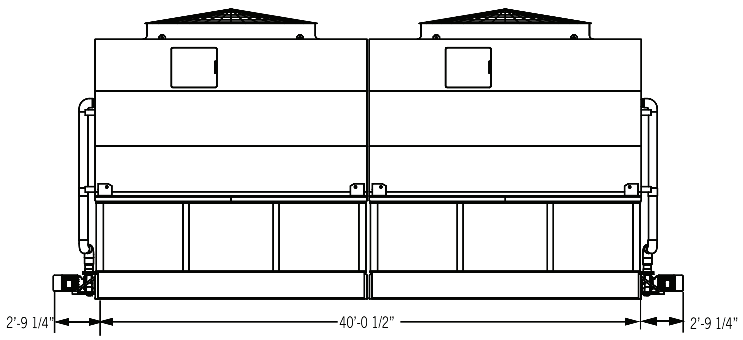
Face A:
PCC 24' x 24', 24' x 36' and 24' x 40' Units



Face D:
PCC 24' x 24' Units



Face D:
PCC 24' x 36' Units



Face D:
PCC 24' x 40' Units

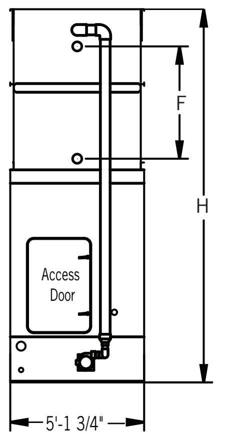
NOTES:

1. Model number denotes R-717 capacity in evaporator tons at a 96.3°F condensing temperature, a 20°F suction temperature, and a 78°F entering wet-bulb temperature.
2. R-22 tons are at a 105°F condensing temperature, a 40°F suction temperature, and a 78°F entering wet-bulb temperature.
3. Operating weight is for the unit with the water level at the overflow level and with the coil charged with R-717.
4. The R-22 operating charge is 1.93 times the R-717 charge; R-134a is 1.98 times.
5. Drain size is based on a bottom connection.
6. For R-22 and R-134a, the coil connection quantity may double.
7. Standard make-up, drain, and overflow connections are MPT.
8. Coil inlet and outlet connections are beveled for welding.

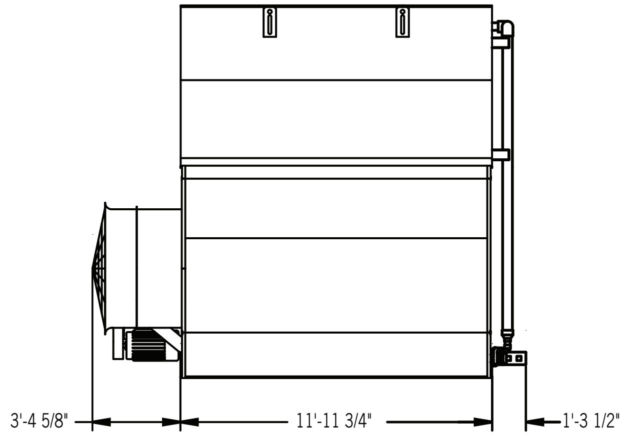
Do not use for construction. Refer to factory certified dimensions. This catalog includes data current at the time of publication, which should be reconfirmed at the time of purchase.

Nom. Box Size	Model Number[1]	Base Heat Rejection (MBH)	R-22 Tons[2]	Fan Motor (HP)	Airflow Rate (CFM)	Pump Motor (HP)	Spray Flow Rate (GPM)	Approximate Weight (lbs)			R-717 Operating Charge[4] (lbs)	Internal Coil Volume (ft^3)	Remote Sump			F	H
								Ship Weight	Heaviest Section	Oper. Weight[3]			Drain Size[5] (in)	Vol. Req. (gal)	Approx. Oper. Weight (lbs)		
24' x 24'	PCC-0996-2424N040	20,643	1,405	40	256,180	(4) 5	610	67,840	13,930	96,530	2,059	222	(4) 10	1,480	93,453	4'-9"	20'-6"
	PCC-1060-2424N060	21,970	1,495	60	299,330			62,410	12,570	90,770	1,729	187			87,693	4'-1"	19'-10"
	PCC-1172-2424N060	24,291	1,653	60	274,990			76,750	16,150	105,920	2,543	275			102,843	5'-4"	21'-1"
	PCC-1236-2424N080	25,618	1,743	80	305,360			71,860	14,930	100,760	2,262	244			97,683	4'-9"	20'-6"
	PCC-1320-2424N100	27,359	1,862	100	326,140			71,980	14,960	100,880	2,262	244			97,803	4'-9"	20'-6"
	PCC-1384-2424N100	28,685	1,952	100	308,130			81,150	17,250	110,580	2,796	302			107,503	5'-4"	21'-1"
	PCC-1460-2424N120	30,261	2,059	120	325,870			81,350	17,300	110,780	2,796	302			107,703	5'-4"	21'-1"
	PCC-1584-2424N160	32,831	2,234	160	354,930			82,100	17,490	111,530	2,796	302			108,453	5'-4"	21'-1"
	PCC-1420-2424N100	29,431	2,003	100	293,760			85,530	18,350	115,440	3,276	354			112,363	4'-1"	19'-10"
	PCC-1500-2424N120	31,090	2,115	120	310,490			85,730	18,400	115,640	3,276	354			112,563	4'-1"	19'-10"
	PCC-1580-2424N160	32,748	2,228	160	351,960			81,810	17,420	111,420	2,977	322			108,343	4'-1"	19'-10"
	PCC-1624-2424N160	33,660	2,290	160	337,920			86,490	18,590	116,400	3,276	354			113,323	4'-1"	19'-10"
24' x 36'	PCC-1947-2436N160	40,348	2,745	160	550,330	(4) 7.5	921	92,890	18,730	135,730	2,549	275	(4) 12	2,192	130,538	4'-1"	20'-2"
	PCC-1501-2436N060	31,118	2,117	60	416,890			95,860	19,470	138,940	2,795	302			133,748	4'-9"	20'-9"
	PCC-1738-2436N080	36,019	2,451	80	416,710			105,020	21,760	148,660	3,355	362			143,468	4'-9"	20'-9"
	PCC-2092-2436N160	43,370	2,951	160	512,130			106,500	22,130	150,140	3,355	362			144,948	4'-9"	20'-9"
	PCC-2223-2436N200	46,065	3,134	200	547,820			106,920	22,240	150,560	3,355	362			145,368	4'-9"	20'-9"
	PCC-1848-2436N080	38,306	2,606	80	389,430			119,410	25,360	164,160	4,463	482			158,968	4'-1"	20'-2"
	PCC-2037-2436N120	42,226	2,873	120	440,050			120,410	25,610	165,160	4,463	482			159,968	4'-1"	20'-2"
	PCC-2132-2436N160	44,187	3,006	160	509,240			114,970	24,250	159,350	4,087	441			154,158	4'-1"	20'-2"
	PCC-2254-2436N160	46,719	3,179	160	459,770			127,970	27,500	173,180	4,915	531			167,988	4'-1"	20'-2"
	PCC-2325-2436N200	48,189	3,279	200	512,200			121,310	25,840	166,060	4,463	482			160,868	4'-1"	20'-2"
	PCC-2400-2436N200	49,741	3,384	200	491,270			128,390	27,610	173,590	4,915	531			168,398	4'-1"	20'-2"
	PCC-2518-2436N240	52,191	3,551	240	518,820			128,790	27,710	173,990	4,915	531			168,798	4'-1"	20'-2"
24' x 40'	PCC-2159-2440N160	44,742	3,040	160	586,313	(4) 7.5	4,100	96,120	19,273	143,700	2,820	305	(4)12	2,268	99,916	4’-1”	20’-6”
	PCC-1710-2440N060	35,449	2,409	60	443,344			99,728	20,173	147,590	3,095	334			103,798	4’-9”	21’-1”
	PCC-1948-2440N080	40,383	2,744	80	441,029			109,968	22,733	158,450	3,718	402			114,658	4’-9”	21’-1”
	PCC-2143-2440N120	44,413	3,018	120	499,801			110,288	22,813	158,770	3,718	402			114,978	4’-9”	21’-1”
	PCC-2306-2440N160	47,786	3,247	160	545,080			111,168	23,033	159,650	3,718	402			115,858	4’-9”	21’-1”
	PCC-2436-2440N200	50,500	3,432	200	583,394			111,268	23,058	159,750	3,718	402			115,958	4’-9”	21’-1”
	PCC-2060-2440N080	42,686	2,901	80	413,573			126,240	26,803	175,960	4,956	535			132,176	4’-1”	20’-6”
	PCC-2210-2440N100	45,812	3,113	100	423,609			134,240	28,803	184,460	5,459	590			140,676	4’-1”	20’-6”
	PCC-2250-2440N120	46,634	3,169	120	467,009			126,560	26,883	176,280	4,956	535			132,496	4’-1”	20’-6”
	PCC-2302-2440N120	47,703	3,242	120	447,537			134,440	28,853	184,660	5,459	590			140,876	4’-1”	20’-6”
	PCC-2345-2440N160	48,608	3,303	160	540,558			120,880	25,463	170,180	4,537	490			126,396	4’-1”	20’-6”
	PCC-2468-2440N160	51,158	3,476	160	487,941			135,320	29,073	185,540	5,459	590			141,756	4’-1”	20’-6”
	PCC-2540-2440N200	52,638	3,577	200	544,823			127,540	27,128	177,260	4,956	535			133,476	4’-1”	20’-6”
	PCC-2615-2440N200	54,201	3,683	200	522,062			135,420	29,098	185,640	5,459	590			141,856	4’-1”	20’-6”
	PCC-2734-2440N240	56,668	3,851	240	551,139			136,424	29,349	186,650	5,459	590			142,866	4’-1”	20’-6”

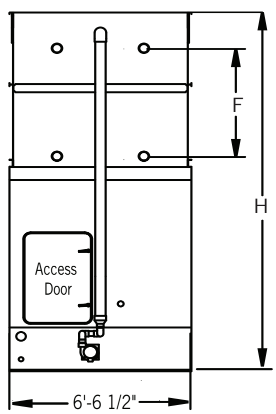
VCA Engineering Data



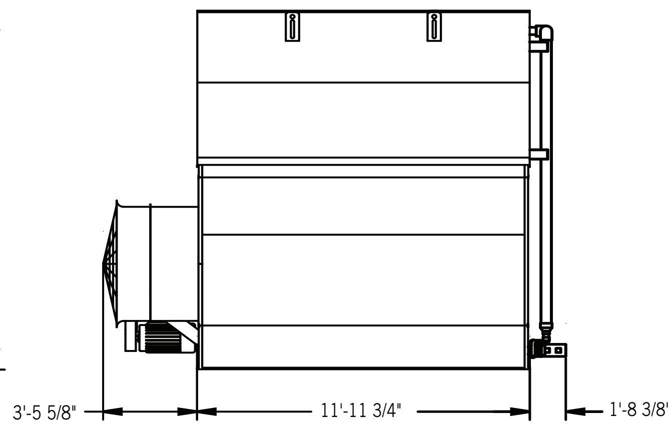
Face A: VCA 5' x 12' Units



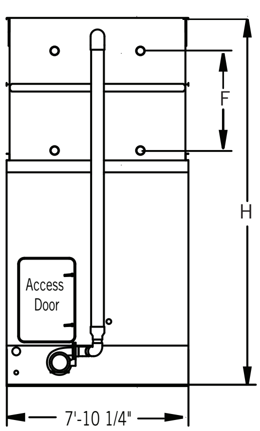
Face C: VCA 5' x 12' Units



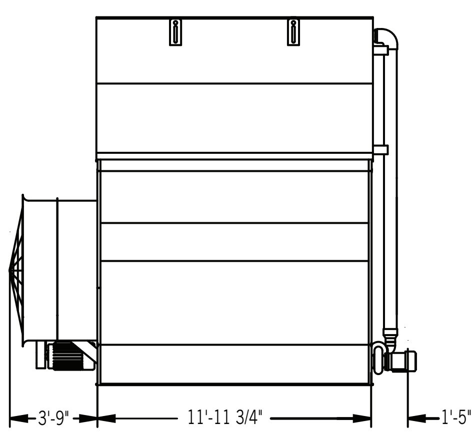
Face A: VCA 6' x 12' Units



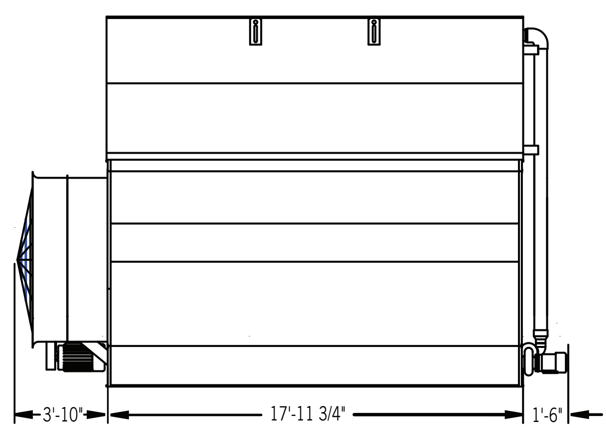
Face C: VCA 6' x 12' Units



Face A: VCA 8' x 12' and 8' x 18' Units



Face C: VCA 8' x 12' Units



Face C: VCA 8' x 18' Units

NOTE: Up-to-date engineering data, free product selection software, and more can be found at **www.BaltimoreAircoil.com**.

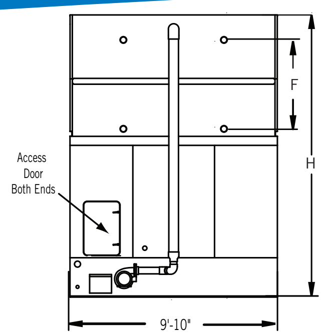
Nom. Box Size	Model Number[1]	Base Heat Rejection (MBH)	R-717 Tons[2]	Fan Motor (HP)	Airflow Rate (CFM)	Pump Motor (HP)	Spray Flow Rate (GPM)	Approximate Weight (lbs)			R-717 Operating Charge[5] (lbs)	Internal Coil Volume (ft^3)	Remote Sump			F	H
								Ship Weight	Heaviest Section[3]	Oper. Weight[4]			Drain Size[6] (in)	Volume Req. (gal)	Approx. Oper. Weight (lbs)		
5' x 12'	VCA-122A	1,793	87	3	23,800	1.5	260	6,390	4,350	9,490	185	20	6	239	7,490	2'-10"	12'-10"
	VCA-138A	2,029	98	5	25,900			6,400	4,350	9,500	185	20			7,500	2'-10"	12'-10"
	VCA-150A	2,205	107	7.5	28,300			6,430	4,350	9,530	185	20			7,530	2'-10"	12'-10"
	VCA-161A	2,367	114	10	31,100			6,440	4,350	9,540	185	20			7,540	2'-10"	12'-10"
	VCA-154A	2,264	109	5	24,500			7,270	5,220	10,420	229	25			8,420	3'-7"	13'-7"
	VCA-170A	2,499	121	7.5	28,000			7,300	5,220	10,450	229	25			8,450	3'-7"	13'-7"
	VCA-182A	2,675	129	10	30,800			7,310	5,220	10,460	229	25			8,460	3'-7"	13'-7"
	VCA-178A	2,617	126	7.5	27,300			8,170	6,090	11,360	273	30			9,360	4'-4"	14'-4"
	VCA-191A	2,808	136	10	30,100			8,180	6,090	11,370	273	30			9,370	4'-4"	14'-4"
6' x 12'	VCA-174A	2,558	124	5	31,400	2	330	8,170	5,770	11,960	241	26	8	197	8,740	2'-10"	12'-10"
	VCA-192A	2,822	136	7.5	36,000			8,200	5,770	11,990	241	26			8,770	2'-10"	12'-10"
	VCA-206A	3,028	146	10	39,650			8,210	5,770	12,000	241	26			8,780	2'-10"	12'-10"
	VCA-227A	3,337	161	15	45,400			8,280	5,770	12,070	241	26			8,850	2'-10"	12'-10"
	VCA-195A	2,867	138	5	30,600			9,310	6,910	13,160	299	32			9,940	3'-7"	13'-7"
	VCA-215A	3,161	153	7.5	35,050			9,340	6,910	13,190	299	32			9,970	3'-7"	13'-7"
	VCA-235A	3,455	167	10	38,750			9,350	6,910	13,200	299	32			9,980	3'-7"	13'-7"
	VCA-259A	3,807	184	15	44,400			9,420	6,910	13,270	299	32			10,050	3'-7"	13'-7"
8' x 12'	VCA-261A	3,837	185	10	43,400	3	400	11,720	8,170	16,230	362	39	8	243	12,550	3'-7"	15'-2"
	VCA-288A	4,234	204	15	49,700			11,800	8,170	16,310	362	39			12,630	3'-7"	15'-2"
	VCA-308A	4,528	219	20	54,700			11,830	8,170	16,340	362	39			12,660	3'-7"	15'-2"
	VCA-273A	4,013	194	10	42,400			13,080	9,530	17,660	432	47			13,980	4'-4"	16'-0"
	VCA-301A	4,425	214	15	48,550			13,160	9,530	17,740	432	47			14,060	4'-4"	16'-0"
	VCA-322A	4,733	229	20	53,400			13,190	9,530	17,770	432	47			14,090	4'-4"	16'-0"
8' x 18'	VCA-323A	4,748	229	10	59,100	5	600	14,990	9,810	21,710	436	47	10	332	16,150	2'-10"	14'-5"
	VCA-356A	5,233	253	15	67,650			15,070	9,810	21,790	436	47			16,230	2'-10"	14'-5"
	VCA-382A	5,601	271	20	74,500			15,090	9,810	21,810	436	47			16,250	2'-10"	14'-5"
	VCA-396A	5,821	281	15	65,700			17,070	11,810	23,900	541	58			18,340	3'-7"	15'-2"
	VCA-424A	6,233	301	20	72,300			17,090	11,810	23,920	541	58			18,360	3'-7"	15'-2"
	VCA-416A	6,115	295	15	64,200			19,070	13,810	26,000	647	70			20,440	4'-4"	16'-0"
	VCA-446A	6,556	317	20	70,650			19,090	13,810	26,020	647	70			20,460	4'-4"	16'-0"

NOTES:

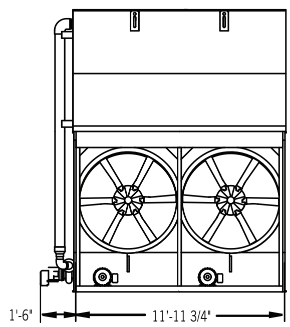
1. Model number denotes nominal tons using R-22 at a 105°F condensing temperature, a 40°F suction temperature, and a 78°F entering wet-bulb temperature.
2. R-717 tons are at a 96.3°F condensing temperature, a 20°F suction temperature, and a 78°F entering wet-bulb temperature.
3. Unless otherwise noted, the coil section is the heaviest section.
4. Operating weight is for the unit with the water level at the overflow level and with the coil charged with R-717.
5. The R-22 operating charge is 1.93 times the R-717 charge; R-134a is 1.98 times.
6. Drain size is based on a bottom connection.
7. Coil inlet and outlet connections are 4" beveled for welding.

Do not use for construction. Refer to factory certified dimensions. This catalog includes data current at the time of publication, which should be reconfirmed at the time of purchase.

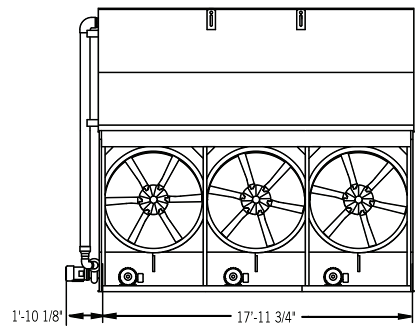
VCA Engineering Data



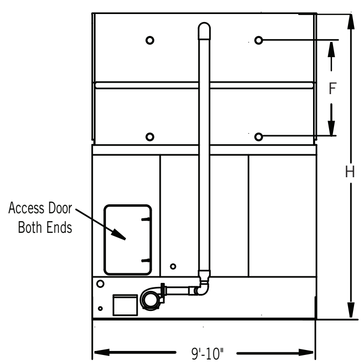
Face A: VCA 10' x 12' and 10' x 18' Units



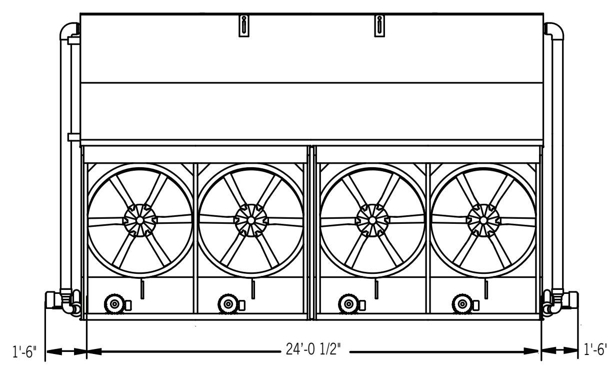
Face D: VCA 10' x 12' Units



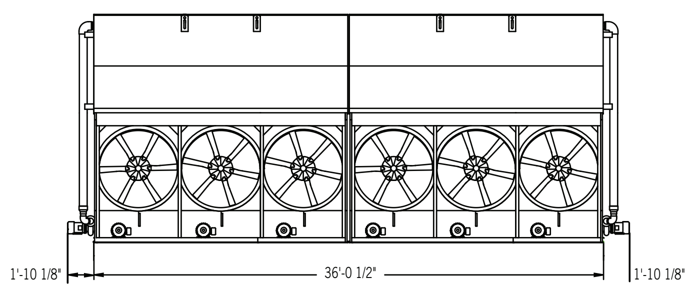
Face D: VCA 10' x 18' Units



Face A: VCA 10' x 24' and 10' x 36' Units



Face D: VCA 10' x 24' Units



Face D: VCA 10' x 36' Units

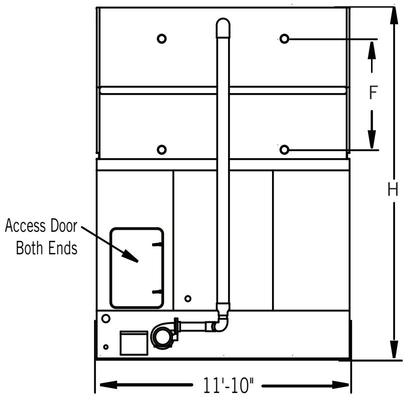
NOTES:

1. Model number denotes nominal tons using R-22 at a 105°F condensing temperature, a 40°F suction temperature, and a 78°F entering wet-bulb temperature.
2. R-717 tons are at a 96.3°F condensing temperature, a 20°F suction temperature, and a 78°F entering wet-bulb temperature.
3. Unless otherwise noted, the coil section is the heaviest section.
4. Operating weight is for the unit with the water level at the overflow level and with the coil charged with R-717.
5. The R-22 operating charge is 1.93 times the R-717 charge; R-134a is 1.98 times.
6. Drain size is based on a bottom connection.
7. Coil inlet and outlet connections are 4" beveled for welding.

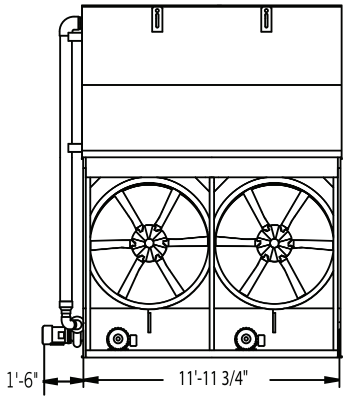
Do not use for construction. Refer to factory certified dimensions. This catalog includes data current at the time of publication, which should be reconfirmed at the time of purchase.

								Approximate Weight (lbs)					Remote Sump				
Nom. Box Size	Model Number[1]	Base Heat Rejection (MBH)	R-717 Tons[2]	Fan Motor (HP)	Airflow Rate (CFM)	Pump Motor (HP)	Spray Flow Rate (GPM)	Ship Weight	Heaviest Section[3]	Oper. Weight[4]	R-717 Operating Charge[5] (lbs)	Internal Coil Volume (ft^3)	Drain Size[6] (in)	Volume Req. (gal)	Approx. Oper. Weight (lbs)	F	H
10' x 12'	VCA-300A	4,410	213	(2) 5	59,800	5	500	12,270	8,360	18,340	370	40	8	305	13,740	2'-10"	13'-10"
	VCA-331A	4,866	235	(2) 7.5	68,500			12,330	8,360	18,400	370	40			13,800	2'-10"	13'-10"
	VCA-340A	4,998	241	(2) 5	55,400			13,950	10,040	20,110	458	50			15,510	3'-7"	14'-7"
	VCA-375A	5,513	266	(2) 7.5	63,400			14,010	10,040	20,170	458	50			15,570	3'-7"	14'-7"
	VCA-402A	5,909	285	(2) 10	69,800			14,030	10,040	20,190	458	50			15,590	3'-7"	14'-7"
	VCA-407A	5,983	289	(2) 10	65,400			15,710	11,720	21,960	547	59			17,360	4'-4"	15'-4"
	VCA-401A	5,895	285	(2) 7.5	54,500			16,660	12,690	22,970	608	66			18,370	4'-4"	15'-4"
	VCA-429A	6,306	305	(2) 10	60,000			16,680	12,690	22,990	608	66			18,390	4'-4"	15'-4"
	VCA-473A	6,953	336	(2) 15	68,600			16,820	12,690	23,130	608	66			18,530	4'-4"	15'-4"
	VCA-393A	5,777	279	(2) 5	49,900			18,440	14,530	24,850	707	76			20,250	5'-1"	16'-2"
	VCA-433A	6,365	307	(2) 7.5	57,100			18,500	14,530	24,910	707	76			20,310	5'-1"	16'-2"
	VCA-464A	6,821	329	(2) 10	62,800			18,520	14,530	24,930	707	76			20,330	5'-1"	16'-2"
	VCA-512A	7,526	364	(2) 15	71,900			18,660	14,530	25,070	707	76			20,470	5'-1"	16'-2"
10' x 18'	VCA-460A	6,762	327	(3) 5	87,700	7.5	760	17,770	12,010	26,970	551	60	10	418	19,950	2'-10"	13'-10"
	VCA-507A	7,453	360	(3) 7.5	100,400			17,870	12,010	27,070	551	60			20,050	2'-10"	13'-10"
	VCA-543A	7,982	386	(3) 10	110,500			17,900	12,010	27,100	551	60			20,080	2'-10"	13'-10"
	VCA-510A	7,497	362	(3) 5	87,200			20,260	14,500	29,600	685	74			22,580	3'-7"	14'-7"
	VCA-560A	8,232	398	(3) 7.5	95,700			20,360	14,500	29,700	685	74			22,680	3'-7"	14'-7"
	VCA-600A	8,820	426	(3) 10	105,300			20,390	14,500	29,730	685	74			22,710	3'-7"	14'-7"
	VCA-585A	8,600	415	(3) 7.5	93,600			22,860	17,000	32,330	819	88			25,310	4'-4"	15'-4"
	VCA-620A	9,114	440	(3) 10	100,500			22,890	17,000	32,360	819	88			25,340	4'-4"	15'-4"
	VCA-488A	7,174	346	(3) 3	60,300			24,240	18,510	33,800	912	98			26,780	4'-4"	15'-4"
	VCA-609A	8,952	432	(3) 7.5	81,800			24,370	18,510	33,930	912	98			26,910	4'-4"	15'-4"
	VCA-653A	9,599	464	(3) 10	90,000			24,400	18,510	33,960	912	98			26,940	4'-4"	15'-4"
	VCA-707A	10,393	502	(3) 10	94,200			27,150	21,260	36,860	1,061	115			29,840	5'-1"	16'-2"
	VCA-779A	11,451	553	(3) 15	107,900			27,370	21,260	37,080	1,061	115			30,060	5'-1"	16'-2"
10' x 24'	VCA-662A	9,731	470	(4) 7.5	137,000	(2) 5	1,020	24,750	8,410	36,900	740	80	(2) 8	582	27,870	2'-10"	13'-10"
	VCA-680A	9,996	483	(4) 5	110,800			27,990	10,090	40,310	917	99			31,280	3'-7"	14'-7"
	VCA-750A	11,025	533	(4) 7.5	126,800			28,110	10,090	40,430	917	99			31,400	3'-7"	14'-7"
	VCA-804A	11,819	571	(4) 10	139,600			28,160	10,090	40,480	917	99			31,450	3'-7"	14'-7"
	VCA-760A	11,172	540	(4) 7.5	118,800			31,470	11,770	43,970	1,094	118			34,940	4'-4"	15'-4"
	VCA-814A	11,966	578	(4) 10	130,800			31,520	11,770	44,020	1,094	118			34,990	4'-4"	15'-4"
	VCA-858A	12,613	609	(4) 10	120,000			33,460	12,740	46,080	1,216	131			37,050	4'-4"	15'-4"
	VCA-946A	13,906	672	(4) 15	137,200			33,740	12,740	46,360	1,216	131			37,330	4'-4"	15'-4"
	VCA-866A	12,730	615	(4) 7.5	114,200			37,090	14,580	49,910	1,414	153			40,890	5'-1"	16'-2"
	VCA-928A	13,642	659	(4) 10	125,600			37,140	14,580	49,960	1,414	153			40,940	5'-1"	16'-2"
	VCA-1024A	15,053	727	(4) 15	143,800			37,420	14,580	50,240	1,414	153			41,220	5'-1"	16'-2"
	VCA-S700A	10,296	497	(4) 5	110,800			27,250	19,440	39,570	912	99			30,540	3'-7"	14'-7"
	VCA-S828A	12,173	588	(4) 10	139,600			27,420	19,440	39,740	912	99			30,710	3'-7"	14'-7"
	VCA-S838A	12,325	595	(4) 10	130,800			30,730	22,750	43,230	1,092	118			34,200	4'-4"	15'-4"
	VCA-S884A	12,991	627	(4) 10	120,000			32,790	24,810	45,410	1,216	131			36,380	4'-4"	15'-4"
10' x 36'	VCA-920A	13,524	653	(6) 5	175,400	(2) 7.5	1,540	35,710	12,100	54,110	1,102	119	(2) 10	807	40,240	2'-10"	13'-10"
	VCA-1086A	15,964	771	(6) 10	221,000			35,970	12,100	54,370	1,102	119			40,500	2'-10"	13'-10"
	VCA-1020A	14,994	724	(6) 5	174,400			40,700	14,590	59,370	1,370	148			45,500	3'-7"	14'-7"
	VCA-1120A	16,464	795	(6) 7.5	191,400			40,890	14,590	59,560	1,370	148			45,690	3'-7"	14'-7"
	VCA-1200A	17,640	852	(6) 10	210,600			40,960	14,590	59,630	1,370	148			45,760	3'-7"	14'-7"
	VCA-1062A	15,611	754	(6) 5	163,600			45,690	17,090	64,630	1,638	177			50,760	4'-4"	15'-4"
	VCA-1169A	17,199	831	(6) 7.5	187,200			45,880	17,090	64,820	1,638	177			50,950	4'-4"	15'-4"
	VCA-1240A	18,228	880	(6) 10	201,000			45,950	17,090	64,890	1,638	177			51,020	4'-4"	15'-4"
	VCA-1218A	17,905	865	(6) 7.5	163,600			48,900	18,600	68,030	1,823	197			54,160	4'-4"	15'-4"
	VCA-1306A	19,198	927	(6) 10	180,000			48,970	18,600	68,100	1,823	197			54,230	4'-4"	15'-4"
	VCA-1414A	20,786	1,004	(6) 10	188,400			54,460	21,340	73,880	2,122	229			60,010	5'-1"	16'-2"
	VCA-1558A	22,903	1,106	(6) 15	215,800			54,890	21,340	74,310	2,122	229			60,440	5'-1"	16'-2"

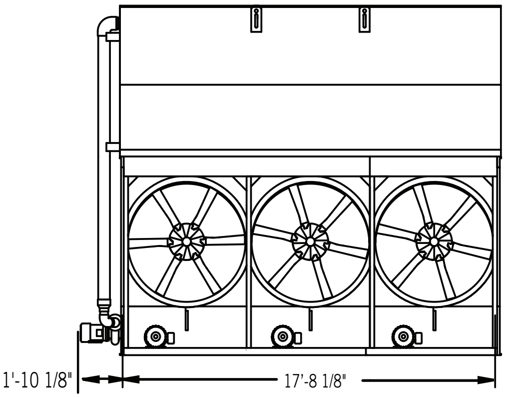
VCA Engineering Data



Face A: VCA 12' x 12' and 12' x 18' Units



Face D: VCA 12' x 12' Units



Face D: VCA 12' x 18' Units

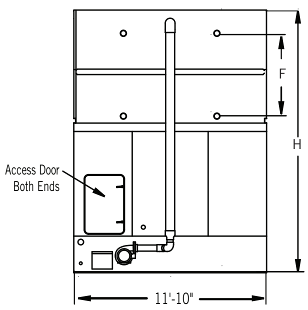
NOTES:

1. Model number denotes nominal tons using R-22 at a 105°F condensing temperature, a 40°F suction temperature, and a 78°F entering wet-bulb temperature.
2. R-717 tons are at a 96.3°F condensing temperature, a 20°F suction temperature, and a 78°F entering wet-bulb temperature.
3. Unless otherwise noted, the coil section is the heaviest section.
4. Operating weight is for the unit with the water level at the overflow level and with the coil charged with R-717.
5. The R-22 operating charge is 1.93 times the R-717 charge; R-134a is 1.98 times.
6. Drain size is based on a bottom connection..

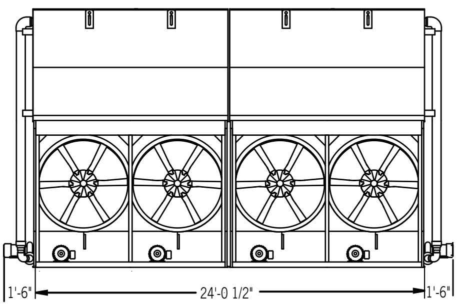
Do not use for construction. Refer to factory certified dimensions. This catalog includes data current at the time of publication, which should be reconfirmed at the time of purchase.

Nom. Box Size	Model Number[1]	Base Heat Rejection (MBH)	R-717 Tons[2]	Fan Motor (HP)	Airflow Rate (CFM)	Pump Motor (HP)	Spray Flow Rate (GPM)	Approximate Weight (lbs) Ship Weight	Approximate Weight (lbs) Heaviest Section[3]	Approximate Weight (lbs) Oper. Weight[4]	R-717 Operating Charge[5] (lbs)	Internal Coil Volume (ft^3)	Remote Sump Drain Size[6] (in)	Remote Sump Volume Req. (gal)	Remote Sump Approx. Oper. Weight (lbs)	F	H
12' x 12'	VCA-302A	4,439	214	(2) 3	50,400	5	610	14,040	10,020	21,770	455	49	8	506	17,050	2'-10"	13'-10"
	VCA-342A	5,027	243	(2) 5	59,750			14,060	10,020	21,790	455	49			17,070	2'-10"	13'-10"
	VCA-377A	5,542	268	(2) 7.5	68,400			14,020	10,020	21,750	455	49			17,030	2'-10"	13'-10"
	VCA-404A	5,939	287	(2) 10	75,300			14,040	10,020	21,770	455	49			17,050	2'-10"	13'-10"
	VCA-381A	5,601	271	(2) 5	59,800			16,040	12,070	23,880	564	61			19,160	3'-7"	14'-7"
	VCA-420A	6,174	298	(2) 7.5	68,400			16,070	12,070	23,910	564	61			19,190	3'-7"	14'-7"
	VCA-451A	6,630	320	(2) 10	73,100			16,090	12,070	23,930	564	61			19,210	3'-7"	14'-7"
	VCA-471A	6,924	334	(2) 10	71,400			18,130	14,110	26,080	673	73			21,360	4'-4"	15'-4"
	VCA-513A	7,541	364	(2) 15	81,750			18,200	14,110	26,150	673	73			21,430	4'-4"	15'-4"
	VCA-491A	7,218	349	(2) 10	71,200			19,170	15,150	27,180	735	79			22,460	4'-4"	15'-4"
	VCA-541A	7,953	384	(2) 15	81,500			19,240	15,150	27,250	735	79			22,530	4'-4"	15'-4"
	VCA-580A	8,526	412	(2) 20	89,700			19,480	15,150	27,490	735	79			22,770	4'-4"	15'-4"
	VCA-537A	7,894	381	(2) 10	67,300			21,290	17,270	29,420	854	92			24,700	5'-1"	16'-2"
	VCA-584A	8,600	415	(2) 15	77,040			21,360	17,270	29,490	854	92			24,770	5'-1"	16'-2"
	VCA-626A	9,202	444	(2) 20	85,200			21,460	17,270	29,590	854	92			24,870	5'-1"	16'-2"
	VCA-661A	9,717	469	(2) 25	91,800			21,600	17,270	29,730	854	92			25,010	5'-1"	16'-2"
12' x 18'	VCA-526A	7,732	373	(3) 5	89,700	7.5	920	20,240	14,570	31,950	679	73	10	695	24,500	2'-10"	13'-10"
	VCA-581A	8,541	413	(3) 7.5	102,650			20,270	14,570	31,980	679	73			24,530	2'-10"	13'-10"
	VCA-623A	9,158	442	(3) 10	113,000			20,280	14,570	31,990	679	73			24,540	2'-10"	13'-10"
	VCA-582A	8,555	413	(3) 5	87,000			23,280	17,610	35,160	844	91			27,710	3'-7"	14'-7"
	VCA-642A	9,437	456	(3) 7.5	99,600			23,310	17,610	35,190	844	91			27,740	3'-7"	14'-7"
	VCA-688A	10,114	488	(3) 10	109,650			23,320	17,610	35,200	844	91			27,750	3'-7"	14'-7"
	VCA-602A	8,849	427	(3) 5	85,100			26,320	20,650	38,360	1,009	109			30,910	4'-4"	15'-4"
	VCA-664A	9,761	471	(3) 7.5	97,400			26,350	20,650	38,390	1,009	109			30,940	4'-4"	15'-4"
	VCA-711A	10,452	505	(3) 10	107,150			26,360	20,650	38,400	1,009	109			30,950	4'-4"	15'-4"
	VCA-785A	11,540	557	(3) 15	122,650			26,440	20,650	38,480	1,009	109			31,030	4'-4"	15'-4"
	VCA-751A	11,025	533	(3) 10	106,800			27,940	22,230	40,070	1,102	119			32,620	4'-4"	15'-4"
	VCA-827A	12,157	587	(3) 15	122,200			28,020	22,230	40,150	1,102	119			32,700	4'-4"	15'-4"
	VCA-887A	13,039	630	(3) 20	134,500			28,160	22,230	40,290	1,102	119			32,840	4'-4"	15'-4"
	VCA-895A	13,157	635	(3) 15	115,000			31,230	25,440	43,540	1,282	138			36,090	5'-1"	16'-2"
	VCA-957A	14,068	679	(3) 20	126,080			31,370	25,440	43,680	1,282	138			36,230	5'-1"	16'-2"
	VCA-1010A	14,847	717	(3) 25	135,800			31,500	25,440	43,810	1,282	138			36,360	5'-1"	16'-2"

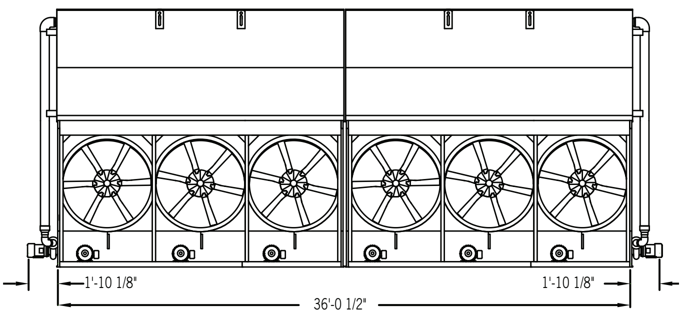
VCA Engineering Data



Face A:
VCA 12' x 24' and 12' x 36' Units



Face D: VCA 12' x 24' Units



Face D: VCA 12' x 36' Units

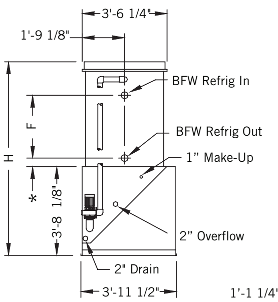
NOTES:

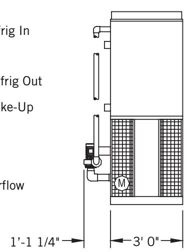
1. Model number denotes nominal tons using R-22 at a 105°F condensing temperature, a 40°F suction temperature, and a 78°F entering wet-bulb temperature.
2. R-717 tons are at a 96.3°F condensing temperature, a 20°F suction temperature, and a 78°F entering wet-bulb temperature.
3. Unless otherwise noted, the coil section is the heaviest section.
4. Operating weight is for the unit with the water level at the overflow level and with the coil charged with R-717.
5. The R-22 operating charge is 1.93 times the R-717 charge; R-134a is 1.98 times.
6. Drain size is based on a bottom connection..

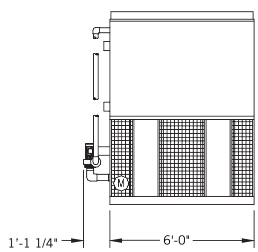
Do not use for construction. Refer to factory certified dimensions. This catalog includes data current at the time of publication, which should be reconfirmed at the time of purchase.

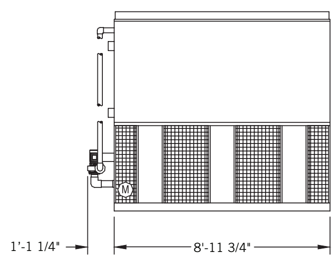
Nom. Box Size	Model Number[1]	Base Heat Rejection (MBH)	R-717 Tons[2]	Fan Motor (HP)	Airflow Rate (CFM)	Pump Motor (HP)	Spray Flow Rate (GPM)	Approximate Weight (lbs): Ship Weight	Approximate Weight (lbs): Heaviest Section[3]	Approximate Weight (lbs): Oper. Weight[4]	R-717 Operating Charge[5] (lbs)	Internal Coil Volume (ft³)	Remote Sump: Drain Size[6] (in)	Remote Sump: Volume Req. (gal)	Remote Sump: Approx. Oper. Weight (lbs)	F	H
12' x 24'	VCA-605A	8,894	430	(4) 3	100,800	(2) 5	1,240	28,030	10,090	43,490	911	98	(2) 8	986	34,060	2'-10"	13'-10"
	VCA-684A	10,055	486	(4) 5	119,500			28,050	10,090	43,510	911	98			34,080	2'-10"	13'-10"
	VCA-754A	11,084	535	(4) 7.5	136,800			28,090	10,090	43,550	911	98			34,120	2'-10"	13'-10"
	VCA-808A	11,878	574	(4) 10	150,600			28,100	10,090	43,560	911	98			34,130	2'-10"	13'-10"
	VCA-762A	11,201	541	(4) 5	119,600			32,140	12,140	47,810	1,129	122			38,380	3'-7"	14'-7"
	VCA-840A	12,348	596	(4) 7.5	136,800			32,180	12,140	47,850	1,129	122			38,420	3'-7"	14'-7"
	VCA-902A	13,259	640	(4) 10	146,200			32,190	12,140	47,860	1,129	122			38,430	3'-7"	14'-7"
	VCA-879A	12,921	624	(4) 7.5	129,800			36,270	14,180	52,160	1,347	145			42,730	4'-4"	15'-4"
	VCA-942A	13,847	669	(4) 10	142,800			36,280	14,180	52,170	1,347	145			42,740	4'-4"	15'-4"
	VCA-1026A	15,082	728	(4) 15	163,500			36,360	14,180	52,250	1,347	145			42,820	4'-4"	15'-4"
	VCA-982A	14,435	697	(4) 10	142,400			38,340	15,210	54,350	1,470	159			44,920	4'-4"	15'-4"
	VCA-1082A	15,905	768	(4) 15	163,000			38,420	15,210	54,430	1,470	159			45,000	4'-4"	15'-4"
	VCA-1160A	17,052	824	(4) 20	179,400			38,730	15,210	54,740	1,470	159			45,310	4'-4"	15'-4"
	VCA-1075A	15,803	763	(4) 10	134,600			42,590	17,340	58,840	1,708	184			49,420	5'-1"	16'-2"
	VCA-1170A	17,199	831	(4) 15	154,080			42,670	17,340	58,920	1,708	184			49,500	5'-1"	16'-2"
	VCA-1252A	18,404	889	(4) 20	170,400			42,840	17,340	59,090	1,708	184			49,670	5'-1"	16'-2"
	VCA-1321A	19,419	938	(4) 25	183,600			42,980	17,340	59,230	1,708	184			49,810	5'-1"	16'-2"
	VCA-S870A	12,789	618	(4) 7.5	136,800			31,450	23,540	47,120	1,124	121			37,690	3'-7"	14'-7"
	VCA-S932A	13,700	662	(4) 10	146,200			31,460	23,540	47,130	1,124	121			37,700	3'-7"	14'-7"
	VCA-S972A	14,288	690	(4) 10	142,800			35,500	27,580	51,390	1,345	145			41,960	4'-4"	15'-4"
	VCA-S1071A	15,744	760	(4) 15	163,500			35,580	27,580	51,470	1,345	145			42,040	4'-4"	15'-4"
	VCA-S1019A	14,979	723	(4) 10	153,400			37,630	29,710	53,640	1,470	159			44,210	4'-4"	15'-4"
	VCA-S1124A	16,523	798	(4) 15	163,000			37,700	29,710	53,710	1,470	159			44,280	4'-4"	15'-4"
	VCA-S1204A	17,699	855	(4) 20	179,400			37,710	29,710	53,720	1,470	159			44,290	4'-4"	15'-4"
12' x 36'	VCA-930A	13,671	660	(6) 3	151,400	(2) 7.5	1,860	40,610	14,690	64,030	1,358	147	(2) 10	1,345	49,160	2'-10"	13'-10"
	VCA-1052A	15,464	747	(6) 5	179,400			40,630	14,690	64,050	1,358	147			49,180	2'-10"	13'-10"
	VCA-1162A	17,081	825	(6) 7.5	205,300			40,670	14,690	64,090	1,358	147			49,220	2'-10"	13'-10"
	VCA-1246A	18,316	885	(6) 10	226,000			40,690	14,690	64,110	1,358	147			49,240	2'-10"	13'-10"
	VCA-1284A	18,875	912	(6) 7.5	199,200			46,740	17,720	70,490	1,687	182			55,630	3'-7"	14'-7"
	VCA-1376A	20,227	977	(6) 10	219,300			46,760	17,720	70,510	1,687	182			55,650	3'-7"	14'-7"
	VCA-1204A	17,699	855	(6) 5	170,200			52,780	20,760	76,860	2,017	218			62,000	4'-4"	15'-4"
	VCA-1327A	19,507	942	(6) 7.5	194,800			52,820	20,760	76,900	2,017	218			62,040	4'-4"	15'-4"
	VCA-1422A	20,903	1,010	(6) 10	214,300			52,840	20,760	76,920	2,017	218			62,060	4'-4"	15'-4"
	VCA-1570A	23,079	1,115	(6) 15	245,300			52,920	20,760	77,000	2,017	218			62,140	4'-4"	15'-4"
	VCA-1501A	22,065	1,066	(6) 10	213,600			56,000	22,340	80,270	2,203	238			65,410	4'-4"	15'-4"
	VCA-1654A	24,314	1,174	(6) 15	244,400			56,080	22,340	80,350	2,203	238			65,490	4'-4"	15'-4"
	VCA-1774A	26,078	1,260	(6) 20	269,000			56,330	22,340	80,600	2,203	238			65,740	4'-4"	15'-4"
	VCA-1790A	26,313	1,271	(6) 15	230,000			62,490	25,550	87,120	2,564	277			72,260	5'-1"	16'-2"
	VCA-1914A	28,136	1,359	(6) 20	252,160			62,740	25,550	87,370	2,564	277			72,510	5'-1"	16'-2"
	VCA-2019A	29,679	1,433	(6) 25	271,600			62,870	25,550	87,500	2,564	277			72,640	5'-1"	16'-2"

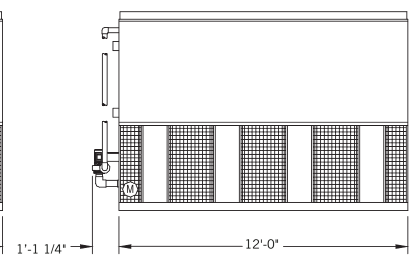
VC1 Engineering Data











*4 1/4" On VC1-10-20
4 3/4" On VC1-30-135

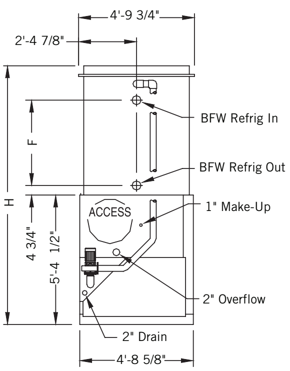
Face A: VC1 3' x 3', 3'x 6', 3' x 9' and 3' x 12' Units

Face D: VC1 3' x 3' Units

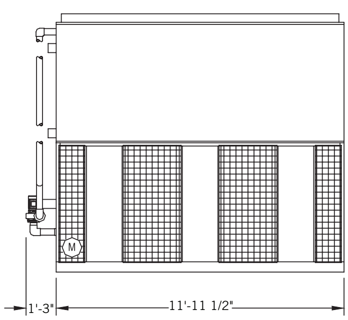
Face D: VC1 3' x 6' Units

Face D: VC1 3' x 9' Units

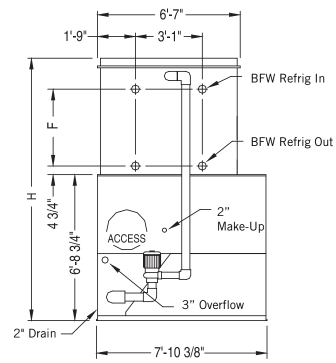
Face D: VC1 3' x 12' Units



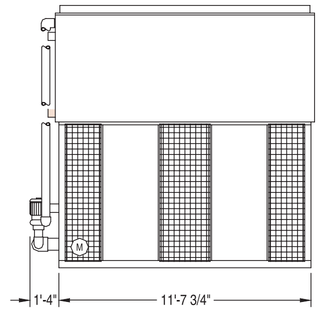
Face A: VC1 4.5' x 12' Units



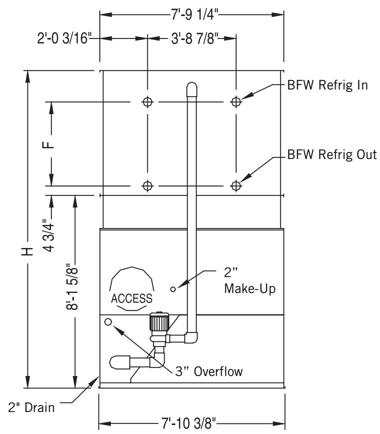
Face D: VC1 4.5' x 12' Units



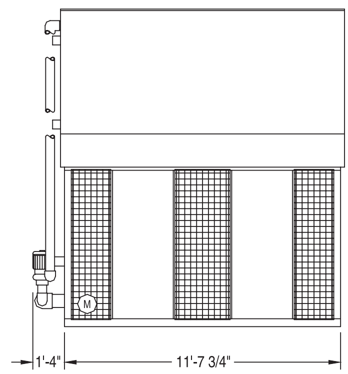
Face A: VC1 6' x 12' Units



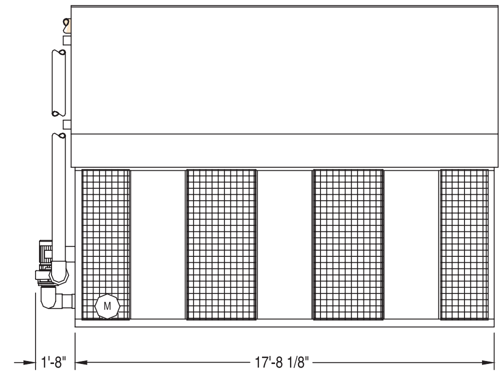
Face D: VC1 6' x 12' Units



Face A: VC1 8' x 12' and 8' x 18' Units



Face D: VC1 8' x 12' Units



Face D: VC1 8' x 18' Units

NOTE: Up-to-date engineering data, free product selection software, and more can be found at **www.BaltimoreAircoil.com**.

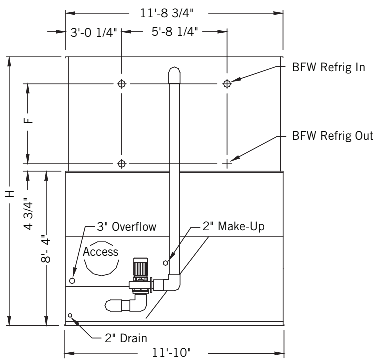
Nom. Box Size	Model Number[1]	Base Heat Rejection (MBH)	R-717 Tons[2]	Fan Motor (HP)[3]	Airflow Rate (CFM)	Pump Motor (HP)	Spray Flow Rate (GPM)	Approximate Weight (lbs) Ship Weight	Approximate Weight (lbs) Heaviest Section[4]	Approximate Weight (lbs) Oper. Weight[5]	R-717 Operating Charge[6] (lbs)	Internal Coil Volume (ft³)	Remote Sump Drain Size[7] (in)	Remote Sump Volume Req. (gal)	Remote Sump Approx. Oper. Weight (lbs)	F	H
3' x 3'	VC1-10	147	7	1/2	2,900	0.3	35	1,270	*1,270	1,400	19	2	2.5	25	1,220	1'-2 1/4"	6'-7 1/4"
	VC1-15	221	11	1	3,800			1,460	*1,460	1,600	25	2.7			1,420	1'-10 3/4"	7'-3 3/4"
	VC1-20	294	14	1.5	4,400			1,620	1,000	1,770	32	3.5			1,590	2'-7 1/4"	8'-0 1/4"
	VC1-25	368	18	3	5,300			1,670	1,050	1,820	34	3.5			1,640	2'-7 1/4"	8'-0 1/4"
3' x 6'	VC1-30	441	21	3	8,200	0.5	75	2,010	*2,010	2,300	35	3.5	3	50	1,990	1'-1 1/4"	6'-7 1/4"
	VC1-38	559	27	3	8,900			2,240	*2,240	2,560	45	5			2,250	1'-9 3/4"	7'-3 3/4"
	VC1-46	676	33	3	8,500			2,540	1,650	2,880	61	6.5			2,570	2'-6 1/4"	8'-0 1/4"
	VC1-52	764	37	5	10,200			2,590	1,700	2,930	65	6.5			2,620	2'-6 1/4"	8'-0 1/4"
	VC1-58	853	41	5	9,800			2,860	1,940	3,230	76	8			2,920	3'-2 3/4"	8'-8 3/4"
	VC1-65	956	46	7.5	11,600			2,930	2,010	3,300	80	8			2,990	3'-2 3/4"	8'-8 3/4"
3' x 9'	VC1-72	1,058	51	5	12,300	0.75	115	3,510	2,400	4,210	60	9.6	4	75	3,770	2'-9 1/4"	8'-3 1/4"
	VC1-80	1,176	57	7.5	14,500			3,580	2,470	4,280	100	9.6			3,840	2'-9 1/4"	8'-3 1/4"
	VC1-90	1,323	64	7.5	14,000			4,000	2,850	4,750	110	12			4,310	3'-6 1/2"	9'-0 1/2"
3' x 12'	VC1-100	1,470	71	7.5	19,600	1	150	4,450	3,060	5,420	120	13	4	105	4,830	2'-9 1/4"	8'-3 1/4"
	VC1-110	1,617	78	10	22,000			4,530	3,140	5,500	130	13			4,910	2'-9 1/4"	8'-3 1/4"
	VC1-125	1,838	89	10	21,000			5,060	3,640	6,080	145	16			5,490	3'-6 1/2"	9'-0 1/2"
	VC1-135	1,985	96	15	23,000			5,180	3,640	6,160	145	16			5,570	3'-6 1/2"	9'-0 1/2"
4.5' x 12'	VC1-150	2,205	106	10	28,200	1.5	220	7,480	4,920	8,730	170	18	6	140	7,880	2'-9 1/4"	9'-11 5/8"
	VC1-165	2,426	117	10	27,200			8,060	5,830	9,680	210	25			8,830	3'-6 1/2"	10'-8 7/8"
	VC1-185	2,720	131	15	33,300			8,170	5,930	9,770	210	23			8,920	3'-6 1/2"	10'-8 7/8"
	VC1-205	3,014	145	20	35,800			8,820	6,580	10,420	245	27			9570	4'-3 3/4"	11'-6 1/8"
6' x 12'	VC1-N208	3,058	148	15	39,650	2	305	10,170	6,580	13,710	230	25	6	360	11,460	2'-9 1/4"	11'-3 7/8"
	VC1-N230	3,381	163	15	38,550			11,410	8,220	15,000	245	31			12,750	3'-6 1/2"	12'-1 1/8"
8' x 12'	VC1-N243	3,572	172	20	46,150	3	385	10,720	7,050	15,140	290	32	6	260	13,040	2'-9 1/4"	12'-9 1/8"
	VC1-N257	3,778	182	25	49,700			10,770	7,050	15,190	290	32			13,090	2'-9 1/4"	12'-9 1/8"
	VC1-N275	4,043	195	20	44,800			12,130	8,460	16,700	360	40			14,600	3'-6 1/2"	13'-6 3/4"
	VC1-N301	4,425	213	25	47,150			13,580	9,860	18,210	430	47			16,110	4'-3 3/4"	14'-3 5/8"
	VC1-N315	4,631	223	30	50,100			13,600	9,860	18,230	430	47			16,130	4'-3 3/4"	14'-3 5/8"
8' x 18'	VC1-N338	4,969	240	20	60,450	5	580	15,630	10,390	22,360	435	48	8	520	19,110	2'-9 1/4"	12'-9 1/8"
	VC1-N357	5,248	253	25	65,100			15,680	10,390	22,410	435	48			19,160	2'-9 1/4"	12'-9 1/8"
	VC1-N373	5,483	265	30	69,200			15,700	10,390	22,430	435	48			19,180	2'-9 1/4"	12'-9 1/8"
	VC1-N417	6,130	296	30	67,200			17,880	12,570	24,820	540	59			21,570	3'-6 1/2"	13'-6 3/4"
	VC1-N470	6,909	333	40	72,250			20,250	14,750	27,410	645	71			24,160	4'-3 3/4"	14'-3 5/8"

NOTES:

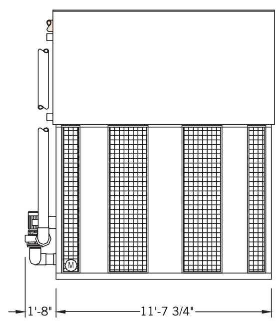
1. Model number denotes nominal tons using R-22 at a 105°F condensing temperature, a 40°F suction temperature, and a 78°F entering wet-bulb temperature.
2. R-717 tons are at a 96.3°F condensing temperature, a 20°F suction temperature, and a 78°F entering wet-bulb temperature.
3. Fan horsepower is at 0" external static pressure.
4. Operating weight is for the unit with the water level at the overflow level and with the coil charged with R-717.
5. The R-22 operating charge is 1.93 times the R-717 charge; R-134a is 1.98 times.
6. Drain size is based on a bottom connection.
7. Coil inlet and outlet connections are 3" BFW for VC1-10 through VC1-25 and are 4" BFW for all other models.
8. For VC1-10 through VC1-205, the riser pipe diameter is 3".
   For VC1-N208 through VC1-315, the riser pipe diameter is 4".
   For VC1-N338 through VC1-N470, the riser pipe diameter is 6".
9. Asterisk * denotes unit ships in one piece.

Do not use for construction. Refer to factory certified dimensions. This catalog includes data current at the time of publication, which should be reconfirmed at the time of purchase.

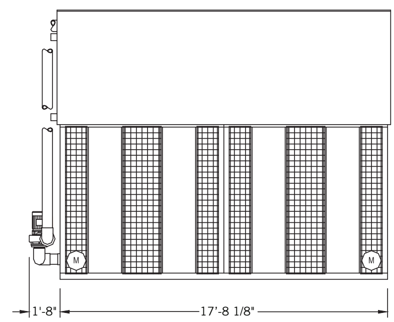
VC1 Engineering Data



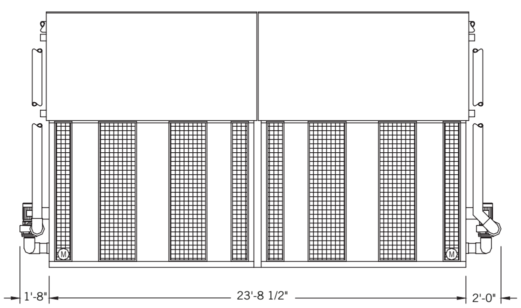
Face A: VC1 12' x 12', 12' x 18', 12' x 24' and 12' x 36 Units



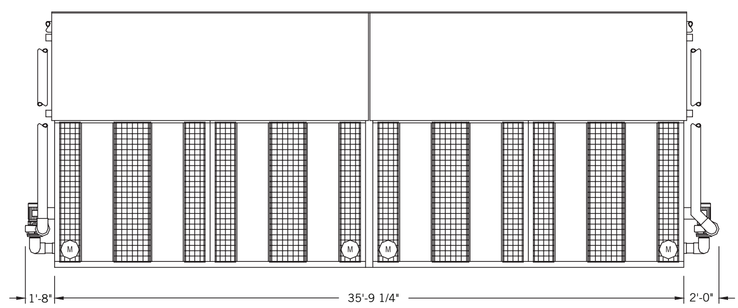
Face D: VC1 12' x 12' Units



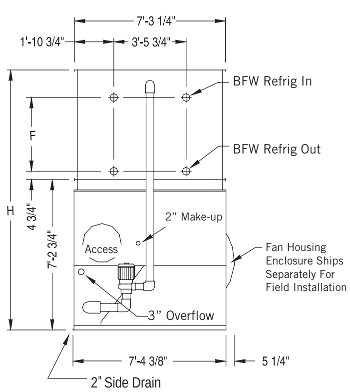
Face D: VC1 12' x 18' Units



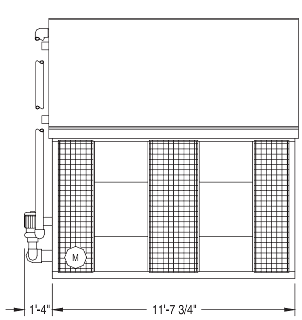
Face D: VC1 12' x 24' Units



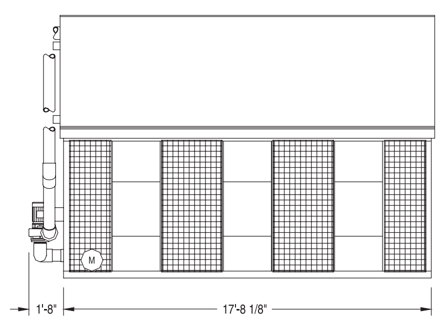
Face D: VC1 12' x 36' Units



Face D: VC1 7.4' x 18' and 7.4' x 12' Units



Face D: VC1 7.4' x 12' Units



Face D: VC1 7.4' x 18' Units

NOTE: Designed to minimize ocean freight costs, VC1-C models fit in standard dry van containers.

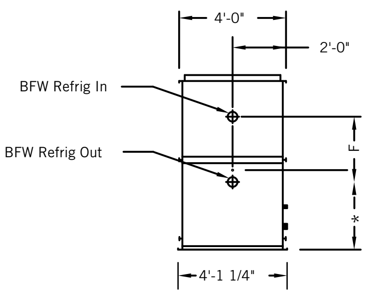
Nom. Box Size	Model Number[1]	Base Heat Rejection (MBH)	R-717 Tons[2]	Fan Motor (HP)[3]	Airflow Rate (CFM)	Pump Motor (HP)	Spray Flow Rate (GPM)	Approximate Weight (lbs): Ship Weight	Approximate Weight (lbs): Heaviest Section[4]	Approximate Weight (lbs): Oper. Weight[5]	R-717 Operating Charge[6] (lbs)	Internal Coil Volume (ft³)	Remote Sump: Drain Size[7] (in)	Remote Sump: Volume Req. (gal)	Remote Sump: Approx. Oper. Weight (lbs)	F	H
12' x 12'	VC1-386	5,674	274	30	74,250	5	585	15,810	10,300	23,860	445	49	8	600	19,350	2'-9 1/4"	12'-11 1/2"
	VC1-436	6,409	309	30	72,050			17,880	12,370	26,140	550	60			21,630	3'-6 1/2"	13'-8 3/4"
	VC1-467	6,865	331	40	79,300			18,070	12,370	26,330	550	60			21,820	3'-6 1/2"	13'-8 3/4"
	VC1-454	6,674	322	30	70,400			19,950	14,440	28,430	655	72			23,920	4'-3 3/4"	14'-6"
	VC1-487	7,159	345	40	77,500			20,140	14,440	28,620	655	72			24,110	4'-3 3/4"	14'-6"
	VC1-516	7,585	366	50	83,450			20,180	14,440	28,660	655	72			24,150	4'-3 3/4"	14'-6"
12' x 18'	VC1-540	7,938	383	(2) 15	97,250	5	835	22,850	15,170	35,090	665	72	10	710	28,530	2'-9 1/4"	12'-11 1/2"
	VC1-579	8,511	411	(2) 20	107,050			22,870	15,170	35,110	665	72			28,550	2'-9 1/4"	12'-11 1/2"
	VC1-612	8,996	434	(2) 25	115,300			22,970	15,170	35,210	665	72			28,650	2'-9 1/4"	12'-11 1/2"
	VC1-646	9,496	458	(2) 20	103,900			25,990	18,290	38,560	825	90			32,000	3'-6 1/2"	13'-8 3/4"
	VC1-683	10,040	484	(2) 25	111,950			26,090	18,290	38,660	825	90			32,100	3'-6 1/2"	13'-8 3/4"
	VC1-715	10,511	507	(2) 30	118,950			26,130	18,290	38,700	825	90			32,140	3'-6 1/2"	13'-8 3/4"
	VC1-748	10,996	530	(2) 30	116,200			29,240	21,400	42,140	990	108			35,580	4'-3 3/4"	14'-6"
	VC1-804	11,819	570	(2) 40	127,900			29,620	21,400	42,520	990	108			35,960	4'-3 3/4"	14'-6"
12' x 24'	VC1-772	11,348	548	(2) 30	148,500	(2) 5	1,170	31,560	⊙ 10,960	47,930	890	98	(2) 10	1,360	39,760	2'-9 1/4"	12'-11 1/2"
	VC1-872	12,818	618	(2) 30	144,100			35,700	12,370	52,490	1,100	121			44,320	3'-6 1/2"	13'-8 3/4"
	VC1-934	13,730	662	(2) 40	158,600			36,080	12,370	52,870	1,100	121			44,700	3'-6 1/2"	13'-8 3/4"
	VC1-908	13,348	644	(2) 30	140,800			39,840	14,440	57,070	1,310	144			48,900	4'-3 3/4"	14'-6"
	VC1-974	14,318	691	(2) 40	155,000			40,220	14,440	57,450	1,310	144			49,280	4'-3 3/4"	14'-6"
	VC1-1032	15,170	732	(2) 50	166,900			40,300	14,440	57,530	1,310	144			49,360	4'-3 3/4"	14'-6"
12' x 36'	VC1-1158	17,023	821	(4) 20	214,100	(2) 5	1,670	45,710	⊙ 15,340	70,450	1,330	146	(2) 12	2,090	57,180	2'-9 1/4"	12'-11 1/2"
	VC1-1224	17,993	868	(4) 25	230,600			45,910	⊙ 15,540	70,650	1,330	146			57,380	2'-9 1/4"	12'-11 1/2"
	VC1-1366	20,080	969	(4) 25	223,900			52,120	18,290	77,520	1,650	181			64,250	3'-6 1/2"	13'-8 3/4"
	VC1-1430	21,021	1014	(4) 30	237,900			52,200	18,290	77,600	1,650	181			64,330	3'-6 1/2"	13'-8 3/4"
	VC1-1496	21,991	1061	(4) 30	232,400			58,420	21,400	84,480	1,980	216			71,210	4'-3 3/4"	14'-6"
	VC1-1608	23,638	1140	(4) 40	255,800			59,180	21,400	85,240	1,980	216			71,970	4'-3 3/4"	14'-6"
7.4' x 12'	VC1-C216	3,175	153	15	40,060	3	385	10,270	6,680	14,880	265	29	6	360	12,780	2'-9 1/4"	11'-10 1/4"
	VC1-C231	3,396	164	20	44,090			10,280	6,680	14,890	265	29			12,790	2'-9 1/4"	11'-10 1/4"
	VC1-C242	3,557	172	15	38,870			11,560	7,970	16,300	330	36			14,200	3'-6 1/2"	12'-7 1/2"
	VC1-C260	3,822	184	20	42,790			11,570	7,970	16,310	330	36			14,210	3'-6 1/2"	12'-7 1/2"
	VC1-C274	4,028	194	25	46,090			11,620	7,970	16,360	330	36			14,260	3'-6 1/2"	12'-7 1/2"
	VC1-C286	4,204	203	30	48,980			11,640	7,970	16,380	330	36			14,280	3'-6 1/2"	12'-7 1/2"
	VC1-C299	4,395	212	30	47,830			12,920	9,250	17,720	390	43			15,620	4'-3 3/4"	13'-4 3/4"
	VC1-C320	4,704	227	40	52,650			13,110	9,250	17,910	390	43			15,710	4'-3 3/4"	13'-4 3/4"
7.4' x 18'	VC1-C339	4,983	241	25	62,180	5	580	15,050	9,830	22,040	395	43	8	520	18,790	2'-9 1/4"	11'-10 1/4"
	VC1-C354	5,204	251	30	66,080			15,070	9,830	22,060	395	43			18,810	2'-9 1/4"	11'-10 1/4"
	VC1-C380	5,586	269	40	72,730			15,260	9,830	22,250	395	43			19,000	2'-9 1/4"	11'-10 1/4"
	VC1-C396	5,821	281	30	64,180			17,050	11,810	24,240	490	54			20,990	3'-6 1/2"	12'-7 1/2"
	VC1-C424	6,233	301	40	70,640			17,240	11,810	24,430	490	54			21,180	3'-6 1/2"	12'-7 1/2"
	VC1-C445	6,542	316	40	69,020			19,240	13,810	26,630	590	64			23,380	4'-3 3/4"	13'-4 3/4"
	VC1-C469	6,894	333	50	74,340			19,280	13,810	26,670	590	64			23,420	4'-3 3/4"	13'-4 3/4"

NOTES:

1. Model number denotes nominal tons using R-22 at a 105°F condensing temperature, a 40°F suction temperature, and a 78°F entering wet-bulb temperature.
2. R-717 tons are at a 96.3°F condensing temperature, a 20°F suction temperature, and a 78°F entering wet-bulb temperature.
3. Fan horsepower is at 0" external static pressure.
4. Unless noted with ⊙, the coil section is the heaviest section.
5. Operating weight is for the unit with the water level at the overflow level and with the coil charged with R-717.
6. The R-22 operating charge is 1.93 times the R-717 charge; R-134a is 1.98 times.
7. Drain size is based on a bottom connection.
8. Coil inlet and outlet connections are 4" beveled for welding.
9. For VC1-386 through VC1-1608, the riser pipe diameter is 6". For VC1-C216 through VC1-C489, the riser pipe diameter is 4".

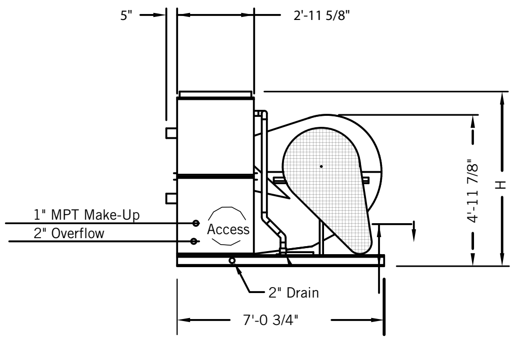
Do not use for construction. Refer to factory certified dimensions. This catalog includes data current at the time of publication, which should be reconfirmed at the time of purchase.

VCL Engineering Data

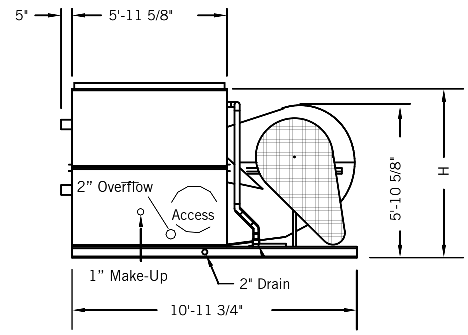


*2'-5 5/16" On VCL-016 - VCL-035
2'-5 3/16" On All Other Models

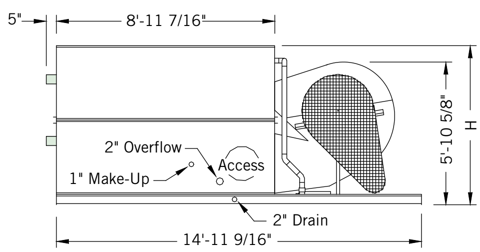
Face A:
VCL 4' x 3', 4' x 6', 4' x 9' and 4' x 12' Units



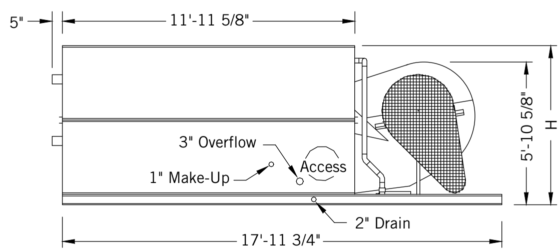
Face D:
VCL 4' x 3' Units



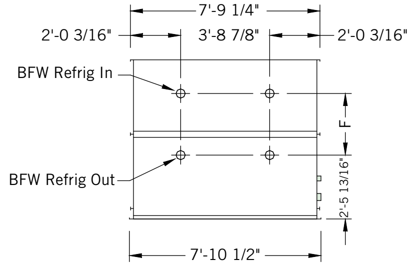
Face D:
VCL 4' x 6' Units



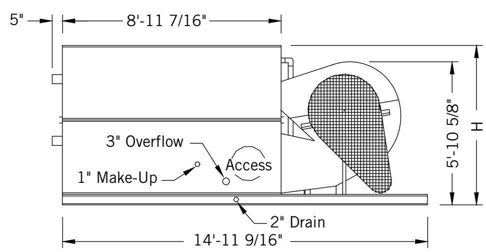
Face D:
VCL 4' x 9' Units



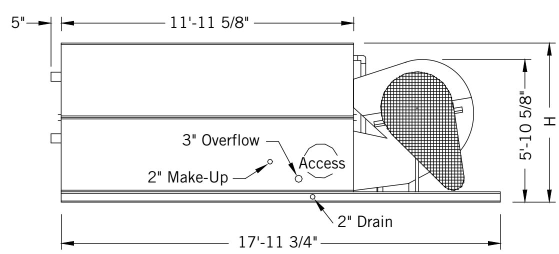
Face D:
VCL 4' x 12' Units



Face D:
VCL 8' x 9' and 8' x 12' Units



Face D:
VCL 8' x 9' Units



Face D:
VCL 8' x 12' Units

Nom. Box Size	Model Number[1]	Base Heat Rejection (MBH)	R-717 Tons[2]	Fan Motor (HP)[3]	Airflow Rate (CFM)	Pump Motor (HP)	Spray Flow Rate (GPM)	Approximate Weight (lbs)		R-717 Operating Charge[5] (lbs)	Internal Coil Volume (ft^3)	Remote Sump			F	H
								Ship Weight	Oper. Weight[4]			Drain Size[6] (in)	Volume Req. (gal)	Approx. Oper. Weight (lbs)		
4' x 3'	VCL-016	235	11	1	7,040	0.3	45	1,660	2,210	23	2.5	3	40	1,860	1'-2 1/4"	5'-2 1/4"
	VCL-019	279	13	2	8,310			1,690	2,240	23	2.5			1,890	1'-2 1/4"	5'-5"
	VCL-024	353	17	2	8,010			1,900	2,470	34	3.3			2,120	1'-10 3/4"	6'-3 3/4"
	VCL-029	426	21	2	7,660			2,120	2,700	44	4.3			2,350	2'-7 1/4"	6'-10"
	VCL-035	515	25	3	8,140			2,360	2,960	52	5.2			2,610	3'-3 3/4"	7'-6 1/2"
4' x 6'	VCL-038	559	27	3	12,800	0.5	94	2,400	3,530	44	4.4	4	95	2,980	1'-1 1/4"	5'-2 1/4"
	VCL-044	647	31	2	12,620			2,760	3,940	62	6.3			3,390	1'-9 3/4"	6'-1"
	VCL-048	706	34	3	14,250			2,790	3,970	62	6.3			3,420	3'-6 1/4"	6'-1"
	VCL-054	794	38	5	16,150			2,810	3,990	62	6.3			3,440	1'-9 3/4"	6'-3 3/4"
	VCL-058	853	41	3	13,570			3,180	4,370	83	8.2			3,820	2'-6 1/4"	6'-7 1/4"
	VCL-065	956	46	5	15,600			3,200	4,390	83	8.2			3,840	2'-6 1/4"	6'-7 1/4"
	VCL-073	1,073	52	5	15,150			3,610	4,820	101	10			4,270	3'-2 3/4"	7'-3 3/4"
	VCL-079	1,161	56	7.5	16,690			3,680	4,890	101	10			4,340	3'-2 3/4"	7'-6 1/2"
4' x 9'	VCL-087	1,279	62	5	19,280	1	142	4,380	6,130	122	12	4	200	5,840	2'-7 1/4"	6'-10 1/4"
	VCL-096	1,411	68	7.5	21,570			4,410	6,160	122	12			5,870	2'-7 1/4"	6'-10 1/4"
	VCL-102	1,499	72	10	23,730			4,440	6,190	122	12			5,900	2'-7 1/4"	6'-10 1/4"
	VCL-108	1,588	77	7.5	21,200			4,990	6,770	159	15			6,480	3'-6 1/4"	7'-8 9/16"
	VCL-115	1,691	82	10	22,970			5,020	6,800	159	15			6,510	3'-6 1/4"	7'-8 9/16"
	VCL-120	1,764	85	10	22,210			5,620	7,440	182	18			7,150	4'-3 3/4"	8'-4 3/4"
4' x 12'	VCL-134	1,970	95	10	25,130	1.5	192	6,160	8,590	203	20	6	250	7,990	3'-6 1/4"	7'-8 9/16"
	VCL-148	2,176	105	15	28,400			6,220	8,650	203	20			8,050	3'-6 1/4"	7'-8 9/16"
	VCL-155	2,279	110	15	28,000			6,950	9,450	242	24			8,850	4'-3 3/4"	8'-4 3/4"
8' x 9'	VCL-167	2,455	118	10	36,870	1.5	284	8,030	11,570	244	24	6	385	10,850	2'-7 1/4"	6'-10 1/4"
	VCL-185	2,720	131	15	41,560			8,090	11,630	244	24			10,910	2'-7 1/4"	6'-10 1/4"
	VCL-209	3,072	148	15	40,780			9,270	12,870	317	30			12,150	3'-6 1/4"	7'-8 9/16"
	VCL-223	3,278	158	20	44,290			9,280	12,880	317	30			12,160	3'-6 1/4"	7'-8 9/16"
	VCL-234	3,440	166	20	43,480			10,460	14,140	364	35			13,420	4'-3 3/4"	8'-4 3/4"
8' x 12'	VCL-257	3,778	182	20	47,860	2	384	11,080	16,000	406	40	8	405	14,260	3'-6 1/4"	7'-8 9/16"
	VCL-271	3,984	192	20	47,370			12,480	17,540	484	47			15,800	4'-3 3/4"	8'-4 3/4"
	VCL-286	4,204	203	25	50,670			12,520	17,580	484	47			15,840	4'-3 3/4"	8'-4 3/4"
	VCL-299	4,395	212	30	53,520			12,560	17,620	484	47			15,880	4'-3 3/4"	8'-4 3/4"

NOTES:

1. Model number denotes nominal tons using R-22 at a 105°F condensing temperature, a 40°F suction temperature, and a 78°F entering wet-bulb temperature.
2. R-717 tons are at a 96.3°F condensing temperature, a 20°F suction temperature, and a 78°F entering wet-bulb temperature.
3. Fan horsepower is at 0" external static pressure.
4. Operating weight is for the unit with the water level at the overflow level and with the coil charged with R-717.
5. The R-22 operating charge is 1.93 times the R-717 charge; R-134a is 1.98 times.
6. Drain size is based on a bottom connection.
7. Coil inlet and outlet connections are 4" beveled for welding.
8. For VCL-016 through VCL-155, the riser pipe diameter is 3". For VCL-167 through VCL-299, the riser pipe diameter is 4".

Do not use for construction. Refer to factory certified dimensions. This catalog includes data current at the time of publication, which should be reconfirmed at the time of purchase.

CXVT and CXVB Structural Support

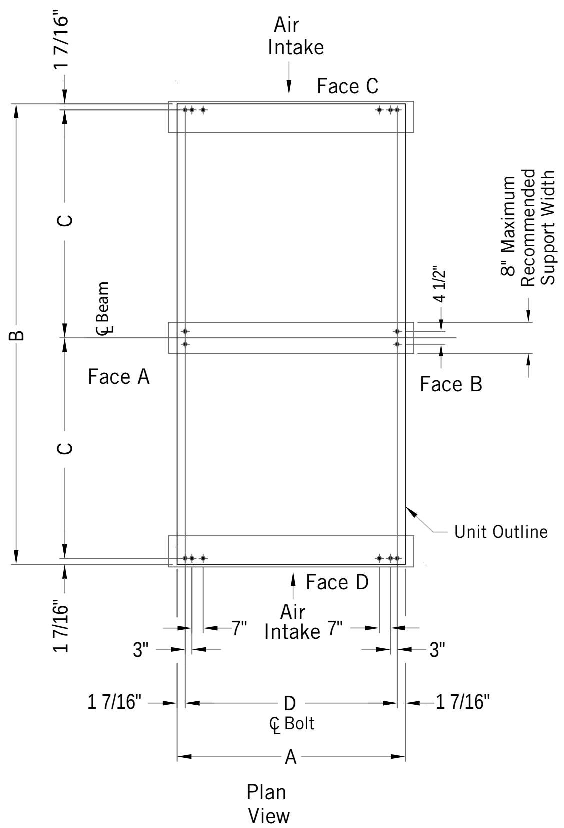
The recommended support arrangement for CXVT and CXVB Evaporative Condensers consists of parallel structural members positioned per the tables below. In addition to providing adequate support, the members also serve to raise the unit above any solid foundation to ensure access to the bottom of the unit. To support CXVT on columns or in an alternate arrangement not shown here, consult your local BAC Representative.

NOTES:

1. Support members and anchor bolts shall be designed, furnished, and installed by others.
2. Design of support members and anchor bolts shall be in accordance with the strength and serviceability requirements of the applicable building code and project specifications.
3. Support members shall be level at the top.
4. Refer to the certified unit support drawing for loading and additional support requirements.
5. If vibration isolation (provided by others) is used, the isolators should be located under a structural base that complies with one of the recommended support arrangements. Contact your local BAC Representative for all other isolator configurations.
6. CXVB 8.5' and 12' models can be cantilevered up to 2' on the side opposite the air inlet.

CXVT SINGLE CELL STANDARD ONLY

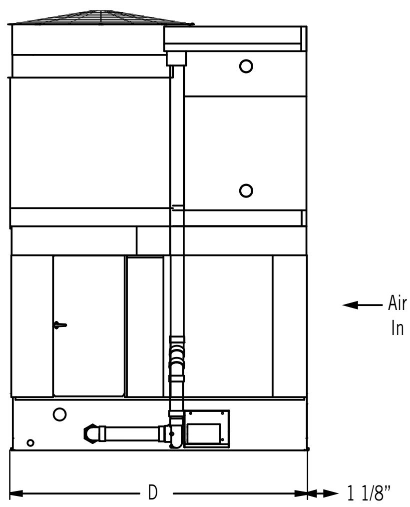
Model Number	A	B	C	D
CXVT-x-1224-x and XECXVTx-1224-x	11'-11"	24'-1/2"	11'-10 13/16"	11'-8 1/8"
CXVT-x-1426-x and XECXVTx-1426-x	13'-11 1/8"	26'-3 1/2"	13'-5/16"	13'-8 1/4"



CXVT

CXVB

Model Number	D
CXVB-x-0806	8'-3 1/2"
CXVB-x-0809	8'-3 1/2"
CXVB-x-0812	8'-3 1/2"
CXVB-x-0818	8'-3 1/2"
CXVB-x-1212	11'-7 3/4"
CXVB-x-1218	11'-7 3/4"
CXVB-x-1224	11'-7 3/4"
CXVB-x-1236	11'-7 3/4"



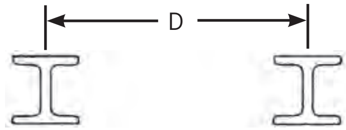
CXVB

Series V Models Structural Support

The recommended support arrangement for VCA, VC1, and VCL Evaporative Condensers consists of parallel structural members running the full length of the unit. In addition to providing adequate support, the members also serve to raise the unit above any solid foundation which might restrict air movement or prevent access to the unit. Refer to the BAC unit certified print for bolt hole location.

Center line distances between bolt holes are tabulated in the table below.

Model Number	D
VCA-122A thru 191A	4'-11 1/2"
VCA-174A thru 259A	6'-4 1/4"
VCA-261A thru 322A	7'-8"
VCA-323A thru 446A	7'-8"
VCA-300A thru 512A	9'-7 1/2"
VCA-460A thru 1558A	9'-7 1/2"
VCA-S700A thru S884A	9'-7 1/2"
VCA-302A thru 661A	11'-7 1/4"
VCA-526A thru 2019A	11'-7 1/4"
VCA-S870A thru S1204A	11'-7 1/4"
VC1-10 thru 25	3'-9 3/8"
VC1-30 thru 65	3'-9 3/8"
VC1-72 thru 90	3'-9 3/8"
VC1-100 thru 135	3'-9 3/8"
VC1-150 thru 205	4'-6 1/4"
VC1-N208 thru N315	7'-7 5/8"
VC1-N338 thru N470	7'-7 5/8"
VC1-386 thru 516	11'-7 1/4"
VC1-540 thru 804	11'-7 1/4"
VC1-772 thru 1032	11'-7 1/4"
VC1-1158 thru 1608	11'-7 1/4"
VC1-C216 thru C320	7'-1 5/8"
VC1-C339 thru C469	7'-1 5/8"
VCL-016 thru 035	3'-11"
VCL-038 thru 079	3'-11"
VCL-087 thru 120	3'-11"
VCL-134 thru 155	3'-11"
VCL-167 thru 234	7'-8 1/4"
VCL-257 thru 299	7'-8 1/4"



NOTES:

1. Support members and anchor bolts shall be designed, furnished, and installed by others.
2. Design of support members and anchor bolts shall be in accordance with the strength and serviceability requirements of the applicable building code and project specifications.
3. Support members shall be level at the top.
4. Refer to the certified unit support drawing for loading and additional support requirements.
5. Models VC1-386 through VC1-1608 can be supported with structural members on nominal 10' wide centers. In this case, the fan section will overhang the supports approximately 2'. Contact your local BAC Representative for exact dimensions.
6. The length of the support members shall be at least equal to the length of the basin. Refer to Engineering Data for basin dimensions.
7. If vibration isolation (provided by others) is used, the isolators should be located under a structural base that complies with one of the recommended support arrangements. Contact your local BAC Representative for all other isolator configurations.

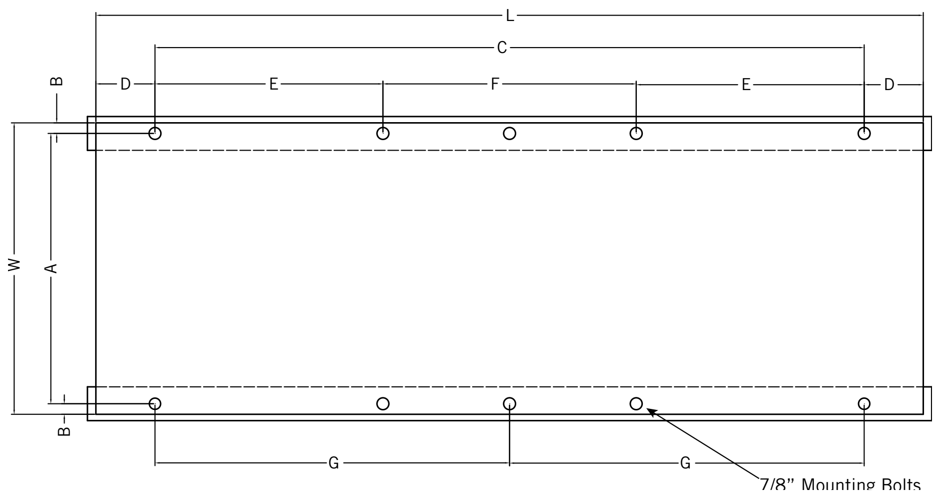
PCC Structural Support

The recommended support arrangement for the PCC Evaporative Condenser consists of parallel structural members positioned as shown on the drawing below. In addition to providing adequate support, the members also serve to raise the unit above any solid foundation to ensure access to the bottom of the unit. The PCC Evaporative Condenser may also be supported on columns at the anchor bolt locations shown.

To support a PCC Evaporative Condenser on columns with an alternate support arrangement, or the optional structurally upgraded unit, consult your local BAC Representative.

NOTES:

1. Contact your local BAC Representative for multi-cell or structurally upgraded unit support.
2. Support members and anchor bolts shall be designed, furnished, and installed by others.
3. Design of support members and anchor bolts shall be in accordance with the strength and serviceability requirements of the applicable building code and project specifications.
4. Support members shall be level at the top.
5. Refer to the certified unit support drawing for loading and additional support requirements.
6. The length of the support members shall be at least equal to the length of the basin. Refer to engineering data for basin dimensions. Support data are tabulated in the table to the right.
7. If vibration isolation (provided by others) is used, the isolators should be located under a structural base that complies with one of the recommended support arrangements. Contact your local BAC Representative for all other isolator configurations.



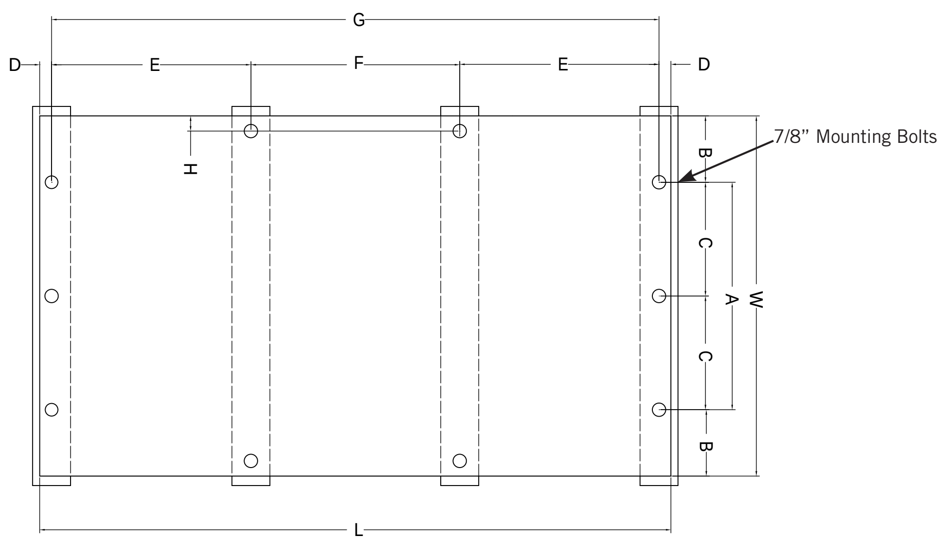
Single Cell Standard Unit Only

SINGLE CELL STANDARD UNIT ONLY

Model Number	L	W	A	B	C	D	E	F	G	Anchor Bolt Qty.
PCC-x-0406x	5'-11 3/4"	4'	3'-9 3/4"	1 1/8"	2'-5 1/4"	9 1/4"	—	—	—	4
PCC-x-0412x	11'-11 3/4"	4'	3'-9 3/4"	1 1/8"	10'-5 1/4"	9 1/4"	—	—	—	4
PCC-x-0709x	8'-11 3/4"	7'-3 1/4"	7'-1"	1 1/8"	8'-3 3/4"	4"	—	—	4'-1 7/8"	6
PCC-x-0718x	17'-11 3/4	7'-3 1/4"	7'-1"	1 1/8"	17'-3 3/4"	4"	5'-8 3/32"	5'-11 1/2"	—	8
PCC-x-1212x	11'-11 3/4"	11'-10"	11'-7 3/4"	1 1/8"	11'-3 3/4"	4"	—	—	5'-7 7/8"	6
PCC-x-1218x	17'-11 3/4	11'-10"	11'-7 3/4"	1 1/8"	17'-3 3/4"	4"	5'-8 3/32"	5'-11 1/2"	—	8
PCC-x-1220x	19'-11 3/4"	11'-10"	11'-7 3/4"	1 1/8"	19'-2 3/4"	6 1/2"	6'-7 3/8"	5'-11 1/2"	—	8

PCC Alternative Structural Support

For replacement installations, the PCC Evaporative Condenser has been designed to match the supports of many existing evaporative condensers without modifications. Shown below is the most common support arrangement which can be accommodated by the PCC. If individual point support is required, or if the existing support arrangement is not shown as below, consult your local BAC Representative for assistance.



Single Cell Standard Unit – Alternative Structural Support

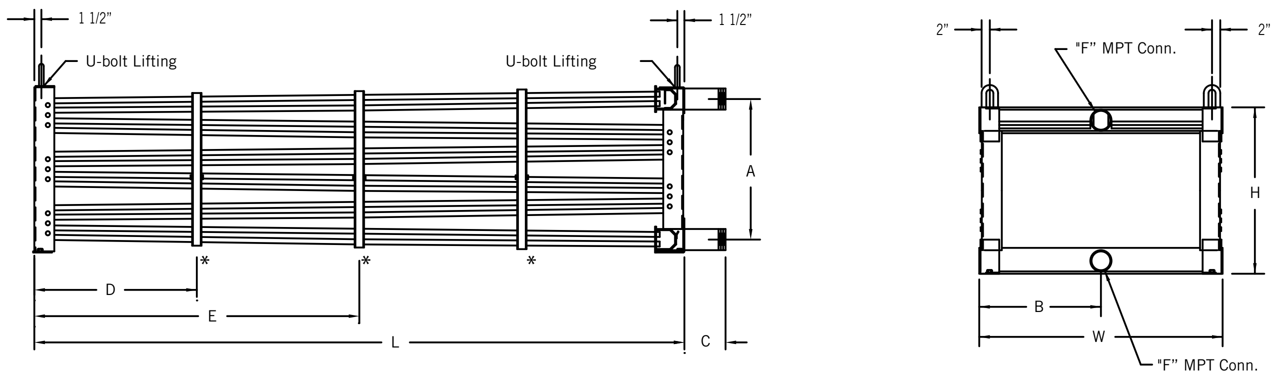
SINGLE CELL STANDARD UNIT – ALTERNATIVE STRUCTURAL SUPPORT

Model Number	L	W	A	B	C	D	E	F	G	H	Anchor Bolt Qty.
PCC-x-0406x	5'-11 3/4"	4'-0"	3'-4"	4"	3'-9 1/2"	1 1/8"	—	—	—	—	4
PCC-x-0412x	11' 11-3/4"	4'-0"	3'-4"	4"	11'-9 1/2"	1 1/8"	—	—	—	—	4
PCC-x-0709x	8'-11 3/4"	7'-3 1/4"	6'-7 1/4"	4"	—	1 1/8"	—	—	—	—	4
PCC-x-0718x	17'-11 3/4"	7'-3 1/4"	6'-7 1/4"	4"	—	1 1/8"	5'-11"	5'-11 1/2"	17'-9 1/2"	1 1/8"	8
PCC-x-1212x	11'-11 3/4"	11'-10"	11'-2"	4"	5'-7"	1 1/8"	—	—	—	—	6
PCC-x-1218x	17'-113/4"	11'-10"	11'-2"	4"	5'-7"	1 1/8"	5'-11"	5'-11 1/2"	17'-9 1/2"	1 1/8"	10
PCC-x-1220x	19'-11 3/4"	11'-10"	11'-2"	4"	5'-7"	1 1/8"	6'-11"	5'-11 1/2"	19'-9 1/2"	1 1/8"	10

NOTES:

1. Contact your local BAC Representative for multi-cell or structurally upgraded unit support.
2. Support members and anchor bolts shall be designed, furnished, and installed by others.
3. Design of support members and anchor bolts shall be in accordance with the strength and serviceability requirements of the applicable building code and project specifications.
4. Support members shall be level at the top.
5. Refer to the certified unit support drawing for loading and additional support requirements.
6. The length of the support members shall be at least equal to the length of the basin. Refer to engineering data for basin dimensions. Support data are tabulated in the table to the left.
7. If vibration isolation (provided by others) is used, the isolators should be located under a structural base that complies with one of the recommended support arrangements. Contact your local BAC Representative for all other isolator configurations.

Hydrocooling Coils



Model Number	Surface Area (ft^2)	Linear Feet	Shipping Weight (lbs)	A	B	C	D	E	F	H	L	W
HCC-091	145	527	614	2'-1 1/4"	1'-5"	8 3/4"	—	—	3"	2'-5 3/4"	2'-9"	2'-11 3/4"
HCC-092	197	716	777	2'-10 3/4"						3'-3 1/4"		
HCC-093	248	902	889	3'-8 1/4"						4'-3/4"		
HCC-181	309	1,124	992	2'-0 1/4"	1'-5"	8 3/4"	—	—	4"	2'-5 3/4"	5'-9"	2'-11 3/4"
HCC-182	414	1,505	1,302	2'-9 3/4"						3'-3 1/4"		
HCC-183	520	1,891	1,597	3'-7 1/4"						4'-0 3/4"		
HCC-271	470	1,709	1,490	2'-6"	1'-5"	8 3/4"	—	4'-4 1/2"	4"	2'-11 1/2"	8'-9"	2'-11 3/4"
HCC-272	630	2,291	1,877	3'-5 1/4"						3'-10 3/4"		
HCC-273	789	2,869	2,383	4'-4 1/2"						4'-10"		
HCC-361	634	2,305	1,851	2'-6"	1'-5"	8 3/4"	—	5'-10 1/2"	4"	2'-11 1/2"	11'-9"	2'-11 3/4"
HCC-362	847	3,080	2,476	3'-5 1/4"						3'-10 3/4"		
HCC-363	1,060	3,855	3,040	4'-4 1/2"						4'-10"		
HCC-501	923	3,356	2,770	2'-6"	2'-0 3/4"	8 3/4"	—	5'-10 1/2"	4"	2'-11 1/2"	11'-9"	4'-3 1/2"
HCC-502	1,230	4,473	3,603	3'-5 1/4"						3'-10 3/4"		
HCC-503	1,540	5,600	4,467	4'-4 1/2"						4'-10"		
HCC-751	683	2,482	2,221	2'-6"	2'-0 3/4"	8 3/4"	—	4'-4 1/2"	4"	2'-11 1/2"	8'-9"	4'-3 1/2"
HCC-752	915	3,328	2,833	3'-5 1/4"						3'-10 3/4"		
HCC-753	1,145	4,164	3,454	4'-4 1/2"						4'-10"		
HCC-1501	1,400	5,091	4,432	2'-6"	2'-0 3/4"	8 3/4"	4'-5 1/2"	8'-10 3/4"	4"	2'-11 1/2"	17'-9 1/2"	4'-3 1/2"
HCC-1502	1,875	6,818	5,511	3'-5 1/4"						3'-10 3/4"		
HCC-1503	2,345	8,527	6,769	4'-4 1/2"						4'-10"		

NOTE:

* Models HCC-271 through 1503, HCC-441 through 664, HCC-731 through 844, and HCC-431XV through HCC-664XV are supported at intermediate frames.

Do not use for construction. Refer to factory certified dimensions. This catalog includes data current at the time of publication, which should be reconfirmed at the time of purchase.

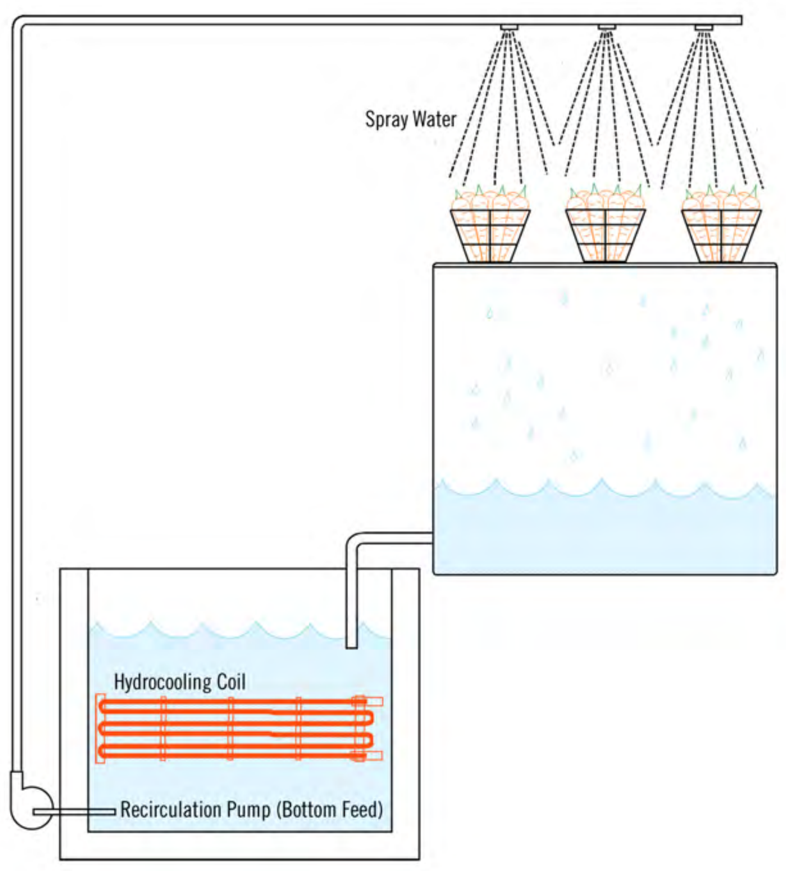
Model Number	Surface Area (ft²)	Linear Feet	Shipping Weight (lbs)	A	B	C	D	E	F	H	L	W
HCC-710	77	280	500	1'-2 1/4"	1'-5 7/8"	8 3/4"	—	—	3"	1'-6 3/4"	2'-9"	2'-11 3/4"
HCC-711	119	433	614	1'-10 3/4"						2'-3 1/4"		
HCC-712	161	585	777	2'-7 1/4"						2'-11 3/4"		
HCC-713	203	738	899	3'-3 3/4"						3'-8 1/4"		
HCC-720	167	607	810	1'-1 1/4"	1'-5 7/8"	8 3/4"	—	—	4"	1'-6 3/4"	5'-9"	2'-11 3/4"
HCC-721	253	920	992	1'-9 3/4"						2'-3 1/4"		
HCC-722	339	1,233	1,302	2'-6 1/4"						2'-11 3/4"		
HCC-723	425	1,545	1,697	3'-2 3/4"						3'-8 1/4"		
HCC-731	385	1,400	1,490	2'-0"	1'-5 7/8"	8 3/4"	—	4'-4 7/16"	4”	2'-5 1/2"	8'-8 7/8"	2'-11 3/4"
HCC-732	515	1,873	1,877	2'-9 1/4"						3'-2 3/4”		
HCC-733	646	2,349	2,383	3'-6 1/2"						4'-0"		
HCC-741	521	1,894	1,960	2'-0"	1'-5 7/8"	8 3/4"	—	5'-10 1/2"	4”	2'-5 1/2"	11'-9"	2'-11 3/4"
HCC-742	693	2,520	2,476	2'-9 1/4"						3'-2 3/4"		
HCC-743	867	3,153	3,040	3'-6 1/2"						4'-0"		
HCC-841	750	2,727	2,770	2'-0"	2'-1 1/2"	8 3/4"	—	5'-10 1/2"	4"	2'-5 1/2"	11'-9"	4'-3"
HCC-842	999	3,633	3,603	2'-9 1/4"						3'-2 3/4”		
HCC-843	1,251	4,549	4,467	3'-6 1/2"						4'-0"		
HCC-844	1,499	5,451	5,730	4'-3 3/4"						4'-9 1/4"		
HCC-441	651	2,367	2,075	2'-0"	1'-10"	8 3/4"	—	5'-10 1/2"	4"	2'-5 1/2"	11'-9"	3'-8"
HCC-442	871	3,167	2,624	2'-9 1/4"						3'-2 3/4”		
HCC-443	1,092	3,971	3,255	3'-6 1/2"						4'-0"		
HCC-444	1,312	4,771	3,886	4'-3 3/4"						4'-9 1/4"		
HCC-461	989	3,596	3,090	2'-0"	1'-10"	8 3/4"	5'-10 15/16"	—	4"	2'-5 1/2"	17'-9 3/8"	3'-8"
HCC-462	1,323	4,811	3,910	2'-9 1/4"						3'-2 3/4"		
HCC-463	1,655	6,018	4,901	3'-6 1/2"						4'-0"		
HCC-464	1,989	7,232	5,892	4'-3 3/4"						4'-9 1/4"		
HCC-641	996	3,622	3,110	2'-0"	2'-9 5/8"	8 3/4"	—	5'-10 1/2"	4"	2'-5 1/2"	11'-9"	5'-7 1/4"
HCC-642	1,333	4,847	3,935	2'-9 1/4"						3'-2 3/4"		
HCC-643	1,670	6,073	4,889	3'-6 1/2"						4'-0"		
HCC-644	2,006	7,294	5,843	4'-3 3/4"						4'-9 1/4"		
HCC-661	1,513	5,502	5,430	2'-0"	2'-9 5/8"	8 3/4"	5'-10 15/16"	—	4"	2'-5 1/2"	17'-9 3/8"	5'-7 1/4"
HCC-662	2,024	7,360	6,868	2'-9 1/4"						3'-2 3/4"”		
HCC-663	2,533	9,211	7,313	3'-6 1/2"						4'-0"		
HCC-664	3,042	11,061	8,764	4'-3 3/4"						4'-9 1/4"		

Model Number	Surface Area (ft²)	Linear Feet	Shipping Weight (lbs)	A	B	C	D	E	F	H	L	W
HCC-421XV	318	1,160	1,015	2'-0"	1'-6 7/8"	8 3/4"	—	—	4"	2'-5 1/2"	5'-6 1/4"	3'-1 3/4"
HCC-422XV	423	1,546	1,325	2'-9 1/4"						3'-2 3/4"		
HCC-423XV	529	1,932	1,655	3'-6 1/2"						4'-0"		
HCC-424XV	635	2,319	1,975	4'-3 3/4"						4'-9 1/4"		
HCC-431XV	491	1,789	1,510	2'-0"	1'-6 7/8”	8 3/4"	—	4'-3 1/8”	4"	2'-5 1/2"	8'-6 1/4"	3'-1 3/4"
HCC-432XV	654	2,386	1,990	2'-9 1/4"						3'-2 3/4"		
HCC-433XV	818	2,982	2,470	3'-6 1/2"						4'-0"		
HCC-434XV	981	3,579	2,950	4'-3 3/4"						4'-9 1/4"		
HCC-441XV	664	2,419	2,010	2'-0"	1'-6 7/8"	8 3/4"	—	5'-9"	4"	2'-5 1/2"	11'-6 1/4"	3'-1 3/4"
HCC-442XV	885	3,226	2,650	2'-9 1/4"						3'-2 3/4"		
HCC-443XB	1,106	4,032	3,290	3'-6 1/2"						4'-0"		
HCC-444XV	1,328	4,839	3,930	4'-3 3/4"						4'-9 1/4"		
HCC-641XV	1,062	3,871	3,225	2'-0"	2'-5 11/16"	8 3/4"	—	5'-9"	4"	2'-5 1/2"	11'-6 1/4"	4'-11 3/8"
HCC-642XV	1,416	5,161	4,240	2'-9 1/4"						3'-2 3/4"		
HCC-643XB	1,770	6,452	5,275	3'-6 1/2"						4'-0"		
HCC-644XV	2,124	7,742	6,290	4'-3 3/4"						4'-9 1/4"		
HCC-661XV	1,616	5,887	4,795	2'-0"	2'-5 11/16"	8 3/4"	5'-10"	11'-8"	4"	2'-5 1/2"	17'-6 1/4"	4'-11 3/8"
HCC-662XV	2,155	7,849	6,320	2'-9 1/4"						3'-2 3/4"		
HCC-663XV	2,694	9,812	7,880	3'-6 1/2"						4'-0"		
HCC-664XV	3,233	11,774	9,440	4'-3 3/4"						4'-9 1/4"		

PRODUCT SPOTLIGHT:

Hydrocooling Coils

Baltimore Aircoil's Hydrocooling Coils (HCCs) are refrigerant coils used to chill water typically used as part of a system in which chilled water absorbs heat from recently harvested produce (see figure below). In this application, near freezing water is sprayed over the produce immediately after harvest in order to maintain flavor and help prevent premature spoilage. The process water is circulated over the HCC and is cooled to a temperature of approximately 33°F (0.56°C). The chilled water is then pumped and sprayed over the produce and eventually returns to the sump where heat in the water is absorbed by the refrigerant in the coil.



BAC's HCCs coils provide superior operational and cleaning advantages. Dirt and other debris that is washed from the product can easily be removed as a result of the widely spaced tubes. Also, the coils can operate close to freezing temperatures since small amounts of ice will not damage the coil. However, caution should be taken to not allow a significant accumulation of ice to form so that it does not degrade thermal performance.

HCCs are all prime surface continuous steel tubing, with no intermediate butt welds, and the maximum allowable working pressure is 300 psig (2,068 kPa). The coil is encased in a steel framework and the entire assembly is hot-dip galvanized after fabrication. The coil is designed for low pressure drop and for free drainage of the liquid refrigerant. The basis of design for the hydrocooling coil is a bottom refrigerant feed system.For applications other than bottom feed systems, please contact your local BAC representative.

TrilliumSeries™ Condenser

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TrilliumSeries™ Condenser

The TrilliumSeries™ Condenser uses a patented Dry-Coil Adiabatic™ Design that saves energy, reduces refrigerant charge, and lowers operating costs. With the use of proprietary logic and EcoFlex controls, the On-Demand Adiabatic™ Pre-Cooler uses water only on the hottest days to maintain condensing temperatures that typical air cooled technology cannot achieve. **Because of this, the TrilliumSeries™ Condenser provides the lowest total cost of ownership solution for supermarket refrigeration systems.**

The TrilliumSeries Condenser

REDUCES SYSTEM ENERGY

- Up to 37% annual system energy reduction
- Up to 44% peak energy reduction
- Direct drive VSEC motor(s) minimize fan energy required

REDUCES WATER CONSUMPTION

- Water is used only when the ambient temperature requires it
- Water from the unit can be used for irrigation
- Water monitoring package minimizes water use (option)

REDUCES INSTALLATION COST

- 60% lower refrigerant charge with the microchannel coil may help meet EPA's Greenchill Certification
- Reduces overall system size by operating at lower condensing temperatures

NEEDS MINIMAL MAINTENANCE

- Takes same time as air cooled
- No water treatment required
- On-Demand Adiabatic™ Pre-Cooler Media can be replaced in ½ hour
- Easily spray off coated microchannel coils
- Self Clean Mode in control sequence

PROVIDES LONG TERM RELIABILITY

- UL Approved Unit
- Coated microchannel coils tested per ASTM G85-A4 for 3000+ hours
- Industrial grade Stainless Steel and an exclusive Thermosetting Hybrid Polymer coating on all structural panels provides long term reliability

The following chart compares the TrilliumSeries™ Condenser to air cooled and evaporative equipment for both new construction and replacement projects. The TrilliumSeries Condenser has an advantage in many categories versus air cooled equipment. For more detailed information on each topic, please go to the page listed.

Benefits of the TrilliumSeries Condenser		Page	New Construction		Replacement	
			TrilliumSeries™ Condenser	Air Cooled	TrilliumSeries™ Condenser	Air Cooled
Energy Savings	Reduces monthly energy bill	F4-F5	✓		✓	
	Reduces peak demand	F5	✓		✓	
	Qualifies for energy rebates	F6	✓	✓[1]	✓	✓[1]
	Built in energy tracking	F6	✓	✓	✓	✓
Water Savings	Reduces water use	F7	✓		✓	
	Water use monitoring	F7	✓		✓	
	Reduces monthly water bill	F7	✓		✓	
Installation Savings	Significantly reduces refrigerant charge	F8	✓ (microchannel)		✓ (microchannel)	
	Saves space	F4	✓		✓	
	Reduces weight	F4	✓		✓	
Other Benefits	Maintenance	F8	✓	✓	✓	✓
	Long term reliability	F8	✓	✓	✓	✓
	Shrinks size of the rack	F4	✓			
	Increases system capacity	F4			✓	
	California Title 24	F4	✓		✓	
	Transcritical CO_2 systems	F13-F15	✓	✓[2]	✓	✓[2]

NOTES:

1. Air cooled condensers with VSEC motors may qualify for energy rebates.
2. Air cooled gas coolers can be used for transcritical CO_2 applications in only certain climates (see **Page F13**).

The TrilliumSeries Condenser has the advantage!

Benefits

Ownership Benefits

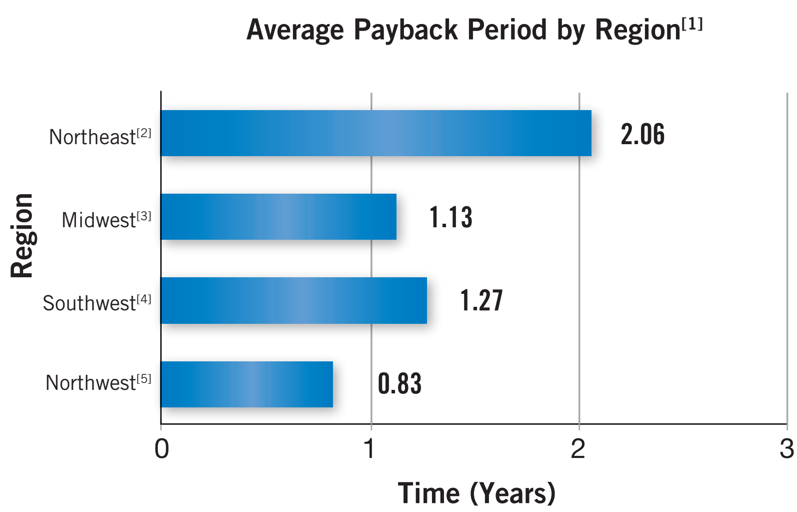
The TrilliumSeries™ Condenser provides the lowest total cost of ownership compared to air cooled units.

INSTALLATION ADVANTAGES

- 60% lower refrigerant charge with the microchannel coil may help meet EPA's Greenchill Certification
- Compact and lighter in weight
- Single point electrical connection
- Direct drive VSEC motors and Whisper Quiet Fans are standard
- For new stores, reduces overall system size by operating at lower condensing temperatures
- Exempt from Title 24 legislation
- For refrigeration upgrades, increases system capacity without changing out expensive racks

ECONOMIC ADVANTAGES

- Attractive payback time frames
- Lower total cost of ownership



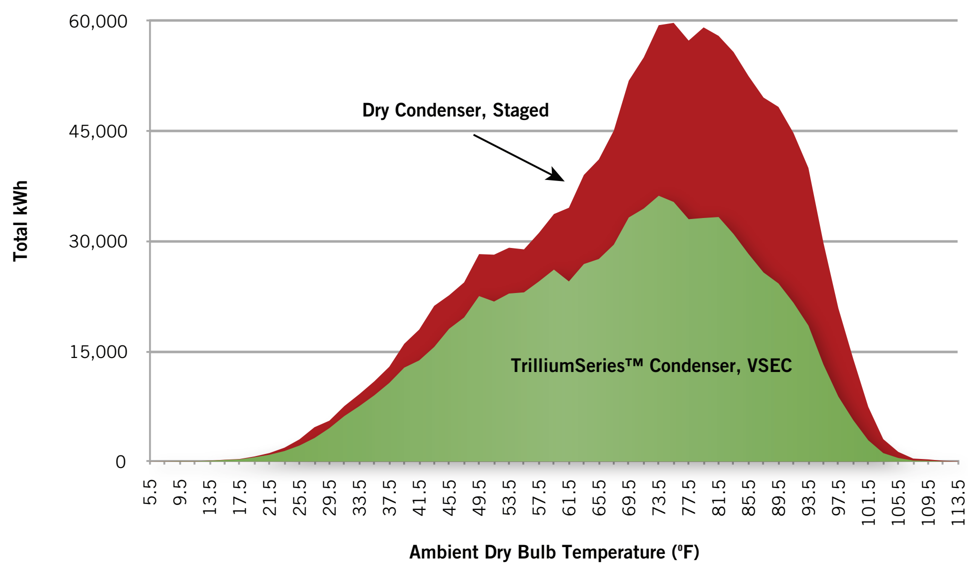
NOTES:

1. Average payback periods based on current analyses performed. Specific payback periods vary. Utility prices (electricity, water, etc) vary by state and system details vary by job.
2. Northeast region includes MA, MD, CT, DC, NJ, NY, PA, and RI.
3. Midwest region includes MN and MO.
4. Southwest region includes LA, TX, and Southern CA.
5. Northwest region includes Northern CA, OR, and UT.

System Energy Savings Reduce Monthly Energy Bills

- Reduced condensing temperatures
- Less compressor work
- Direct drive VSEC motors minimize fan energy required

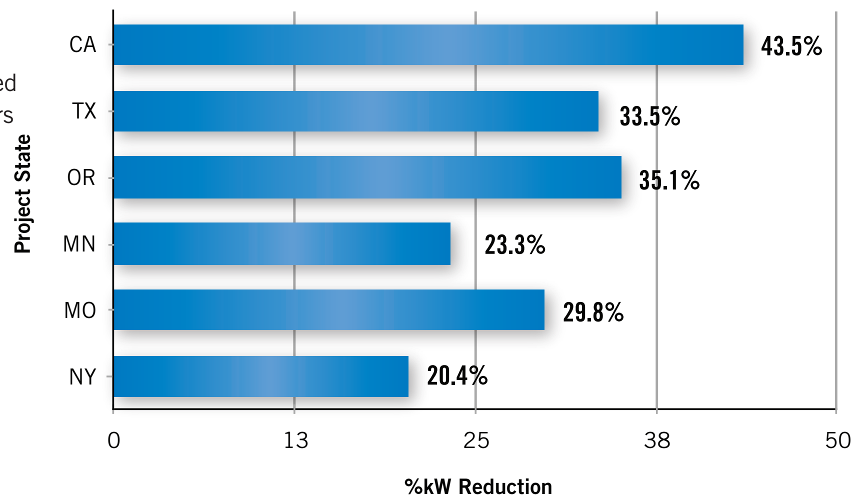
Annual 37% System Energy Reduction for El Paso, Texas



Peak Energy Savings

- Up to 44% peak energy reduction compared to air cooled units by operating compressors at significantly lower condensing temperatures
  - Peak energy is more expensive than off peak energy
  - Reduces peak demand charges
  - Potential for substantial state and local energy rebates

Average Peak Energy Reduction in %kW by State



Benefits

Rebates

Most states offer utility incentives and rebates which further decrease the initial investment of the TrilliumSeries™ Condenser.

Type of Rebate	Example based on www.dsireusa.org
Custom	Custom Measures and Retro-commissioning: $0.11/kWh saved up to 75% of incremental cost
Refrigeration	• Refrigeration Equipment: $35-$1000/unit • Air Conditioning and Refrigeration: $0.09 - $0.15/kWh saved
VFDs on Fan Motors or Other Controls	• Variable Frequency Drives: $80/HP • Refrigeration Controls: $75-$100/Controller

Dsireusa.org is a website with information on state, local, utility, and federal incentives and policies that promote renewable energy and energy efficiency. Established in 1995 and funded by the U.S. Department of Energy, DSIRE is an ongoing project of the N.C. Solar Center and the Interstate Renewable Energy Council.

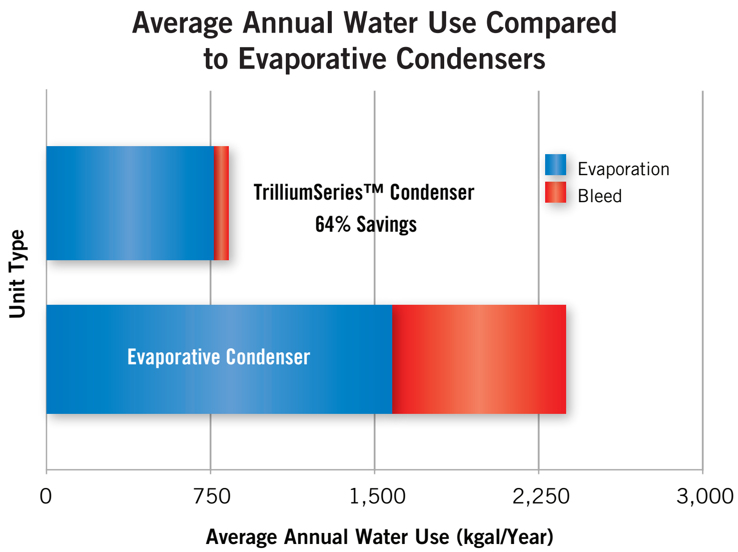
For custom rebates, an analysis of the overall system energy savings from air cooled to the TrilliumSeries Condenser may be necessary and is available from Baltimore Aircoil Company.

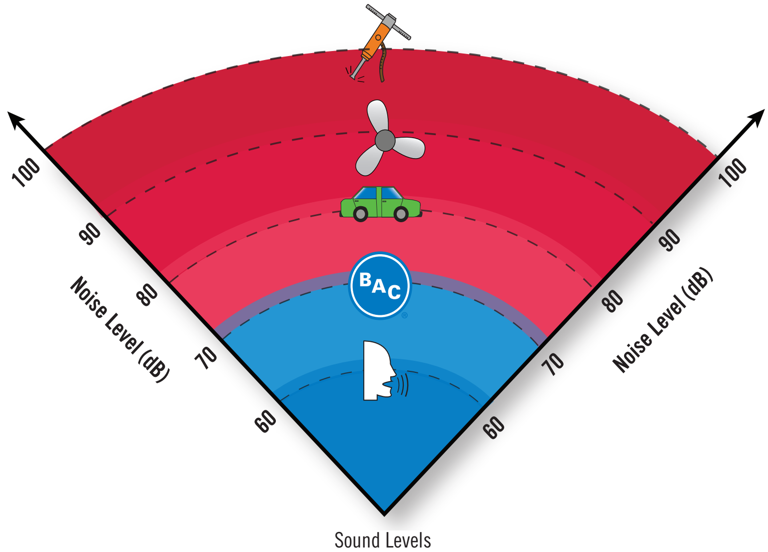
Optional Built-in Energy Tracking / Alarms

- Optional alarms for the fans, pumps and valves reduce high head pressure instances
- Optional energy monitoring maintains efficient operation over the life of the product

On-Demand Adiabatic™ Pre-Cooler

- Water is used ONLY when the ambient temperature requires it
  - Water spray saturates and cleans the On-Demand Adiabatic™ Pre-Cooler media of any dust and debris
- No water treatment is required
- Free draining prevents stagnant water
- LEED® Points available for Water Efficiency (WE) Credit Outdoor Water Use Reduction, and Credit Water Metering based on LEED 4 Rating System.
- **CONTROLS OPTIONS**
  - **WATER QUALITY SENSOR** (OPTION) – Flushes the sump based on a factory preset conductivity level to minimize water use.
  - **WATER MONITORING** (OPTION) – This option monitors the amount of purged water and maintains efficient operation over the life of the product.





Low Sound

- Whisper Quiet Fans are standard
- Direct drive VSEC fan motors vary the fan speed eliminating sudden starts and stops

Benefits

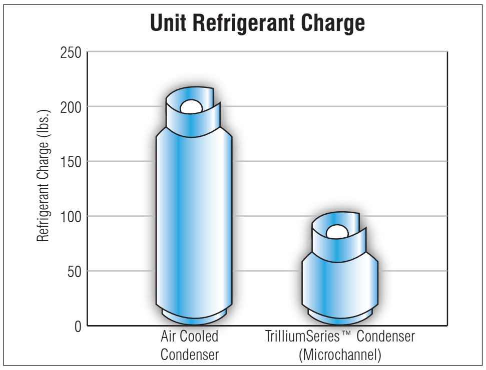
Easy Maintenance

- Requires the same time to maintain as an air cooled condenser
- Water treatment is not required
  - Water is turned on only when ambient temperature requires it
  - Water spray saturates and cleans the On-Demand Adiabatic™ Pre-Cooler media of any dust and debris
- On-Demand Adiabatic™ Pre-Cooler media acts as a filter to prevent debris from reaching the microchannel coil
  - Can be removed without tools for easy coil inspection
- Clean-out ports on both ends of water distribution header facilitate easy cleaning
- The EcoFlex Controls maintain a clean sump
- Pump and strainer are easily accessible from the access hatch

Easy Access to Pump and Strainer

Charge Reduction

- 60% less charge than comparable air cooled condensers with the microchannel
- Reduced charge may help meet EPA's Greenchill commitments
- Lowers greenhouse gas emissions of the supermarket refrigeration system



Charge Reduction

Peace of Mind

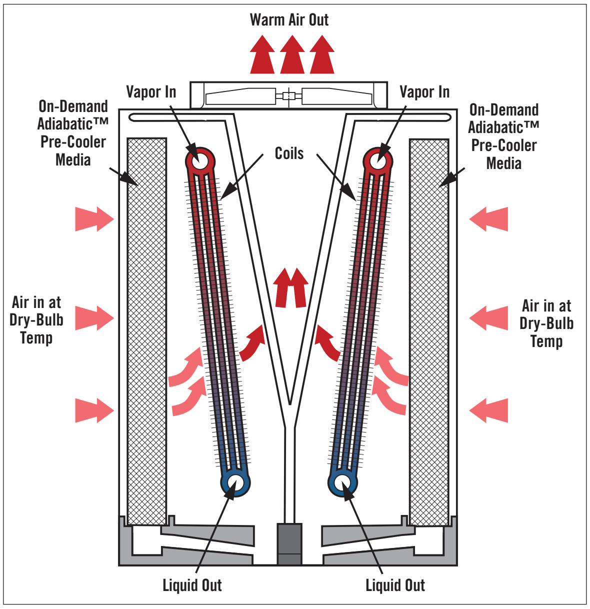
- All units are equipped with state of the art EcoFlex controls, On-Demand Adiabatic™ Pre-Cooler, and daily automatic sump clean out
- Critical components are stocked and ship within 24-hours
- Manual discrete spray system (water bypass) standard
- Durable materials of construction extend the life of the unit
- Sump and drain pans drain freely
- Ability to switch fans from automatic to manual fan override in case of control signal loss
- Access hatch sensor shuts off the fan when the hatch is opened
- UL Approved unit
- Coated microchannels independently tested per G85-A4 for 3,000+ hours

Discrete Spray System

Modes of Operation

Dry Mode

When the ambient air is below the set point, the unit runs as a dry cooler to save water and energy. The ambient air condenses the refrigerant in the microchannel coils which is then returned to the system.



Dry Mode Operation

NOTE: For transcritical CO_2 operation, the coil operates with vapor in and vapor out. For subcritical CO_2 operation, the coil operates with liquid in and liquid out.

On-Demand Adiabatic™ Pre-Cooler Mode

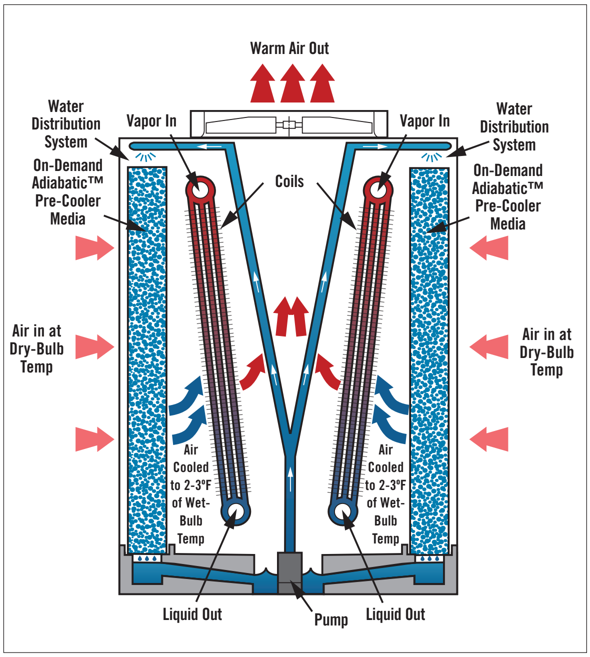
When the unit is in On-Demand Adiabatic™ Pre-Cooler mode, water is evenly sprayed over the highly efficient media. The air is humidified as it passes through the media, cooling temperatures down to 2-3ºF above wet-bulb temperature. Such substantial depression of the dry bulb temperature results in a major increase in dry cooling capacity.

The cooler air passes over the coil and condenses the refrigerant in the coil which is then returned to the system. In the sump there is an industrial duty pump that recirculates the water. Part of the distributed water is evaporated, while the excess water assists in rinsing the On-Demand Adiabatic™ Pre-Cooler media. The EcoFlex Controls determine when the water is purged from the sump.

ON-DEMAND ADIABATIC™ PRE-COOLER OPERATION MODES

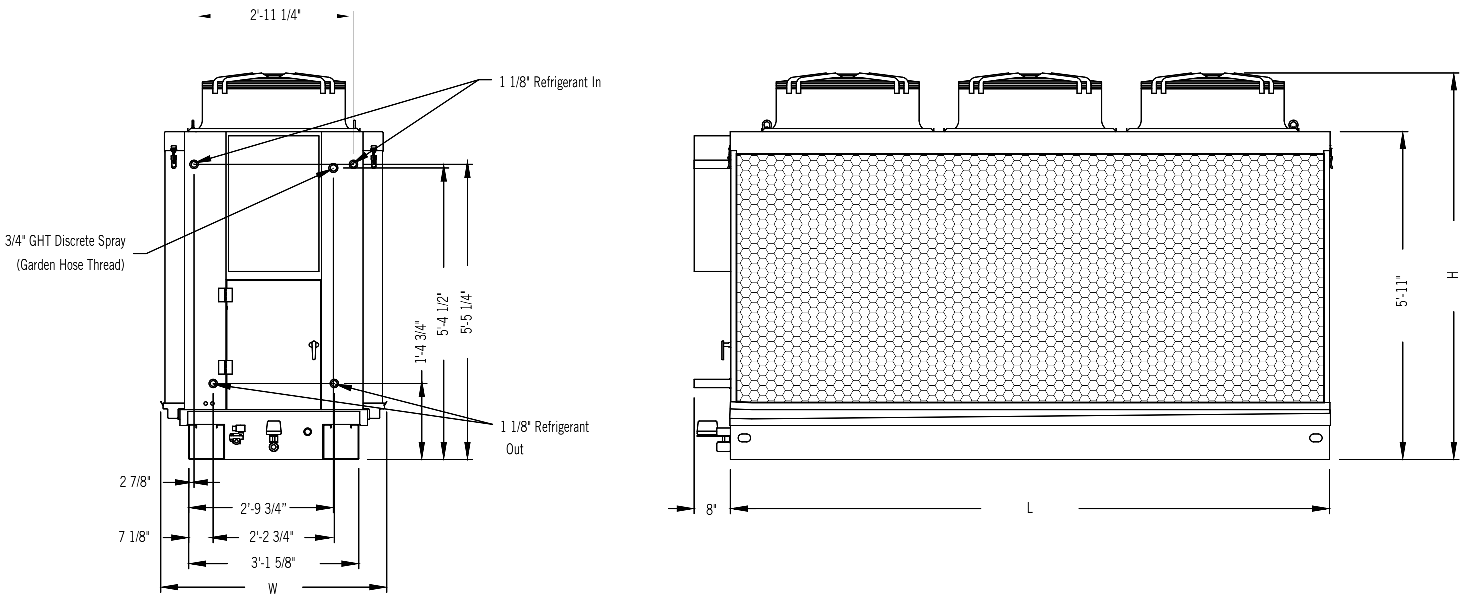
There are three different ways to optimize unit operation.

- **Standard Logic (Default):** The controller will start the Pre-Cooler Mode at a preset outside air temperature to increase the unit's capacity and efficiency.
- **Water Saver Logic:** The controller will optimize the unit's dry efficiency and only use water when the conditions require the extra cooling capacity. Pre-Cooler Mode will be initiated only when the outside air temperature is above the switch point and the fans are running at 90% or above for over 60 seconds. This mode will recheck conditions every two hours.
- **Energy Saver Logic:** The controller will optimize its sequence so that the least amount of energy is consumed to meet the present load of the unit. Pre-Cooler Mode will be initiated at 10 degrees below the switch point and if the fan speed is above 35%.



On-Demand Adiabatic™ Pre-Cooler Mode

Engineering Data



Model	Fan Qty	Base Heat Rejection (MBH)[1]	Base Tons	Motor HP	Pump HP	Airflow (CFM)	Total Unit FLA at 460V	Unit Length (L)	Unit Width (W)	Unit Height (H)	Shipping Weight (lbs)	Operating Weight (lbs)
TSDC-033-3	1	391	33	3.0	0.25	14,890	4.4	5'-11"	4'-2"	7'-0"	1,280	1,450
TSDC-059-6.2	2	702	59	6.2	0.25	28,000	8.7	8'-7"	4'-2"	7'-0"	1,740	1,950
TSDC-086-9.6	3	1,026	86	9.6	0.25	41,400	13.0	11'-9"	4'-2"	7'-0"	2,300	2,550
TSDC-116-12.4	4	1,405	117	12.4	0.25	56,000	16.8	16'-3"	4'-4"	7'-1/2"	3,200	3,550

NOTES:

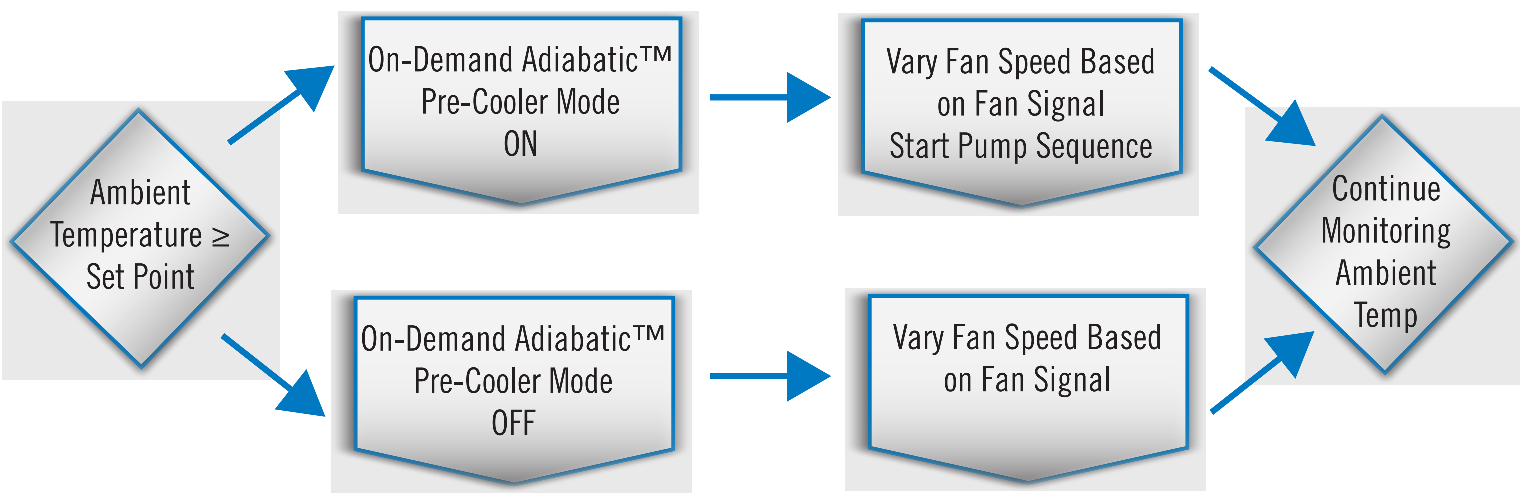
1. Base Heat Rejection (MBH) is based on R-134a 95°F dry-bulb/76°F wet-bulb and 105°F condensing temperature.
2. The water make-up connection is 3/4”. The water drain connection is 1 1/4”. The water overflow connection is 1 1/2”.

Do not use for construction. Refer to factory certified dimensions. This catalog includes data current at the time of publication, which should be reconfirmed at the time of purchase. Up-to-date engineering data, free product selection software, and more can be found at **www.BaltimoreAircoil.com.**

EcoFlex Controls

The TrilliumSeries™ Condenser is furnished standard with state of the art EcoFlex Controls that provide efficient year round performance. Each unit is shipped with custom controls logic that reduces energy consumption and optimizes water usage. The system is pre-programmed and ready to operate upon arrival from the factory.

Controls Logic

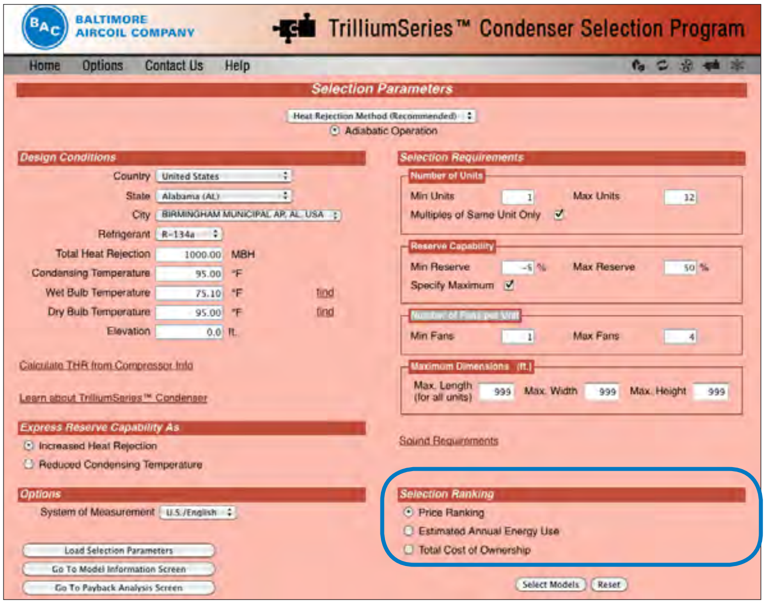


EcoFlex Controls Logic Features

- **ENERGY MONITORING** – Measures the energy use of the TrilliumSeries Condenser and verifies efficient operation over the life of the equipment.
- **WATER MONITORING** – Measures the water use and maintains efficient operation of the unit.
- **ALARMS** – Signals provided for fans, pumps, or valves to reduce instances of high system head pressure.
- **COMMUNICATIONS CARDS** – Allows for seamless integration over Modbus and BACnet to monitor all system components in a single location.
- **SELF CLEAN MODE** – Once every 24 hours, the EcoFlex Controls turn on the Self Clean Mode which reverses the fans and blows dirt/debris off the microchannel and the On-Demand Adiabatic™ Pre-Cooler media.
  - Further reduces maintenance of the unit
  - Maintains long term performance of the unit

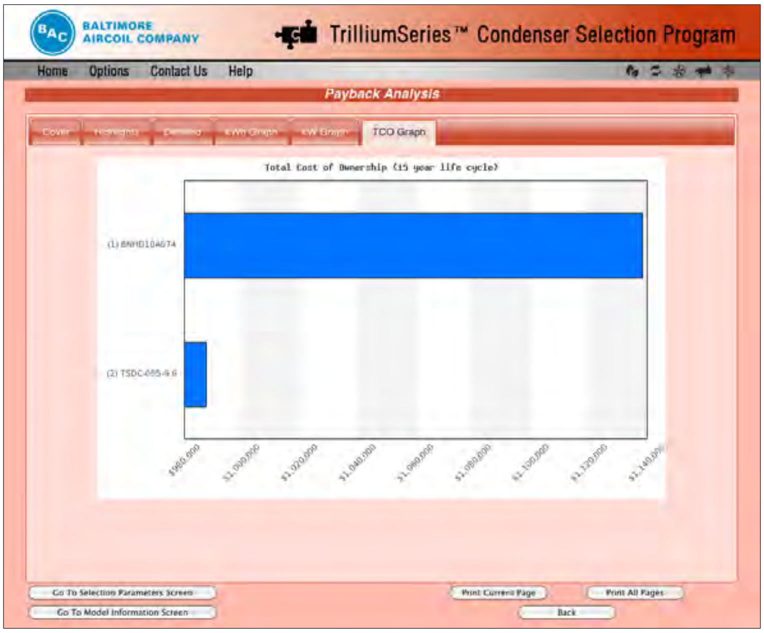
Selection and Payback Analysis Software

The TrilliumSeries™ Condenser program allows you to select the optimum unit based on ASHRAE design conditions and weather profile by bin data that are pre-populated by city and state.



Selection

You can select the product based on estimated annual energy use, total cost of ownership over 15 years of operation, or first cost.



Comparison

Example of total cost of ownership compared to an equally sized air cooled condenser with staged fans based on energy, water, refrigerant use, and other annual operating costs such as maintenance.

The total cost of ownership of the TrilliumSeries Condenser is substantially less than an air cooled condenser with staged fans.

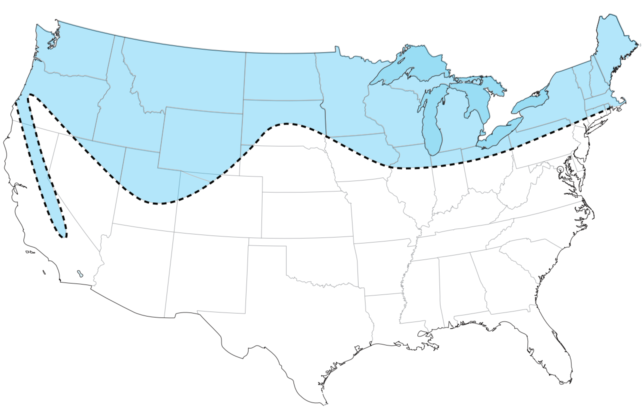
TrilliumSeries™ Condenser for Transcritical CO_2 Applications

The TrilliumSeries Condenser empowers transcritical CO_2 applications throughout the United States.

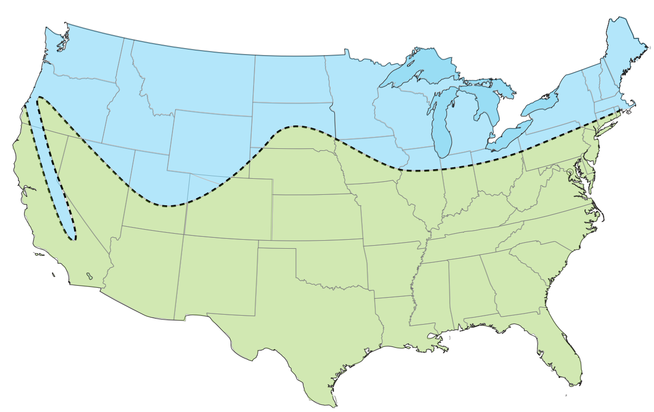
There are many benefits of CO_2 refrigeration systems including:

- **NO REGULATORY LIABILITY OR RESTRICTIONS**
- **NO EXPENSIVE FUTURE RETROFITS DUE TO REFRIGERANT PHASE OUT**
- **REDUCED SYSTEM CARBON FOOTPRINT WITH GLOBAL WARMING POTENTIAL OF “1” AND OZONE DEPLETING POTENTIAL OF “0”**
- **LOW INSTALLED COST DUE TO LOWER REFRIGERANT PRICES AND NO REFRIGERANT TAX**

With an estimated 2,885 European food retail stores using CO_2 transcritical refrigeration systems, their application is constantly expanding to other countries including Canada and the Northern part of the United States. Energy efficient, economical refrigeration systems are normally limited to colder climates due to the limitations of air cooled gas coolers.



Climate Limitation of CO_2 Systems with Air Cooled Condensers



TrilliumSeries Condenser Expands CO_2 Applications

However, by using the TrilliumSeries Condenser’s unique adiabatic design, it is possible to eliminate their restrictions due to warmer climates and save additional energy in cooler ones.

TrilliumSeries™ Condenser Transcritical CO_2 Benefits:

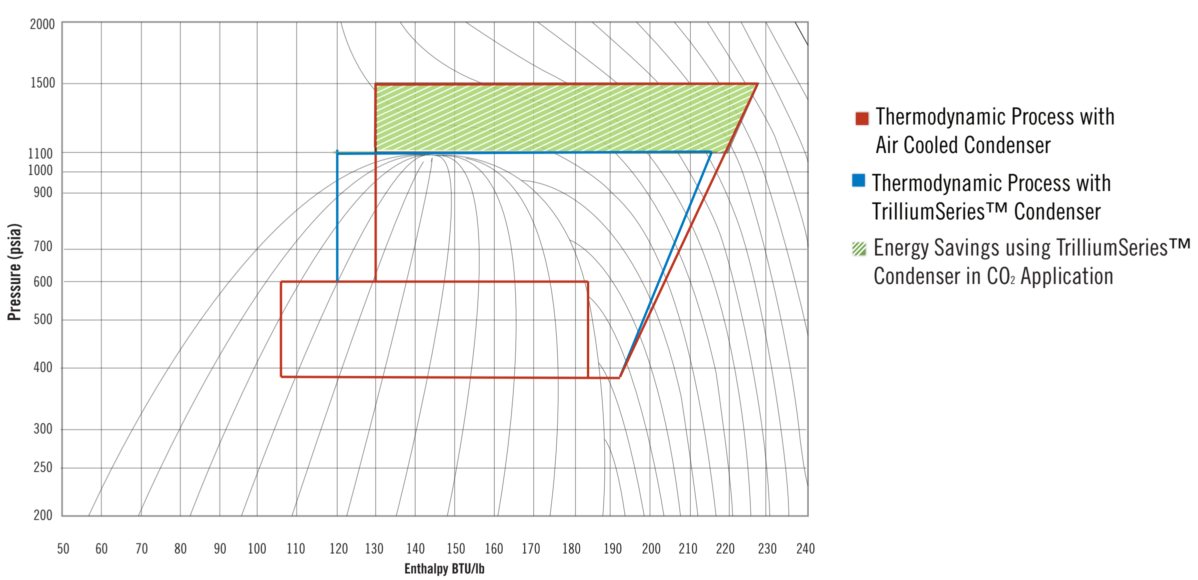
- LOWER TOTAL COST OF OWNERSHIP
- REDUCED COMPRESSOR WORK
- HIGH EFFICIENCY VSEC MOTORS
- NO WATER TREATMENT
- INTELLIGENT CONTROLS
- LOWER OPERATING PRESSURE

Example

The critical point of CO_2 is 87.8°F which means that the system is a condenser in subcritical mode when the high side is below 85°F and is a gas cooler in transcritical mode above 85°F.

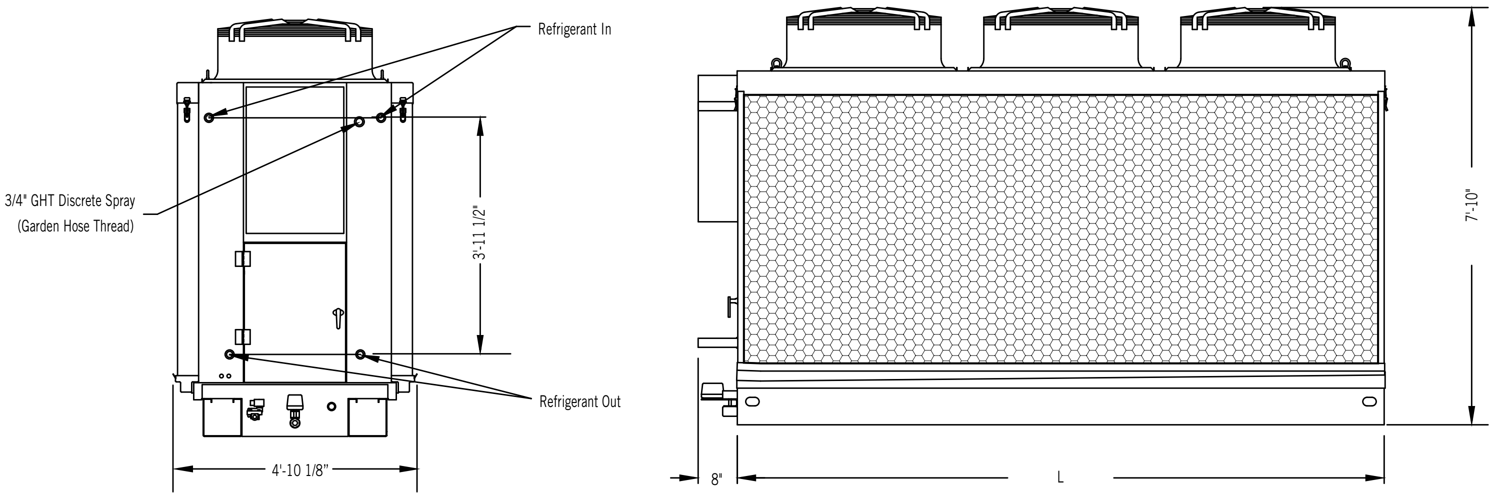
Condenser Type	Air Cooled	TrilliumSeries Condenser
Summer Conditions	95°F Dry Bulb	95°F Dry Bulb/75°F Wet Bulb
Air Temp to the Condenser	95°F	78°F to 80°F
Gas Temperature	230°F in, 105°F out	176°F in, 87°F out
Gas Pressure	1,500 psi	1,100 psi

The TrilliumSeries Condenser allows energy efficient operation of CO_2 transcritical systems throughout the U.S. by reducing the refrigerant temperature from 105°F to 87°F.



Using the TrilliumSeries Condenser drastically reduces your direct and indirect carbon emissions while making energy efficient designs possible in any climate!

Engineering Data for CO_2 Applications



Model	Fan Qty	Base Heat Rejection (MBH) [1]	Base Tons	Motor BHP	Airflow (CFM)	Pump HP	Unit FLA at 460V	Unit Length (L)	Shipping Weight (lbs)	Operating Weight (lbs)
TSDC-C02-044-3	1	530	44	3	15,200	0.25	4.4	5'-3"	1,650	1,840
TSDC-C02-077-6.2	2	828	77	6	28,800	0.25	8.2	7'-11"	2,300	2,530
TSDC-C02-112-9.6	3	1,344	112	9.6	42,600	0.25	13	11'-1"	2,970	3,250
TSDC-C02-152-12.4	4	1,828	152	12	57,500	0.25	16.2	15'-7"	3,940	4,290

NOTE:

1. Base Heat Rejection (MBH) is based on R-744 200°F CO_2 gas cooling with 90°F dry-bulb/76°F wet-bulb ambient.

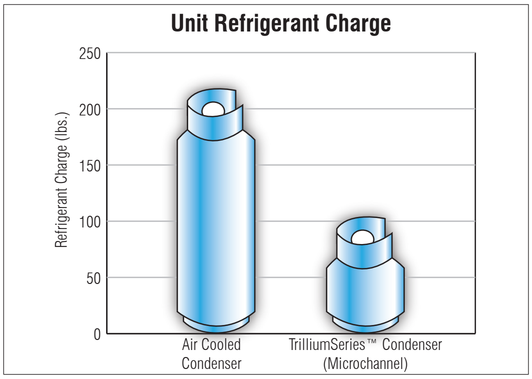
Do not use for construction. Refer to factory certified dimensions. This catalog includes data current at the time of publication, which should be reconfirmed at the time of purchase. Up-to-date engineering data, free product selection software, and more can be found at **www.BaltimoreAircoil.com.**

PRODUCT SPOTLIGHT:

Microchannel

At the core of BAC's TrilliumSeries™ Condenser is a robust industrial grade all aluminum, microchannel heat exchanger. The microchannel was chosen for its high heat transfer efficiency, low charge, and superior corrosion resistance.

Corrosion Resistant Microchannel Coil with Top Feed Design



60% Refrigerant Charge Reduction

Corrosion Resistance Testing

- Tested to ASTM G85-09 A4 standard
  - 3,000 hours of continuous salt spray and sulfur dioxide testing
  - Tested with pressurized coils to verify longevity
- 3,500 hours continuous hard water testing
- The coated all aluminum construction significantly reduces dissimilar metal galvanic corrosion common in copper aluminum coils
- Special alloys and brazing flux maximize corrosion resistance
- High quality epoxy coating doubles the coil's corrosion resistance

Technology Benefits

- 60% less refrigerant charge
- 40% higher thermal efficiency
- 30% smaller face area
- Unique top feed design with vertical tubes allows for gravity drainage of the condensed refrigerant that also eliminates the need for external manifolding

Industrial Design

- 450 psig maximum allowable working pressure
- Each coil proof tested and helium leak checked
- Thicker aluminum channel walls
- Each coil ships with standard holding charge
- Coils available with either copper or black steel connections for easy installation

Insist on an industrial coated aluminum microchannel and the TrilliumSeries™ Condenser
to increase your energy efficiency and reduce your total cost of ownership!

HXV Hybrid Cooling Tower

TABLE OF CONTENTS

The HXV, BAC's Closed Circuit Hybrid Cooling Tower offers a unique solution to some of the most challenging projects in the world. This product utilizes Combined Flow Technology with the addition of a finned dry coil to bring you the best of both evaporative and dry cooling in a single, energy efficient, and water conserving unit. This is achieved by optimizing combined dry/wet, adiabatic, and dry operating modes. The HXV delivers a comprehensive solution for a variety of applications where continuous operation is critical, water costs are high, water supply is limited, or plume is a concern.

BAC's HXV Provides an

Energy Efficient Water Saving Solution

Large Range of Capacities
160 to 305 Tons in a Single Cell
Up to 1,300 USGPM for Process Applications

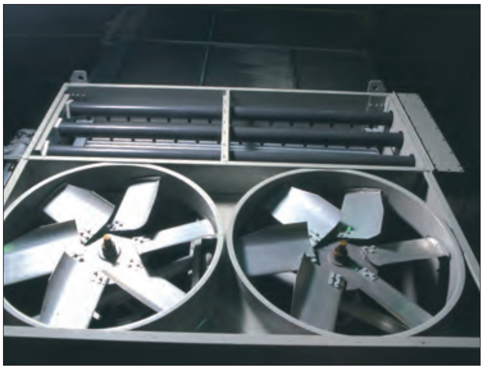
- Wet Adiabatic Dry Operation
- Water Saving Technology
- High Temperature Cooling
- Low Energy Consumption
- Easy Maintenance

Low Environmental Impact

HXV Benefits

Low Environmental Impact

- **ENERGY EFFICIENT**
  - Advanced Coil Technology reduces evaporation directly off the coil and minimizes the potential for scaling and fouling, maintaining long term capacity
  - Closed loop cooling process further reduces fouling, maintaining process efficiency
  - Premium efficient/inverter duty fan motors
  - Independent fan operation (optional)
  - BALTIGUARD™ Fan System provides redundancy and energy savings by providing a pony motor (optional)
- **SOUND REDUCTION OPTIONS**
  - Fan is high efficiency and low sound
  - For further reduced sound levels, sound attenuation is available
- **WATER SAVINGS MAXIMIZED IN ALL 3 MODES (SEE PAGE F22)**



Energy Efficient Low Sound Fan

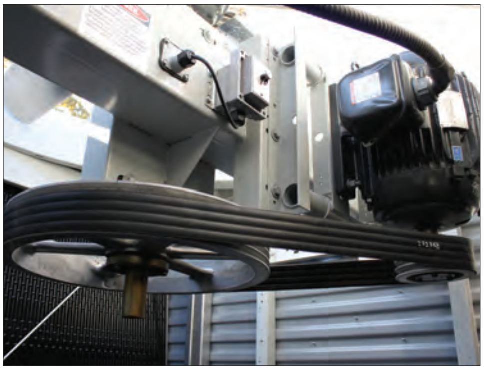
Durable Construction

- Enhanced longevity with a variety of durable materials of construction (see **page F26** for details)
- Panels are constructed of rugged G-235 mill galvanized steel
- Prime surface coil design is hot dip galvanized after fabrication (HDGAF)
- Electrostatic coating on dry finned coils prevent corrosion without impeding performance

Prime Surface Coil HDGAF

Reliable Year-Round Operation

- Dry mode of operation can be used in extremely cold climates where freezing is a concern
- BALTIDRIVE® Power Train Fan System
  - 10% minimum fan speed is required
- Combined inlet shields for easy visual inspection of the air-water interface



BALTIDRIVE® Power Train Fan System

Easy Maintenance

- Crossflow configuration provides direct access for easy maintenance to the cold water basin, spray distribution system, coil, and drive system
- Hinged access doors and internal walkway are standard providing easy access to the unit's cold water basin, drift eliminators, fan drive system, and heat transfer coil
- Drift eliminators are easily removed for access to the prime surface coil
- Spray distribution system is easy to inspect while the unit is operating

Spray Distribution For Easy Nozzle Inspection

Easy Installation

- Modular design allows units to ship in three sections to minimize size and weight of the heaviest lift
- Easily mounts on parallel I-Beams
- Units ship complete with motors and drives factory installed and aligned

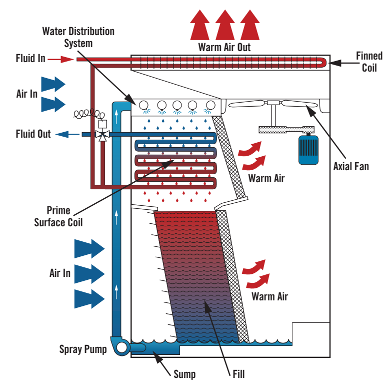
Modular Design

HXV Modes of Operation

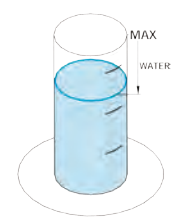
Modes of Operation

Combined Wet/Dry Mode

This mode employs the use of both coils, the dry finned coil and the prime surface coil. Water is sprayed over the prime surface coil, allowing evaporative cooling to occur, before falling over the fill, further cooling the spray water.



Combined Dry/Wet Operation Mode



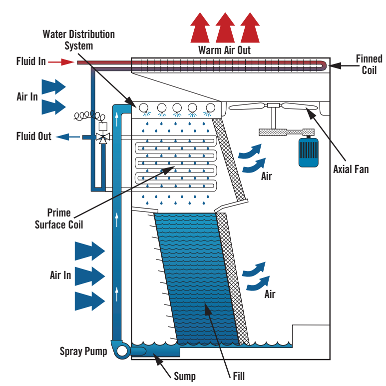
Water Consumption

BENEFITS

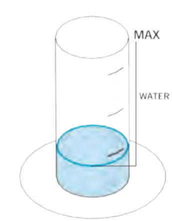
Provides the most capacity by employing the use of both coils. Water is saved in this mode as the finned, dry coil, reduces the amount of heat that needs to be rejected in the prime surface coil. Flow through the wet coil can also be controlled and adjusted as ambient temperature and/or heat load drops.

Adiabatic Mode

In this mode, the process fluid bypasses the prime surface coil, and instead only circulates through the dry finned coil. Recirculating water serves to saturate and adiabatically pre-cool the incoming ambient air, resulting in significantly lower air temperatures and greatly increasing the rate of sensible heat transfer.



Adiabatic Mode



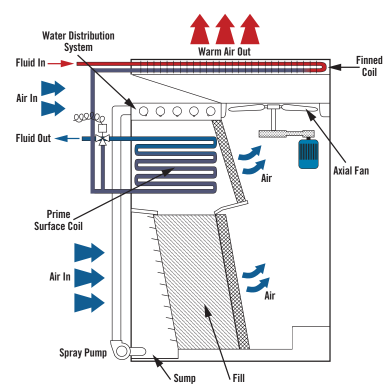
Water Consumption

BENEFITS

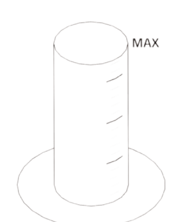
Provides a middle capacity range when outside temperatures will not allow for dry cooling.

Dry Mode

In this mode, the spray water is turned off, saving pump energy, and the fluid to be cooled is circulated through both the finned and prime surface coils. Both coils receive full flow, utilizing the maximum heat transfer surface area.



Dry Mode



Water Consumption

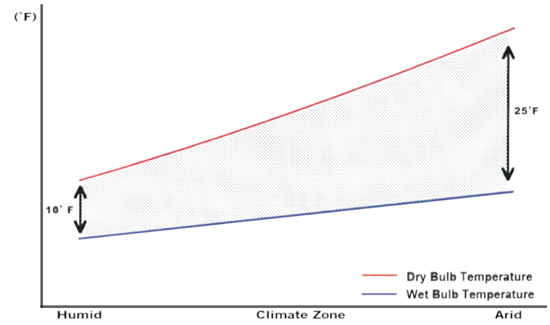
BENEFITS

No water consumption occurs in this mode and plume is completely eliminated. This is the best mode of operation during extremely cold weather.

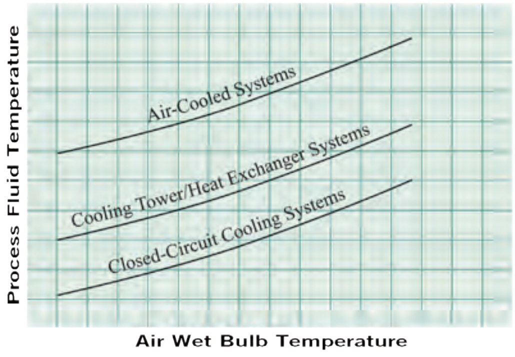
How Will the HXV Work for You?

HXV First Cost Benefits

Heat rejection equipment must be selected for the maximum heat load at summer peak air temperatures. In most climates peak wet-bulb temperatures are significantly lower than peak dry-bulb temperatures. Evaporative cooling equipment is selected on the ambient air wet-bulb therefore has a greater temperature driving force, allowing the use of lower system temperatures. This greater driving force also allows the use of less heat transfer surface area. Since the HXV utilizes evaporative cooling during peak load operation it inherently benefits from this advantage. Evaporatively cooled units have a plan area and fan horsepower advantage over the typical air-cooled arrangement, saving on support structures and electrical hook-ups. The HXV design also avoids the corrosion and scaling that can be associated with spraying of standard air-cooled equipment on design days for additional capacity. The lower process fluid temperatures that can be achieved compared to air-cooled systems and the greatly reduced fouling factors of closed loop cooling result in lower first cost of process equipment such as chillers or refrigeration compressors. Lastly, the costs associated with plume abatement are eliminated, as the design is inherently plume-free.



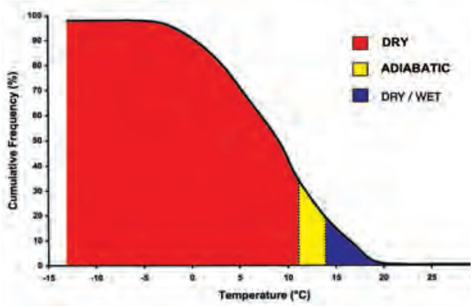
Dry-bulb/Wet-bulb Difference Versus Climate Zone



Closed Circuit Cooling Systems offer the Lowest Fluid Temperatures

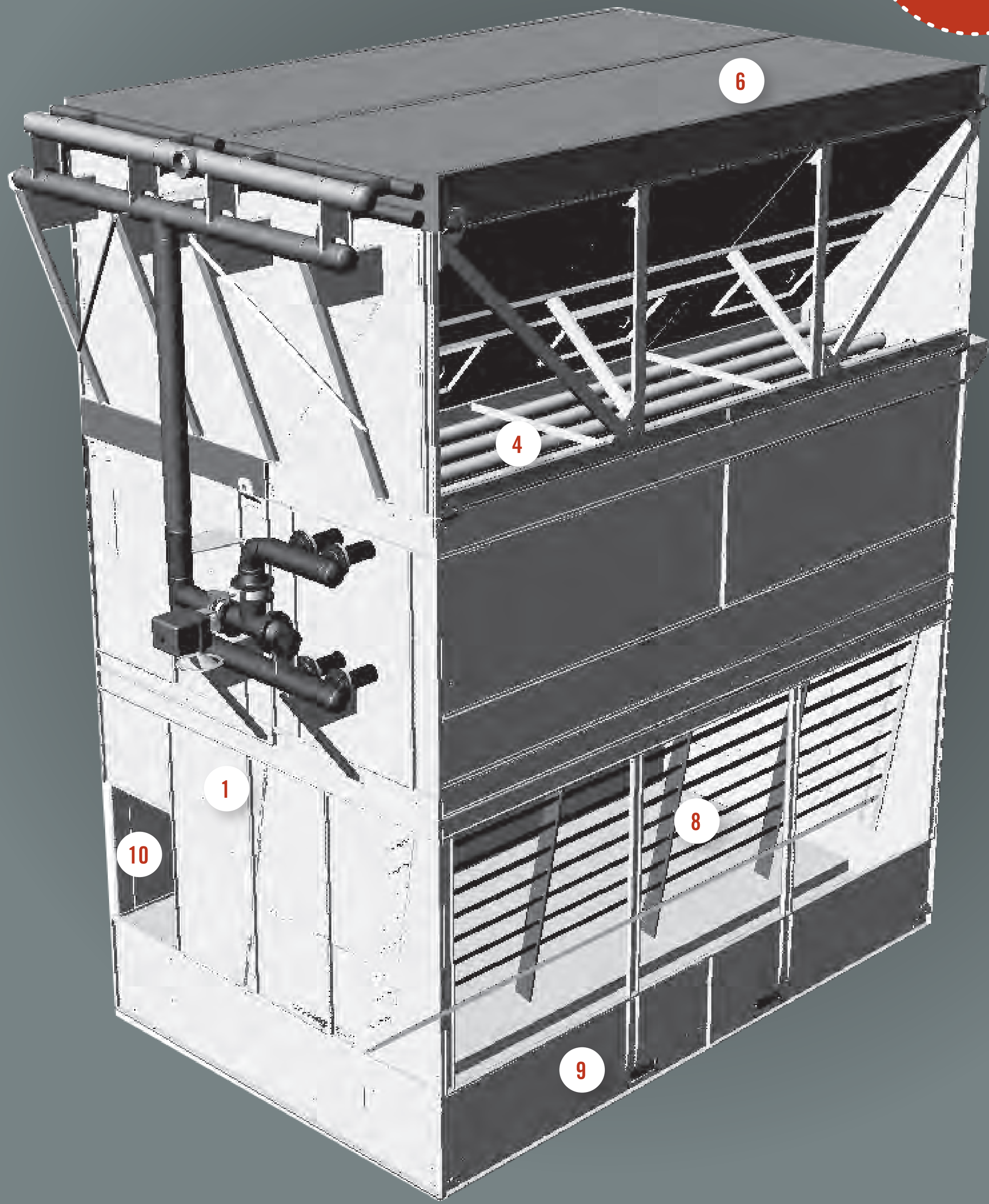
HXV Operating Cost Benefits

Due to its water saving concept and combined flow design, the HXV offers significant operating cost benefits. Water consumption is minimized throughout the year. During peak summer operation a large amount of heat load is already transferred by the finned coil. As the ambient temperature and/or heat load drops, the amount of evaporative heat transfer is further reduced by controlling the flow through the wet coil. This reduces the evaporation loss and blow-down as well as water treatment requirements compared to conventional evaporative cooling equipment. In the adiabatic mode a small amount of water is needed to saturate the air and the amount of blow-down is reduced even further. Finally in the dry mode no water is used at all (while saving the energy associated with running the spray pump). With HXV hybrid units, water savings up to 70% as compared to traditional closed circuit systems is possible. Depending on local water costs and availability, this advantage alone can pay for the equipment in as little as two years through cost savings in water use, water treatment chemicals, and higher system efficiencies. In addition, fouling potential associated with open circuit cooling towers is eliminated through both the closed loop cooling system and the Combined Flow Technology design of the HXV, assuring peak efficiency and energy savings over time. Finally, the induced draft propeller fan design results in low fan energy requirements compared to centrifugal fan units.



Typical Annual Distribution of Ambient Temperature with the Three Operating Modes

HXV
Construction Details



1 Heavy-Duty Construction

- Heavy-gauge G-235 (Z700 Metric) mill galvanized steel panels

2 BALTIDRIVE® Power Train (Not Shown)

- Premium efficient, cooling tower duty motors fit for VFD applications
- 5-year motor and drive warranty
- Corrosion resistant cast aluminum sheaves
- Heavy-duty bearings with a minimum L_{10} of 80,000 hours
- Premium quality, solid backed, multi-groove belt

3 Low HP Axial Fan (NOT SHOWN)

- Quiet operation
- High efficiency

4 Water Distribution System

- Overlapping spray patterns ensure proper water coverage
- BAC 360 Spray Nozzle, large non-clog nozzles
- Visible and accessible during operation

5 Prime Surface Coil (NOT SHOWN)

- Continuous serpentine, steel tubing
- Hot-dip galvanized after fabrication (HDGAF)
- Pneumatically tested at 375 psig
- Sloped tubes for free drainage of fluid
- Fabricated per ASME B31.5 standards
- When required, orders shipping to Canada are supplied with a CRN

6 Dry Finned Coil

- Copper tubing with high density aluminum fins coated with a proprietary protection system
- Pneumatically tested at 320 psig
- Sloped tubes for drainage of fluid

7 BACross® Fill with Integral Drift Eliminators

- High efficiency heat transfer surface
- Recyclable Polyvinyl chloride (PVC)
- Impervious to rot, decay, and biological attack
- Flame spread rating of 5 per ASTM E84
- Elevated off the cold water basin

8 FRP Air Intake Louvers

- Corrosion resistant
- UV-resistant finish
- Maintenance free

9 Recirculating Spray Pump

- Close coupled, bronze fitted centrifugal pump
- Totally enclosed fan cooled (TEFC) motor
- Bleed line with metering valve installed from pump discharge to overflow

10 Hinged Access Doors

- Inward swinging door on each end wall
- Opens to a standard internal walkway

HXV
Custom Features & Options

Materials of Construction

Determining the appropriate material of construction for a project depends on several factors, including water quality, climate and environmental conditions, availability of time and manpower for maintenance, unit lifetime requirements and budget. BAC provides the widest variety of material of construction options in the industry and has the ability to provide a solution to meet all conditions and budgets. Options such as thermosetting hybrid polymer and stainless steel provide superior corrosion resistance and durability at a tremendous value.

Customer Valued

STANDARD CONSTRUCTION

G-235 mill galvanized steel is the heaviest commercially available galvanized steel, universally recognized for its strength and corrosion resistance. To assure long-life, G-235 mill galvanized steel is used as the standard material of construction for all units. All exposed cut edges are protected with a thick zinc coating after fabrication to ensure the zinc rich corrosion barrier is maintained for all over protection. With proper maintenance and water treatment, G-235 galvanized steel products will provide an excellent service life under the operating conditions normally encountered in comfort cooling and industrial applications. Air intake louvers are constructed of UV-resistant, fiberglass reinforced polyester (FRP).

Standard Construction Installation

Customer Valued

THERMOSETTING HYBRID POLYMER (OPTION)

A thermosetting hybrid polymer coating, used to extend equipment life, is applied to select G-235 mill galvanized steel components of the unit. The polymerized coating is baked onto the galvanized steel and creates a barrier to the already corrosion resistant galvanized steel. The thermosetting hybrid polymer has been tested to withstand 6,000 hours in a 5% salt spray without blistering, chipping, or loss of adhesion.

Thermosetting Hybrid Polymer

STAINLESS STEEL (OPTION)

Several stainless steel material of construction options are available.

- **WELDED STAINLESS STEEL COLD WATER BASIN**
  A welded stainless steel cold water basin is available. All steel panels and structural members of the cold water basin are constructed from stainless steel. Seams between panels inside the cold water basin are welded, an advantage over bolted stainless steel cold water basins for minimizing susceptibility to leaks at basin seams. The basin is leak tested at the factory and welded seams are provided with a 5-year, leak-proof warranty.
- **ALL STAINLESS STEEL CONSTRUCTION**
  Steel panels and structural elements are constructed of stainless steel. Seams between panels inside the cold water basin are welded. The basin is leak tested at the factory and welded seams are provided with a 5-year leak-proof warranty.

Multi-Cell Installation

Fill

BACross® Fill, BAC's patented crossflow hanging fill, was developed after years of extensive research. BACross® Fill is made of PVC and is optimized to provide the most efficient thermal capacity. PVC is virtually impervious to rot, decay, and biological attack. The fill is elevated above the cold water basin floor to facilitate cleaning and maintenance. The air stream with minimum pressure drop to prevent water loss with negligible impact on efficiency.

BACross® Fill Manufacturing

STANDARD FILL

Standard fill can be used in applications with spray water temperatures up to 130°F (54.4°C). The fill and drift eliminators are formed from self-extinguishing PVC having a flame spread rating of 5 per ASTM E84.

HIGH TEMPERATURE FILL (OPTION)

An optional high temperature fill material is available which increases the maximum allowable spray water temperature to 140°F (60°C). The BAC selection program determines if a fill change is required by considering all of the design requirements. The spray water temperature should not be confused with the temperature of the process fluid contained in the coil, which can go up to 180°F (82.2°C).

HXV
Custom Features & Options

Coil Configurations

BAC offers a large selection of coil configuration options to fulfill any thermal and pressure drop requirements.

Customer Valued

STANDARD PRIME SURFACE COIL

The standard evaporative coil is constructed of continuous lengths of all prime surface steel. The coil is hot-dip galvanized after fabrication (HDGAF) to apply a thick zinc corrosion barrier over the entire exterior surface of the coil. The coil is designed for low pressure drop with sloping tubes for free drainage of fluid. Each coil is pneumatically tested at 375 psig (2,586 kPa) and is fabricated per ASME B31.5 standards to ensure the highest quality and integrity.

LOW PRESSURE DROP COIL DESIGNS

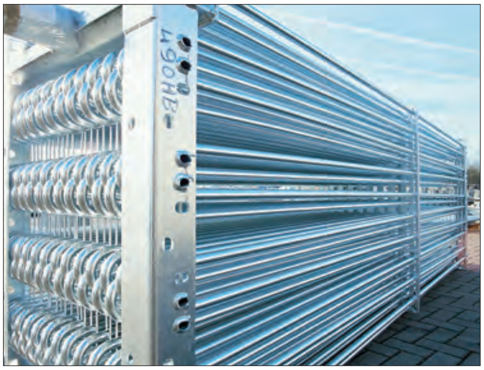
BAC's coils are designed and are available to meet all system pressure drop requirements. A higher pressure drop across the coil requires greater system pumping energy, and therefore increases operating costs. BAC's coil configurations drastically reduce pressure drop with minimal impact on thermal performance.

STAINLESS STEEL COIL (OPTION)

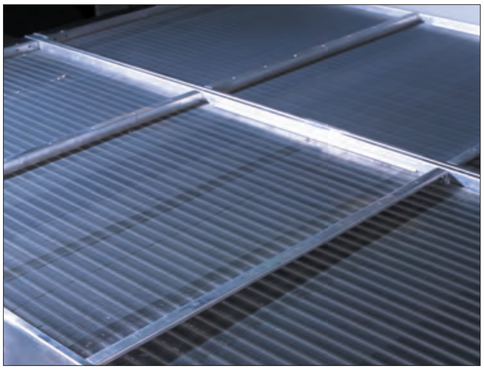
Coils are available in stainless steel for specialized applications. The coil is designed for low pressure drop with sloping tubes for free drainage of fluid. Each coil is pneumatically tested at 375 psig (2,586 kPa) and is fabricated per ASME B31.5 standards to ensure the highest quality and integrity.

MULTIPLE CIRCUIT COILS (OPTION)

Split coil configurations are available to allow separate process fluid (or refrigerant) loops through the same unit. Separate loops may be needed for multiple applications requiring different temperature processes or multiple types of process fluids.



Prime Surface Coil



Finned Coil

NOTE: A Canadian Registration Number (CRN) is required for all pressure vessels over 15 psi entering Canada. The CRN identifies that the design of a boiler, pressure vessel, or fitting has been accepted and registered for use in Canada. CRN is available for all BAC Dual coil configurations shipped in Canada.

Standard Dry Finned Coil

The standard finned coil is constructed of copper with aluminum fins and further protected with the a proprietary protection system. The proprietary protection system protects the fins and coils assuring long lasting nominal performance. A proprietary protection system inhibits debris accumulation and microbial corrosion on heat transfer surfaces. Consult your local BAC Representative for selection assistance.

Standard Dry Finned Coil

Water Distribution System

The HXV water distribution system is provided with BAC 360 Spray Nozzles. These nozzles are large orifice and non-clogging. The design of the HXV uses parallel air and water flow for inspection and access to the top of the coil during full operation.

STANDARD SPRAY WATER PUMP

The HXV comes standard with an integral spray water pump sized to distribute the recalculating water over the coil maximizing capacity. The patented BAC 360 Spray Nozzles are non-clog, ensure even flow over the coil area, and are simple to remove for maintenance. Parallel flow of air and spray water allow for inspection and access to the top of the coils during full operation.

Standard Spray Water Pump

HXV
Custom Features & Options

Access Options

BAC provides a broad offering of access options. Our evaporative equipment is designed to be the most easily maintained for sustaining capacity over a longer life. All BAC platforms and ladders are OSHA compliant to ensure personnel safety and code compliance.

Customer Valued

STANDARD INTERNAL WALKWAY

An internal walkway is standard, allowing access to the spacious plenum area for maintenance and inspections of the basin, make-up, fill, and drive system.

EXTERNAL PLATFORMS AND LADDER PACKAGES (OPTION)

Every external platform is preassembled and pre-fitted at the factory to ensure that every component will fit and function exactly as described. The platform will ship secured in the basin and attach quickly in the field with minimum fasteners. Platforms, ladders, and safety cages can be added at the time of order or as an aftermarket item. Safety gates are available for all handrail openings. All components are designed to meet OSHA requirements.

INTERNAL SERVICE PLATFORM AND LADDER PACKAGES (OPTION)

For access to the motor and drive assemblies, an internal ladder and upper service platform with handrails is available on larger units. Safety gates are available for all handrail openings, and all components are designed to meet OSHA requirements.

INTERNAL LADDER (OPTION)

For access to the motor and drive assemblies on single air intake models, a movable internal ladder is available.

External Platform and Ladder

Internal Walkway with Large Access Door

Sound Options

Recognition for the importance of sound reduction is growing and can be a very important design criterion for any project. BAC maintains the widest selection of sound mitigating options in the market place and can provide the most cost effective option to meet any requirement.

Customer Valued

STANDARD LOW SOUND FAN

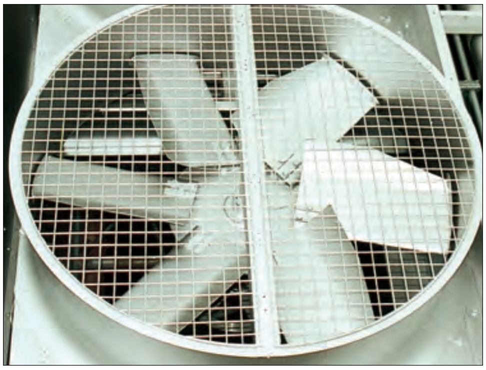
A low sound fan is standard to optimize low sound levels and maximize thermal performance.

SOUND ATTENUATION (OPTION)

Factory designed, tested and rated sound attenuation options are available for both the air intake and discharge. Consult your local representative regarding available options.

SINGLE-SIDE AIR INTAKE

Single-side air intake units can be placed close to solid walls, reducing the size of enclosures and allowing for more profitable use of premium space. Also, the panel opposite the air intake, called the blankoff panel, is inherently quiet. Positioning the blankoff panel towards the sound sensitive direction insulates sensitive areas from higher sound levels.



Standard Low Sound Fan

Sound Attenuation

Air Intake Options

In a hybrid closed circuit cooling tower, airborne debris can be entrained in the water through the unit's air intake. The HXV has several options for air intake accessories that prevent debris from entering the system and maintain even unobstructed flow through the unit. Reducing the amount of debris that enters the tower lowers maintenance requirements and helps to maintain thermal efficiency.

Customer Valued

COMBINED INLET SHIELDS (CIS)

The Combined Inlet Shields' (CIS) bent flow path blocks sunlight from the cold water basin and fill section and acts as a screen to prevent debris from entering the unit. These benefits result in a significant reduction in algae growth, debris accumulation, and scale build-up. CIS are constructed from corrosion and UV resistant PVC, are CTI certified, and are installed in easy to handle sections that are separate from the fill section to facilitate removal, inspection, and replacement. The use of CIS results in lower maintenance costs and ease of maintenance over the life of the unit.

HXV
Custom Features & Options

Cold Water Basin

The spray water collects in the cold water basin which is pumped back over the heat transfer coil. During operation, the HXV cold water basin eliminates any stagnant water zones, which are susceptible to biological growth.

Mechanical Water Level Control

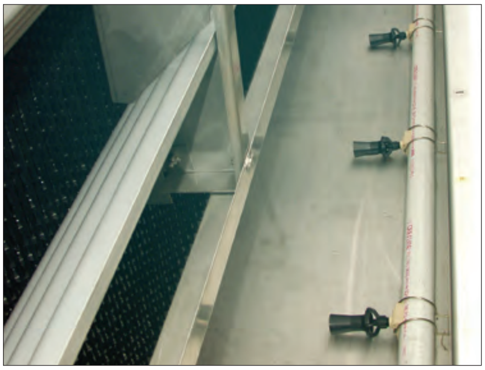
STANDARD MECHANICAL WATER LEVEL CONTROL

Mechanical make-up valves must operate continuously in the moist and turbulent environment existing within evaporative cooling equipment. Due to this environment, the operation of the valve must be simple, and the valve must be durable. BAC's high quality mechanical water level control assembly is standard with all units, and has been specially designed to provide the most reliable operation while being easy to maintain. This accessory is omitted for remote sump applications.

Electric Water Level Control

ELECTRIC WATER LEVEL CONTROL (OPTION)

BAC's Electric Water Level Control (EWLC) is a state-of-the-art conductivity actuated, probe type liquid level control. The hermetically sealed EWLC is engineered and manufactured specifically for use in evaporative cooling systems and is equipped with an error code LED which illuminates to indicate status, including when the water and/or probes are dirty. The EWLC option replaces the standard mechanical make-up valve, and includes a slow closing solenoid activated valve in the make-up water line to minimize water hammer. EWLC is recommended when more precise water level control is required and in areas that experience sub-freezing conditions.



Basin Sweeper Piping

BASIN SWEEPER PIPING (OPTION)

Basin sweeper piping is an effective method of reducing sediment that may collect in the cold water basin of the unit. A complete piping system, including nozzles, is provided in the cold water basin to connect to side stream filtration equipment (provided by others). For more information on filtration systems, consult the "Filtration Guide" found on **page J241**.

Customer Valued

BASIN HEATERS (OPTION)

Although most HXV units will operate dry in the winter, basin heaters are available for freeze protection when required. Basin heaters prevent freezing of the water in the cold water basin when the unit is idle. Factory-installed electric immersion heaters, which maintain 40°F (4.4°C) water temperature, are a simple and inexpensive way of providing such protection.

HEATER kW DATA

Model Number	0°F (-17.8°C) Ambient Heaters		-20°F (-28.9°C) Ambient Heaters	
	Number of Heaters	kW per Heater	Number of Heaters	kW per Heater
HXV-64X, Q64X	1	12	1	16
HXV-66X, Q66X	1	16	1	21

NOTE: This table is based on 460V/3 phase/60 Hz power.

Basin Heater

LOW AND HIGH LEVEL ALARMS (OPTION)

Low and high level alarm float switches are available to provide added control to your equipment operation. Level alarms can alert operators to an abnormal operating condition to ensure the highest system efficiency with minimal water usage.

HXV
Custom Features & Options

Drive System Options

The fan drive system provides the cooling air necessary to reject unwanted heat from the system to the atmosphere. All BAC drive systems use premium efficient cooling tower duty motors and include BAC's comprehensive 5-year motor and drive warranty. Cooling tower duty motors are specially designed for harsh environment inside a cooling tower and have permanently lubricated bearings, drastically decreasing the maintenance requirement of the motor. BAC belt drive systems are the most durable and maintenance friendly drive systems on the market, including single nut adjustment for belt tensioning to make belt tensioning simple.

Customer Valued

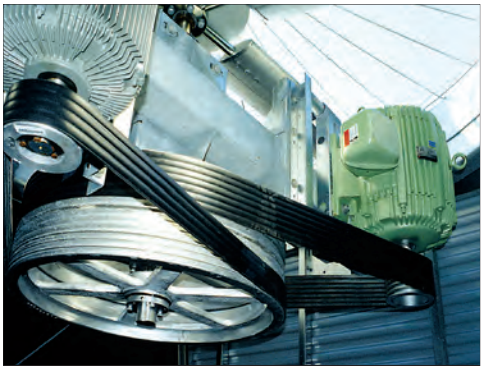
STANDARD BALTIDRIVE® POWER TRAIN

The BALTIDRIVE® Power Train utilizes special corrosion resistant materials of construction and state-of-the-art technology to ensure the ease of maintenance and reliable year-round performance. This BAC engineered drive system consists of a specially designed powerband and two cast aluminum sheaves located at minimal shaft centerline distances to maximize belt life. As compared to a gear drive system, this specially engineered belt drive system provides many advantages. The BALTIDRIVE® Power Train requires only periodic inspection of components and belt tensioning, which is simple with a single nut adjustment, and requires less down time. Only fan lubrication is required for routine maintenance. Belt drive systems also have the added advantage of being suitable for variable frequency drive (VFD) applications without requiring expensive optional accessories.

BALTDRIVE® Power Train

BALTIGUARD™ FAN SYSTEM (OPTION)

The BALTIGUARD™ Fan System consists of two standard single-speed fan motor and drive assemblies. One drive assembly is sized for full speed and load, and the other is sized approximately 2/3 speed and consumes only 1/3 the design horsepower. This configuration allows the reserve capacity of a standby motor in the event of failure. As a minimum, approximately 70% capacity will be available from the low horsepower motor, even on a design wet-bulb day. Controls and wiring are the same as those required for a two-speed, two-winding motor. Redundant motors are available by increasing the size of the standby fan motor of the BALTIGUARD™ Fan System to the size of the main motor. This provides 100% motor redundancy and the greatest level of reliability.



BALTIGUARD™ Fan System

BALTIGUARD PLUS™ FAN SYSTEM (OPTION)

The BALTIGUARD PLUS™ Fan System builds on the advantages of the BALTIGUARD™ Fan System by adding a variable frequency drive (VFD) to either the pony or the main motor, depending on system requirements. This offers the benefits of additional capacity control and energy savings, along with the redundancy offered by the BALTIGUARD™ Fan System. Alternatively, a VFD can be added to BOTH the pony and main motor, for complete capacity control and redundancy under any load.

BALTIGUARD PLUS™ Fan System Used for VFD Applications

INDEPENDENT FAN OPERATION (OPTION)

Models HXV-64X and Q64X are provided with one fan motor driving two fans as standard. Models HXV-66X and Q66X are provided with two fan motors driving three fans as standard. The independent fan option consists of one fan motor and drive assembly for each fan to allow independent operation, adding an additional step of fan cycling and capacity control. This option ensures complete redundancy for the fan and motor system.

VIBRATION CUTOUT SWITCH (OPTION)

A factory mounted vibration cutout switch is available to effectively protect against rotating equipment failure. BAC can provide either a mechanical or solid-state electronic vibration cutout switch in a NEMA 4 enclosure to ensure reliable protection. Additional contacts can be provided on either switch type to activate an alarm. Remote reset capability is also available on either switch type.

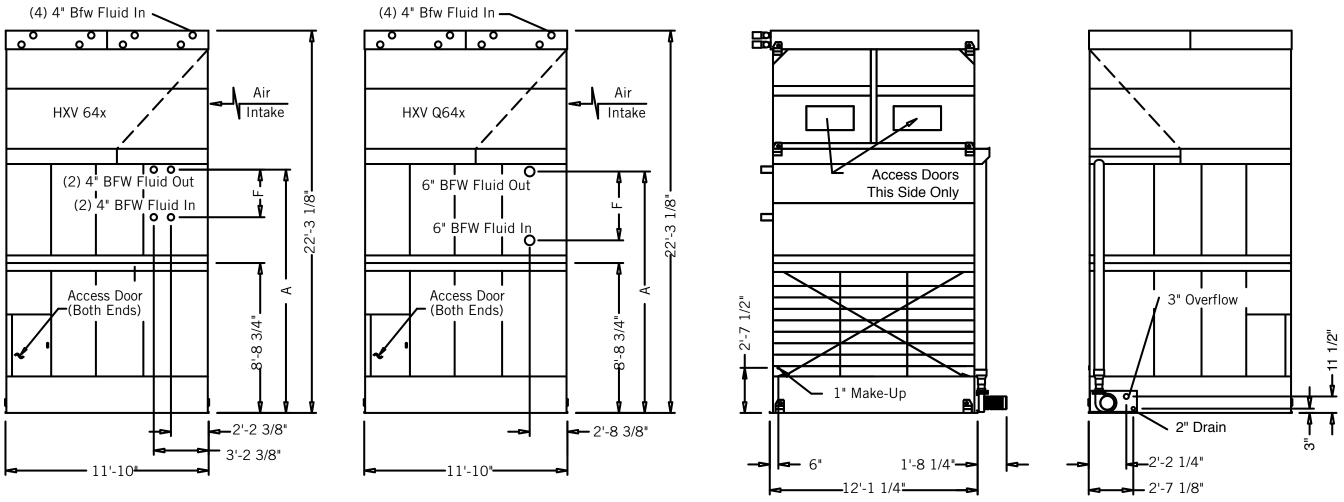
Vibration Cutout Switch

EXTENDED LUBRICATION LINES (OPTION)

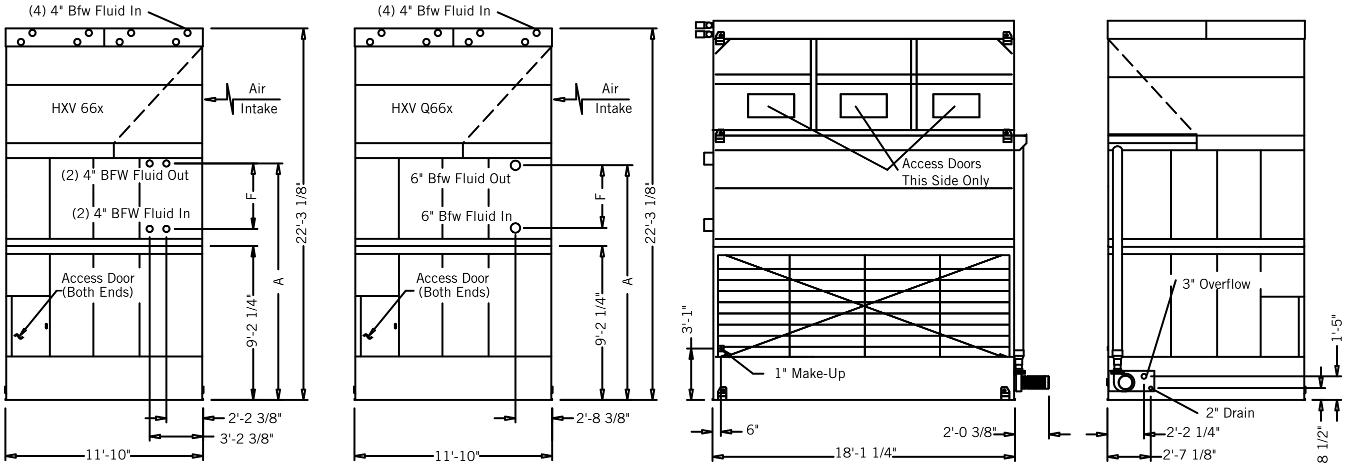
Extended lubrication lines are available for lubrication of the fan shaft bearings. Fittings are located on the exterior casing panel next to the access door.

HXV Engineering Data

HXV-64x/Q64x



HXV-66x/Q66x



Do not use for construction. Refer to factory certified dimensions. This catalog includes data current at the time of publication, which should be reconfirmed at the time of purchase.

Model Number	Nominal Tons[1]	Motor HP		Weights (lbs)			Dimensions	
		Fan	Pump	Operating[2]	Shipping	Heaviest Section (Coil)	A	F
HXV-641-OM	160	30	5	24,800	15,000	23,700	14'-2"	2'-0"
HXV-642-OM	180	30	5	26,300	16,100	25,200	14'-2"	2'-10"
HXV-Q640-OM	164	30	5	26,300	16,100	25,200	14'-1"	2'-8"
HXV-Q641	191	30	5	29,300	18,200	28,200	14'-1"	4'-2"
HXV-661-OM	252	30 & 15	7.5	35,700	21,600	34,600	14'-8"	2'-0"
HXV-662-OM	283	30 & 15	7.5	38,000	23,200	36,800	14'-8"	2'-10"
HXV-Q660-OM	268	30 & 15	7.5	38,000	23,200	36,800	14'-6"	2'-6"
HXV-Q661	305	30 & 15	7.5	42,400	28,400	41,300	14'-6"	4'-0"

NOTES:

1. Nominal tons of cooling represents the capability to cool 3 USGPM of water from 95˚F entering water temperature to 85˚F leaving water temperature at a 78˚F entering wet-bulb temperature.
2. Operating weight is for the tower with the water level in the cold water basin at the overflow.
3. The actual size of the inlet and outlet connection may vary with the design flow rate. Consult the unit print for dimensions.
4. Pipe sizes are nominal diameters. Standard connections are beveled-for-welding (BFW).
5. Dimensional drawings show standard (right hand) arrangements with the standard finned coil arrangement.

Winter Operation

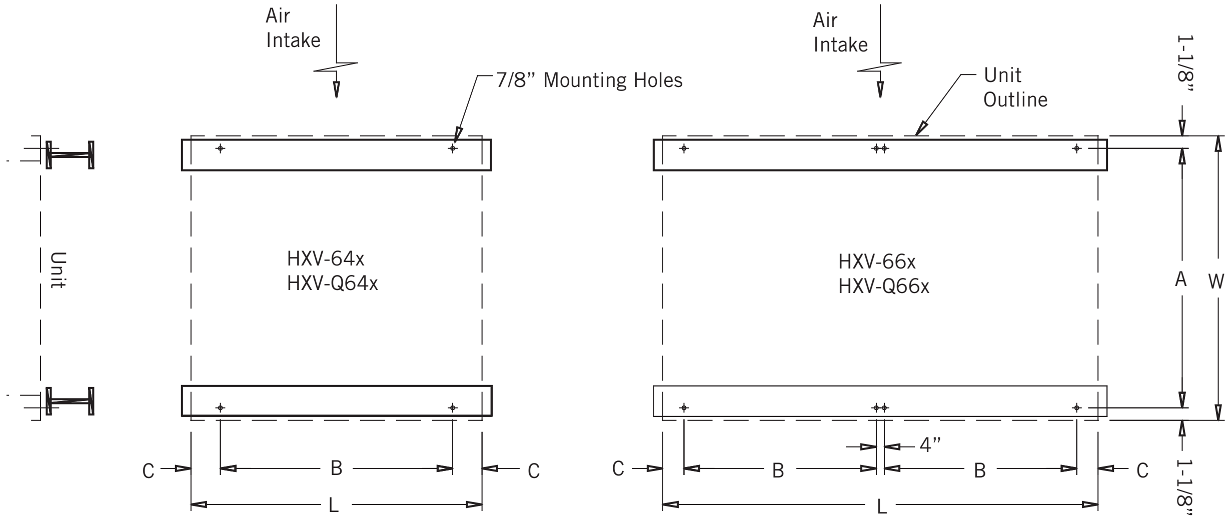
Model Number	Heat Loss Data (BTU/HR, Standard Unit)	Internal Coil Volumes		Cold Water Basin Volume at Operating Level (gal)
		Prime Surface Coil (gal)	Finned Coil (gal)	
HXV-641-OM	904,180	163	119	207
HXV-642-OM	962,184	218	119	207
HXV-Q640-OM	962,184	218	119	207
HXV-Q641	1,074,780	326	119	207
HXV-661-OM	1,354,564	255	170	314
HXV-662-OM	1,436,452	340	170	314
HXV-Q660-OM	1,436,452	340	170	314
HXV-Q661	1,596,816	510	170	314

NOTES:

1. Heat loss data based on 50˚F (-10.0˚C) coil water and -10.0˚F (-23.3˚C) with a 45 MPH (72.4 Km/hr) wind velocity (fans and pump are off).
2. Electric immersion heaters with thermostat and low level cutout. All components are factory installed in the unit basin. Heaters are selected to maintain 40˚F (4.4˚C) basin water at 0˚F (-17.8˚C) ambient temperature. In outdoor locations, trace heating and insulation of spray pump(s) (by others) may be required for freeze protection.

HXV Structural Support

The recommended support arrangement for HXV Hybrid Cooling Towers consists of parallel support members positioned as shown in the drawings. In addition to providing adequate support, the members also serve to raise the unit above any solid foundation to ensure access to the bottom of the tower. To support an HXV on columns or in an alternate arrangement not shown here, consult your local BAC Representative.



Model Number	W	L	A	B	C	Number of Anchor Bolts
HXV-64X	11'-10"	12'-2"	11'-8"	10'-6"	10"	4
HXV-Q64X	11'-10"	12'-2"	11'-8"	10'-6"	10"	4
HXV-66X	11'-10"	18'-2"	11'-8"	8'	11"	8
HXV-Q66X	11'-10"	18'-2"	11'-8"	8'	11"	8

NOTES:

1. Support members and anchor bolts shall be designed, furnished, and installed by others.
2. Design of support members and anchor bolts shall be in accordance with the strength and serviceability requirements of the applicable building code and project specifications.
3. Support members shall be level at the top.
4. Refer to the certified unit support drawing for loading and additional support requirements.
5. If vibration isolation (provided by others) is used, the isolators should be located under a structural base that complies with one of the recommended support arrangements. Contact your local BAC Representative for all other isolator configurations.

Ice Thermal Storage

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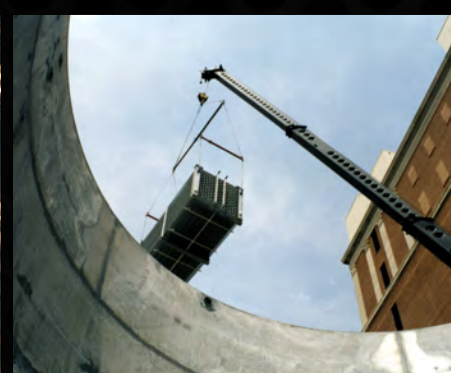
Ice Thermal Storage products store cooling while shifting energy usage to off-peak hours, dramatically reducing cooling costs and stress on the electrical grid. Environmentally friendly, ice thermal storage reduces greenhouse gas emissions and can qualify for LEED® certification credits. BAC has thousands of successful installations worldwide, and is the global leader in the application of ice thermal storage.



BAC's Ice Thermal Storage:

Promoting Sustainable Development

Thousands of Installations Worldwide
Ranging from 90 – 125,000 Ton-Hours

- Reduced Environmental Impact
- Reduced Energy Costs
- Saves Energy
- Lower System First Cost
- LEED® Credit Opportunities

Intelligent Water Saving Solutions

Low Environmental Impact

Ice Thermal Storage Benefits

Reduced Environmental Impact

- **LOWER GREEN HOUSE GAS EMISSIONS** – Storing energy as ice during off-peak hours, such as at night, allows the system to take advantage of cleaner, less expensive, more efficient energy sources. Also, lower ambient temperatures at night reduce energy line losses by 4-5% versus during the day.
- **FEWER "PEAKER" PLANTS** – Base energy loads are normally provided by highly efficient energy sources that are continuously providing power. As demand rises, peaker plants must be brought online. These plants tend to utilize less efficient sources. By lowering peak demand and spreading the cooling systems energy requirements more evenly over a 24 hour period, ice thermal storage can contribute to reducing the need to build new peaker plants.
- **LOWER REFRIGERANT CHARGE** – Reduced peak demand allows for the use of smaller chillers. Smaller chillers require lower refrigerant charges, which reduce the use of ozone depleting refrigerants and the overall impact on the environment.

Supports Clean Renewable Energy

The unpredictable nature of renewable resources and their inability to provide energy on demand make energy storage necessary in order for clean energy sources to become a viable substitute in the growing energy market. Ice thermal storage provides an economic strategy for utilizing renewable energy for cooling systems. Cloud cover and varying weather conditions can affect continuity of power from wind and solar energy sources, and there is no guarantee that energy can be reliably provided when it is needed most. Studies show that wind speeds are weaker during the day and that most wind turbines are getting less than 25% of the installed capacity during the hottest hours of the day. Ice storage can utilize renewable energy sources when they are available and provide cooling on demand.

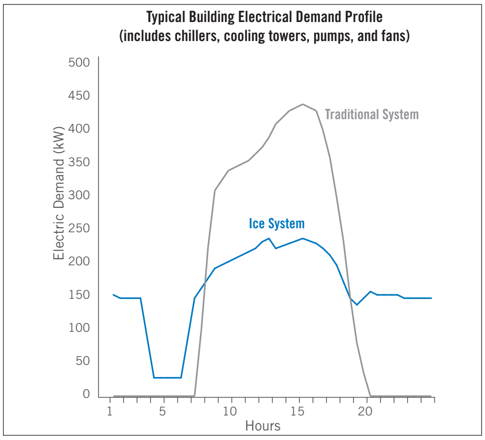
Solar Panels

TSUM Installation

Wind Turbines

Reduced Energy Cost

The use of electricity at night versus peak daytime hours can lead to large savings on energy bills. Ice thermal storage can lower peak electrical demand for the system by 50% or more. Since most electrical rates include demand charges during peak demand times and/or higher day versus night kWh charges, savings can be substantial. In areas with "real time pricing", where the electric rate varies hour-by hour based on the market price of electricity, day to night kWh cost can vary by 500-1000%.

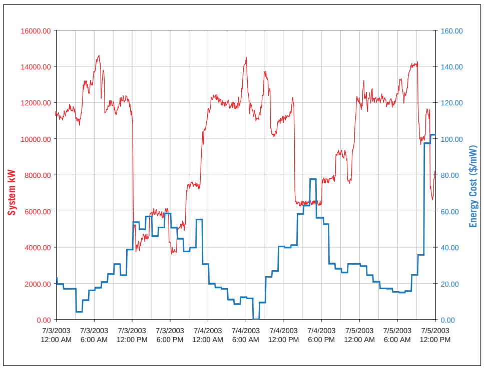


Typical Building Electrical Demand Profile

Saves Energy

When the system is designed to take advantage of the low supply water temperature available from an ice storage system, energy use is significantly reduced.

- **REDUCED HORSEPOWER** – Low temperature chilled water utilizes lower horsepower pumps and provides low temperature air that utilizes lower horsepower fans. BAC's patented coil configuration combined with high heat transfer steel coil material produces the lowest possible discharge temperatures.
- **INCREASED CHILLER EFFICIENCY** – Lower condensing temperatures at night, when combined with chillers operating at full load, increases the efficiency of the chiller. Chiller efficiency decreases significantly at low loads. A conventional chiller in a traditional system will operate at less than 50% capacity for half the year.



Real Time Pricing

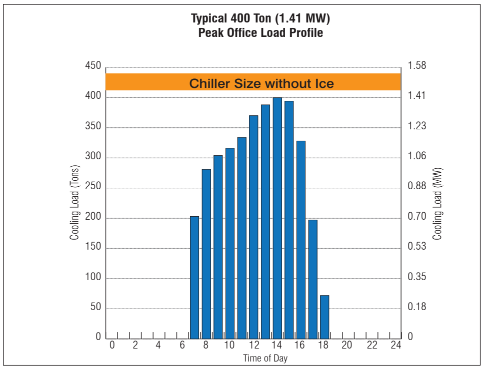
District Cooling Piping Installation

Ice Thermal Storage Benefits

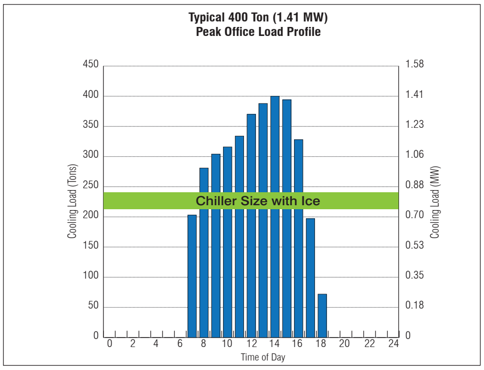
Low First Cost

Systems with ice thermal storage can be installed at the same or lower first cost than traditional systems when designed to take advantage of the colder supply water available from ice.

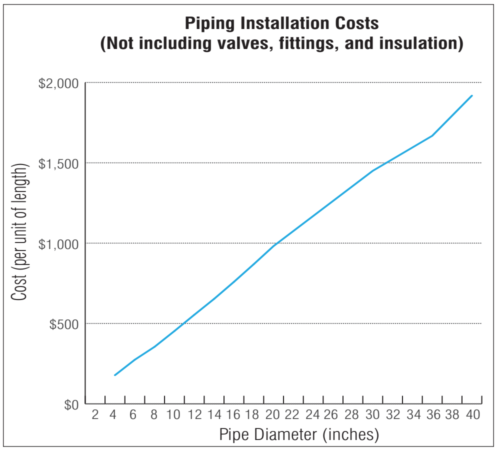
- **SMALLER CHILLER AND HEAT REJECTION EQUIPMENT** – By designing the system around 24-hour per day chiller operation, the size of chillers, cooling towers, or condensers required for an ice storage system are significantly reduced. A typical ice thermal storage design includes chillers and cooling towers that provide 50-60% of the peak cooling load.
- **REDUCED PIPING AND PUMPING SIZES** – Flow rate requirements are reduced by taking advantage of the greater temperature gradient achieved when utilizing the colder supply water available with ice. This provides substantial savings in the chilled water distribution loop. A range of 18˚F (10˚C) instead of the more traditional 10˚F (5.5˚C) results in a significant reduction in the size of pumps and piping for the chilled water system.
- **REDUCED DUCTING AND FAN SIZES** – Low supply water temperatures allow for low temperature air distribution, resulting in minimized ducting and fan horsepower (HP). Low temperature air can significantly improve air quality and occupant comfort.
- **REDUCED ELECTRICAL DISTRIBUTION** – Smaller chillers, heat rejection equipment, pumps, and fans require less horsepower, which results in smaller transformers, switchgear, wire sizes, and starter panels.
- **REDUCED GENERATOR SIZE** – The generator capacity required for back-up energy will be significantly reduced when the peak electrical load of the facility is reduced using ice storage.
- **REBATES** – Many utilities offer attractive load shift incentives and rebates which can further reduce the initial investment of the Ice Thermal Storage system significantly. Rebate amounts can range from $500/ton shifted in Florida to $2600/kw shifted in New York City.



Chiller Size without Ice



Chiller Size with Ice Thermal Storage System

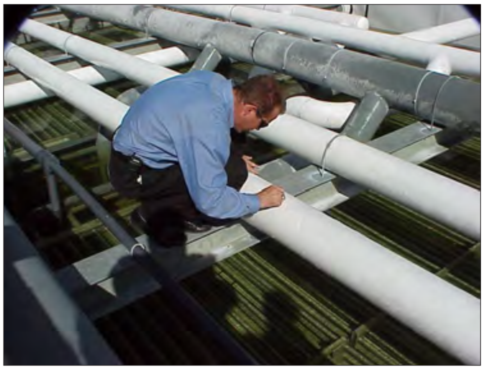


Reduced Piping Installation Costs

Supports Industry Standards

Introduced in 2009, ASHRAE Standard 189.1, *Standard for the Design of High-Performance, Green Buildings Except Low-Rise Residential Buildings*, was the first code intended for commercial green building standard in the United States. It provides a total building stainability package for those who strive to design, build and operate green buildings.

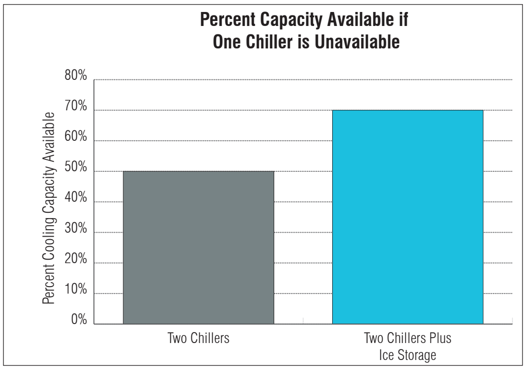
Section 7.4.5.1 of ASHRAE 189.1 requires projects to contain automatic systems, such as demand limiting or load shifting, that are capable of reducing electric peak demand by at least 10% of projected peak demand. Ice thermal storage has the capability to exceed these limits and provide a sustainable solution for a variety of applications.



Reduced Maintenance with No Moving Parts

Reduced Maintenance

With smaller system components (chiller, cooling tower, pumps, air distribution, etc.) as compared to a conventional system design, there is less equipment to maintain. Parts and labor required to maintain the system decrease. Ice thermal storage equipment itself includes no moving parts, and therefore does not require additional maintenance.



Increased Reserve Capacity

Redundancy Improves System Reliability

Critical systems often require high cooling capacities to prevent damage to their systems and remain operational. In the event of chiller failure or failure of any other significant cooling system component, the cooling capacity stored in the ice can continue to be used for system cooling. Some critical facilities, such as data centers, may designate an ice thermal storage system for the sole purpose of providing emergency cooling for back-up purposes.

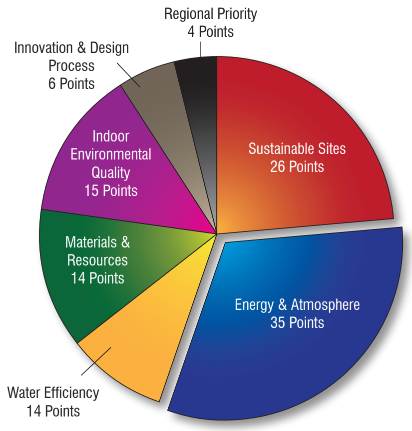
Ice Thermal Storage and LEED®

Cost initiatives provided by utility companies to shift load to off-peak hours is due to the ability to utilize cheaper, cleaner, and more efficient energy sources. Cleaner energy usage along with reduced energy consumption by a low temperature system has a significant effect on reducing environmental impact.

The acceptance of ice thermal storage technology as a green technology is demonstrated by the potential to qualify for a significant number of LEED® points with a properly designed ice thermal storage system. LEED® was created to define the "green building" by establishing a common standard of measurement, all while raising consumer awareness of green building benefits. A voluntary certification system, LEED® promotes whole-building design practices as it recognizes environmental leadership in the building industry. For more information on LEED® refer to the "Codes and Standards" section on **page J22**.

A number of LEED® 2009 credits can be earned when ice thermal storage technology is incorporated in the HVAC design.

United States Green Building Council



LEED Point Breakdown for New Construction

Reduced Refrigerant Charge

Energy and Atmosphere (EA)

- **OPTIMIZE ENERGY PERFORMANCE -** Up to 18 points available. Points can be earned in this category by improving building performance. A properly designed ice thermal storage system is capable of reducing energy costs up to 48%, therefore qualifying for the maximum number of points. Ice is made during off-peak power rates when costs are lower. Also, by taking advantage of lower water and air temperatures, ice thermal storage can reduce energy consumption which helps to achieve additional cost savings.
- **ENHANCED REFRIGERANT MANAGEMENT** - Up to 2 points available. This credit is attainable for projects that select refrigerants and refrigeration equipment that minimize the contribution of ozone depleting compounds below designated thresholds or eliminates emission. Partial ice storage systems can reduce the chiller size by up to 40% compared to conventional chilled water plants, therefore holding a smaller refrigerant charge.

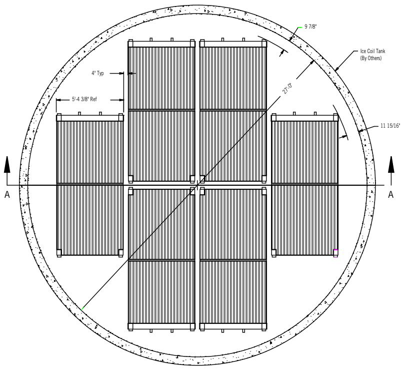
Indoor Environmental Quality (IEQ)

ENHANCED ACOUSTICAL PERFORMANCE – 1 point available. To qualify for this acoustical credit, background noise from HVAC systems must be reduced to 40 dBA or less. A full storage ice thermal storage system can provide chilled water during operating hours without turning on chillers and cooling towers, significantly reducing the sound contribution of HVAC equipment.

Sound Sensitive Applications

Innovation in Design (ID)

- **INNOVATION IN DESIGN** – Up to 5 points available. Awarded for exceptional performance, Ice thermal storage can qualify as an innovative technology that can help reduce energy consumption and carbon emissions.
- **DEMAND RESPONSE** – To encourage participation in demand response programs and technology, this new credit could be worth up to 2 points. Ice thermal storage technology is ideally suited for participation in demand response programs by shifting demand to off-peak load hours.



Innovation in Design

LEED Project: Taipei 101 The Worlds Tallest Green Building

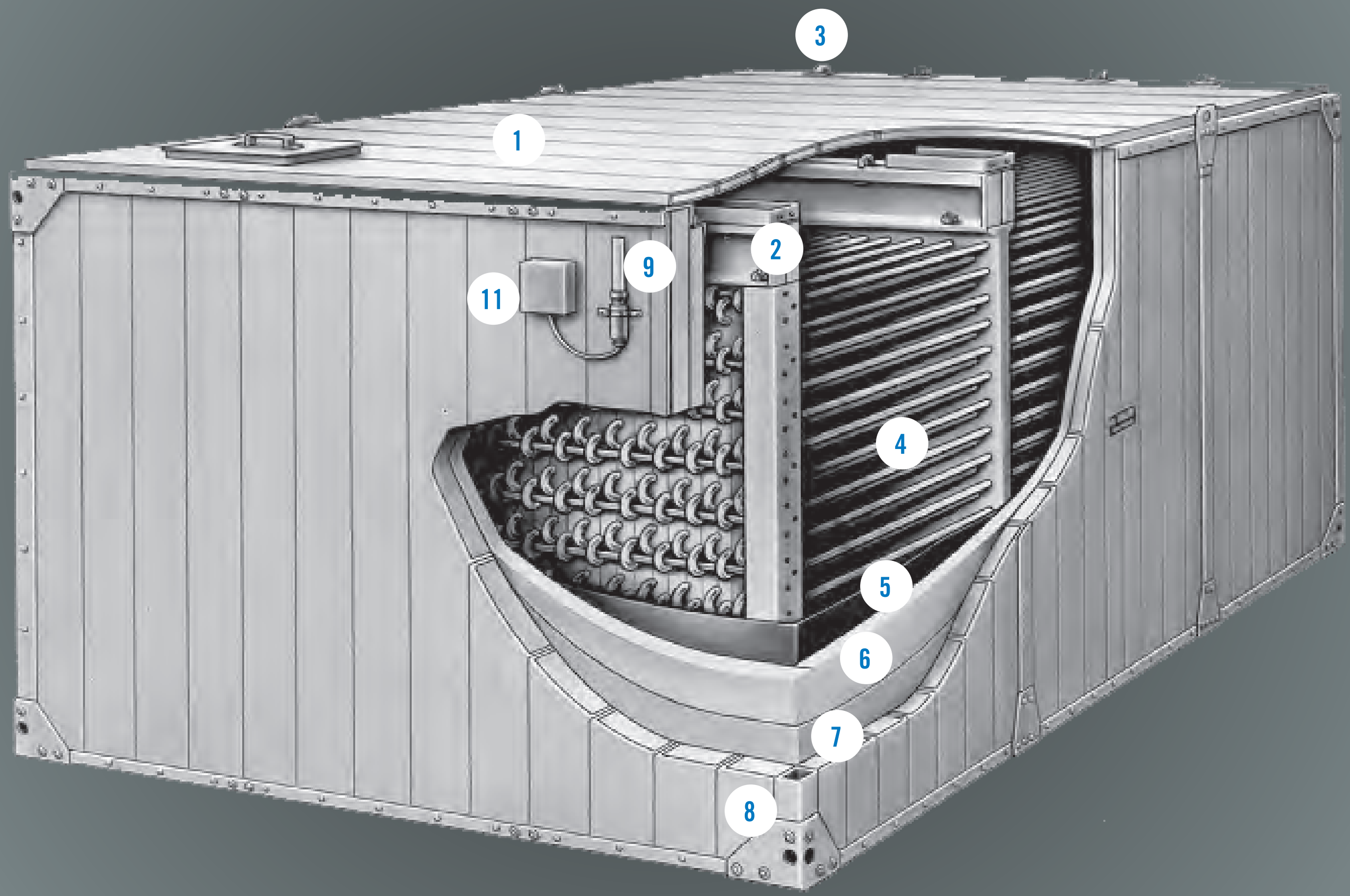
Taipei 101 received LEED Platinum certification in existing building operation and maintenance in the summer of 2011. Platinum is the highest LEED rating a building can attain. Projects that have attained this rigorous level of LEED certification are among the most sustainable buildings in the world.

Taipei 101 is located in the central government and business district of Taipei, Taiwan. The building consists of a shopping and entertainment complex and office tower. Completed in August 2002, the 101-floor tower was the world’s tallest building at that time at 508 meters high.

BAC ice thermal storage equipment (36,450 ton-hours or 128.3 MWh) was selected because of its ability to provide low fluid temperatures, in this case 36°F (2°C). Low supply temperatures allowed economical selection of pressure isolation heat exchangers on the 42nd and 74th floors. Additionally, the low supply temperature allowed cold air distribution to be used throughout, thus reducing first costs and operating costs while providing improved occupant comfort.

Taipei 101

ICE CHILLER® Thermal Storage Unit
for HVAC Applications



1 Covers

- Watertight
- G-235 (Z700 Metric) hot-dip galvanized steel panels
- Insulated with 2” expanded polystyrene insulation

2 Coil Support Beams

- Prevent contact between coil and primary liner

3 Glycol Connections

- Grooved for mechanical coupling

4 Galvanized Steel Coil

- Continuous serpentine, steel tubing
- Hot-dip galvanized after fabrication (HDGAF)
- Pneumatically tested at 375 psig
- Rated for 300 psig operating pressure

5 Primary Liner

- Single piece
- 48-hour integrity test before shipment

6 Extruded Polystyrene Insulation

- 1.5” thick, installed between primary and secondary liners

7 Secondary Liner/Vapor Barrier

- Prevents moisture from penetrating through the insulation

8 Wall Panels

- Heavy-gauge galvanized steel with double brake flanges
- 3” of expanded polystyrene insulation

9 Sight Tube

- Visual indicator of water level corresponding to the amount of ice in the unit

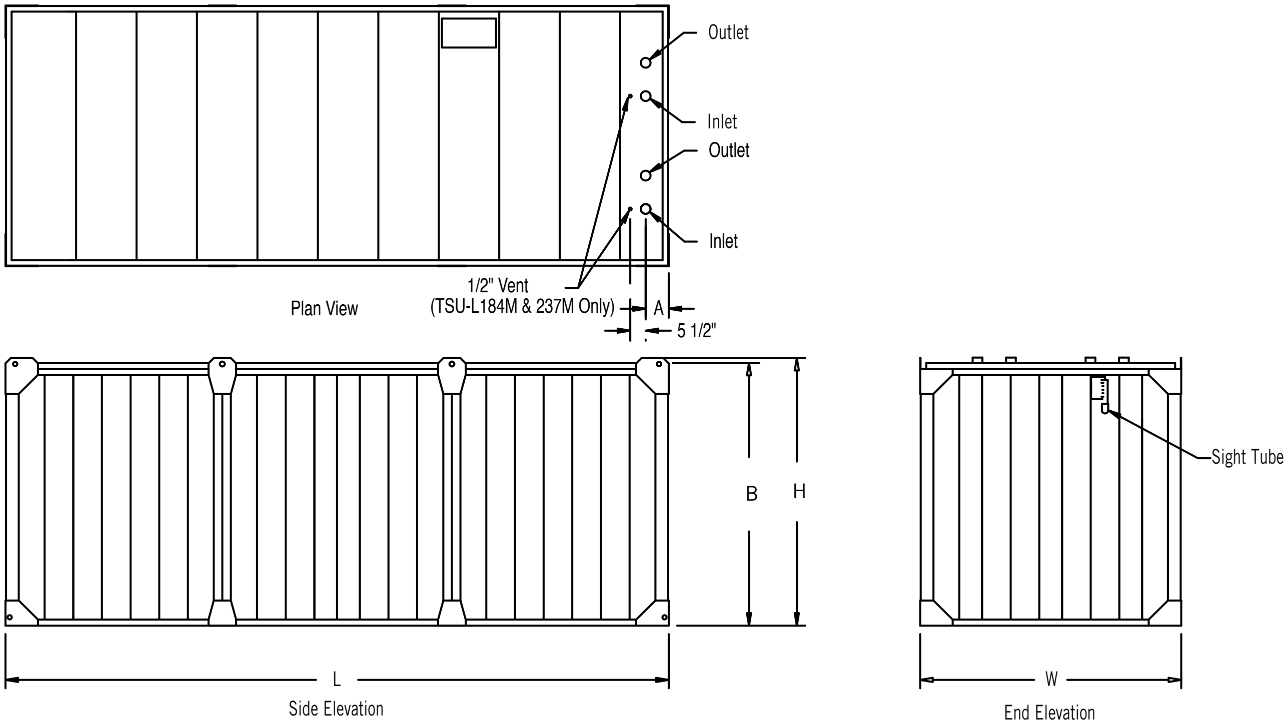
10 Operating Control (Not Shown)

- High-level float switch and low water cutout mounted on the outside of the tank
- Provided on all tanks

11 Ice Inventory Sensor (Optional)

- Differential pressure transmitter provides an electrical 4-20 mA output signal which is proportional to the amount of ice in inventory

TSUM Engineering Data



Model Number	Weights (lbs)		Volumes (gal)		Dimensions					Connection Size
	Operating	Shipping	Tank (Water)	Coil (Glycol)	L	W	H	A	B	
TSU-237M	39,100	9,750	2,990	260	10'-7 5/8"	7'-10 3/8"	8'-0"	8 5/8"	7'-10"	2"
TSU-476M	73,900	16,750	5,840	495	19'-10 1/4"	7'-10 3/8"	8'-0"	9 3/4"	7'-10"	3"
TSU-594M	93,100	20,200	7,460	610	19'-10 1/4"	9'-9 1/4"	8'-0"	9 3/4"	7'-10"	3"
TSU-761M	113,800	24,000	9,150	790	19'-10 1/4"	11'-9 3/4"	8'-0"	9 3/4"	7'-10"	3"
TSU-L184M	31,700	8,300	2,330	205	10'-7 5/8"	7'-10 3/8"	6'-6 3/4"	8 5/8"	6'-4 3/4"	2"
TSU-L370M	59,700	14,100	4,560	385	19'-10 1/4"	7'-10 3/8"	6'-6 3/4"	9 3/4"	6'-4 3/4"	3"
TSU-L462M	75,000	17,000	5,820	477	19'-10 1/4"	9'-9 1/4"	6'-6 3/4"	9 3/4"	6'-4 3/4"	3"
TSU-L592M	91,650	20,300	7,140	602	19'-10 1/4"	11'-9 3/4"	6'-6 3/4"	9 3/4"	6'-4 3/4"	3"

NOTES:

1. Unit should be continuously supported on a flat level surface.
2. All connections are grooved for mechanical coupling.

Do not use for construction. Refer to factory certified dimensions. This catalog includes data current at the time of publication, which should be reconfirmed at the time of purchase.

Engineering Considerations – HVAC

Modes of Operation

ICE BUILD

In this operating mode, ice is built by circulating a solution of inhibited ethylene/propylene glycol through the coils contained in the ICE CHILLER® Thermal Storage Unit. **Figure 1** illustrates typical chiller supply temperatures for 8, 10, and 12 hour build cycles with a chiller flow rate associated with 5˚F (2.8˚C) range. As build time increases, so does minimum glycol temperature. When a larger temperature range is the basis for chiller selection, the chiller supply temperatures will be lower than shown.

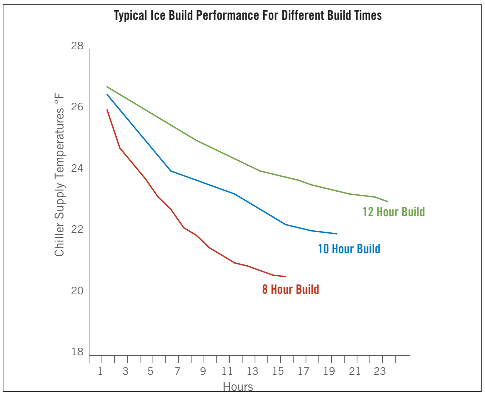


Figure 1

ICE BUILD WITH COOLING

When cooling loads exist during the ice build period, some of the cold glycol used to build ice is diverted to the cooling load to provide the required cooling. The amount of glycol diverted is determined by the building loop set point temperature. BAC recommends that this mode of operation be applied on systems using primary/secondary pumping. This reduces the possibility of damaging the cooling coil or heat exchanger by pumping cold glycol, lower than 32°F (0°C), to the equipment.

Modular Ice Thermal Storage Unit

COOLING - ICE ONLY

In this operating mode the chiller is off. The heat is rejected from the system by melting ice stored in the modular ICE CHILLER Thermal Storage Unit.

COOLING - CHILLER ONLY

In this operating mode the chiller supplies all the building cooling requirements. Glycol flow is diverted around the thermal storage equipment to allow the cold supply glycol to flow directly to the cooling load. Temperature is maintained by the chiller.

NOTE: See **page G14** and **G15** for system schematics and control logic.

COOLING - ICE WITH CHILLER

In this operating mode, cooling is provided by the combined operation of the chiller and ice storage equipment. The glycol chiller precools the warm return glycol. The partially cooled glycol solution then passes through the ICE CHILLER Thermal Storage Unit where it is cooled by the ice to the design temperature.

Engineering Considerations – HVAC

System Schematics

Two basic flow schematics are applied to select ICE CHILLER® Thermal Storage Units. **Figure 2** illustrates a single piping loop with the chiller installed upstream of the thermal storage equipment. This design allows the thermal storage system to operate in four of the five possible operating modes. They are Ice Build, Cooling-Ice Only, Cooling-Chiller Only and Cooling-Ice with Chiller.

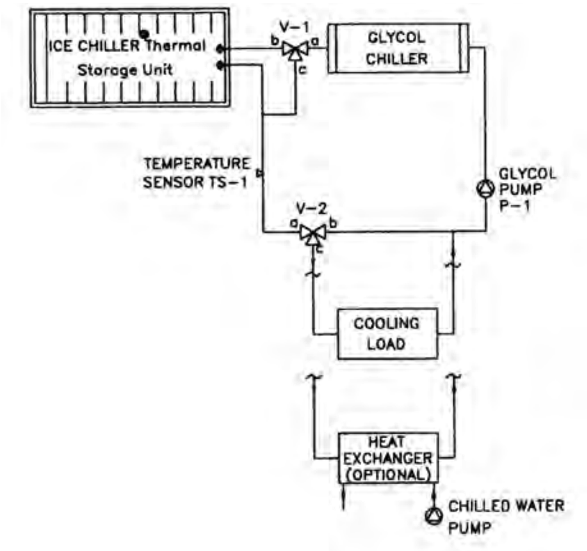


Figure 2

FOR FIGURE 2 THE FOLLOWING CONTROL LOGIC IS APPLIED

Mode	Chiller	P-1	V-1	V-2
Ice Build	On	On	A-B	A-B
Cooling - Ice Only	Off	On	Modulate	A-C
Cooling - Chiller Only	On	On	A-C	A-C
Cooling - Ice with Chiller	On	On	Modulate	A-C

Valve V-1 modulates in response to temperature sensor, TS-1. Valve V-2 could be positioned to either maintain a constant flow, less than P-1, or modulate in response to the return glycol temperature from the cooling load.

When the building loop contains chilled water, a heat exchanger must be installed to separate the glycol loop from the building's chilled water loop. On applications where an existing water chiller is available, it can be installed in the chilled water loop to reduce the load on the thermal storage system.

This design should not be used when there is a requirement to build ice and provide cooling. This would require the cold return glycol from the thermal storage equipment be pumped to the cooling load or heat exchanger. Since the glycol temperature is below 32°F (0°C), the cooling coil or heat exchanger is subject to freezing. The flow schematic illustrated in **Figure 3** details a primary/secondary pumping loop with the chiller located upstream of the thermal storage equipment. This design allows the system to operate in all five operating modes.

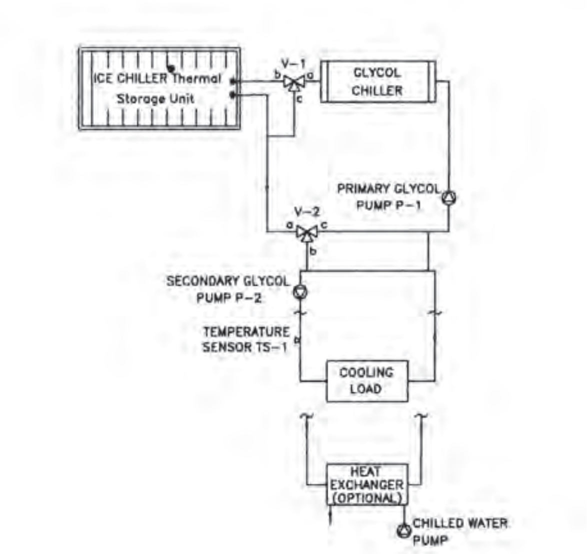


Figure 3

FOR FIGURE 3 THE FOLLOWING CONTROL LOGIC IS APPLIED:

Mode	Chiller	P-1	P-2	V-1	V-2
Ice Build	On	On	Off	A-B	A-C
Ice Build with Cooling	On	On	On	A-B	Modulate
Cooling - Ice Only	Off	On	On	Modulate	A-B
Cooling - Chiller Only	On	On	On	A-C	A-B
Cooling - Ice with Chiller	On	On	On	Modulate	A-B

Valve V-1 and Valve V-2 modulate, depending on the operating mode, in response to temperature sensor, TS-1. The benefit provided by the primary/secondary pumping loop is that the system can build ice and provide cooling without fear of freezing a cooling coil or heat exchanger. This system design also allows for different flow rates in each of the pumping loops. When the flow rates in the pumping loops are different, the glycol flow rate in the primary loop should be greater than or equal to the glycol flow rate in the secondary loop. As in the single loop schematic, a heat exchanger and a base water chiller can be added to the system schematic.

Variations to these schematics are possible but these are the most common for ice storage systems. One variation positions the chiller downstream of the ice storage equipment. By positioning the chiller downstream of the ice, the chiller is used to maintain the required supply temperature. In **Figures 2** and **3**, the chiller is installed upstream of the ice. This offers two significant advantages compared to system designs that locate the chiller downstream of the ice. First, the chiller operates at higher glycol temperatures to precool the return glycol. This enables the chiller to operate at a higher capacity which reduces the amount of ice required. Second, since the chiller is operating at higher evaporator temperatures, the efficiency (kW/TR) of the chiller is improved.

Engineering Considerations – HVAC

Installation

ICE CHILLER® Thermal Storage Units are designed to be installed indoors or outdoors. The units must be installed on a continuous flat level surface. The pitch of the slab must not exceed 1/8" over a 10' span. **Figure 4** details ICE CHILLER Thermal Storage Unit layout guidelines. The units should be positioned so there is sufficient clearance between units and adjacent walls to allow easy access. When multiple units are installed, a minimum of 18" is recommended side-to-side and 3'-0" end-to-end for access to the operating controls.

When installed indoors, the access and slab requirements described above also apply. The units should be placed close to a floor drain in the event they need to be drained. The minimum height requirement above the tank for proper pipe installation is 3'. **Figure 5** illustrates the recommended overhead clearance for ICE CHILLER Thermal Storage Units.

For large ton–hour applications, BAC will provide ICE CHILLER Thermal Storage Coils for installation in field fabricated concrete tanks. When coils are required, BAC's manufacturing capabilities allow coils to be manufactured in the size and configuration necessary to meet specific site and performance requirements. The concrete tank design is to be completed by a qualified structural engineer. **Figure 6** illustrates the ICE CHILLER Thermal Storage Coil layout guidelines. For large projects that require ICE CHILLER Coils, contact your local BAC Representative for selection and dimensional information.

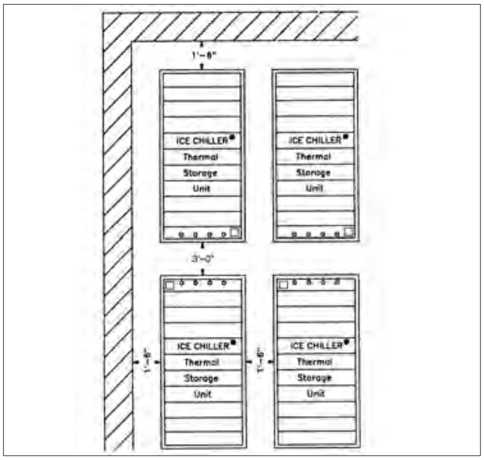


Figure 4

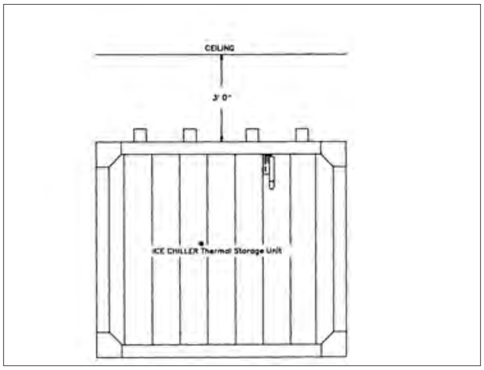


Figure 5

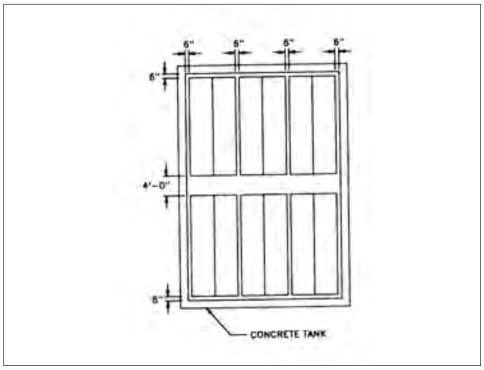


Figure 6

Unit Piping

Piping to the ICE CHILLER® Thermal Storage Unit should follow established piping guidelines. The coil connections on the unit are galvanized steel and are grooved for mechanical coupling.

For single tank applications, each pair of manifolded coil connections should include a shut-off valve, so the unit can be isolated from the system. **Figure 7** illustrates the valve arrangement for a single unit. It is recommended that the piping include a bypass circuit to allow operation of the system without the ICE CHILLER Thermal Storage Unit in the piping loop. This bypass can be incorporated into the piping design by installing a three way modulating valve. This valve can also be used to control the leaving glycol temperature from the thermal storage unit. Temperature and pressure taps should be installed to allow for easier flow balancing and system troubleshooting. A relief valve, set at a maximum of 300 psi, must be installed between the shut-off valves and the coil connections to protect the coils from excessive pressures due to hydraulic expansion. The relief valve should be vented to a portion of the system which can accommodate expansion.

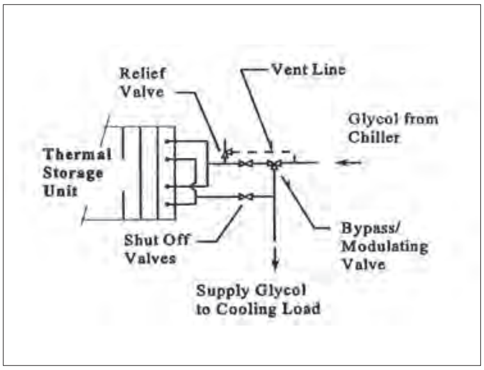


Figure 7

NOTE: The system must include an expansion tank to accommodate changes in fluid volume. Adequately sized air vents must be installed at the high points in the piping loop to remove trapped air from the system.

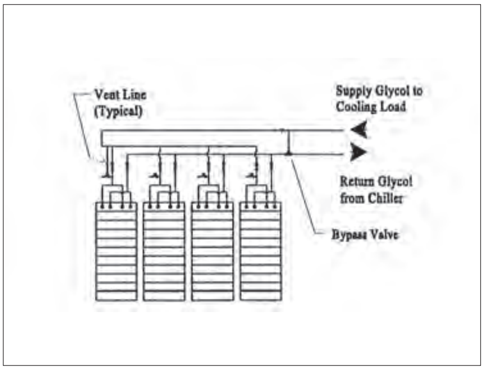


Figure 8

Figure 8 illustrates reverse return piping for multiple units installed in parallel. The use of reverse return piping is recommended to ensure balanced flow to each unit. Shut-off valves at each unit can be used as balancing valves.

When large quantities of ICE CHILLER Thermal Storage Units are installed, the system should be divided into groups of units. Then, balancing of each unit can be eliminated and a common balancing valve for each group of units installed. Shut-off valves for isolating individual units should be installed but not used for balancing glycol flow to the unit.

Engineering Considerations – HVAC

Controls

To ensure efficient operation of the ICE CHILLER® Thermal Storage Units, each system is provided with factory installed operating controls. A brief description of the controls follow.

Once the ice build cycle has been initiated, the glycol chiller should run at full capacity without cycling or unloading until the ICE CHILLER Thermal Storage Units are fully charged. When the units are fully charged, the chiller should be turned off and not allowed to re-start until cooling is required. The ice build cycle is terminated by the operating control assembly. This assembly includes a low water cutout and a shut-off switch. The low water cutout prevents the ice build mode from starting if there is insufficient water in the tank. The shut-off switch will terminate the build cycle when the units are fully charged and will prevent the next ice build mode from starting until 15% of the ice has melted.

NOTE: Multiple operating control assemblies must be wired in series so that a full build signal from any one tank will terminate the ice build cycle.

An inventory sensor that provides a 4 - 20 mA signal is available. This sensor should be used for determining the amount of ice in inventory, but not to terminate the ice build cycle. Complete operating control details are provided in the *Installation, Operation and Maintenance Manual*, that can be found at www.BaltimoreAircoil.com.

Glycol

ICE CHILLER Thermal Storage Units typically use a 25% (by weight) solution of industrially inhibited ethylene/propylene glycol for both corrosion protection and freeze protection. Industrial grade inhibited glycol is specifically designed to prevent corrosion in HVAC and heat transfer equipment. Inhibitors are used to prevent the ethylene glycol from becoming acidic and to protect the metal components in the thermal storage system. The system's lowest operating temperature should be 5°F to 7°F (2.8°C to 3.9°C) above the glycol freeze point. The freeze point for a system with 25% by weight ethylene glycol is 13°F (10.6°C); the freeze point for a system with 25% by weight propylene glycol is 15°F (9.4°C).

Acceptable industrial grade inhibited glycol solutions are DOWTHERM® SR–1, DOWFROST® HD and UCARTHERM®. Use of other brands of glycol in ICE CHILLER Thermal Storage Products should be approved by BAC.

DOWTHERM® SR-1, DOWFROST® and UCARTHERM® are registered trademarks of The Dow Chemical Company or its subsidaries.

NOTE: Uninhibited glycol and automotive antifreeze are NOT to be used on thermal storage applications.

Water Treatment

In the near freezing temperatures of the ICE CHILLER Thermal Storage Unit, scale and corrosion are naturally minimized. Therefore, water treatment for these two conditions may not be required or may require minimal attention unless the water is corrosive in nature. To control biological growth, a biocide may be needed to prevent the spread of iron bacteria or other organisms. For specific recommendations, consult a reputable local water treatment company and follow the guidelines in Table 1. To assure full capacity of the ICE CHILLER Thermal Storage Unit, water treatment should not alter the freeze point of the water in the tank.

TABLE 1: WATER QUALITY GUIDELINES

Property of Water	Recommended Levels
pH	6.5 to 9.0[1]
Total Suspended Solids	25 ppm
Total Dissolved Solids (TDS)	1,500 ppm
Conductivity	2,400 (microohms/cm)
Alkalinity as $CaCO_3$	500 ppm[2]
Calcium Hardness as $CaCO_3$	50 to 600 ppm[2]
Chlorides (CL)	250 ppm
Sulfates	250 ppm
Silica	150 ppm

NOTE: A pH of 8.3 or higher requires periodic passivation of the galvanized steel to prevent "white rust," the accumulation of white, waxy, nonprotective zinc corrosion on galvanized steel surfaces.

Winterization

NOTE: Precautions must be taken to protect the unit and associated piping from freezing conditions.

Heat tracing and insulation should be installed on all piping connected to the unit. The sight tube, operating controls and optional inventory sensor must be protected if the units are installed outdoors and exposed to sub-freezing ambient conditions. For this purpose, BAC can provide an optional heated enclosure, complete with a 100 W heater. Otherwise, the sight tube, operating controls and optional inventory sensor must be heat traced and insulated. It is not necessary to drain the unit during cold weather.

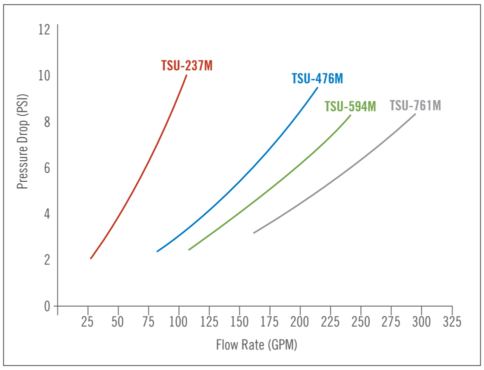


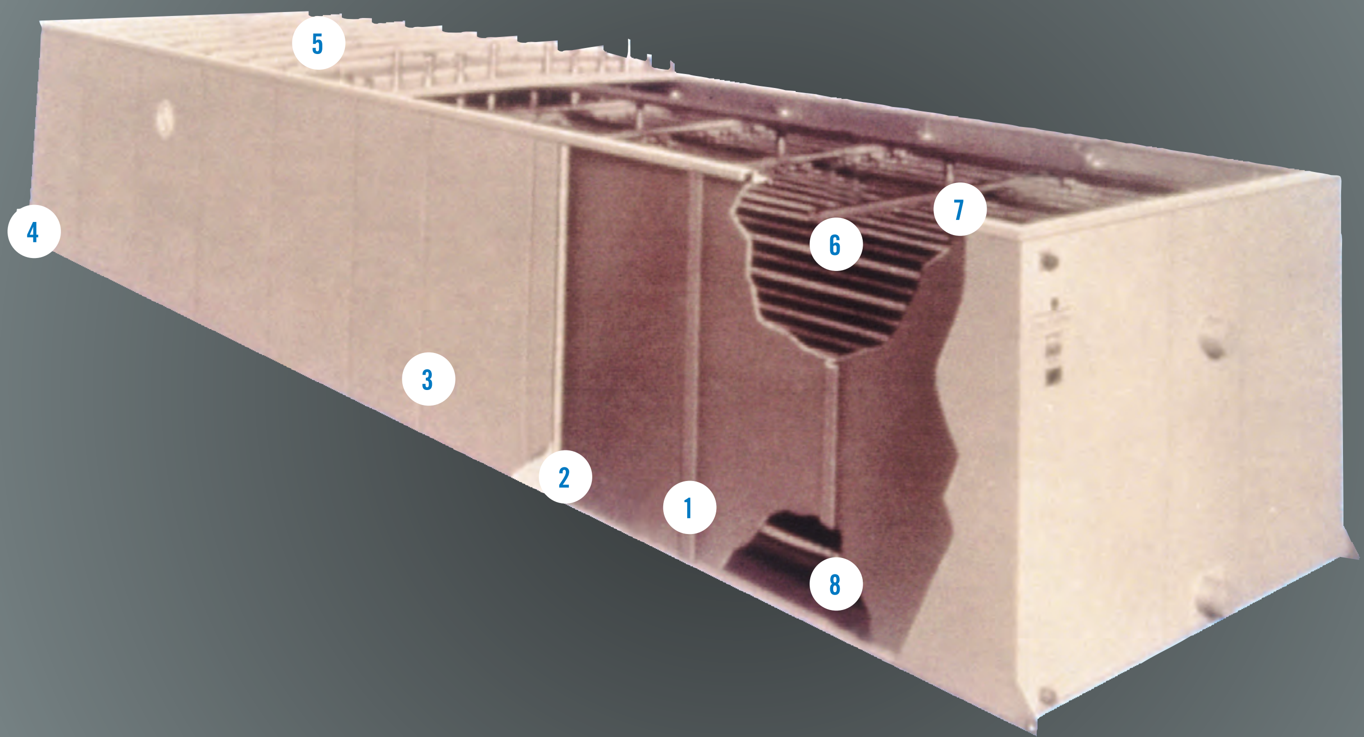
Figure 9

Pressure Drop

The ICE CHILLER® Thermal Storage Unit is designed for low pressure drop. **Figure 9** shows the pressure drop associated with each unit for a 25% solution of industrially inhibited ethylene glycol. Data for flow rates not shown should not be extrapolated from the performance curve. Pressure drops for flow rates not presented in this chart, and for alternative fluids, are available by contacting the local BAC Representative.

ICE CHILLER® Thermal Storage Unit

for Industrial and Process Cooling Applications



1 Tank

- The tank is constructed of heavy gauge, hot-dip galvanized steel reinforced with full-length structural steel angles beneath and on all four sides. All seams are welded to ensure watertight construction. A zinc rich coating is applied to all exposed edges and welds.

2 Insulation

- Expanded polystyrene insulation is provided between the tank and the exterior panels. The insulation is three inches thick (R-13) on the tank sides and ends, two inches thick (R-8) on the bottom and one inch thick inside the covers.

3 Exterior Panels

- Exterior panels sealed at all seams provide a complete vapor barrier and protect the insulation. They are furnished with a thermosetting hybrid polymer.

4 Air Blower

- Centrifugal regenerative blower for field mounting to supply low pressure air for agitation of the water. Blower is furnished with an inline air filter, check valve and rain shield for field installation.

5 Covers

- Sectional insulated tank covers are provided with a thermosetting hybrid polymer. Covers are interlocking and rain shedding.

6 Coil

- The coil is constructed of multiple prime surface serpentine steel circuits and tested at 375 psig air pressure under water. It is encased in a steel frame, and the entire assembly is hot-dip galvanized after fabrication. For ammonia systems, purge connections are provided on each coil for oil maintenance.

7 ICE-LOGIC™ ICE THICKNESS CONTROLLER

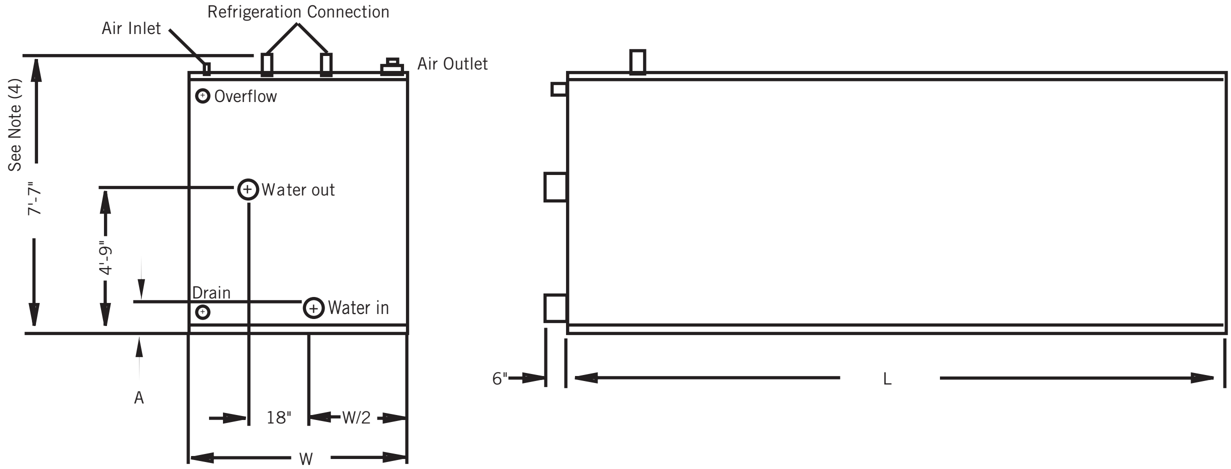
- An electronic, multi-point adjustable ice thickness control is mounted on the unit. A control relay is provided for deactivating the refrigeration system when a full build of ice is reached.

8 Air Distributor

- Low pressure air from the air blower is distributed below the coils through multiple perforated Schedule 40 PVC pipes.

TSU (E, F & G) Engineering Data

NOMINAL 5' WIDE UNITS:
MODELS TSU-125E TO TSU-235E AND TSU-145F TO TSU-270F

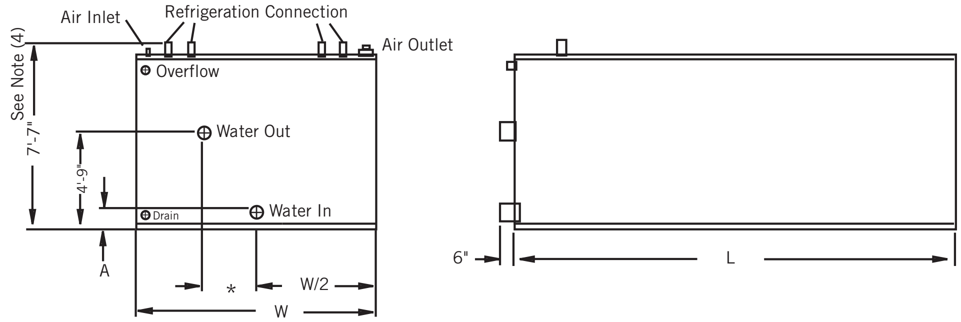


Model Number	LBS of Ice[2]		Approx. Shipping Weight (lbs)	Approx. Operating Weight (lbs)	Air Pump (HP)	Water Volume (gal)	Pull Down Volume (gal)	Coil Volume (ft³)	R-717 Charge (lbs)[5]	Water Conn. In/Out	W	L	A
	Gravity Flooded	Pump Recirculated											
E Series													
TSU-125E	9,330	10,808	5,500	23,500	3	2,080	270	9	245	3"	5'-3 1/8"	10'-1"	4.5"
TSU-155E	11,410	12,250	6,230	28,000	3	2,520	320	10	275	3"	5'-3 1/8"	12'-1"	4.5"
TSU-180E	13,580	14,580	7,070	32,600	3	2,960	380	12	325	3"	5'-3 1/8"	14'-1"	4.5"
TSU-210E	15,660	16,740	8,090	37,400	3	3,400	440	13	355	4"	5'-3 1/8"	16'-0"	5"
TSU-235E	17,830	18,910	8,830	41,900	3	3,840	490	15	410	4"	5'-3 1/8"	18'-0"	5"
F Series													
TSU-145F	10,660	11,500	5,730	23,700	3	2,070	40	10	275	3"	5'-3 1/8"	10'-1"	4.5"
TSU-175F	13,080	14,080	6,500	28,100	3	2,510	45	12	325	3"	5'-3 1/8"	12'-1"	4.5"
TSU-205F	15,490	16,580	7,370	32,800	3	2,950	55	13	355	3"	5'-3 1/8"	14'-1"	4.5"
TSU-240F	17,910	18,990	8,370	37,600	3	3,390	65	15	410	4"	5'-3 1/8"	16'-0"	5"
TSU-270F	20,330	21,490	9,140	42,100	3	3,820	70	17	460	4"	5'-3 1/8"	18'-0"	5"

NOTES:

1. All dimensions are in feet and inches. Weights are in pounds.
2. Pounds of ice capacity is based on R-717. For other refrigerants, consult your BAC Representative.
3. Dimensions showing location of connections are approximate and should not be used for prefabrication of connecting piping.
4. Dimension is installed height. Coils are capped for shipping and storage. Add 3 inches for shipping height.
5. Refrigerant charge listed is operating charge for gravity flooded system at 15°F (-9°C). For other feed systems, consult your BAC Representative.
6. ICE CHILLER® Thermal Storage Units should be continuously supported on a flat level surface.

NOMINAL 8' AND 10' WIDE UNITS:
MODELS TSU-190E TO TSU-505E AND TSU-220F TO TSU-580F



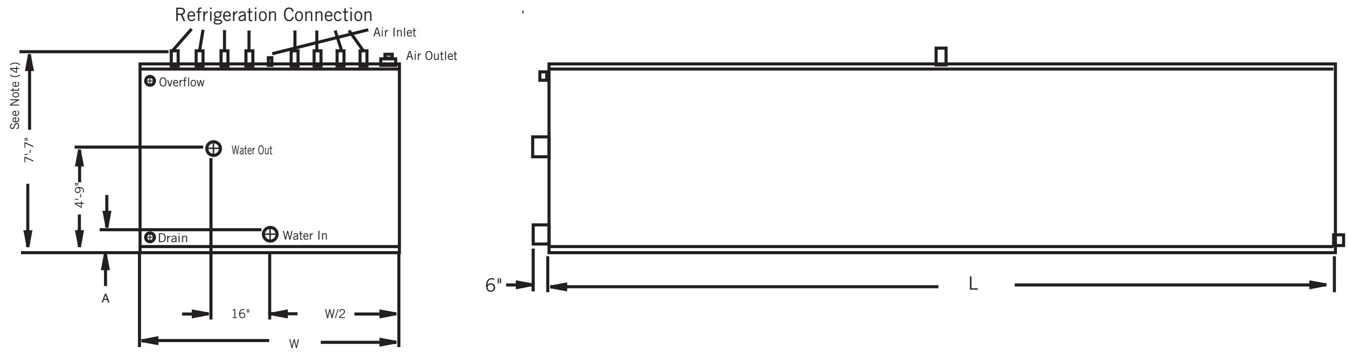
*18" On TSU-190E-365E; TSU-220F-420F
*16" On TSU-290E-505E; TSU-330F-580F

Model Number	LBS of Ice[2]		Approx. Shipping Weight (lbs)	Approx. Operating Weight (lbs)	Air Pump (HP)	Water Volume (gal)	Pull Down Volume (gal)	Coil Volume (ft^3)	R-717 Charge (lbs)[5]	Water Conn. In/Out	W	L	A
	Gravity Flooded	Pump Recirculated											
E Series													
TSU-190E	14,410	15,580	7,670	36,200	3	3,300	420	15	410	4"	7'-10 1/2"	10'-1"	5"
TSU-230E	17,580	18,910	8,740	43,200	3	4,000	510	17	465	4"	7'-10 1/2"	12'-1"	5"
TSU-280E	20,910	22,490	9,700	50,200	3	4,700	600	19	515	4"	7'-10 1/2"	14'-1"	5"
TSU-320E	24,240	25,910	11,120	57,700	3	5,400	700	22	600	4"	7'-10 1/2"	16'-0"	5"
TSU-365E	27,570	29,240	12,100	64,500	3	6,100	800	24	650	6"	7'-10 1/2"	18'-0"	6"
TSU-290E	21,740	23,490	9,950	53,400	3	5,040	640	21	570	6"	9'-9 3/8"	12'-1"	6"
TSU-345E	25,820	27,820	11,200	62,000	3	5,920	760	23	625	6"	9'-9 3/8"	14'-1"	6"
TSU-395E	29,900	32,070	12,900	71,300	3	6,800	860	26	705	6"	9'-9 3/8"	16'-0"	6"
TSU-450E	33,990	36,150	14,050	80,000	3	7,080	980	29	790	6"	9'-9 3/8"	18'-0"	6"
TSU-505E	37,980	40,070	14,700	88,600	3	8,550	1090	32	870	6"	9'-9 3/8"	20'-0"	6"
F Series													
TSU-220F	16,410	17,660	8,040	36,500	3	3,290	60	16	435	4"	7'-10 1/2"	10'-1"	5"
TSU-265F	20,240	21,490	9,150	43,600	3	3,990	70	19	515	4"	7'-10 1/2"	12'-1"	5"
TSU-320F	23,990	25,660	10,180	50,600	3	4,680	90	21	570	4"	7'-10 1/2"	14'-1"	5"
TSU-370F	27,660	29,400	11,700	58,100	3	5,380	100	24	650	4"	7'-10 1/2"	16'-0"	5"
TSU-420F	31,400	33,240	12,730	65,100	3	6,070	110	26	705	6"	7'-10 1/2"	18'-0"	6"
TSU-330F	24,990	26,820	10,460	53,900	3	5,020	95	23	625	6"	9'-9 3/8"	12'-1"	6"
TSU-395F	29,650	31,740	11,780	62,510	3	5,890	110	26	705	6"	9'-9 3/8"	14'-1"	6"
TSU-455F	34,150	36,240	13,430	71,800	3	6,770	130	29	790	6"	9'-9 3/8"	16'-0"	6"
TSU-515F	38,820	40,980	14,650	80,500	3	7,640	140	32	870	6"	9'-9 3/8"	18'-0"	6"
TSU-580F	43,480	45,570	15,370	89,200	3	8,520	160	35	950	6"	9'-9 3/8"	20'-0"	6"

NOTE: See notes on previous page.

TSU (E, F & G) Engineering Data

NOMINAL 10' WIDE UNITS (CONTINUED): MODELS TSU-590E TO TSU-1080E AND TSU-675F TO TSU-1230F

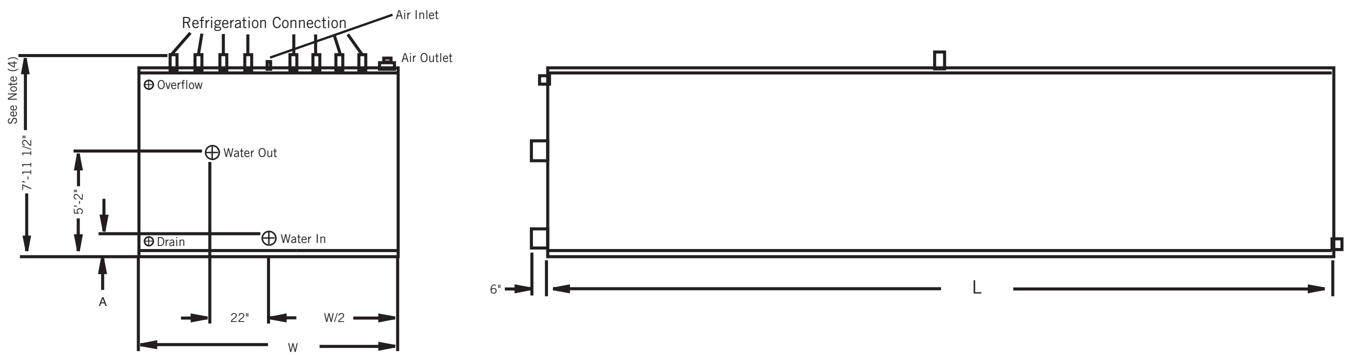


Model Number	LBS of Ice[2]		Approx. Shipping Weight (lbs)	Approx. Operating Weight (lbs)	Air Pump (HP)	Water Volume (gal)	Pull Down Volume (gal)	Coil Volume (ft³)	R-717 Charge (lbs)[5]	Water Conn. In/Out	W	L	A
	Gravity Flooded	Pump Recirculated											
E Series													
TSU-590E	44,650	48,150	18,200	106,900	3	10,240	1,320	42	1,140	6"	9'-9 3/8"	23'-11"	6"
TSU-700E	52,560	56,560	20,820	124,500	3	12,030	1,540	47	1,275	6"	9'-9 3/8"	27'-11"	6"
TSU-810E	60,730	64,890	24,300	144,400	5	13,790	1,760	53	1,440	8"	9'-9 3/8"	31'-10"	7"
TSU-910E	68,890	73,220	26,600	160,200	5	15,540	1,990	58	1,575	8"	9'-9 3/8"	35'-10"	7"
TSU-1080E	80,630	85,130	30,060	186,200	5	18,180	2,330	67	1,820	8"	9'-9 3/8"	41'-9"	7"
F Series													
TSU-675F	51,150	54,980	19,240	107,900	3	10,200	190	46	1,250	6"	9'-9 3/8"	23'-11"	6"
TSU-800F	60,140	64,220	21,960	125,600	3	11,980	230	52	1,410	6"	9'-9 3/8"	27'-11"	6"
TSU-920F	69,470	73,800	25,380	143,700	5	13,700	260	59	1,600	8"	9'-9 3/8"	31'-10"	7"
TSU-1040F	78,891	83,300	27,820	161,300	5	15,480	290	65	1,765	8"	9'-9 3/8"	35'-10"	7"
TSU-1230F	92,460	96,130	31,460	187,500	5	18,100	340	74	2,010	8"	9'-9 3/8"	41'-9"	7"

NOTES:

1. All dimensions are in feet and inches. Weights are in pounds.
2. Pounds of ice capacity is based on R-717. For other refrigerants, consult your BAC Representative.
3. Dimensions showing location of connections are approximate and should not be used for prefabrication of connecting piping.
4. Dimension is installed height. Coils are capped for shipping and storage. Add 3 inches for shipping height.
5. Refrigerant charge listed is operating charge for gravity flooded system at 15°F (-9°C). For other feed systems, consult your BAC Representative.
6. ICE CHILLER® Thermal Storage Units should be continuously supported on a flat level surface.

NOMINAL 12' WIDE UNITS:
MODELS TSU-840F TO TSU-1520F AND TSU-940G TO TSU-1710G



Model Number	LBS of Ice[2]		Approx. Shipping Weight (lbs)	Approx. Operating Weight (lbs)	Air Pump (HP)	Water Volume (gal)	Pull Down Volume (gal)	Coil Volume (ft^3)	R-717 Charge (lbs)[5]	Water Conn. In/Out	W	L	A
	Gravity Flooded	Pump Recirculated											
F Series													
TSU-840F	62,980	68,310	24,120	146,500	5	14,240	1,800	55	1,490	8"	11'-9"	23'-11"	7"
TSU-990F	74,470	80,470	26,900	170,000	5	16,650	2,100	63	1,710	8"	11'-9"	27'-11"	7"
TSU-1140F	85,880	92,960	31,460	200,600	5	19,080	2,320	71	1,925	8"	11'-9"	31'-10"	7"
TSU-1290F	97,380	105,210	34,340	218,800	5	21,500	2,710	78	2,115	8"	11'-9"	35'-10"	7"
TSU-1520F	114,540	123,280	38,660	254,400	5	25,150	2,900	90	2,440	8"	11'-9"	41'-9"	7"
G Series													
TSU-940G	70,890	75,970	25,440	147,700	5	13,960	280	61	1,655	8"	11'-9"	23'-11"	7"
TSU-1110G	83,880	89,630	28,340	171,400	5	16,350	330	70	1,900	8"	11'-9"	27'-11"	7"
TSU-1280G	96,880	102,380	33,220	196,900	5	18,730	380	79	2,145	8"	11'-9"	31'-10"	7"
TSU-1450G	109,540	114,790	36,260	220,600	5	21,110	420	87	2,360	8"	11'-9"	35'-10"	7"
TSU-1710G	129,120	132,700	40,820	256,400	5	24,690	490	100	2,710	8"	11'-9"	41'-9"	7"

NOTES:

1. All dimensions are in feet and inches. Weights are in pounds.
2. Pounds of Ice Capacity is based on R-717. For other refrigerants, consult your BAC Representative.
3. Dimensions showing location of connections are approximate and should not be used for prefabrication of connecting piping.
4. Dimension is installed height. Coils are capped for shipping and storage. Add 3 inches for shipping height.
5. Refrigerant charge listed is operating charge for gravity flooded system at 15°F (-9°C). For other feed systems, consult your BAC Representative.
6. ICE CHILLER® Thermal Storage Units should be continuously supported on a flat level surface.

Engineering Considerations – Refrigeration

Suitable For: Industrial Refrigeration, Process Cooling, and Batch Cooling

For industrial applications, stored cooling using ICE CHILLER® Thermal Storage Units provides many opportunities for savings: smaller compressors and likewise smaller system components and electrical equipment; shifting or leveling of energy usage peaks; and efficient use of equipment. Also, since ice storage systems are sized to operate primarily at full capacity, compressor wear from capacity adjustment is minimized, providing maintenance savings over the life of the compressor. Stored cooling from ICE CHILLER Thermal Storage Units supplies consistently low temperature water, making it appropriate for daily and/or infrequent cooling loads in many industrial processes such as:

- Bakeries
- Dairies
- Breweries, Wineries, Distilleries
- Chemical/Plastics Manufacturers
- Laboratories
- Food Product Cooling
- Bottling Process
- Vegetable/Fruit Cooling

PRINCIPLE OF OPERATION

The basic ice storage system includes an ICE CHILLER Thermal Storage Unit, a refrigeration system, and ice water pump as shown in **Figure 10**.

When no cooling load exists, the refrigeration system operates to build ice on the outside surface of the coil. This refrigeration effect is provided by feeding refrigerant directly into the coil. To increase the heat transfer during the ice build cycle the water is agitated by air bubbles from a low pressure air distribution system beneath the coil. When the ice has reached design thickness, BAC's exclusive ICE-LOGIC™ Ice Thickness Controller sends a signal to turn off the refrigeration system.

When chilled water is required for cooling, the ice water pump is started, and the meltout cycle begins. Warm water returning from the load circulates through the ICE CHILLER Thermal Storage Unit and is cooled by direct contact with the melting ice. During this cycle, the tank water is agitated to provide more uniform ice melting and a constant supply water temperature of 34°F (1˚C) to 36°F (2˚C).

For a closed chilled water loop, see **Figure 11**. With this system, warm return water from the load is pumped through a heat exchanger and cooled by the ice water circuit from the ICE CHILLER Thermal Storage Unit.

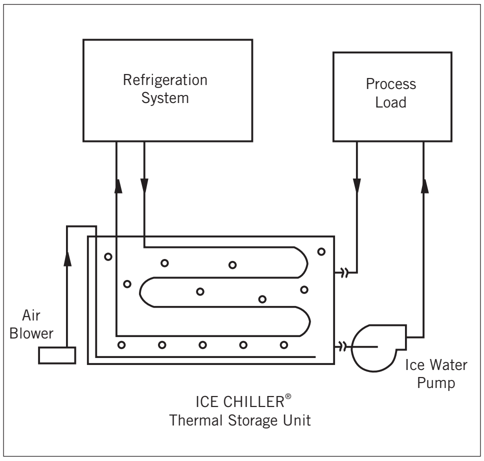


Figure 10

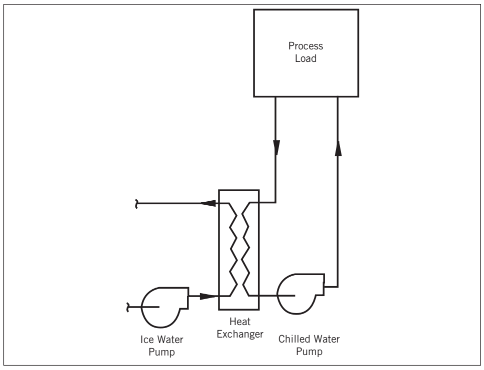


Figure 11

Energy Efficient Design

The ICE CHILLER® Thermal Storage Unit coils are designed for efficient energy use in building ice and constant leaving water temperatures during the meltout cycle.

Compared to traditional ice builders used in the past for industrial refrigeration, the ICE CHILLER Thermal Storage Unit design with its smaller diameter coil circuits and thinner ice (**Figure 12**) results in more evaporator surface per ton-hour of latent storage. Ice builds to a thin 2.0 inches, which results in more than a 16% gain in refrigeration system efficiency by permitting compressor operation at higher suction pressures.

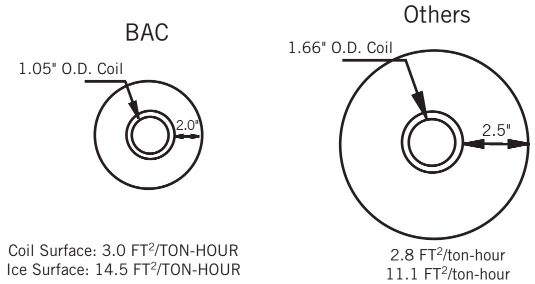


Figure 12

The ICE CHILLER Thermal Storage Unit is specifically designed to provide consistent 34- 36°F supply water temperatures throughout the melt cycle. Two keys to maintaining this consistently low temperature are an extensive ice surface area and direct contact of the water to be cooled with the ice. As shown in **Figure 12**, the unique BAC coil design provides over 30% more ice surface than traditional designs. This provides a greater surface area for the warm return water to come into direct contact, making consistent cold temperatures available throughout the entire melt cycle.

The ICE CHILLER Thermal Storage Unit is designed for efficient operation with either of two liquid refrigerant feed systems: gravity flooded with surge drum or pumped recirculation. With either arrangement, liquid refrigerant is supplied to the coils at a rate several times greater than that required to satisfy the load. This excess flow rate thoroughly wets the entire internal surface of the coil, assuring high heat transfer coefficients throughout to efficiently utilize the entire coil surface for ice building.

Engineering Considerations – Refrigeration

System Design Flexibility

The system design involving an ICE CHILLER® Thermal Storage Unit can range from full storage to partial storage of the cooling load requirements.

- **Full Storage** – With full storage, the ICE CHILLER Thermal Storage Unit generates and stores ice to handle the entire cooling load. The refrigeration system operates to build the ice only during no-load periods when utility rates are usually lowest. This design offers the maximum energy cost savings, but requires the largest ice storage capacity and refrigeration system.
- **Partial Storage** – A partial storage system builds ice during no-load periods as with the full storage system. However, the refrigeration system continues to operate during the cooling load period. The compressor operation supplements the stored cooling capacity of the ICE CHILLER Thermal Storage Unit to satisfy the cooling requirements. Since a portion of the cooling requirement is supplied by the refrigeration system, a partial storage system will require less storage capacity.
- **Parallel Chilled Water Evaporator** – The most common type of partial ice storage is the parallel evaporator system. During the melt cycle, cooling is provided by the refrigeration system to a separate evaporator for direct water chilling. By using a separate evaporator, the refrigeration system gains system efficiency from operation at higher suction pressures.

  The refrigeration system will operate continuously during full design load. At less than full load the compressor operates only as needed to supplement the ICE CHILLER Thermal Storage Unit. When the load is less than 50% of design, this system can operate in the full storage mode. Systems which often operate at part load can benefit most from a partial system with equipment sizes typically over 50% smaller than required for full storage. For additional information on ICE CHILLER Thermal Storage Units and their system design options consult your BAC Representative.
- **System Load** – The system load is the amount of cooling capacity that must be generated and stored, expressed in ton-hours or Btu. (1 ton-hour = 12,000 Btu = 83.3 pounds of ice). This load is equal to the area under the typical system load profile curve **(Figure 13).**

Thermal Storage Unit Selection

Full Storage

1. From the system load profile (**Figure 13**) establish the required system cooling capacity in ton-hours. This is the ton-hours of storage required.
2. Determine the build time, which is the number of hours with no load that is available for ice building. If less than ten (10) hours, consult your BAC Representative.
3. For a gravity flooded ammonia feed system, continue the selection with the gravity flooded procedure on **pages G30** and **G31**. For a pump recirculated ammonia feed system, continue the selection with the pump recirculated procedure on **pages G31** and **G32**.

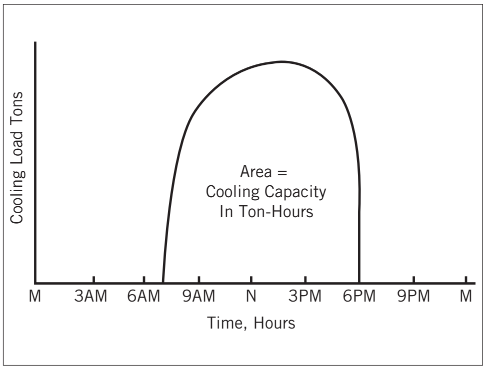


Figure 13

Parallel Chilled Water Evaporator Partial Storage

1. From the system load profile (**Figure 13**), establish the required system cooling capacity in ton-hours and the number of hours this cooling is needed.
2. Determine the cooling capacity in tons of the compressor operating with the parallel evaporator (**Figure 14**) during the cooling load hours established in Step 1.
3. Multiply the cooling capacity of the compressor operating with parallel evaporator found in Step 2 times the number of cooling load hours found in Step 1. This gives the capacity in ton-hours that will be handled by direct refrigeration during the cooling period.
4. Subtract the direct cooling ton-hours found in Step 3 from the total system cooling capacity found in Step 1. This is the storage capacity in ton-hours that are required in ice storage.
5. Determine the build time, which is the number of hours with the compressor dedicated to ice building. If less than ten hours, consult your local BAC Representative.
6. For gravity flooded ammonia feed system, continue the selection with the gravity procedure on **pages G30** and **G31**. For a pump recirculated ammonia feed system, continue the selection with the pump recirculated procedure on **pages G31** and **G32**.

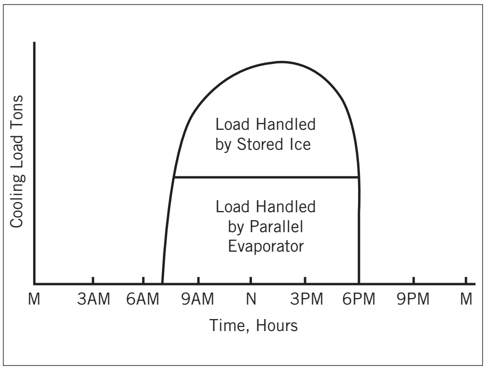


Figure 14

Unit Selection - Ammonia

SELECTION PROCEDURE – GRAVITY FLOODED

1. Enter **Table 2** and read down the base ton-hours column to the capacity which meets or exceeds the ton-hours of storage required. Select either an E, F, or G series unit. (Units are grouped by tank width in **Table 2**. Refer to **pages G22** thru **G25** for unit dimensions.)
2. Read the selected unit from the model number column on the left.
3. Calculate the Storage Factor for the selected unit.

$$\frac{\text{Base Ton-Hours}}{\text{Ton-Hours of Storage Required}} = \text{Storage Factor}$$

4. Using the Storage Factor from Step 3 and the available build time, enter **Table 3** to find the design evaporator temperature.
5. Determine the design compressor capacity in tons.

$$\frac{\text{Ton-Hours of Storage Required}}{\text{Build Time (hrs)}} = \text{Compressor Tons}$$

6. Using the design conditions from Steps 4 and 5, select a compressor. (Note: The evaporator temperature must be adjusted for the system suction line losses to arrive at the compressor saturated suction temperature.)
7. Once the compressor has been selected, use the compressor manufacturer's heat rejection data to size a BAC Evaporative Condenser or Cooling Tower.

EXAMPLE: Gravity Flooded Ammonia

Given: 16,700 lbs ice required storage capacity, 14 hours available build time

To get ton-hours of storage required:

$$\frac{\text{16,700 lbs ice required storage capacity}}{\text{83.3 lbs ice per Ton-Hour}} = \text{201 Ton-Hours}$$

1. Enter the base ton-hours column of **Table 2** and find 211 ton-hours, which is the smallest value that meets or exceeds the 201 ton-hours of storage required.
2. Read to the left to find the selected model number, in this case a TSU-230E.
3. Calculate the Storage Factor.

$$\frac{\text{211 Ton-Hours of Storage Required}}{\text{201 Ton-Hours of Storage Required}} = 1.05$$

4. Using the Storage Factor of 1.05 from Step 3 and the build time of 14 hours, enter **Table 3** to find the design evaporator temperature of 19.9°F.
5. Calculate the design compressor capacity.

$$\frac{\text{201 Ton-Hours of Storage Required}}{\text{14 Hours of Build Time}} = \text{14.4 Tons}$$

6. Based on the design evaporator conditions of 14.4 tons at a 19.9°F evaporator temperature (17.9°F saturated suction temperature, with 2.0°F estimated suction line losses), select an ammonia refrigerant compressor.
7. Select a BAC Evaporative Condenser or Cooling Tower to match the compressor manufacturer's heat rejection requirements.

APPLICATION NOTES:

1. To use the selection procedures, the ton-hours of storage capacity required and the available build time must first be known. For guidance on estimating these values refer to the TSU selection on **page G29** or contact your local BAC Representative.
2. The evaporator temperatures for each build time are "average" values. During the build cycle, the temperature will initially be about 8°F (-13˚C) above the "average" and gradually drop through the cycle to about 4°F (-15˚C) below the "average" when full ice is reached. Throughout the cycle the refrigeration system should be allowed to run fully loaded. Reciprocating and rotary screw compressors are suitable for this duty. If in doubt about the use of a particular compressor, review the application with the compressor manufacturer.
3. The capacities of all BAC ICE CHILLER® Thermal Storage Units are based on latent storage (ice) only. The temperature of the water supplied from the storage tank for most system designs will be 34°(-1˚C) - 36°F (-2˚C) throughout the latent storage discharge (melt) cycle. For specific system design requirements, contact your local BAC Representative.
4. For selections based on other refrigerants, contact your local BAC Representative.
5. These procedures assume that no system cooling load occurs while ice is being formed. For ICE CHILLER Thermal Storage Unit selections involving systems with continuous cooling loads consult your local BAC Representative.

Table 2. Base Storage Capacity (ton-hours) For Gravity Flooded Ammonia Feed[1]

TSUE-Series Units		F-Series Units		F-Series Units	
Model Number	**Base Ton-Hrs**	**Model Number**	**Base Ton-Hrs**	**Model Number**	**Base Ton-Hrs**
TSU-125E	112	**TSU-145F**	128	**TSU-840F**	756
TSU-155E	137	**TSU-175F**	157	**TSU-990F**	894
TSU-180E	163	**TSU-205F**	186	**TSU-1140F**	1,031
TSU-210E	188	**TSU-240F**	215	**TSU-1290F**	1,169
TSU-235E	214	**TSU-270F**	244	**TSU-1520F**	1,375
TSU-190E	173	**TSU-220F**	197		
TSU-230E	211	**TSU-265F**	243		
TSU-280E	251	**TSU-320F**	288		
TSU-320E	291	**TSU-370F**	332		
TSU-365E	331	**TSU-420F**	377		
TSU-290E	261	**TSU-330F**	300		
TSU-345E	310	**TSU-395F**	356		
TSU-395E	359	**TSU-455F**	410		
TSU-450E	408	**TSU-515F**	466		
TSU-505E	456	**TSU-580F**	522		
TSU-590E	536	**TSU-675F**	614		
TSU-700E	631	**TSU-800F**	722		
TSU-810E	729	**TSU-920F**	834		
TSU-910E	827	**TSU-1040F**	947		
TSU-1080E	968	**TSU-1230F**	1,110		

G-Series Units	
Model Number	**Base Ton-Hrs**
TSU-940G	851
TSU-1110G	1,007
TSU-1280G	1,163
TSU-1450G	1,315
TSU-1710G	1,550

Table 3. Design Evaporator Temperature (°F) for Gravity Flooded Ammonia Feed[1]

Storage Factor	Build Time (hrs)				
	10	**11**	**12**	**13**	**14**
1.00	14.3	15.7	17.2	18.3	19.4
1.05	15.6	16.8	18.1	19.0	19.9
1.10	16.5	17.7	18.9	19.7	20.5
1.15	17.4	18.5	19.6	20.3	21.1
1.20	18.1	19.1	20.2	20.9	21.7
1.25	18.8	19.7	20.7	21.4	22.1
1.30	19.4	20.3	21.2	21.9	22.6

NOTE:

1. Interpolation between values is permitted, but extrapolation of values is not.

SELECTION PROCEDURE – PUMP RECIRCULATED

1. Enter **Table 4** and read down the base ton-hours column to the capacity which meets or exceeds the ton-hours of storage required. Select either an E, F, or G Series unit. (Units are grouped by tank width in **Table 4**. Refer to **pages G22** thru **G25** for unit dimensions.
2. Read the selected unit from the model number column on the left.
3. Calculate the Storage Factor for the selected unit.

$$\frac{\text{Base Ton-Hours}}{\text{Ton-Hours of Storage Required}} = \text{Storage Factor}$$

4. Using the Storage Factor from Step 3 and the available build time, enter **Table 5** to find the design evaporator temperature.
5. Determine the design compressor capacity in tons.

$$\frac{\text{Ton-Hours of Storage Required}}{\text{Build Time (hrs)}} = \text{Compressor Tons}$$

6. Using the design conditions from Steps 4 and 5, select a compressor. Note: The evaporator temperature must be adjusted for the system suction line losses to arrive at the compressor saturated suction temperature.
7. Once the compressor has been selected, use the compressor manufacturer's heat rejection data to size a BAC Evaporative Condenser or Cooling Tower.

EXAMPLE: Pump Recirculated Ammonia

GIVEN: 700 ton-hours required storage, 11 hours available build time

1. Enter the base ton-hours column of **Table 4** and find 771 ton-hours, which is the smallest value that meets or exceeds the 700 ton-hours of storage required.
2. Read to the left to find the selected model number, in this case a TSU-800F.
3. Calculate the Storage Factor.
4. Using the Storage Factor of 1.10 from Step 3 and the build time of 11 hours, enter **Table 5** to find the design evaporator temperature of 17.7 °F.

$$\frac{\text{771 Base Ton-Hour}}{\text{700 Ton-Hours of Storage Required}} = 1.10$$

5. Calculate the design compressor capacity.

$$\frac{\text{700 Ton-Hours of Storage Required}}{\text{11 Hours Build Time}} = 63.6 \text{ Tons}$$

6. Based on the design evaporator conditions of 63.6 tons at a 17.7 °F evaporator temperature (15.7 °F saturated suction temperature, with 2.0 °F estimated suction line losses), select an ammonia refrigerant compressor.
7. Select a BAC Evaporative Condenser or Cooling Tower to match the compressor manufacturer's heat rejection requirements.

Unit Selection - Ammonia

Table 4.Base Storage Capacity (ton-hours) For Pump Recirculated Ammonia Feed[1]

E Series Units		F-Series Units		F-Series Units	
Model Number	Base Ton-Hours	Model Number	Base Ton-Hours	Model Number	Base Ton-Hours
TSU-125E	121	**TSU-145F**	138	**TSU-840F**	820
TSU-155E	147	**TSU-175F**	169	**TSU-990F**	966
TSU-180E	175	**TSU-205F**	199	**TSU-1140F**	1,116
TSU-210E	201	**TSU-240F**	228	**TSU-1290F**	1,263
TSU-235E	227	**TSU-270F**	258	**TSU-1520F**	1,480
TSU-190E	187	**TSU-220F**	212		
TSU-230E	227	**TSU-265F**	258	G-Series Units	
TSU-280E	270	**TSU-320F**	308	Model Number	Base Ton-Hours
TSU-320E	311	**TSU-370F**	353		
TSU-365E	351	**TSU-420F**	399		
TSU-290E	282	**TSU-330F**	322	**TSU-940G**	912
TSU-345E	334	**TSU-395F**	381	**TSU-1110G**	1,076
TSU-395E	385	**TSU-455F**	435	**TSU-1280G**	1,229
TSU-450E	434	**TSU-515F**	492	**TSU-1450G**	1,378
TSU-505E	481	**TSU-580F**	547	**TSU-1710G**	1,593
TSU-590E	578	**TSU-675F**	660		
TSU-700E	679	**TSU-800F**	771		
TSU-810E	779	**TSU-920F**	886		
TSU-910E	879	**TSU-1040F**	1,000		
TSU-1080E	1,022	**TSU-1230F**	1,154		

Table 5. Design Evaporator Temperature (°F) for Pump Recirculated Ammonia Feed[1]

Storage Factor	Build Time (hrs)				
	10	11	12	13	14
1.00	14.3	15.7	17.1	18.1	19.1
1.05	15.5	16.8	18.1	19.0	20.0
1.10	16.5	17.7	19.0	19.9	20.8
1.15	17.4	18.5	19.7	20.5	21.4
1.20	18.3	19.3	20.4	21.2	22.0
1.25	19.0	20.0	21.0	21.7	22.5
1.30	19.7	20.6	21.6	22.3	23.0

NOTE:

1. Interpolation between values is permitted, but extrapolation of values is not.

Custom Coils

When space is limited and a fully customized thermal storage solution is desired, BAC manufactures custom ice thermal storage coils that will meet project specific requirements. BAC has done extensive research and testing on the build and melt characteristics of ice storage. This research and testing has resulted in selection capabilities unmatched by any other company in the industry.

Plaza Robles Before

Plaza Robles After

MINIMAL SPACING REQUIREMENTS

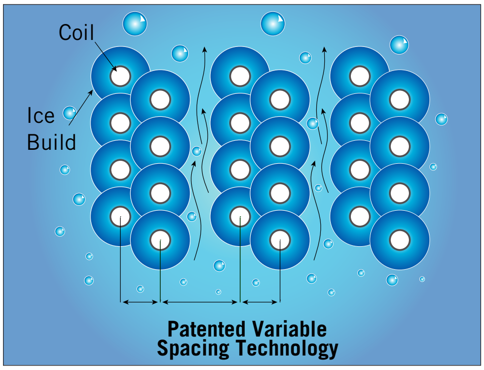
BAC Ice Thermal Storage Coils are designed to be stacked in custom built tanks. Each coil is assembled in a durable structural steel frame constructed to support the weight of the coil stack with a full ice build. Concrete tanks can be built below ground and buried. The above ground space can then be utilized for a multitude of purposes including parking lots, playgrounds, and landscaping.

CUSTOM COIL SELECTION

BAC utilizes hour-by-hour project specific temperature and load profile predictions for project selections. Many design factors are taken into consideration including, the physical space available, load profile, discharge temperatures, chiller capacity, and operating sequence. With both internal melt and external melt capability, BAC can provide a custom solution that best meets the project needs.

PATENTED VARIABLE SPACING TECHNOLOGY

BAC coils are designed with patented variable spacing technology and counter current glycol flows in adjacent circuits. This coil configuration maintains water flow around the coils, and is "self-correcting" to allow ice melt close to design limit without manual operator intervention. BAC coils are constructed with high heat transfer steel coil material that produces constant, low discharge temperatures, and maximum storage capacity. These low discharge temperatures increase the efficiency of the entire cooling system.



Patented Variable Spacing Technology

QUALITY DESIGN AND CONSTRUCTION

BAC is ISO 9001:2010 certified and all products undergo closely controlled manufacturing processes to ensure the highest quality design and standards. Ice thermal storage coils are constructed of continuous 1.05" O.D. (outside diameter) prime surface serpentine steel tubing, with no intermediate butt welds, and are leak tested at the factory up to 375 psig.

Proven Technology

BAC has successfully applied ice storage technology to thousands of installations worldwide, ranging in size from 90 to 125,000 ton-hours (0.3 to 441.3 MWh). BAC has the applications knowledge and experience to assist in the design, installation, and operation of any ice thermal storage system. Installations include office buildings, hospitals, manufacturing processes, schools, universities, sports arenas, produce storage facilities, hotels, and district cooling applications.

The ICE CHILLER® Product includes a variety of factory-assembled units. For large applications, where space is limited, ICE CHILLER Thermal Storage Coils are available for installation in customer supplied field-erected tanks.

BAC's Ice Thermal Storage product line offers system design flexibility. Ice thermal storage can be built using various refrigerants or glycols in steel coils to provide either chilled water or chilled glycol to the cooling system. This flexibility, combined with a broad range of application experiences, allows BAC to provide a cost effective product to meet your specific requirements.

TSUM Installation Catonsville Community College

BAC ICE Coil Installation Camden Yards

Johns Hopkins Applied Physics Lab

JOHNS HOPKINS APPLIED PHYSICS LAB

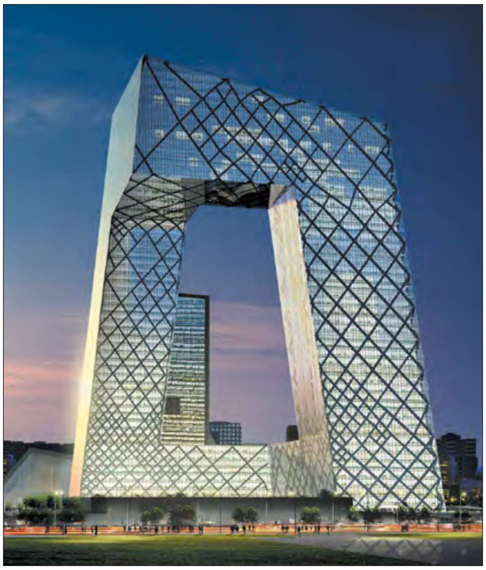
The Johns Hopkins University Applied Physics Lab in Laurel, MD installed 5,600 ton-hours (19.8 MWh) of ICE CHILLER Thermal Storage Coils in underground rectangular tanks to cool the Steven Mueller Building which houses offices, labs and clean rooms. Another 2,800 ton-hours (9.9 MWh) of ICE CHILLER Thermal Storage Coils were added to cool adjacent office and lab buildings. The ice thermal storage allowed the Applied Physics Lab to save over $150,000 per year on its electric bill.

CCTV

As one of the most important supporting facilities of the 2008 Beijing Olympic Games, the CCTV headquarters is the largest cultural facility and construction project ever approved by the Chinese State Development and Planning Commission. The two main buildings are a series of horizontal and vertical sections, establishing it as an architecturally one of a kind 'earthbound' structure rather than a traditional skyscraper. The CCTV tower allows China State Television to broadcast more than 200 channels. They were limited to only 16 channels in their previous facility.

As a significant building, it was essential that CCTV utilize an advanced and reliable air conditioning system. Television stations produce a great deal of heat from large light loads in studios and electronics equipment which also require lower than normal operating temperatures. Furthermore, a reliable emergency cooling system is essential in case of a power failure. BAC's Ice Thermal storage was the best solution, utilizing 24 sets of external-melt coils (TSC-950S) which provide 22,800 ton-hours of ice thermal storage capacity.

Using an external melt ice thermal storage system, BAC Ice Thermal Storage equipment supplies constant cold water at 34˚ F (1.1°C). A system like this reduces operation costs by supplying a constant source of cold water while also providing emergency cooling capacity. BAC Ice Thermal Storage is used during peak energy periods to reduce the electric demand and achieve the lowest operating cost. During mild weather, the ice thermal storage system can meet all of the peak hour cooling requirements, eliminating the need to run the chillers during peak demand periods.



CCTV

Emergency Cooling

VERIZON

Verizon, the provider of telephone service to a large portion of the east coast, uses an ICE CHILLER® Thermal Storage Unit to provide back-up cooling to one of its computer centers in Silver Spring, MD. If the chiller that provides cooling goes down for any reason, the system immediately switches over to the ice thermal storage system for cooling. The pump on the ice thermal storage system is on continuous power back-up with the computers. There is enough ice to provide cooling to the entire system for 30 minutes. This gives Verizon enough time to clear the alarm or get the back-up generator running and the chiller back on line.

Verizon

Proven Technology

STEVENSON UNIVERSITY

Modular ICE CHILLER® Thermal Storage Units were part of an expansion that doubled the size of this private college in Baltimore, MD. The new facilities added 135,700 ft^2 (12,620 m^2) of space to the campus and include a 400-seat auditorium and theater, gymnasium, student center, video center, computer classrooms, kitchen and administrative offices. The architect designed the new buildings with the intention that the structure be part of the visual space. This reduced the space allotted for the mechanical equipment. The engineer designed a low temperature air system that delivers 45°F (7°C) air temperature to VAV series fan powered boxes. The use of smaller piping and ductwork made it possible to avoid architectural changes that would affect the aesthetics of the design.

Stevenson University

FRIENDSHIP ANNEX 3 OFFICE BUILDING

The HVAC renovation of Friendship Annex (FANX) in Baltimore, MD received the "Outstanding Engineering Achievement of the Year Award" from the Engineering Society of Baltimore. Low temperature air distribution cools these renovated buildings. To meet federal guidelines, a comprehensive study of five alternate systems was made using life cycle costing. The analysis showed ice thermal storage with low temperature chilled water and low temperature air to be the most economical system. A total of 15,230 ton-hours (53.8 MWh) of ICE CHILLER Thermal Storage Units were installed for the two buildings.

Friendship Annex 3 Office Building

Retrofit

MERCHANDISE MART

Merchandise Mart in Chicago, Illinois, installed 26,400 ton-hours (93.2 MWh) of ICE CHILLER Thermal Storage Coils in a retrofit of the building's air-conditioning system. The Merchandise Mart was built in 1930. The increased air-conditioning load on the building from computers, other electrical equipment, and increased people density made the old system too small. With low temperature water, ice thermal storage allowed the retrofit of the air conditioning system to go ahead without replacing piping and ductwork. Increasing the temperature ranges on the piping and air distribution system allowed the Merchandise Mart to install an ice storage system at a lower first cost than a conventional system.

Merchandise Mart

District Cooling

NOVA SOUTHEASTERN UNIVERSITY

Located in steamy Fort Lauderdale, FL, NSU is one of the nation's largest independent universities. In 2009 NSU began phase 1 of its expansion project and set out to find a cooling solution for their growing campus. Their goal was to provide chilled water to the entire university from one central energy plant. In 2008, Hill York installed the first BAC ice tank, with a cooling capacity of 2,220 tons and 19,800 ton-hours of ice storage capacity.

In 2015, NSU completed phase 2 of the cooling system as the campus further expands, installing three more BAC ice thermal systems, total 79,200 ton-hours of ice storage capacity, making it one of the largest thermal energy storage systems in the United States.

The ice thermal storage system used at NSU is a sustainable alternative to traditional cooling that stores energy as ice during off-peak hours, allowing the system to take advantage of cleaner and more efficient energy sources.

To avoid the high cost of electricity during peak hours, the chillers at NSU are turned off during on-peak periods to reduce running cost. With ice melting providing the cooling needs on the campus, the plant is able to achieve running cost of less than $8/hour during peak hours.

NOVA Southeastern University

VEOLIA

Veolia Energy Baltimore Cooling has supplied chilled water and related HVAC building services to downtown Baltimore business corridor since 1996. Delivering more than 32,000 tons of cooling capacity and approximately 76,000 ton-hours of low temperature chilled water to cool 48 customers with more than 11.5 million square feet of conditioned space, the district cooling system is one of the largest ice thermal storage systems in the country. Customers served include university facilities, several Federal, State and City government facilities, public housing complexes, prestigious office buildings, healthcare facilities, and hotels in downtown and Inner Harbor East. Veolia's district cooling plant utilizes stacked BAC coils in both steel and concrete tanks. The flexibility and stackability of BAC ice coils allowed the cooling plant to overcome the limitations and site constraints of a congested downtown area.

Veolia

Proven Technology

Food Processing

ZIPPY'S RESTAURANT CENTRAL FACILITY

At Zippy's in Honolulu, HI, food is cooked in a central kitchen where it is cooled and packaged for use in local Zippy's restaurants. The FDA requires that the food in the cooking vessels be cooled to 45°F (7°C) in less than one hour to prevent contamination. The cooking vessels in the kitchen need varying amounts of cooling depending on the dish that is being prepared, and when it finishes its cooking cycle. Because of the varying cooling load from day to day and hour to hour and the need for a quick cool down period, standard chillers are not a good match for this application. Ice thermal storage with its variable capacity and low supply temperature is an excellent match for this process cooling application.

Zippy's

Power Generation

WOLVERINE POWER

Wolverine Power, located in central Michigan, is a generation and transmission electric cooperative. For a new generating plant with (2) 22-megawatt Rolls Royce turbines, Wolverine Power elected to use ice thermal storage for their turbine inlet air cooling. They installed 7,610 ton-hours (26.9 MWH) of ICE CHILLER® Thermal Storage Units to generate 40°F (4.4°C) chilled water, which provides 55°F (13°C) inlet air. The generating plant's ice storage capacity can be used over a 16-hour period as partial storage or over a 4-hour period as full storage, depending on the value of power on the open market. During peak summer time, the increased power capacity is worth up to $3,500 per hour in electricity sales.

Wolverine Power

Remote Sump Tanks

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BAC's RS Remote Sump Tanks can easily be added to cooling towers, closed circuit cooling towers, or evaporative condenser systems and are offered in a variety of sizes and materials. Remote sump tanks can eliminate other methods of freeze protection and are often installed indoors in a heated space to prevent freezing of the recirculating water during cold weather operation. Adding a remote sump tank can simplify water treatment for multiple cell installations and facilitate dry operation of closed circuit cooling towers and evaporative condensers by eliminating the need to drain the cold water basin when switching from wet to dry operation.

RS Remote Sump Tanks: For Water Treatment and Freeze Protection

Single Tank Capacity 94-1,390 US Gallons
Maximum Storage Volume

- Ideal for Freeze Protection
- Simplify Water Treatment
- Low Installed Cost
- Easy Maintenance
- Long Service Life

Benefits, Custom Features & Options

Benefits

LOW INSTALLED COST

- **SUPPORT STEEL** – All models mount directly on parallel I-beams.

EASY MAINTENANCE

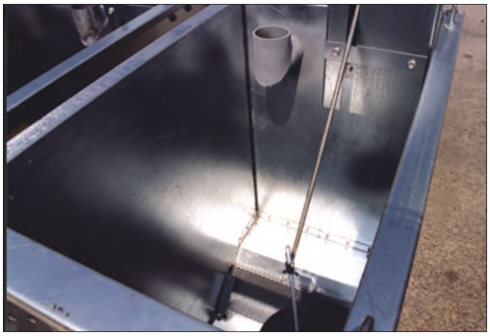
- **INTERNAL ACCESS** – The interior of the unit is easily accessible for adjusting the float valve, cleaning the strainer, or flushing the remote sump tank.

RELIABLE YEAR-ROUND OPERATION

- **FREEZE PROTECTION** – For reliable year-round operation, the remote sump tank offers freeze protection when installed indoors in a heated area, eliminating the need to install cold water basin heaters.

LONG SERVICE LIFE

- **MATERIALS OF CONSTRUCTION** – Available in galvanized steel or with a thermosetting hybrid polymer.



Internal Access for Easy Maintenance

Custom Features & Options

CONSTRUCTION OPTIONS

- **STANDARD CONSTRUCTION**
  G-235 hot-dip galvanized steel is the heaviest commercially available galvanized steel, universally recognized for its strength and corrosion resistance. To assure long-life, G-235 hot-dip galvanized steel is used as the standard material of construction for all units. All exposed cut edges are protected with a zinc-rich coating after fabrication to ensure the zinc rich corrosion barrier is maintained for all over protection. With proper maintenance and water treatment, G-235 galvanized steel products will provide an excellent service life under the operating conditions normally encountered in comfort cooling and industrial applications.

- **THERMOSETTING HYBRID POLYMER (OPTION)**
  A thermosetting hybrid polymer coating used to extend equipment life, is applied to select hot-dip galvanized steel components of the remote sump tank. The thermosetting hybrid polymer has been tested to withstand 6,000 hours in a 5% salt spray without blistering, chipping, or loss of adhesion.

HOT WELL/COLD WELL ARRANGEMENT (OPTION)

A water tight center baffle is provided, along with additional suction and drain connections and strainer, for separate storage of hot and cold water. This arrangement is provided with a single make-up assembly. The hot well/cold well arrangement is frequently used with highly variable loads to even out the load put on the evaporative cooling equipment.

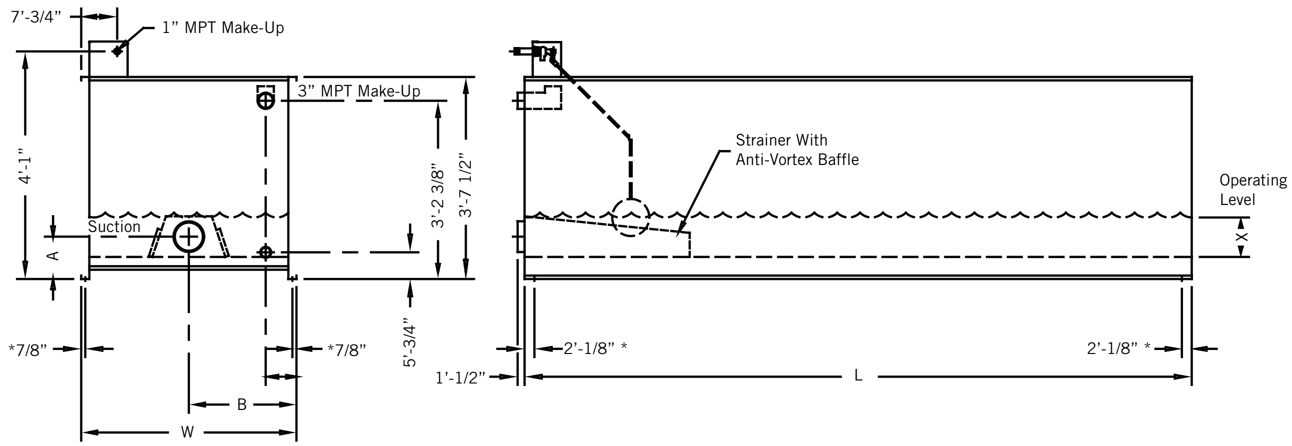
ELECTRIC WATER LEVEL CONTROL (OPTION)

BAC Electric Water Level Controls (EWLC) are state-of-the-art conductivity actuated, probe type liquid level controls. The hermetically sealed EWLC is engineered and manufactured specifically for use in evaporative cooling systems and are equipped with an error code LED which illuminates to indicate status, including when the water and/or probes are dirty. The EWLC option replaces the standard mechanical make-up valve. EWLC is recommended when more precise water level control is required, in areas that experience sub-freezing conditions, and where the incoming supply water pressure is outside the normal 15 to 50 psig pressure range of the standard mechanical make-up valve.

TANK COVERS (OPTION)

Covers with lifting handles are available.

Engineering Data



Model Number	Shipping Weights (lbs)	Maximum Weight (lbs)[1]	Maximum Storage Volume (gal)	"X" Minimum Operating Level[2]	Net Available Volume (gal)	Dimensions				Suction MPT
						W	L	A	B	
RS 94	240	1,070	94	8 1/2"	72	1'-11"	3'-1"	8"	1'	4"
RS 212	350	2,220	212	8 1/2"	163	3'-11"	3'-1"	8"	2'	4"
RS 335	470	3,410	335	8 1/2"	257	3'-11"	4'-7"	8"	2'	4"
RS 457	610	4,630	457	8 1/2"	351	3'-11"	6'-0"	10"	2'	6"
RS 702	800	6,970	702	8 1/2"	539	3'-11"	9'	10"	2'	6"
RS 946	1,030	9,340	946	8 1/2"	727	3'-11"	12'	10"	2'	6"
RS 1390	1,260	13,470	1,390	8 1/2"	1,068	5'-7"	12'	10"	2'-10"	6"

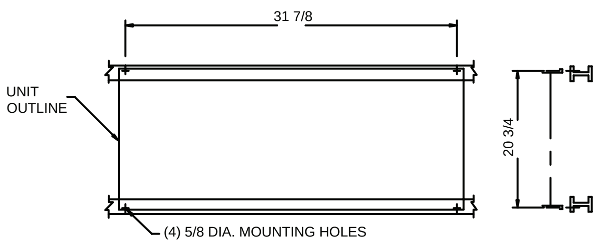
NOTES:

1. Maximum weight is for tank filled with water to spillout.
2. Minimum operating level "X" is measured from inside bottom of tank.

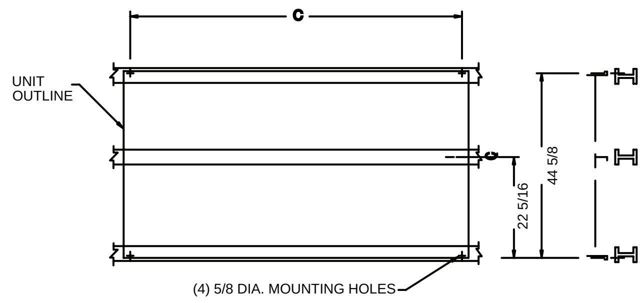
Do not use for construction. Refer to factory certified dimensions. This catalog includes data current at the time of publication, which should be reconfirmed at the time of purchase.

Structural Support

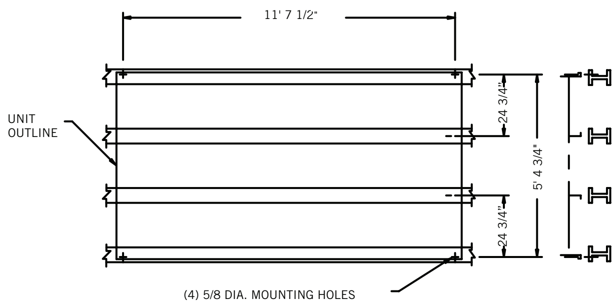
The recommended support arrangement for the RS Remote Sump Tank consists of parallel structural members running the full length of the unit, spaced as shown in the following drawings. In addition to providing adequate support, the members also serve to raise the unit above any solid foundation to assure access to the bottom of the unit. To support a RS Remote Sump Tank in an alternate support arrangement, consult your local BAC Representative.



RS-94



RS-212 thru 946



RS-1390

Model Number	C
RS 94	—
RS 212	2'-8"
RS 335	4'-2"
RS 457	5'-8"
RS 702	8'-8"
RS 946	11'-8"
RS 1390	—

NOTES:

1. Support members and anchor bolts shall be designed, furnished, and installed by others.
2. Design of support members and anchor bolts shall be in accordance with the strength and serviceability requirements of the applicable building code and project specifications.
3. Support members shall be level at the top.
4. Refer to the certified unit support drawing for loading and additional support requirements.

TECHNICAL RESOURCES

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Comparison of Heat Rejection Methods

Overview

Cooling systems utilize one of three primary methods for heat rejection in the cooling process: air cooling, water cooling, or adiabatic cooling. These methods are commonly used to service any number of applications including dehumidifying air, fluid cooling, and industrial applications.

Fundamental Methods

Air Cooled: A process by which air passes over a coil or channel containing fluid. Heat is transferred from the coil directly to the air.

Water Cooled: This process utilizes a spray system to pass water over coils or fill media to reject heat to the atmosphere through evaporation. The spray water itself or the fluid contained in the coil can then be used by a cooling system.

Adiabatic: This method is a two stage process that uses a combination of air and water to reject heat. Below a set temperature, the process will run dry. This is similar to an air cooled method where process fluid is run through a coil or micro channel with air flowing over it. When a peak temperature is reached, the air is pre-cooled by pulling it through a pad moistened with a small amount of water. This brings the air close to the ambient wet-bulb temperature, allowing for greater heat rejection when it is blown over the coil. Unlike a water cooled method, the water does not flow directly over the coil.

The Value of Efficiency

With higher performance and lower operating costs, water cooled methods offer the best long-term investment for any cooling system. Systems that utilize a water cooled heat rejection method are approximately 35% more energy efficient than their air cooled counterparts. Systems with adiabatic heat rejection operate with efficiencies mid-way between air and water cooled methods. While not attaining the same energy cost savings as water cooled technology, they do offer a better investment over air cooled technology, especially in locations where water availability is limited or where there is a large gap between the dry-bulb and wet-bulb.

The savings from energy efficient cooling methods will continue to grow as time moves forward. The global demand for energy is projected to increase nearly 50% between years 2011 and 2035.[1] For cooling systems this means the total cost of ownership will become more dependent upon their efficiency. Installation costs, even for systems that are initially more expensive, are quickly offset by highly efficient methods like water cooled technology, saving money in the long run.

NOTE:

1. Annual Energy Outlook (DOE/EIA -0383/2011).

In addition to direct energy costs, cooling system selection can be affected by many local and national entities that are becoming increasingly focused on energy savings and environmental responsibility. Standards such as ASHRAE 90.1, regulations such as California Title 24, and certifications such as LEED® are different facets of this movement, all of which recognize the growing need for responsible energy consumption. Methods of heat rejection that meet these needs are more likely to be compliant with codes, approved for job sites, and even qualify for incentives.

From project specification to daily operation, a cooling system's efficiency will affect all aspects of a project. To get the best value for system owners, the method of heat rejection should be carefully analyzed for the life span of the cooling system.

Installation Considerations

There are many factors that can influence the selection of a cooling system. Typically the size of the system, the required design conditions, the operating sound level, along with the aforementioned efficiency, and price of the system all play a major role during the decision making process. **Table 1** compares the three heat rejection methods against these criteria:

Criteria	Air Cooled	Water Cooled	Adiabatic
Heat Transfer Medium	Air	Water	Air and Water
Temperature Effects	Highly dependent on the ambient dry-bulb temperature, lower performance at higher temperatures	Codependency on wet-bulb temperatures offers high performance across temperatures ranges	Limited codependency on dry-bulb and wet-bulb temperatures provides a buffer for warm weather performance
Efficiency	Least	Best	Middle
Footprint	Largest	Smallest	Middle
Water Usage	None	High	Low
Sound	High	Low	Low
Total Cost of Ownership	High	Low	Middle
Benefits	No water usage	Highest energy efficiency, most flexible temperature options	Low maintenance and improved performance over air cooled methods
Challenges	Lowest efficiency, largest footprint per ton	Highest water usage	Limited capacity, lack of availability

Table 1. Comparison of Heat Rejection Methods

Comparison Summary

Traditional systems using air cooled heat rejection will meet design specifications when absolutely no water is available; however, these systems require the most space, largest operating budget, and maintain the highest levels of sound during operation. Adiabatic based cooling systems are a technological improvement to air cooled methods, providing a middle ground on efficiency, sound, total cost of ownership, and ability to operate with minimal water. Systems with water cooled heat rejection offer the best performance, smallest foot print, largest capacity, and most ideal operating considerations. For a customized recommendation for the best heat rejection solution to meet your cooling needs contact your local BAC Representative.

Comparison of Heat Rejection Methods

Cost Analysis: Air Cooled vs. Water Cooled

In the cooling industry there are two major technologies that dominate the marketplace: air cooled heat rejection and water cooled heat rejection. Other cooling methods exist, such as adiabatic technology, however their installations are limited and vary widely in performance based on the method of pre-cooling the air. As a result, the following analysis will only consider air-based and water-based chilled water cooling systems. The analysis will cover the costs for energy, water, water treatment, and equipment of each system. By comparing these values, the overall costs of ownership and advantages of each system can be determined.

Design Assumptions

In order to perform a detailed analysis, there are a number of assumptions that must be established. For a direct comparison, this example will consider two systems operating in identical environments, serving identical applications. The annual operating time for both systems is estimated at 4380 hours. Since the systems will not be operating at 100% load the entire time, this time is evaluated as the Integrated Part Load Value (IPLV), which accounts for a combination of loading conditions. The first system is equipped with a 500 ton water cooled, centrifugal chiller with a variable speed drive. The second system is a 500 ton air cooled rotary-screw water chiller. For each system, the following parameters will be used to determine their energy consumption:

Parameter	Water Cooled System	Air Cooled System
Chiller Efficiency [Full Load] (kW/ton)[1]	0.6	1.255
Chiller Efficiency [IPLV] (kW/ton)[1]	0.4	0.941
System Capacity (Tons)	500	500
IPLV Average Capacity (Tons)	290	290
Condenser Water Pump (HP)	30	—
Cooling Tower Fan (HP)	30	—
Hours of Operation (Integrated Part Load Value)	4,380	4,380

Energy Consumption

Energy usage and the corresponding costs have the largest overall impact on the cost of a cooling system. To calculate the energy consumption the following energy equations can be applied to the design data for each system:

Chiller Energy Usage = IPLV Efficiency * Average Capacity

Fan Energy Usage (kW) = Power (HP) * 0.7457 * IPLV Efficiency

Condenser Pump Energy Usage (kW) = Power (HP) * 0.7457

Annual Energy Consumption = Hours of Operation * $\sum$ Energy Usage

Peak Chiller Power = Full Load Efficiency * System Capacity

Peak Fan Power = Power (HP) * 0.7457

Peak Energy Demand =

(Peak Chiller Power + Peak Fan Power + Condenser Pump Energy Usage)

NOTES:

1. Minimum efficiency as required by ASHRAE 90.1-2010.

Applying these equations gives the following energy values for each system:

Parameter	Water Cooled System	Air Cooled System
Chiller Energy Usage (kW)	116	273
Condenser Pump Energy Usage (kW)	22	—
Fan Energy Usage (kW)	9	—
Annual Energy Consumption (kWh at 4,380 IPLV)	645,259	1,195,258
Peak Energy Demand (kW)	345	628

Electricity Costs

Electricity costs for each system depend upon the energy usage charge and demand charge. To calculate the costs, average utility rates as noted below are applied to the previously calculated energy values. The rates are in the mid-range for most of the national averages, however for individual projects the exact values will vary. In this case, the energy rate is calculated at $0.103/kWh, and the demand rate at $13.44/kW. These rates can be applied using the equations below:

Energy Usage Charge = Annual Energy Consumption * Energy Rate

Demand Charge = Demand Rate * Peak Energy Demand (kW)

This results in the following values:

	Water Cooled System	Air Cooled System
Energy Charge	$66,462	$123,112
Demand Charge	$4,633	$8,433
Total Annual Electricity Cost	**$71,095**	**$131,545**

By looking at the total electricity cost for each system, it can be observed that the water cooled system electrical operating cost is approximately 46% lower than its air cooled counterpart. This gives the water cooled system a significant advantage over the air cooled system with regards to the continuing electricity costs for each system. There are, however, other factors beyond energy consumption that influence a system's total operating cost.

Water Costs

Unlike an air cooled system, water cooled systems will incur annual water, sewage, and chemical treatment costs. These costs are best measured empirically, however they can be estimated from design parameters and operating conditions. For this example the costs for water, sewage, and chemical treatment are estimated for Baltimore, Maryland. As with the energy rates, the water costs for this area fall in the middle range of most national averages, however they will vary for specific installations.

Comparison of Heat Rejection Methods

For a system utilizing a cooling tower operating at a flow rate of 1500 USGPM, given a water supply charge of $2.90/1000 gal and sewage charge of $5.31/1000 gal, the associated water costs can be estimated as follows:

Water Parameter	Annual Cost
Annual Water Supply	$9,186
Annual Sewage	$4,047
Annual Chemical Treatment	$7,000
Annual Water Related Costs	$20,233

Total Annual Costs

The sum of water and energy related costs make up the bulk of the total operating cost for a cooling system. Due to their frequency and amount, these expenditures comprise the majority of the total cost of ownership throughout the lifetime of the system. Given a sufficient period of time, the system with a lower annual cost will provide greater savings during the lifecycle of the cooling system. In this case, it can be observed that the water cooled system offers approximately 31% savings on annual costs. This savings maintains the water cooled advantage identified in the total electricity costs. The exact annual totals for each system are as follows:

	Water Cooled System	Air Cooled System
Total Annual Cost:	**$91,328**	**$131,545**

Equipment and Installation Costs

Unlike energy and water costs, equipment and installation costs represent a single expenditure that only occurs at the beginning of the cooling system's life cycle. Systems utilizing air cooled technology often use fewer components and in this regard carry an installation advantage over water cooled systems. Estimated costs for equipment and installation of each system are listed below. These values have been collected from multiple sources and will vary for individual installations.

500 Ton Air Cooled Chiller System Costs	Equipment Cost	Installation Cost[2]
Air Cooled Chiller, 500 Ton	$171,500	$16,700

500 Ton Air Cooled Chiller System Costs

500 Ton Water Cooled Chiller System Costs	Equipment Cost	Installation Cost[2]
Water Cooled Centrifugal Chiller, 500 Ton	$125,000	$15,300
Axial Fan, Induced Draft, 500 Ton Cooling Tower	$46,800	$5,150
250 L.F. Chilled Water Piping	$6,875	$12,748
30 HP Condenser Pump	$6,550	$1,210
Mechanical Room Space	$22,400	
Total:	**$207,625**	**$34,408**

500 Ton Water Cooled Chiller System Costs

NOTE:

2. Installation cost does not include material cost associated with connecting the equipment to the system.

Total Cost Comparison

The total for any system will be a combination of an initial cost plus a recurring annual cost. Over the lifetime of a system the annual costs will constitute the majority of the total expenditures. Below are the total costs for both systems where the annual cost will occur every year of the cooling system's usable life:

500 Ton System	Water Cooled System	Air Cooled System
Equipment and Installation Cost	$242,033	$188,200
Total Annual Cost	$91,328	$131,545

Water Cooled Payback Period: 1.3 years

An important figure to consider when comparing these two systems is the cost difference payback period. This period is the time it will take for the total cost of the system with the higher initial cost to become equal in cost to the other system. In this example, it can be observed that the water cooled system has approximately $54,000 more in initial equipment and installation costs; however, this system incurs approximately $40,000 less in annual costs. After approximately 1.3 years the $54,000 gap will be eliminated through annual savings. After this time, the total costs for a water cooled system will offer significant savings over the air cooled system. Given that the reasonable life span of a water based cooling system is approximately 17 years, the total water cooled benefit is approximately $630,000; resulting in a clear financial advantage over the air cooled system.

Conclusion

Air cooled systems may offer lower initial costs, but they cannot compete in regards to the total cost of ownership except in locations with a combination of very low electricity costs and very high water costs. The benefits of water cooled systems are directly linked to their efficiency of operation. By consuming less electricity, these types of systems save end users money and energy over the lifetime of their cooling system. Furthermore, as global energy demands continue to rise, the cost for electricity will increase accordingly. As these changes happen, the cost of operation will become even more important, giving further advantage to water cooled systems.

The analysis presented here provides a valid basis for determining overall trends among the major contributors to cooling system costs. There are, however, additional aspects that can influence the cost of ownership. For example, air cooled systems generally operate at higher sound levels than water cooled systems. For comparable acoustical performance, an air cooled system would need to be equipped with low sound accessories. There are also operating environment considerations that should be taken into account. In coastal regions, air cooled equipment must be equipped with special coil coatings to ensure reliable operation. The additional cost of these accessories would increase the initial cost of the air cooled system and shorten the payback period of the water cooled system. Furthermore, since water cooled systems have a smaller footprint per ton, the overall space requirements and aesthetics of system components may very well factor into the choice of cooling products. For assistance with system selection and the specific benefits that a water cooled system can offer you, contact your local BAC Representative.

Wet-Bulb Temperature Selection

This section contains tables that are commonly used for the design and sizing of evaporative cooling equipment, reproduced from Chapter 14 of the 2013 ASHRAE Handbook-Fundamentals.

Overview

The data presented in the tables represents different climatic conditions throughout North America. Dry-bulb temperature data represents the sensible component of outdoor air, whereas wet-bulb temperature data represents the amount of moisture that the air can evaporate. Evaporative cooling equipment selection is based on wet-bulb temperature, as units rely on the process of evaporation to reject heat.

Columns in the table are organized to present dry-bulb and wet-bulb temperatures corresponding to 0.4%, 1% and 2% annual cumulative frequency of occurrence. Each temperature in a column represents the value that is exceeded by the indicated percentage of hours in a year (8,760). For instance, according to *Appendix: Design Conditions for Selected Locations* from the 2013 ASHRAE Handbook-Fundamentals, the wet-bulb temperature in Huntsville, Alabama will exceed 78.4ºF as shown in Evaporation WB/MCDB column on average 35 hours (0.4%) in any given year. As cooling systems must be designed to meet the peak cooling load, most comfort cooling and light industrial application designs are based on 0.4% annual cumulative frequency of occurrence.

APPENDIX: DESIGN CONDITIONS FOR SELECTED LOCATIONS

Meaning of acronyms:
DB: Dry bulb temperature, °F | *WB: Wet bulb temperature, °F* | *MCWB: Mean coincident wet bulb temperature, °F*
Lat: Latitude, ° | *DP: Dew point temperature, °F* | *MCDB: Mean coincident dry bulb temperature, °F*
Long: Longitude, ° | *HR: Humidity ratio, grains of moisture per lb of dry air* | *HDD and CDD 65: Annual heating and cooling degree-days, base 65°F, °F-day*
Elev: Elevation, ft | *WS: Wind speed, mph*

Station	Lat	Long	Elev	Heating DB		Cooling DB/MCWB						Evaporation WB/MCDB				Dehumidification DP/HR/MCDB						Extreme Annual WS			Heat./Cool. Degree-Days	
						0.4%		1%		2%		0.4%		1%		0.4%			1%							
				99.6%	99%	DB	MCWB	DB	MCWB	DB	MCWB	WB	MCDB	WB	MCDB	DP	HR	MCDB	DP	HR	MCDB	1%	2.5%	5%	HDD	CDD 65
United States of America																									*542 sites, 864 more on CD-ROM*	
Alabama																									*11 sites, 7 more on CD-ROM*	
AUBURN OPELIKA ROBE	32.62N	85.43W	778	23.5	27.6	93.9	74.3	91.4	74.2	90.2	73.9	78.0	88.4	77.0	87.2	75.1	135.7	81.9	73.5	128.4	80.4	17.6	15.5	12.9	2377	1953
BIRMINGHAM MUNI	33.56N	86.75W	630	20.5	24.8	95.5	74.9	93.0	74.5	90.9	74.3	78.4	88.5	77.5	87.6	75.9	138.7	82.6	74.8	133.3	81.7	18.4	16.4	14.5	2653	2014
CAIRNS AAF	31.28N	85.71W	302	26.6	30.0	96.2	76.9	94.2	76.5	92.2	76.1	81.1	89.4	79.8	88.3	79.1	152.8	84.4	77.4	144.3	82.8	16.9	14.3	12.4	1785	2471
DOTHAN RGNL	31.32N	85.45W	354	27.4	30.7	96.6	76.1	93.4	75.3	91.5	75.2	79.9	89.7	78.7	88.3	77.4	144.3	83.3	76.3	138.9	82.5	19.3	17.5	15.5	1743	2512
GADSDEN MUNI	33.97N	86.08W	568	18.5	21.5	93.5	74.6	91.3	74.5	90.0	74.3	78.1	89.1	77.1	88.0	74.9	133.6	83.6	73.3	126.5	82.1	16.7	14.2	12.3	3216	1586
HUNTSVILLE/MADISON	34.64N	86.79W	643	18.4	22.5	95.3	75.1	92.8	74.6	90.6	74.1	78.4	88.4	77.6	87.6	75.9	138.7	82.6	74.9	133.8	81.7	20.8	18.6	16.7	3093	1819
MAXWELL AFB	32.38N	86.36W	171	27.0	30.2	97.3	76.7	95.4	76.6	93.5	76.3	80.6	91.2	79.7	90.2	78.0	146.4	84.9	77.0	141.7	84.2	18.0	15.6	13.1	1898	2615
MOBILE/BATES FIELD	30.69N	88.25W	220	27.7	31.0	93.8	76.9	92.0	76.5	90.5	76.1	80.1	88.5	79.1	87.3	78.0	146.6	83.4	77.0	141.9	82.5	20.2	18.2	16.4	1652	2499
MONTGOMERY/DANNELLY	32.30N	86.39W	203	24.3	27.6	96.8	76.1	94.5	76.0	92.6	75.7	79.7	90.7	78.6	89.2	76.8	140.7	84.3	75.8	135.9	83.2	18.6	16.5	14.3	2149	2320
NORTHWEST ALABAMA R	34.75N	87.61W	561	19.1	23.1	96.5	75.3	93.4	74.9	91.2	74.6	78.7	89.7	77.8	88.6	75.7	137.1	83.2	74.9	133.4	82.3	18.8	16.8	14.7	3045	1876
TUSCALOOSA RGNL	33.21N	87.62W	187	21.9	26.2	97.0	76.0	94.3	75.9	92.3	75.6	79.5	90.8	78.5	89.3	76.8	140.6	83.3	75.5	134.3	82.7	17.2	14.8	12.9	2477	2163
Alaska																									*7 sites, 87 more on CD-ROM*	
FAIRBANKS INTL ARPT	64.82N	147.86W	453	-43.5	-38.3	81.3	61.0	78.3	60.0	74.8	58.6	63.2	76.9	61.6	74.2	58.4	74.1	65.4	56.6	69.4	64.3	17.2	14.9	12.3	13517	72
FT. RICHARDSON/BRYA	61.27N	149.65W	377	-19.6	-14.0	74.8	60.3	71.6	58.9	68.3	57.1	61.7	72.7	59.6	69.5	56.3	68.5	65.4	54.9	65.1	62.6	19.3	14.6	11.5	10677	5
ANCHORAGE/ELMENDORF	61.25N	149.79W	213	-15.4	-10.4	73.9	58.5	71.5	57.7	68.1	56.3	60.8	70.0	59.3	67.3	57.3	70.6	61.1	55.5	66.1	60.3	19.0	15.9	12.9	10313	11
ANCHORAGE LAKE HOOD	61.18N	149.96W	131	-8.6	-4.0	73.9	59.5	71.1	58.4	67.9	57.0	61.1	71.7	59.5	68.0	56.6	68.7	63.1	55.1	65.0	62.4	18.5	16.0	13.0	9764	16
ANCHORAGE INTL ARPT	61.18N	149.99W	131	-9.3	-4.8	71.5	58.9	68.3	57.4	65.8	56.2	60.4	68.9	58.9	66.2	56.5	68.2	62.7	55.2	65.2	61.5	20.8	18.5	16.7	10121	5
MERRILL FLD	61.22N	149.86W	138	-11.3	-7.8	73.0	59.4	70.4	58.3	67.9	57.1	61.3	70.4	59.8	67.6	57.2	70.2	63.1	55.6	66.1	62.1	15.2	12.3	10.6	10045	10
JUNEAU	58.36N	134.58W	23	4.5	9.0	73.8	59.6	70.1	58.2	66.5	56.7	61.1	71.3	59.5	67.5	57.2	69.9	61.8	55.9	66.6	60.6	26.7	23.7	19.8	8304	3
Arizona																									*9 sites, 12 more on CD-ROM*	
CASA GRANDE MUNI	32.96N	111.77W	1463	32.1	35.3	108.5	69.5	106.8	69.1	104.9	68.7	73.7	94.4	73.0	94.6	69.8	115.9	79.3	66.9	104.6	79.8	20.5	17.7	15.0	1508	3545
DAVIS MONTHAN AFB	32.17N	110.88W	2703	32.3	35.7	105.8	64.8	103.7	64.8	100.4	64.4	73.3	83.2	72.3	84.6	71.8	129.9	76.7	69.7	120.8	76.6	20.4	18.0	16.0	1405	3345
FLAGSTAFF AIRPORT	35.14N	111.67W	7018	3.9	9.5	85.7	55.6	83.3	55.1	81.2	54.9	61.3	73.0	60.2	72.5	57.9	93.2	63.7	56.5	88.5	63.3	23.7	19.7	17.2	6830	123
LUKE AFB	33.54N	112.38W	1086	35.3	37.8	111.0	70.8	108.6	70.7	106.4	70.4	77.0	97.8	75.8	96.5	72.2	123.9	82.7	70.4	116.3	83.7	20.0	17.3	14.7	1193	3979
PHOENIX/SKY HARBOR	33.44N	111.99W	1106	38.7	41.6	110.3	69.6	108.3	69.4	106.4	69.3	75.8	95.8	75.0	95.3	71.3	120.1	82.3	69.4	112.8	84.5	18.5	16.1	13.0	923	4626
ERNEST A LOVE FLD	34.65N	112.42W	5052	17.7	20.7	94.4	60.8	91.5	60.2	90.0	59.8	66.5	81.4	65.4	80.1	63.1	104.4	70.4	61.3	97.8	70.0	21.0	18.6	16.8	4174	982
TUCSON INTL	32.13N	110.96W	2556	31.6	34.3	106.0	66.2	103.6	66.0	101.5	65.7	72.6	88.6	71.8	88.0	69.3	118.7	76.2	68.0	113.3	76.6	21.5	18.8	16.8	1416	3273
YUMA INTL AIRPORT	32.65N	114.60W	207	42.0	44.8	110.7	73.8	108.6	73.4	106.6	72.7	79.9	96.8	78.5	96.1	75.5	134.6	87.5	73.8	127.1	88.2	20.8	18.4	16.3	666	4728
YUMA MCAS	32.62N	114.60W	213	41.6	44.7	110.9	73.1	108.8	72.8	107.3	72.3	79.7	96.6	78.3	95.8	75.3	133.8	87.0	73.4	125.2	88.1	20.9	18.5	16.4	665	4717
Arkansas																									*11 sites, 15 more on CD-ROM*	
BENTONVILLE MUNI THA	36.35N	94.22W	1296	10.3	16.1	94.6	74.7	91.3	75.0	89.9	74.4	77.6	89.8	76.5	88.2	73.4	130.3	84.3	72.7	127.5	83.5	19.6	17.5	15.7	4045	1372
DRAKE FLD	36.01N	94.17W	1260	10.0	16.2	95.1	74.9	92.5	74.6	90.2	74.3	77.9	89.3	76.8	88.1	74.6	135.9	83.3	73.2	129.5	82.1	20.6	18.7	17.2	3897	1424
FORT SMITH MUNI	35.33N	94.37W	463	17.0	21.7	99.4	76.6	96.8	76.5	93.9	76.1	79.7	92.6	78.6	91.1	76.4	140.0	84.7	75.3	135.1	83.8	20.5	18.1	16.2	3158	2061
JONESBORO MUNI	35.83N	90.65W	276	16.2	19.5	97.0	77.0	94.0	76.3	91.9	75.7	80.2	91.2	79.1	90.2	77.2	143.1	85.7	75.4	134.6	84.2	21.9	19.0	17.2	3504	1952
ADAMS FLD	34.75N	92.23W	256	19.3	23.9	98.7	77.1	95.6	77.3	93.1	76.5	80.2	92.0	79.2	91.0	77.1	142.6	85.3	76.1	137.7	84.3	18.8	16.9	15.3	2918	2170
LITTLE ROCK AFB	34.92N	92.15W	312	17.5	21.7	99.5	77.4	96.7	77.6	93.8	77.0	81.1	92.4	80.1	91.3	78.6	150.2	86.1	77.2	143.0	85.3	17.8	15.2	12.9	3108	2069
LITTLE ROCK/ADAMS F	34.83N	92.25W	568	18.5	23.3	95.4	76.6	93.0	76.3	90.9	75.6	79.1	90.2	78.1	88.8	76.0	138.9	84.7	75.0	134.1	83.9	18.5	16.5	14.7	3158	1938
GRIDER FLD	34.18N	91.94W	213	21.3	25.5	97.3	77.4	95.0	77.4	92.9	76.8	80.4	91.9	79.3	91.0	77.3	143.0	85.9	76.0	136.9	84.9	18.9	17.1	15.3	2700	2230
ROGERS MUNI CARTER F	36.37N	94.10W	1352	10.1	15.9	93.3	73.6	91.0	73.9	89.5	73.5	77.1	88.1	76.0	86.4	73.3	130.4	81.9	72.7	127.7	81.4	21.8	19.0	17.0	4040	1385
SMITH FLD	36.19N	94.48W	1194	10.4	16.2	95.6	74.7	92.6	74.5	90.2	74.2	77.5	90.2	76.4	88.4	73.3	129.4	84.6	72.6	126.3	83.8	23.3	20.2	18.2	3970	1441
TEXARKANA RGNL WEBB	33.45N	94.01W	400	23.3	27.1	98.8	76.3	96.3	76.3	93.5	76.1	79.5	91.4	78.7	90.2	76.6	140.8	84.3	75.5	135.5	83.4	18.8	16.9	15.0	2440	2335
California																									*55 sites, 38 more on CD-ROM*	
ALAMEDA(USN)	37.73N	122.32W	13	39.9	42.1	83.0	64.7	79.0	63.6	75.4	62.5	66.4	78.7	65.1	76.1	62.3	84.0	68.6	61.0	80.3	67.6	20.6	18.5	16.7	2105	209
BAKERSFIELD/MEADOWS	35.43N	119.06W	492	32.2	35.0	102.8	71.0	100.4	69.5	98.2	68.6	73.6	97.5	72.0	95.7	65.2	94.8	87.4	62.9	87.4	85.2	18.4	15.9	13.2	2095	2253
BEALE AFB	39.14N	121.44W	112	32.2	34.9	100.8	70.6	98.0	69.2	95.1	68.1	73.1	96.0	71.3	93.6	64.4	91.1	83.7	63.0	86.5	81.4	21.7	18.5	15.9	2356	1532
BURBANK/GLENDALE	34.20N	118.36W	732	38.6	41.0	97.7	67.4	93.8	66.7	90.9	66.3	72.4	89.7	70.9	87.4	66.5	100.4	77.4	65.6	97.0	76.3	18.4	15.1	12.9	1353	1423
CAMARILLO	34.22N	119.10W	75	37.1	39.2	85.8	62.3	81.8	63.0	79.3	63.4	69.2	78.7	67.9	77.1	65.6	94.7	74.6	63.9	89.2	71.8	25.2	20.1	16.3	1872	374
CAMP PENDLETON MCAS	33.30N	117.35W	79	32.3	35.5	92.1	66.2	88.0	65.7	84.1	65.5	71.6	83.6	70.3	82.0	67.7	102.2	76.7	66.0	96.0	76.1	16.8	14.4	12.5	1764	695
MC CLELLAN PALOMAR	33.13N	117.28W	328	43.1	44.9	82.4	62.7	80.7	63.5	77.1	63.8	70.0	76.7	68.7	75.1	66.5	98.7	73.2	66.0	97.1	72.8	14.0	12.2	10.8	1701	481
CASTLE AFB/MERCED	37.37N	120.57W	197	30.6	32.5	99.5	70.1	97.1	69.3	94.4	68.3	72.3	94.9	70.9	93.3	63.7	89.0	84.3	61.9	83.3	83.9	18.2	14.8	12.6	2629	1474
EL TORO MCAS	33.68N	117.73W	384	40.7	43.9	91.7	67.5	88.3	67.2	85.3	66.4	71.4	85.6	70.1	83.9	66.2	98.0	78.8	64.7	93.0	77.3	14.9	12.0	10.4	1142	1067
FRESNO AIR TERMINAL	36.78N	119.72W	328	31.4	33.7	103.5	70.9	100.8	69.3	98.6	68.3	73.5	97.4	71.9	95.3	65.3	94.7	85.7	63.2	87.9	84.1	18.2	16.3	14.2	2266	2097
FULLERTON MUNICIPAL	33.87N	117.98W	95	39.2	42.8	93.4	67.0	90.6	66.8	88.0	66.7	72.4	86.5	71.0	84.3	67.6	101.7	79.6	65.9	95.8	78.1	12.9	11.0	10.2	1202	1240
S CALIF LOGISTICS	34.60N	117.38W	2884	27.5	30.3	100.7	65.3	98.4	64.7	96.0	63.9	69.8	88.4	68.4	88.2	64.5	101.2	76.9	61.9	92.1	78.6	22.4	18.8	16.7	2661	1911
HAYWARD AIR TERM	37.66N	122.12W	46	36.9	39.0	87.8	65.7	82.3	64.2	78.8	63.2	67.8	82.3	66.0	79.2	62.8	85.6	73.0	61.1	80.5	70.0	19.6	17.7	16.2	2572	288

Meaning of acronyms:
DB: Dry bulb temperature, °F *WB: Wet bulb temperature, °F*
MCWB: Mean coincident wet bulb temperature, °F
Lat: Latitude, °
DP: Dew point temperature, °F
MCDB: Mean coincident dry bulb temperature, °F
Long: Longitude, °
HR: Humidity ratio, grains of moisture per lb of dry air
HDD and CDD 65: Annual heating and cooling degree-days, base 65°F, °F-day
Elev: Elevation, ft
WS: Wind speed, mph

Station	Lat	Long	Elev	Heating DB		Cooling DB/MCWB						Evaporation WB/MCDB				Dehumidification DP/HR/MCDB						Extreme Annual WS			Heat./Cool. Degree-Days	
						0.4%		1%		2%		0.4%		1%		0.4%			1%							
				99.6%	99%	DB	MCWB	DB	MCWB	DB	MCWB	WB	MCDB	WB	MCDB	DP	HR	MCDB	DP	HR	MCDB	1%	2.5%	5%	HDD	CDD 65
IMPERIAL CO	32.83N	115.58W	-56	35.7	37.5	111.2	72.9	109.0	72.7	107.7	72.6	81.1	97.4	79.7	96.8	77.1	140.7	88.5	75.0	131.0	89.1	26.1	22.0	18.8	949	4149
JACK NORTHROP FLD H	33.92N	118.33W	62	44.7	45.7	88.2	63.2	83.7	63.4	81.1	63.5	69.9	79.5	68.7	77.8	66.2	96.7	74.3	64.4	90.7	71.9	16.3	14.0	12.5	1135	782
LANCASTER/FOX FIELD	34.74N	118.22W	2339	21.3	24.9	102.4	66.0	100.0	64.4	97.8	63.5	68.6	95.9	67.0	94.8	58.6	80.0	80.6	55.7	72.1	79.3	29.5	27.0	25.0	2954	1830
LEMOORE NAS	36.33N	119.95W	233	28.4	31.8	103.0	71.6	100.3	70.1	98.5	69.1	74.7	97.6	72.7	95.7	66.4	98.1	89.2	63.9	89.8	86.0	20.3	17.3	14.9	2260	1821
LIVERMORE MUNICIPAL	37.69N	121.82W	397	30.2	33.5	99.0	67.8	94.9	66.6	90.8	65.1	70.1	94.2	68.1	90.7	61.1	81.6	77.4	59.2	76.2	73.6	19.5	17.9	16.3	2773	796
LOMPOC	34.67N	120.47W	89	32.7	35.5	81.4	60.8	77.2	61.1	73.5	60.3	65.4	75.3	63.8	73.4	61.4	81.5	69.1	59.4	76.0	67.7	20.4	18.6	17.2	2838	53
LONG BEACH/LB AIRP.	33.83N	118.16W	39	41.3	43.6	91.1	66.7	87.6	66.5	84.1	65.8	72.0	83.0	70.5	81.0	68.6	105.1	76.0	66.9	99.1	74.9	17.0	14.6	12.5	1190	1062
LOS ANGELES INTL	33.94N	118.41W	325	44.5	46.4	83.7	63.3	80.4	63.6	77.5	64.2	69.9	77.2	68.7	75.5	67.3	101.6	73.7	66.0	97.0	72.5	19.9	17.4	16.0	1295	582
RIVERSIDE/MARCH AFB	33.90N	117.25W	1535	32.1	35.6	100.2	67.0	98.8	66.6	95.5	65.6	71.5	93.3	70.2	91.1	65.8	100.8	74.3	63.9	94.1	72.9	17.8	15.5	12.8	1861	1590
MC CLELLAN AFLD	38.67N	121.40W	75	31.1	34.0	102.1	70.2	99.2	69.2	96.1	68.0	72.3	97.5	70.8	95.3	63.2	87.1	80.2	61.4	81.5	79.4	20.4	17.0	14.4	2269	1605
MODESTO CITY CO HAR	37.63N	120.95W	98	31.1	33.8	101.6	70.3	98.8	68.6	95.8	67.5	72.1	96.6	70.4	94.5	63.0	86.3	84.8	60.9	80.2	81.3	19.2	17.0	15.5	2386	1621
MONTEREY PENINSULA	36.59N	121.85W	220	36.7	38.8	79.0	60.3	73.3	59.1	71.7	58.8	62.8	72.3	61.7	70.2	59.1	75.5	64.6	57.3	70.7	63.7	17.0	14.9	12.7	3281	49
MOUNTAIN VIEW (SUNN	37.42N	122.05W	33	36.2	38.6	88.4	65.6	83.7	64.6	80.7	64.1	68.3	82.4	66.7	79.8	63.1	86.6	74.4	61.4	81.4	71.8	18.9	17.3	15.5	2164	464
NAPA CO	38.21N	122.28W	56	29.6	32.1	91.3	65.8	87.4	65.3	82.3	63.7	68.4	86.5	66.8	83.3	61.4	81.4	74.2	60.5	78.9	73.2	21.2	19.0	17.5	3239	246
SAN BERNARDINO INTL	34.08N	117.23W	1158	33.9	36.5	102.9	69.7	100.2	69.5	97.4	68.8	74.5	95.1	73.0	93.6	68.1	107.7	83.1	66.1	100.5	83.3	16.7	12.9	10.9	1652	1811
OAKLAND/METROP. OAK	37.76N	122.22W	89	36.7	39.0	82.3	64.3	78.7	63.2	74.6	62.4	66.4	78.5	65.0	75.4	62.0	83.4	69.9	61.0	80.4	68.5	23.4	19.9	18.3	2637	155
ONTARIO INTL ARPT	34.05N	117.57W	942	37.1	39.7	100.1	69.9	97.4	68.9	94.6	68.4	74.0	93.6	72.4	91.4	68.1	106.8	80.8	66.1	99.7	78.3	23.1	18.3	16.3	1387	1769
PALM SPRINGS INTL	33.83N	116.51W	449	41.4	44.5	111.2	71.2	109.1	70.8	107.9	70.7	79.1	99.4	77.4	98.0	73.0	124.7	92.3	71.7	119.0	92.1	23.2	20.1	18.0	783	4336
JACQUELINE COCHRAN	33.63N	116.16W	-118	31.2	34.4	111.3	72.5	108.9	72.0	107.3	71.7	79.8	97.6	78.3	97.5	74.8	129.9	89.5	72.8	120.9	89.4	19.9	17.5	15.4	1095	3874
POINT ARGUELLO	34.57N	120.63W	112	45.5	47.5	71.1	N/A	67.7	N/A	65.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	41.6	34.8	31.5	3397	21
PT MUGU (NAWS)	34.12N	119.12W	13	38.8	41.2	81.7	60.1	78.5	61.8	75.2	62.9	69.4	75.0	67.8	73.5	67.3	100.5	72.3	65.5	94.1	71.3	23.1	18.9	16.4	1975	223
PORTERVILLE MUNI	36.03N	119.05W	443	30.2	33.5	100.4	70.1	99.2	69.3	97.0	68.1	72.9	96.8	71.1	94.2	63.8	90.1	86.1	62.7	86.5	84.9	12.9	11.4	10.4	2551	1671
REDDING MUNICIPAL	40.52N	122.31W	502	28.3	30.8	105.9	68.9	102.2	67.6	99.3	66.2	71.7	97.2	70.2	95.2	63.7	90.0	79.9	61.6	83.4	78.7	24.9	19.9	17.0	2724	1888
RIVERSIDE MUNI	33.95N	117.44W	830	36.1	37.3	100.0	69.5	98.5	68.9	94.7	67.8	73.2	93.8	71.5	91.5	66.0	98.9	81.5	64.0	92.1	79.0	20.2	16.7	14.0	1567	1606
SACRAMENTO/EXECUTIV	38.51N	121.49W	26	31.1	33.9	100.1	69.9	97.2	68.7	93.6	67.5	72.6	95.7	70.6	93.2	63.8	88.9	84.4	61.6	82.0	79.8	20.3	18.1	16.2	2495	1213
SACRAMENTO MATHER FL	38.55N	121.29W	95	29.7	32.0	101.6	68.8	98.7	67.3	95.0	66.4	70.9	96.9	69.2	93.8	61.3	81.4	75.3	59.9	77.3	75.4	20.6	17.2	14.1	2687	1215
SACRAMENTO INTL	38.70N	121.59W	33	30.4	33.7	100.5	70.5	98.2	69.6	94.8	68.4	73.2	96.6	71.3	94.2	64.2	89.8	85.1	62.6	85.1	82.8	23.3	19.3	17.3	2425	1390
SALINAS MUNI	36.66N	121.61W	79	33.9	36.3	82.8	62.1	78.7	61.1	74.9	60.6	64.9	77.6	63.5	74.7	60.5	79.1	67.3	59.1	75.1	66.2	20.8	18.7	17.3	2741	105
SAN DIEGO/LINDBERGH	32.74N	117.17W	30	44.8	46.4	83.1	65.0	80.2	65.4	77.8	65.5	71.0	77.6	69.8	76.0	68.5	104.7	74.4	67.4	100.7	73.5	17.1	15.5	13.3	1197	673
MIRAMAR MCAS	32.87N	117.15W	479	38.9	41.4	90.6	66.5	87.6	66.3	83.9	66.2	71.6	83.2	70.4	81.6	67.9	104.2	76.4	66.2	98.4	75.1	15.1	12.5	11.0	1495	844
NORTH ISLAND NAS	32.70N	117.20W	26	44.6	46.0	83.4	64.2	80.7	65.1	78.0	65.1	70.9	77.1	69.5	76.0	68.5	104.9	74.0	66.9	99.1	72.6	18.8	16.5	14.5	1186	684
BROWN FLD MUNI	32.57N	116.98W	525	38.9	42.5	89.7	64.0	84.3	64.7	81.7	64.4	71.0	81.7	69.4	79.2	67.3	102.3	75.3	65.9	97.4	74.0	16.4	13.1	12.1	1681	653
MONTGOMERY FLD	32.82N	117.14W	423	40.7	43.1	90.2	65.9	86.2	65.2	82.3	64.6	71.2	82.5	69.5	79.9	66.5	99.0	75.3	65.8	96.8	74.8	15.8	13.0	12.0	1529	822
SAN FRANCISCO INTL	37.62N	122.40W	20	39.1	41.4	82.8	62.9	78.1	61.9	74.2	61.2	65.5	77.6	64.0	74.6	61.2	80.8	68.2	59.8	76.9	66.8	28.6	25.7	23.6	2689	144
NORMAN Y MINETA SAN	37.36N	121.93W	49	35.8	37.7	91.6	66.1	88.2	65.6	84.2	64.7	69.0	86.1	67.7	83.5	62.8	85.8	75.9	61.3	81.1	74.3	19.5	17.9	16.2	2076	663
SAN LUIS CO RGNL	35.24N	120.64W	207	34.1	36.4	89.5	64.0	84.3	63.2	81.3	62.7	67.3	83.1	65.8	80.4	61.5	82.2	71.0	60.5	79.4	70.0	25.3	22.7	19.7	2213	295
SANTA BARBARA MUNI	34.43N	119.84W	20	34.5	36.7	82.5	63.5	79.4	63.5	76.8	63.0	68.3	76.9	66.9	75.2	64.7	91.7	71.3	63.6	88.2	69.9	19.1	16.6	13.5	2246	196
SANTA MARIA PUBLIC	34.92N	120.47W	240	32.6	35.1	83.8	61.9	79.8	61.0	76.2	60.5	65.9	77.8	64.3	75.4	61.4	81.9	68.7	59.9	77.8	67.5	24.1	20.4	18.3	2760	94
C M SCHULZ SONOMA CO	38.51N	122.81W	148	29.6	31.7	95.3	66.6	91.1	65.9	87.8	64.8	69.2	90.4	67.5	87.8	61.0	80.5	76.6	59.0	75.0	74.0	17.1	15.0	12.7	3047	375
STOCKTON/METROPOLIT	37.89N	121.24W	26	30.5	33.0	100.8	69.9	97.9	68.9	94.8	68.2	73.3	95.8	70.9	94.1	65.1	92.8	85.8	61.7	82.4	80.4	22.8	19.3	17.4	2448	1382
FAIRFIELD/TRAVIS AF	38.27N	121.95W	72	30.0	33.5	99.3	67.2	95.2	66.1	91.1	65.4	69.7	93.7	68.2	90.8	61.1	80.7	73.4	59.3	75.5	72.5	29.8	27.5	25.7	2608	965
VISALIA MUNI	36.32N	119.38W	295	29.9	32.8	99.9	71.8	98.6	71.1	95.5	69.5	74.8	95.2	73.0	93.1	68.1	104.5	85.5	65.7	95.9	84.3	15.3	12.5	10.9	2551	1591
Colorado																										*10 sites, 19 more on CD-ROM*
BUCKLEY AFB	39.70N	104.75W	5663	2.6	8.8	93.4	58.6	91.1	58.6	89.6	58.6	64.4	78.5	63.1	78.4	61.2	100.0	65.6	59.1	92.7	65.8	24.0	19.9	17.2	5734	787
COLORADO SPRINGS/MU	38.81N	104.71W	6171	1.3	7.1	90.4	58.7	88.0	58.4	85.1	58.3	63.4	78.5	62.2	77.3	59.4	95.5	65.6	58.0	90.5	65.3	28.0	24.7	20.9	6160	459
DENVER INTERNATIONA	39.83N	104.66W	5430	0.5	6.6	94.4	60.0	91.7	59.8	89.3	59.6	65.0	80.9	63.8	80.5	61.0	98.1	68.1	59.2	92.2	67.8	26.9	23.5	19.8	5959	777
DENVER/STAPLETON	39.75N	104.87W	5289	-1.4	5.1	93.9	60.7	91.2	60.0	88.5	59.6	64.5	81.8	63.4	80.7	60.1	94.7	67.2	58.5	89.1	67.0	24.3	19.7	17.2	5667	721
CENTENNIAL	39.57N	104.85W	5827	0.0	6.2	91.4	59.9	89.8	59.7	86.5	59.4	65.1	80.9	63.4	79.6	61.0	99.7	68.5	58.7	91.8	68.0	24.8	21.2	18.6	6103	583
FORT COLLINS (AWOS)	40.45N	105.00W	5016	0.0	5.6	93.6	60.5	90.8	60.5	88.2	60.3	65.1	82.1	63.9	81.8	60.7	95.9	69.6	57.5	85.0	69.5	25.9	21.4	18.0	6235	618
FORT COLLINS(SAWRS)	40.58N	105.08W	5003	-2.6	4.8	90.1	60.9	87.2	60.3	84.4	60.1	64.6	80.7	63.6	80.0	59.7	92.3	69.7	58.4	88.1	69.2	20.0	16.8	13.6	6096	462
GRAND JUNCTION/WALK	39.13N	108.54W	4839	5.1	10.2	97.7	61.5	95.1	60.6	92.6	59.8	65.1	85.7	64.0	84.3	60.7	95.0	68.2	58.3	87.0	68.7	23.4	19.2	16.9	5430	1212
GREELEY WELD CO	40.44N	104.62W	4649	-6.3	0.4	95.3	62.3	91.5	62.1	89.8	62.1	67.2	84.3	65.8	83.7	62.7	101.3	72.9	60.8	94.9	71.9	28.1	23.8	19.2	6579	611
PUEBLO MEMORIAL(AW)	38.29N	104.50W	4721	-0.4	6.5	98.5	62.4	95.8	62.2	92.9	61.8	66.9	85.2	65.9	84.4	62.9	102.4	69.2	61.3	96.6	69.1	28.7	24.8	20.5	5473	915
Connecticut																										*5 sites, 3 more on CD-ROM*
BRIDGEPORT/IGOR I.	41.18N	73.15W	16	11.4	15.8	87.7	73.1	84.4	71.5	82.1	70.3	75.9	82.9	74.7	80.8	73.5	124.7	78.9	72.6	121.0	78.1	24.5	20.9	18.7	5274	830
HARTFORD/BRADLEY IN	41.94N	72.68W	180	4.1	9.2	91.4	73.3	88.5	72.0	85.5	70.5	76.3	86.7	74.8	83.9	73.2	124.3	80.3	72.1	119.4	79.2	22.8	19.3	17.5	5935	765
HARTFORD BRAINARD	41.74N	72.65W	20	8.5	12.2	90.7	73.2	88.2	72.4	84.6	70.9	76.9	85.7	75.3	83.2	74.2	127.9	81.1	72.7	121.4	79.8	19.7	18.1	16.5	5510	862

Meaning of acronyms:
DB: Dry bulb temperature, °F
WB: Wet bulb temperature, °F
MCWB: Mean coincident wet bulb temperature, °F
Lat: Latitude, °
DP: Dew point temperature, °F
MCDB: Mean coincident dry bulb temperature, °F
Long: Longitude, °
HR: Humidity ratio, grains of moisture per lb of dry air
HDD and CDD 65: Annual heating and cooling degree-days, base 65°F, °F-day
Elev: Elevation, ft
WS: Wind speed, mph

Station	Lat	Long	Elev	Heating DB		Cooling DB/MCWB						Evaporation WB/MCDB				Dehumidification DP/HR/MCDB						Extreme Annual WS			Heat./Cool. Degree-Days	
						0.4%		1%		2%		0.4%		1%		0.4%			1%							
				99.6%	99%	DB	MCWB	DB	MCWB	DB	MCWB	WB	MCDB	WB	MCDB	DP	HR	MCDB	DP	HR	MCDB	1%	2.5%	5%	HDD	CDD 65
WATERBURY OXFORD	41.48N	73.13W	725	4.1	9.1	87.7	72.7	83.8	71.2	81.4	69.6	75.4	83.4	73.7	80.5	72.9	125.3	79.0	72.0	121.6	77.8	19.6	17.1	15.0	6360	475
WINDHAM AIRPORT	41.74N	72.18W	246	3.5	9.4	89.9	73.1	86.4	72.0	83.7	70.8	76.0	84.9	74.5	82.1	73.1	124.1	79.4	72.4	120.9	78.4	19.4	17.2	15.5	5998	617
Delaware																									*2 sites, 1 more on CD-ROM*	
DOVER AFB	39.12N	75.47W	30	15.5	18.4	91.0	75.6	89.6	75.1	86.3	73.7	78.4	86.5	77.2	84.4	76.6	138.8	81.7	75.0	131.5	80.6	25.2	22.1	19.4	4503	1170
WILMINGTON NEW CAST	39.67N	75.60W	79	13.3	17.3	91.9	75.0	89.4	73.9	86.9	73.1	78.0	87.3	76.7	85.0	75.4	133.3	81.7	74.3	128.3	80.5	24.5	20.6	18.4	4756	1142
Florida																									*32 sites, 28 more on CD-ROM*	
CECIL FLD	30.22N	81.87W	82	27.6	31.8	96.0	76.4	94.0	76.2	92.3	75.9	80.1	89.2	79.0	88.5	77.4	143.1	82.9	76.8	140.2	82.5	18.7	16.6	14.6	1286	2711
DAYTONA BEACH INTL	29.18N	81.06W	43	35.6	39.2	92.8	76.9	90.9	76.8	89.6	76.8	80.0	88.0	79.1	87.1	77.7	144.2	83.7	77.0	140.6	83.1	20.3	18.0	16.3	748	2992
FORT LAUDERDALE HOL	26.07N	80.15W	10	46.7	51.6	91.7	78.2	90.6	78.2	90.0	78.1	81.1	87.9	80.4	87.2	79.3	152.0	84.7	78.6	148.6	84.4	22.2	19.7	18.2	133	4566
FORT MYERS/PAGE FLD	26.59N	81.86W	20	42.5	46.0	93.5	76.7	92.6	76.8	91.3	76.8	80.3	88.1	79.5	87.5	78.4	147.3	83.3	77.4	142.6	82.7	18.8	17.1	15.4	281	3923
GAINESVILLE RGNL	29.69N	82.27W	164	29.6	33.4	93.4	76.4	91.9	76.2	90.5	75.9	79.7	88.3	78.7	87.1	77.4	143.4	83.1	76.5	139.1	82.2	18.4	16.5	14.4	1176	2629
HOMESTEAD ARB	25.48N	80.38W	7	45.9	49.9	90.4	78.7	90.0	78.7	88.4	78.5	81.4	85.6	80.9	85.3	80.8	160.2	83.2	79.4	152.4	82.8	20.3	18.3	16.5	151	4050
JACKSONVILLE/INTNL.	30.49N	81.69W	33	29.4	32.5	94.6	77.3	92.8	77.0	91.0	76.6	80.0	89.6	79.1	88.4	77.4	142.9	83.4	76.7	139.4	82.8	20.0	17.9	16.2	1327	2632
JACKSONVILLE NAS	30.23N	81.68W	23	33.5	36.8	95.7	77.1	93.4	76.3	91.5	76.0	80.5	88.4	79.5	87.9	78.9	150.0	83.7	77.3	142.2	83.1	20.6	18.2	16.4	995	3175
JACKSONVILLE/CRAIG	30.34N	81.52W	43	32.3	35.9	93.5	77.2	91.4	76.9	90.2	76.8	80.2	88.7	79.3	87.6	78.1	146.3	83.8	77.1	141.3	83.1	18.9	17.4	15.8	1217	2645
MACDILL AFB/TAMPA	27.85N	82.50W	13	39.1	43.0	92.6	77.6	91.1	77.5	90.4	77.6	81.5	86.8	80.9	86.5	80.7	159.6	84.2	79.2	151.8	83.5	19.5	17.4	15.8	536	3506
MAYPORT NS	30.40N	81.42W	13	34.2	38.1	94.4	77.4	91.9	77.4	90.3	77.1	80.7	88.8	79.8	88.1	78.8	149.4	85.1	77.4	142.5	84.5	20.4	18.1	16.2	1044	2990
MELBOURNE REGIONAL	28.10N	80.65W	26	38.6	43.1	92.2	77.8	90.6	77.8	89.7	77.9	80.8	87.8	80.0	87.2	79.1	151.2	84.3	77.9	144.9	83.9	21.0	19.1	18.0	467	3496
MIAMI	25.82N	80.30W	30	47.6	51.9	91.8	77.6	90.8	77.6	90.0	77.5	80.3	86.9	79.7	86.8	78.5	148.1	83.5	77.6	143.5	83.3	20.4	18.6	17.0	126	4537
KENDALL TAMIAMI EXEC	25.65N	80.43W	10	45.2	48.5	92.7	78.0	91.2	77.7	90.4	77.6	80.4	87.9	79.7	87.4	79.0	150.6	83.3	77.5	143.0	82.9	20.7	18.9	17.7	176	4110
NAPLES MUNI	26.15N	81.78W	23	43.3	46.6	91.2	77.7	90.4	77.7	89.9	77.7	80.7	87.4	80.0	86.8	79.2	151.4	84.0	78.4	147.8	83.7	18.9	17.0	15.1	290	3747
NASA SHUTTLE LANDING	28.62N	80.69W	10	37.5	42.5	91.7	78.1	90.5	78.0	89.6	77.9	81.0	87.5	80.1	86.6	79.3	152.0	84.0	78.7	148.8	83.6	18.8	16.7	14.8	565	3151
OCALA INTL J TAYLOR	29.17N	82.22W	89	28.8	33.7	93.3	75.5	91.5	75.4	90.7	75.3	79.1	87.8	78.2	87.3	77.0	140.8	82.7	75.3	133.2	82.0	18.0	15.3	12.6	1052	2772
EXECUTIVE	28.55N	81.33W	112	38.7	43.2	93.5	75.9	92.6	75.9	91.0	75.7	79.5	86.8	78.7	86.1	78.1	146.4	82.2	77.0	141.1	81.6	19.3	17.7	15.9	512	3560
ORLANDO/JETPORT	28.43N	81.33W	105	37.8	42.3	93.8	76.5	92.5	76.2	91.1	76.0	79.6	87.5	78.8	86.7	77.6	144.2	81.8	76.9	140.9	81.4	20.2	18.1	16.4	550	3386
ORLANDO SANFORD	28.78N	81.24W	56	36.7	40.9	94.8	75.6	93.0	75.2	91.2	75.2	78.5	88.1	78.0	87.5	75.5	133.6	81.8	75.2	132.6	81.8	20.4	18.1	16.2	646	3314
PANAMA CITY BAY CO	30.21N	85.68W	20	31.8	35.9	92.7	76.7	91.0	76.9	90.2	76.8	81.4	86.9	80.3	86.3	79.5	153.1	83.7	79.0	150.7	83.6	18.7	16.7	15.0	1238	2842
PENSACOLA NAS	30.35N	87.32W	30	29.5	33.2	93.2	78.6	91.4	78.3	90.2	78.0	81.9	88.5	80.8	87.7	80.2	156.7	85.4	79.1	150.9	84.8	20.9	18.7	16.8	1459	2647
PENSACOLA RGNL	30.47N	87.19W	118	29.7	33.7	93.9	77.7	91.9	77.3	90.4	77.1	81.0	88.5	80.1	87.4	79.2	152.3	84.3	78.2	147.1	83.6	20.1	18.1	16.5	1453	2687
SARASOTA BRADENTON	27.40N	82.56W	26	39.2	44.0	92.3	78.8	91.1	78.7	90.3	78.6	82.6	88.8	81.5	87.9	81.2	162.3	86.5	79.6	153.5	85.2	21.0	18.6	16.9	462	3445
SOUTHWEST FLORIDA I	26.54N	81.76W	30	40.5	45.0	93.5	76.8	92.6	76.8	91.1	76.8	80.4	87.8	79.7	87.2	79.0	150.5	82.9	77.6	143.8	82.6	20.6	18.4	16.5	323	3764
ST PETERSBURG CLEAR	27.91N	82.69W	10	42.4	45.4	92.1	77.8	91.0	77.7	90.3	77.6	81.7	87.3	80.6	86.5	80.4	157.8	84.6	79.2	151.4	83.8	20.8	18.7	17.2	456	3677
TALLAHASSEE MUNICIP	30.39N	84.35W	69	25.7	29.0	96.0	76.5	93.8	75.9	92.1	75.5	79.8	89.1	78.8	88.0	77.4	143.0	82.8	76.5	138.7	82.1	18.0	16.0	13.6	1553	2599
TAMPA INTL AIRPORT	27.96N	82.54W	10	38.8	42.9	92.6	77.2	91.4	77.2	90.4	77.1	80.5	88.0	79.9	87.7	78.4	147.7	84.8	77.5	142.9	84.1	18.0	16.0	13.8	527	3563
TYNDALL AFB	30.07N	85.58W	16	31.5	35.6	91.3	78.8	90.2	78.8	88.9	78.6	82.5	87.7	81.4	86.9	81.2	162.1	86.1	79.8	154.9	85.0	19.5	17.3	15.4	1309	2620
VENICE PIER	27.07N	82.45W	16	41.4	45.4	88.1	76.3	86.8	76.8	86.1	77.0	81.6	82.9	79.7	84.1	81.3	162.8	82.4	78.4	147.4	82.2	27.7	23.6	19.6	502	2966
VERO BEACH MUNI	27.66N	80.42W	30	38.7	43.0	91.5	77.8	90.5	77.8	89.6	77.8	80.4	87.9	79.7	87.4	78.6	148.6	84.3	77.3	142.4	83.8	20.3	18.5	17.1	420	3464
WEST PALM BEACH/IN	26.69N	80.10W	20	43.9	48.0	91.4	77.6	90.4	77.7	89.4	77.7	80.2	87.7	79.5	87.1	78.1	146.1	83.6	77.3	142.3	83.4	23.1	20.2	18.6	222	4085
Georgia																									*19 sites, 8 more on CD-ROM*	
ALBANY MUNICIPAL	31.54N	84.19W	194	26.9	29.8	97.0	76.1	94.8	76.0	92.8	75.4	79.8	90.6	78.7	89.2	77.2	142.5	83.4	75.9	136.3	82.3	18.6	16.7	14.6	1764	2551
ATHENS MUNICIPAL	33.95N	83.33W	801	22.4	26.5	95.5	74.8	93.0	74.1	90.7	73.7	77.8	89.2	76.8	87.6	74.8	134.1	81.9	73.7	129.3	80.6	18.3	16.3	14.1	2781	1804
PEACHTREE CITY FALCO	33.36N	84.57W	797	19.1	23.1	93.1	73.5	91.0	73.4	89.9	73.3	77.4	87.6	76.4	86.1	74.7	133.8	80.9	73.3	127.3	79.3	17.4	15.0	12.4	3054	1540
ATLANTA MUNICIPAL	33.64N	84.43W	1027	21.5	26.4	93.9	74.2	91.7	73.9	89.8	73.5	77.3	88.5	76.4	86.7	74.3	133.1	81.3	73.3	128.7	80.2	21.5	19.0	17.1	2671	1893
AUGUSTA/BUSH FIELD	33.37N	81.97W	148	22.5	26.1	97.3	76.0	94.8	75.9	92.6	75.3	79.5	91.0	78.4	89.3	76.7	139.8	83.6	75.6	134.5	82.6	18.8	16.6	14.3	2407	2078
DANIEL FIELD	33.47N	82.04W	423	27.2	29.7	97.1	74.4	93.3	73.4	91.3	73.3	77.6	89.4	77.0	88.2	74.8	132.5	81.0	73.4	126.0	80.0	16.7	14.7	12.6	2135	2316
COLUMBUS METROPOLIT	32.52N	84.94W	394	25.9	29.2	96.6	74.7	94.2	74.5	92.3	74.1	78.1	89.4	77.3	88.1	75.3	134.5	81.9	74.4	130.5	81.1	18.3	16.3	14.3	2083	2339
DEKALB PEACHTREE	33.88N	84.30W	991	21.0	25.4	93.5	73.4	91.4	73.5	90.3	73.0	77.0	88.4	76.1	86.7	73.4	128.8	79.4	73.0	127.2	79.1	18.5	16.4	14.0	2871	1827
MARIETTA/DOBBINS AF	33.92N	84.52W	1070	18.9	24.5	93.6	74.2	91.3	74.2	89.5	73.8	77.3	88.0	76.4	86.6	74.4	133.6	81.7	73.3	128.7	80.6	18.7	16.4	14.1	2970	1758
FORT BENNING	32.33N	85.00W	233	22.9	26.6	97.1	76.0	94.6	76.1	91.5	75.8	81.0	89.7	79.4	89.2	78.9	151.5	84.8	77.0	142.0	83.3	17.1	14.9	12.4	2251	2131
FULTON CO ARPT BROW	33.78N	84.52W	840	20.8	25.2	94.0	74.6	91.5	74.3	90.2	73.8	77.7	88.9	76.7	87.4	74.5	133.2	82.1	73.4	128.0	81.1	17.7	15.5	13.4	2869	1742
LEE GILMER MEM	34.27N	83.83W	1276	21.0	26.6	92.5	73.4	90.5	73.2	88.4	72.6	76.6	86.8	75.5	85.0	73.4	130.1	79.6	72.8	127.5	79.1	19.0	17.0	15.3	3019	1642
HUNTER AAF	32.01N	81.15W	43	27.9	31.7	95.5	77.6	93.4	77.1	91.3	76.9	81.2	88.8	80.1	88.3	79.3	152.3	83.9	77.8	144.7	83.2	18.9	16.7	14.5	1632	2582
MACON/LEWIS B.WILSO	32.69N	83.65W	361	23.9	27.4	96.9	75.6	94.5	75.3	92.4	74.9	79.0	90.2	78.1	88.9	76.1	138.3	83.0	75.2	134.0	82.1	18.1	16.0	13.4	2263	2179
MOODY AFB/VALDOSTA	30.97N	83.19W	236	29.4	33.1	96.0	76.7	94.0	76.3	92.5	76.0	80.2	90.7	79.1	89.5	77.3	143.5	83.9	76.6	139.8	83.3	17.1	14.4	12.4	1438	2683
ROME/RUSSELL(RAMOS)	34.35N	85.16W	643	18.8	22.9	96.7	74.7	93.4	74.0	91.2	73.8	78.1	89.9	77.2	88.7	75.0	134.4	82.6	73.5	127.6	81.6	15.8	12.9	11.4	3111	1762
SAVANNAH MUNICIPAL	32.12N	81.20W	52	27.4	30.4	95.5	77.2	93.3	76.9	91.4	76.3	80.2	89.5	79.3	88.3	78.1	146.1	83.5	77.1	141.3	82.7	18.9	16.9	15.5	1761	2455

Meaning of acronyms:
DB: Dry bulb temperature, °F
WB: Wet bulb temperature, °F
MCWB: Mean coincident wet bulb temperature, °F
Lat: Latitude, °
DP: Dew point temperature, °F
MCDB: Mean coincident dry bulb temperature, °F
Long: Longitude, °
HR: Humidity ratio, grains of moisture per lb of dry air
Elev: Elevation, ft
WS: Wind speed, mph
HDD and CDD 65: Annual heating and cooling degree-days, base 65°F, °F-day

Station	Lat	Long	Elev	Heating DB		Cooling DB/MCWB						Evaporation WB/MCDB				Dehumidification DP/HR/MCDB						Extreme Annual WS			Heat./Cool. Degree-Days	
						0.4%		1%		2%		0.4%		1%		0.4%			1%							
				99.6%	99%	DB	MCWB	DB	MCWB	DB	MCWB	WB	MCDB	WB	MCDB	DP	HR	MCDB	DP	HR	MCDB	1%	2.5%	5%	HDD	CDD 65
VALDOSTA RGNL	30.78N	83.28W	197	27.6	30.6	95.6	77.3	93.5	76.5	92.1	76.1	80.4	89.9	79.4	88.8	78.5	149.0	83.6	77.1	142.2	82.6	16.9	14.7	12.8	1527	2559
ROBINS AFB	32.63N	83.60W	295	25.0	27.9	96.9	75.5	94.6	75.4	91.4	74.8	79.4	90.4	78.4	88.7	77.0	142.0	83.1	75.4	134.3	81.4	18.4	16.0	13.0	2130	2231
Hawaii																										*4 sites, 4 more on CD-ROM*
KALAELOA ARPT	21.30N	158.07W	33	59.5	61.8	90.9	73.2	89.9	73.2	88.9	73.1	78.0	85.8	76.8	85.3	75.4	133.4	82.9	74.1	127.2	82.3	19.4	17.7	16.2	0	4450
HILO INTL	19.72N	155.05W	36	61.5	62.8	85.7	74.1	84.7	73.8	83.9	73.6	76.6	82.1	75.9	81.5	75.1	131.7	79.2	74.1	127.5	78.6	17.4	15.7	13.3	0	3264
HONOLULU INTL	21.33N	157.94W	16	62.0	63.9	89.8	74.0	88.9	73.6	88.1	73.3	77.2	84.8	76.3	84.1	75.0	131.2	81.2	73.8	126.0	80.6	22.2	20.2	18.8	0	4679
KANEOHE BAY (MCAF)	21.45N	157.77W	20	64.0	65.9	84.9	74.4	84.1	74.1	83.3	73.8	77.1	81.9	76.2	81.5	75.3	132.6	80.2	74.4	128.8	79.9	18.8	17.0	15.8	0	4243
Idaho																										*7 sites, 10 more on CD-ROM*
BOISE MUNICIPAL	43.57N	116.22W	2867	8.7	15.5	98.6	63.9	95.4	62.9	92.5	61.9	66.2	92.3	64.7	90.5	57.2	77.5	71.6	54.9	71.3	71.4	21.9	19.0	17.1	5453	957
CALDWELL (AWOS)	43.64N	116.63W	2431	11.5	16.3	97.0	66.4	93.1	64.7	90.5	63.8	68.2	92.3	66.5	89.9	59.3	82.6	77.8	56.9	75.4	77.4	22.1	19.1	16.9	5729	660
COEUR D ALENE AIR TE	47.77N	116.82W	2320	5.5	10.3	91.4	63.0	88.5	62.4	84.2	60.9	65.8	86.4	64.0	84.0	57.4	76.7	71.3	55.4	71.3	70.0	22.2	18.9	16.7	6908	300
IDAHO FALLS RGNL	43.52N	112.07W	4744	-6.7	-0.3	91.5	60.9	89.6	60.6	86.4	59.5	64.5	83.4	62.8	82.6	57.8	85.1	69.9	55.4	78.0	68.3	27.1	24.2	20.6	7701	272
JOSLIN FLD MAGIC VA	42.48N	114.49W	4190	9.0	12.2	94.7	63.2	91.2	62.3	89.7	61.9	66.4	88.8	64.9	86.4	58.8	86.5	75.5	56.5	79.6	74.6	27.9	24.6	20.9	6128	729
LEWISTON NEZ PERCE	46.38N	117.01W	1437	12.0	18.6	98.2	65.3	94.5	64.4	90.9	63.1	67.5	92.4	65.9	90.0	59.4	79.7	72.5	57.1	73.4	71.8	20.8	17.9	15.0	5020	839
POCATELLO MUNICIPAL	42.92N	112.57W	4478	-2.0	3.8	94.6	61.6	91.4	60.9	88.6	60.0	65.1	86.8	63.4	84.8	58.2	85.5	71.0	55.4	77.2	70.7	28.3	25.3	22.3	6938	426
Illinois																										*14 sites, 14 more on CD-ROM*
AURORA MUNICIPAL	41.77N	88.48W	715	-5.6	0.5	90.4	74.2	88.2	73.4	84.4	71.6	77.5	86.4	75.8	83.9	74.7	133.5	82.9	72.9	125.5	80.8	25.9	22.9	19.8	6508	701
CAHOKIA/ST. LOUIS	38.57N	90.16W	413	9.1	12.4	93.4	77.1	91.3	76.2	90.2	75.6	80.1	90.3	78.4	88.8	77.2	143.9	85.1	75.2	134.2	83.9	20.7	18.5	16.6	4545	1398
CHICAGO/MIDWAY	41.79N	87.75W	617	0.2	5.4	91.5	74.6	89.5	73.3	86.5	72.0	78.0	88.1	76.1	85.1	74.9	134.0	84.1	73.0	125.4	82.0	24.5	21.2	19.2	5872	1034
CHICAGO/O'HARE ARPT	41.99N	87.91W	673	-1.5	3.7	91.4	74.3	88.7	73.2	86.0	71.8	77.8	87.8	76.0	84.8	74.7	133.3	83.7	73.0	125.8	81.7	24.6	21.0	19.1	6209	864
DECATUR	39.98N	88.87W	679	0.9	6.6	92.9	76.6	90.6	75.5	88.3	74.3	79.3	89.7	77.8	87.7	76.2	140.3	85.9	74.8	133.5	84.2	24.8	21.6	19.7	5442	1100
GLENVIEW NAS	42.08N	87.82W	653	-0.7	4.8	93.7	75.0	90.2	73.3	87.1	72.1	77.9	90.2	76.2	87.0	74.2	130.7	85.1	72.4	123.1	83.6	20.2	18.0	16.2	6104	909
MOLINE/QUAD CITY	41.47N	90.52W	594	-3.9	1.3	92.9	76.1	90.2	74.8	87.5	73.3	79.1	89.2	77.3	86.9	76.2	139.6	85.2	74.5	131.9	83.1	24.1	20.3	18.3	6074	994
GREATER PEORIA MUNI	40.67N	89.68W	663	-1.5	3.3	92.2	76.2	89.8	75.1	87.2	73.6	79.2	88.5	77.5	86.6	76.4	141.4	85.0	74.8	133.6	83.0	23.4	19.9	18.0	5756	1040
QUINCY RGNL BALDWIN	39.94N	91.19W	768	-0.2	4.8	92.7	76.5	90.1	75.3	87.7	74.1	78.6	89.1	77.4	87.4	75.5	137.2	84.8	74.2	131.3	83.3	24.5	20.8	18.9	5501	1101
GREATER ROCKFORD	42.20N	89.09W	745	-5.8	0.0	91.1	74.6	88.2	73.2	85.5	71.7	78.0	87.4	76.0	84.4	75.1	135.6	83.5	73.2	126.9	81.7	24.4	20.9	19.0	6608	775
SCOTT AFB MIDAMERIC	38.53N	89.83W	459	9.0	12.4	94.8	76.5	91.4	75.5	90.1	75.2	80.3	88.5	78.7	87.2	78.6	151.0	84.6	76.6	141.3	83.1	23.1	19.8	17.7	4579	1401
SPRINGFIELD/CAPITAL	39.85N	89.68W	614	0.4	6.4	92.4	76.6	90.3	75.5	88.0	74.1	79.4	89.4	77.9	87.2	76.4	141.1	85.9	74.9	134.0	84.1	24.7	21.4	19.2	5360	1137
UNIV OF ILLINOIS WI	40.04N	88.28W	764	-0.5	4.2	92.0	76.0	90.0	75.1	87.7	74.1	79.6	88.8	77.7	86.5	76.9	144.3	86.1	75.0	135.0	83.3	27.5	24.6	21.8	5681	1008
DUPAGE	41.91N	88.25W	758	-2.5	1.6	90.3	74.9	87.9	74.0	84.4	72.2	78.2	87.0	76.4	84.3	75.3	136.3	84.1	73.4	127.6	81.4	24.6	21.2	19.1	6429	738
Indiana																										*8 sites, 5 more on CD-ROM*
EVANSVILLE REGIONAL	38.04N	87.54W	387	8.1	13.8	93.7	76.2	91.4	75.7	89.7	74.9	79.4	89.9	78.2	88.1	76.4	139.9	85.2	75.3	134.3	83.7	20.6	18.3	16.4	4424	1437
FORT WAYNE/BAER FLD	41.01N	85.21W	827	-0.7	5.0	90.8	74.3	88.2	73.1	85.5	71.9	77.6	86.8	75.9	84.0	74.8	134.5	82.9	73.2	127.4	80.9	24.8	21.0	18.9	5991	825
GRISSOM ARB	40.65N	86.15W	810	-0.2	5.4	91.6	75.3	88.8	74.6	86.2	73.0	79.4	87.9	77.3	85.3	76.9	144.5	84.7	74.9	134.8	82.3	25.0	20.9	18.7	5777	978
INDIANAPOLIS/I.-MUN	39.71N	86.27W	807	2.0	8.1	91.0	75.1	88.7	74.0	86.4	72.9	78.2	87.5	76.8	85.4	75.3	136.8	83.6	74.0	130.6	82.0	24.7	20.9	18.8	5272	1087
PURDUE UNIV	40.41N	86.94W	636	0.1	5.7	91.6	75.5	89.9	74.5	87.5	73.3	78.6	88.3	77.1	86.1	75.5	136.6	84.3	74.1	130.3	82.4	22.8	19.9	18.2	5524	1014
MONROE CO	39.14N	86.62W	846	3.5	9.7	90.7	75.5	89.6	75.4	87.5	74.1	78.6	86.8	77.4	85.9	75.5	137.7	83.2	74.7	134.0	82.3	19.4	17.3	15.7	5047	1015
SOUTH BEND/ST.JOSEP	41.71N	86.33W	774	0.2	5.8	90.6	74.0	88.0	72.5	85.1	71.3	77.3	86.4	75.4	83.7	74.5	133.0	83.0	72.8	125.2	80.7	23.8	20.4	18.5	6182	796
TERRE HAUTE INTL HU	39.45N	87.30W	591	1.1	8.4	91.8	76.4	90.0	75.7	87.8	74.5	79.5	88.7	77.9	86.7	76.8	142.7	85.3	75.1	134.5	83.3	23.0	19.6	17.9	5166	1078
Iowa																										*9 sites, 38 more on CD-ROM*
AMES MUNI	41.99N	93.62W	955	-6.4	-0.4	90.3	76.2	88.1	74.7	84.4	72.8	78.9	87.0	77.1	85.1	76.6	143.7	84.5	74.7	134.4	82.5	26.4	23.5	20.2	6547	787
ANKENY REGIONAL ARP	41.69N	93.55W	909	-3.7	1.2	93.3	75.4	90.3	74.8	87.6	73.4	78.3	88.4	76.9	86.7	75.4	137.7	84.2	73.4	128.3	82.9	21.7	18.9	17.0	5992	1005
BOONE MUNI	42.05N	93.84W	1161	-5.8	0.2	91.0	77.6	89.5	76.5	86.1	74.0	80.5	88.3	78.5	85.6	78.7	155.8	86.2	76.6	145.0	84.4	26.3	23.3	20.3	6424	882
CEDAR RAPIDS MUNI	41.88N	91.71W	873	-8.4	-2.8	91.0	76.0	88.0	74.4	85.1	72.6	78.5	86.9	76.9	85.0	76.2	141.3	83.9	74.3	132.4	81.9	26.5	23.6	20.4	6705	785
DAVENPORT MUNI	41.61N	90.59W	755	-5.8	0.3	90.1	76.0	88.0	75.0	84.3	72.9	78.3	86.8	76.8	84.8	75.3	136.5	83.5	73.4	127.6	81.8	26.6	23.7	20.4	6311	794
DES MOINES INTL	41.54N	93.67W	965	-5.3	-0.2	92.5	76.4	89.6	75.1	86.9	73.3	78.5	88.5	77.1	86.8	75.6	138.7	84.7	74.1	131.9	83.4	25.4	22.3	19.5	6172	1034
DUBUQUE MUNICIPAL	42.40N	90.70W	1079	-8.4	-2.9	88.8	74.6	85.9	73.2	83.2	71.2	77.4	85.5	75.4	82.9	75.0	136.5	82.6	73.0	127.7	80.3	25.7	22.8	19.9	7023	638
SIOUX CITY MUNI	42.39N	96.38W	1102	-7.8	-2.8	93.1	75.1	90.2	74.2	87.7	73.1	78.7	88.2	77.1	86.8	76.1	141.8	84.8	74.1	132.4	83.4	28.6	25.3	22.3	6682	916
WATERLOO MUNICIPAL	42.55N	92.40W	879	-9.9	-4.8	91.2	75.3	88.4	73.7	85.7	72.2	78.6	87.4	76.7	85.1	76.0	140.5	84.3	74.1	131.4	82.1	26.0	23.3	20.1	6988	775
Kansas																										*10 sites, 19 more on CD-ROM*
FT RILEY/MARSHALL A	39.06N	96.76W	1063	2.9	9.5	99.9	75.3	96.7	75.1	93.5	74.8	78.7	92.0	77.4	91.1	75.1	137.1	86.3	73.4	129.2	84.3	21.0	18.6	16.6	4834	1585
LAWRENCE MUNI	39.01N	95.21W	833	3.4	9.3	98.8	77.2	94.7	76.5	91.1	75.5	80.0	92.4	78.4	90.7	76.6	143.1	87.3	74.9	135.0	85.7	25.0	21.8	19.2	4933	1440
MANHATTAN RGNL	39.13N	96.68W	1070	1.4	8.6	99.6	75.8	96.7	75.9	92.7	74.9	78.7	92.7	77.7	91.5	75.0	136.4	85.8	73.3	128.6	83.7	24.2	20.5	18.3	5144	1440
MC CONNELL AFB	37.62N	97.27W	1371	6.5	12.3	99.4	73.9	96.4	73.8	93.0	73.6	77.8	91.0	76.6	89.7	74.1	133.8	83.7	72.8	128.0	82.7	26.9	24.3	21.1	4312	1695
JOHNSON CO EXECUTIVE	38.85N	94.74W	1073	4.9	9.5	95.2	76.9	91.3	76.2	89.9	75.6	79.1	89.9	77.9	88.8	75.4	138.5	85.3	74.7	135.3	84.4	23.4	20.2	18.3	4779	1388
SALINA MUNI	38.81N	97.66W	1283	3.4	9.2	101.0	73.8	98.0	73.7	94.7	73.2	77.4	92.4	76.2	90.6	73.1	129.1	83.9	72.2	125.0	83.0	27.8	24.9	22.5	4773	1664
FORBES FLD	38.95N	95.66W	1079	2.8	8.9	95.7	75.7	92.6	75.2	90.2	74.6	78.4	90.2	77.3	89.0	75.1	137.2	85.5	73.4	129.3	83.4	26.0	23.6	20.5	4929	1314

Meaning of acronyms:
DB: Dry bulb temperature, °F
WB: Wet bulb temperature, °F
MCWB: Mean coincident wet bulb temperature, °F
Lat: Latitude, °
DP: Dew point temperature, °F
MCDB: Mean coincident dry bulb temperature, °F
Long: Longitude, °
HR: Humidity ratio, grains of moisture per lb of dry air
Elev: Elevation, ft
WS: Wind speed, mph
HDD and CDD 65: Annual heating and cooling degree-days, base 65°F, °F-day

Station	Lat	Long	Elev	Heating DB		Cooling DB/MCWB						Evaporation WB/MCDB				Dehumidification DP/HR/MCDB						Extreme Annual WS			Heat./Cool. Degree-Days	
						0.4%		1%		2%		0.4%		1%		0.4%			1%							
				99.6%	99%	DB	MCWB	DB	MCWB	DB	MCWB	WB	MCDB	WB	MCDB	DP	HR	MCDB	DP	HR	MCDB	1%	2.5%	5%	HDD	CDD 65
TOPEKA/BILLARD MUNI	39.07N	95.63W	886	3.1	8.7	97.1	76.2	93.9	75.9	91.0	75.0	79.0	91.3	77.8	90.1	75.5	137.9	86.3	74.2	132.1	84.7	23.5	20.1	18.3	4902	1446
WICHITA/MID-CONTINE	37.65N	97.43W	1339	7.4	12.2	100.1	73.7	97.0	73.8	93.5	73.7	77.7	90.5	76.5	89.5	74.2	134.2	83.6	72.9	128.5	82.1	28.2	25.6	23.4	4464	1682
COL JAMES JABARA	37.75N	97.22W	1421	7.1	11.5	99.4	74.0	96.8	74.4	92.6	73.9	77.4	91.2	76.4	89.7	73.2	130.2	83.4	72.5	126.9	82.4	27.7	25.0	22.6	4495	1577
Kentucky																									*8 sites, 5 more on CD-ROM*	
BOWLING GREEN WARRE	36.98N	86.44W	538	11.2	16.7	93.4	75.0	91.1	75.2	89.5	74.7	78.4	88.6	77.4	87.3	75.5	136.0	83.6	74.5	131.5	82.5	19.8	17.9	16.1	4063	1427
CINCINNATI/GREATER	39.04N	84.67W	883	5.4	11.3	91.4	74.2	89.2	73.5	86.7	72.5	77.4	87.1	76.1	85.0	74.5	133.1	82.3	73.2	127.6	80.7	21.8	19.1	17.2	4954	1107
FORT CAMPBELL (AAF)	36.67N	87.50W	571	12.3	18.1	93.3	76.0	91.0	76.0	89.8	75.8	79.6	87.6	78.4	86.5	77.3	145.3	83.0	76.6	141.8	82.4	20.1	17.7	15.7	3818	1548
HENDERSON CITY CO	37.81N	87.68W	387	8.8	14.2	93.2	76.4	91.1	76.0	90.0	75.4	79.4	91.0	78.1	89.0	75.5	135.4	86.9	74.6	131.3	85.8	21.0	18.7	16.7	4444	1384
LEXINGTON/BLUE GRAS	38.04N	84.61W	988	8.3	13.6	91.6	73.9	89.6	73.6	87.3	72.8	77.3	87.5	76.1	85.4	74.2	132.6	82.7	73.1	127.5	81.1	20.3	18.0	16.3	4567	1201
BOWMAN FLD	38.23N	85.66W	558	9.7	15.7	93.3	75.1	91.1	74.7	89.6	74.0	78.5	88.6	77.4	87.3	75.4	136.0	83.3	74.6	132.0	82.7	18.7	16.8	14.7	4201	1459
LOUISVILLE/STANDIFO	38.18N	85.73W	489	10.2	15.9	93.8	75.3	91.5	75.0	89.6	74.2	78.7	89.1	77.5	87.9	75.7	136.8	84.7	74.4	131.0	83.2	21.0	18.7	16.8	4109	1572
SOMERSET PULASKI CO	37.05N	84.60W	928	12.3	17.9	94.6	74.9	91.6	74.3	90.3	73.7	78.0	90.5	76.8	88.4	74.1	131.8	84.1	73.0	126.9	82.4	17.9	15.4	12.6	3866	1460
Louisiana																									*12 sites, 8 more on CD-ROM*	
ESLER RGNL	31.40N	92.30W	118	26.6	28.3	97.8	76.7	95.3	77.2	93.0	76.7	80.3	89.7	79.5	89.6	78.3	147.8	83.8	77.1	141.8	83.3	16.5	13.8	12.0	2004	2485
ALEXANDRIA INT	31.34N	92.56W	79	27.4	29.9	97.2	77.1	94.7	77.3	92.8	76.8	80.7	89.5	79.8	89.4	78.9	150.3	84.4	77.3	142.3	84.0	18.6	16.5	14.1	1835	2621
BARKSDALE AFB	32.50N	93.66W	167	23.6	27.2	97.3	76.6	95.0	76.5	92.8	76.5	80.0	90.8	79.0	89.9	77.2	142.5	84.0	76.1	137.4	83.2	19.1	17.0	14.8	2291	2305
BATON ROUGE METRO R	30.54N	91.15W	75	28.5	31.8	94.6	77.6	93.1	77.3	91.5	76.9	80.4	89.0	79.8	88.2	78.5	148.3	83.8	77.5	143.5	83.2	18.7	16.7	15.0	1573	2709
LAFAYETTE RGNL	30.21N	91.99W	43	29.9	33.6	94.6	77.8	92.9	77.6	91.3	77.3	80.7	88.9	80.0	88.3	78.9	150.3	83.7	77.8	144.9	83.3	20.4	18.3	16.5	1463	2806
LAKE CHARLES MUNI	30.13N	93.23W	10	30.3	33.8	94.4	77.8	92.8	77.7	91.2	77.6	81.4	88.5	80.4	87.6	79.4	152.8	84.2	78.7	149.2	83.7	20.5	18.4	16.7	1453	2806
MONROE RGNL	32.51N	92.04W	82	25.2	28.1	97.5	77.8	95.2	77.7	93.1	77.0	81.0	91.4	80.1	90.6	78.5	148.2	85.4	77.3	142.6	84.6	19.0	17.0	15.0	2189	2462
NEW ORLEANS NAS JRB	29.83N	90.03W	0	30.7	34.2	92.8	78.1	91.2	77.8	90.2	77.6	81.9	87.5	80.6	86.6	80.4	157.8	84.6	79.2	151.3	83.6	18.1	16.0	13.6	1444	2626
NEW ORLEANS/MOISANT	29.99N	90.25W	20	33.1	36.3	93.8	78.1	92.2	77.7	90.8	77.5	80.9	88.9	80.2	88.0	79.0	150.6	84.4	78.2	146.5	83.8	20.7	18.7	17.0	1286	2925
LAKEFRONT	30.04N	90.03W	10	35.6	38.6	93.3	78.7	91.8	78.2	90.7	77.9	81.4	89.3	80.6	88.3	79.3	152.3	85.3	78.8	149.7	85.0	24.9	21.0	18.9	1138	3232
SHREVEPORT DOWNTOWN	32.54N	93.74W	180	26.9	29.6	99.2	76.6	96.9	76.5	93.5	76.2	79.6	91.3	78.8	90.2	76.9	141.0	83.1	75.5	134.3	82.7	18.8	16.7	14.9	2149	2628
SHREVEPORT REGIONAL	32.45N	93.82W	259	25.2	28.4	98.5	76.2	96.0	76.3	93.6	76.0	79.4	91.2	78.6	89.9	76.4	139.2	83.2	75.7	135.8	82.7	19.7	17.7	16.1	2117	2535
Maine																									*5 sites, 16 more on CD-ROM*	
AUBURN LEWISTON MUNI	44.05N	70.28W	289	-6.2	-0.1	87.9	70.7	83.6	69.2	81.0	67.5	73.6	83.4	71.4	80.2	70.4	113.1	78.5	68.5	106.0	76.4	20.8	18.5	16.4	7632	308
BANGOR INTL	44.81N	68.82W	194	-7.3	-2.0	87.9	70.7	84.1	69.0	81.1	67.0	73.2	83.1	71.3	80.6	70.2	111.7	78.1	68.2	104.2	75.4	23.5	19.7	18.0	7665	355
BRUNSWICK (NAS)	43.90N	69.93W	75	-2.2	2.1	86.3	70.7	82.8	68.9	80.5	67.3	73.5	82.4	71.5	79.8	70.4	112.4	78.0	69.0	106.7	76.0	23.2	19.5	17.4	7202	367
PORTLAND/INTNL. JET	43.64N	70.30W	62	0.1	4.9	86.8	71.3	83.4	69.9	80.4	68.2	74.1	83.2	72.2	80.2	71.0	114.7	78.8	69.5	108.8	76.6	23.2	19.6	17.6	7023	370
SANFORD RGNL	43.39N	70.70W	243	-6.2	0.3	89.5	71.0	85.2	69.4	82.0	67.8	74.1	84.6	72.1	81.9	71.5	117.4	80.1	69.6	109.6	77.7	20.9	18.5	16.3	7470	350
Maryland																									*3 sites, 4 more on CD-ROM*	
ANDREWS AFB/CAMP SP	38.82N	76.85W	289	15.6	18.4	92.6	74.1	90.2	73.4	87.9	72.8	77.6	86.6	76.3	84.9	75.1	133.1	80.4	73.4	125.3	79.2	24.7	20.7	18.3	4419	1199
BALTIMORE-WASHINGTO	39.17N	76.68W	154	14.0	17.9	94.0	74.9	91.3	74.1	88.7	73.1	78.1	88.6	76.8	86.6	75.3	133.2	82.1	74.1	127.8	80.7	22.3	19.1	17.1	4552	1261
THOMAS POINT	38.90N	76.43W	39	17.6	21.4	86.8	74.7	84.8	74.6	83.1	74.0	79.6	82.7	77.8	81.5	78.7	149.0	81.2	76.9	140.3	80.0	37.7	31.6	26.5	4196	1236
Massachusetts																									*11 sites, 10 more on CD-ROM*	
BARNSTABLE MUNI BOA	41.67N	70.28W	52	9.9	15.6	84.0	73.0	81.5	71.5	79.3	70.2	75.5	81.3	74.2	78.9	73.3	124.1	77.6	72.7	121.5	77.0	24.7	21.2	19.2	5872	511
BOSTON/LOGAN INTL	42.36N	71.01W	30	8.1	13.0	90.6	72.7	87.6	71.7	84.2	70.2	75.9	85.7	74.3	83.0	72.8	122.0	80.6	71.5	116.3	78.6	26.9	24.2	20.9	5596	750
BUZZARDS BAY	41.38N	71.03W	56	12.4	16.7	76.0	N/A	74.4	N/A	73.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	43.8	38.3	34.0	5552	302
CHATHAM MUNI	41.69N	69.99W	69	11.7	17.1	82.1	72.3	80.7	71.6	78.1	70.5	75.1	80.2	73.9	78.2	73.2	123.5	77.6	72.5	120.5	76.7	21.7	18.7	16.7	5688	457
LAWRENCE MUNI	42.72N	71.12W	148	3.4	9.6	90.4	72.8	87.9	71.9	83.9	70.7	75.7	84.8	74.3	82.8	72.8	122.3	79.7	72.1	119.3	79.1	20.4	18.1	16.2	6091	652
MARTHAS VINEYARD	41.39N	70.62W	69	9.5	14.0	83.8	72.5	81.3	71.2	79.1	70.0	75.2	80.9	73.9	78.6	73.1	123.3	77.8	72.4	120.3	76.8	26.0	23.5	20.4	5886	429
NEW BEDFORD RGNL	41.68N	70.96W	79	8.7	12.1	88.2	73.2	84.1	71.7	81.7	70.1	75.8	83.7	74.4	80.9	73.1	123.4	78.7	72.4	120.4	77.8	23.1	19.9	17.9	5833	570
NORWOOD MEM	42.19N	71.17W	49	3.1	9.1	90.4	73.3	88.0	72.6	84.1	70.8	76.5	85.6	74.9	82.9	73.3	124.1	79.5	72.5	120.7	78.7	20.5	18.2	16.3	6233	581
PLYMOUTH MUNICIPAL	41.91N	70.73W	148	5.3	9.9	89.5	73.1	84.4	71.6	82.0	69.9	75.8	84.1	74.4	81.3	73.2	123.9	78.8	72.4	120.6	78.0	23.3	19.9	17.9	6154	553
SOUTH WEYMOUTH NAS	42.15N	70.93W	161	5.9	10.4	91.2	73.8	87.7	72.3	84.7	70.7	76.9	86.8	74.9	83.8	74.1	127.9	81.9	72.2	119.7	79.4	18.5	16.5	14.5	5832	646
WORCESTER REGIONAL ARPT	42.27N	71.88W	1017	1.9	6.7	85.7	71.2	83.0	69.7	80.7	68.1	74.0	81.7	72.3	79.4	71.7	121.5	77.8	70.1	115.1	76.1	25.9	22.9	19.7	6706	462
Michigan																									*15 sites, 44 more on CD-ROM*	
DETROIT CITY	42.41N	83.01W	627	5.2	9.6	90.7	73.4	88.2	72.1	85.5	70.8	76.4	86.4	74.6	83.8	73.2	126.3	81.9	71.9	120.5	80.3	20.4	18.5	17.1	5989	884
DETROIT/METROPOLITA	42.22N	83.35W	663	2.9	8.0	90.4	73.8	87.6	72.6	84.7	71.1	76.9	86.4	75.0	83.4	73.8	129.2	82.3	72.3	122.7	80.2	25.3	22.2	19.5	6103	807
WILLOW RUN	42.24N	83.53W	715	0.8	6.3	90.3	74.0	87.8	72.5	84.3	70.8	76.7	86.3	74.8	83.6	73.3	127.3	81.3	72.2	122.2	80.0	24.7	21.5	19.0	6415	679
FLINT/BISHOP INTL	42.97N	83.75W	768	-0.2	4.5	89.7	73.8	86.7	72.0	83.9	70.3	76.3	85.3	74.4	82.9	73.3	127.4	81.9	71.7	120.4	79.3	23.8	20.4	18.5	6741	594
GRAND RAPIDS/KENT C	42.88N	85.52W	804	2.2	6.9	89.4	73.1	86.5	71.7	83.8	70.1	76.3	85.1	74.4	82.6	73.4	128.2	81.4	71.8	121.0	79.3	24.7	21.0	19.0	6615	639
GROSSE ILE MUNI	42.10N	83.17W	591	7.1	10.2	89.7	74.2	85.9	73.5	82.5	71.8	77.9	84.5	76.2	82.7	75.3	135.8	81.1	73.4	127.2	79.6	20.9	18.6	16.7	5804	863
TULIP CITY	42.75N	86.10W	689	7.2	10.1	88.4	73.3	85.7	72.0	82.3	70.3	76.1	84.2	74.4	82.2	73.1	126.0	80.9	72.2	122.3	79.5	25.7	22.1	19.2	6234	617
JACKSON CO REYNOLDS	42.26N	84.46W	1020	0.5	5.4	88.3	73.4	85.6	71.9	82.7	70.1	76.0	84.4	74.3	82.2	73.2	127.9	80.9	71.8	122.2	79.4	20.2	18.4	16.9	6619	565
KALAMAZOO BATTLE CR	42.24N	85.55W	873	2.8	8.6	90.0	72.8	87.7	71.8	83.9	70.4	75.9	84.6	74.4	82.8	72.8	125.9	81.0	72.0	122.4	79.9	21.7	19.0	17.2	6251	709

Meaning of acronyms:
DB: Dry bulb temperature, °F — *WB: Wet bulb temperature, °F* — *MCWB: Mean coincident wet bulb temperature, °F*
Lat: Latitude, ° — *DP: Dew point temperature, °F* — *MCDB: Mean coincident dry bulb temperature, °F*
Long: Longitude, ° — *HR: Humidity ratio, grains of moisture per lb of dry air* — *HDD and CDD 65: Annual heating and cooling degree-days, base 65°F, °F-day*
Elev: Elevation, ft — *WS: Wind speed, mph*

Station	Lat	Long	Elev	Heating DB		Cooling DB/MCWB						Evaporation WB/MCDB				Dehumidification DP/HR/MCDB						Extreme Annual WS			Heat./Cool. Degree-Days	
				99.6%	99%	0.4% DB	0.4% MCWB	1% DB	1% MCWB	2% DB	2% MCWB	0.4% WB	0.4% MCDB	1% WB	1% MCDB	0.4% DP	0.4% HR	0.4% MCDB	1% DP	1% HR	1% MCDB	1%	2.5%	5%	HDD 65	CDD 65
LANSING/CAPITAL CIT	42.78N	84.58W	873	-1.0	4.2	89.5	73.3	86.4	71.9	83.6	70.2	76.2	85.2	74.3	82.6	73.2	127.6	81.4	71.6	120.6	79.2	24.3	20.6	18.6	6815	575
MUSKEGON	43.17N	86.24W	633	5.2	9.3	86.2	72.4	83.7	71.0	81.5	69.5	75.5	82.4	73.9	80.3	73.2	126.4	79.8	71.8	120.1	78.2	25.3	23.0	20.0	6619	524
OAKLAND CO INTL	42.67N	83.42W	981	1.1	5.7	89.7	73.2	86.2	71.3	83.5	69.9	75.3	84.8	73.5	82.2	72.4	124.6	80.6	70.9	117.9	78.5	24.3	20.8	18.8	6633	641
MBS INTL	43.53N	84.08W	669	0.4	4.6	89.9	73.3	86.6	71.6	83.7	70.3	76.2	85.6	74.2	82.9	73.1	126.1	81.3	71.7	120.1	79.5	24.2	20.7	18.8	6908	580
SELFRIDGE ANGB	42.60N	82.83W	581	2.9	7.4	90.1	73.2	86.5	71.9	83.9	70.7	75.7	85.0	74.1	83.0	72.8	124.1	80.0	71.9	120.6	79.1	21.0	18.8	17.0	6460	645
ST CLAIR CO INTL	42.91N	82.52W	650	0.6	5.5	90.0	73.5	85.9	71.1	82.4	69.5	75.7	84.6	73.8	81.8	72.9	125.0	79.9	71.9	120.8	78.7	18.6	16.6	14.7	6731	465
Minnesota																									*11 sites, 68 more on CD-ROM*	
SKY HARBOR	46.72N	92.03W	610	-10.7	-6.4	85.9	71.6	82.1	69.4	79.3	67.5	75.6	82.7	73.1	79.5	73.2	126.0	78.7	71.8	120.1	77.4	28.0	24.8	21.4	8572	298
DULUTH INTL AIRPORT	46.84N	92.19W	1417	-17.9	-12.5	84.3	69.6	81.3	67.3	78.4	65.4	72.5	81.1	70.1	78.2	69.5	114.4	78.0	67.1	105.2	75.1	24.7	21.1	19.2	9325	210
FLYING CLOUD	44.83N	93.47W	945	-9.4	-6.0	90.5	73.9	88.1	72.7	84.3	70.7	77.3	86.9	75.2	83.9	73.5	129.0	82.8	72.4	124.1	81.3	21.9	19.2	17.4	7343	773
MANKATA RGNL ARPT	44.22N	93.92W	1020	-13.0	-8.3	89.6	73.5	85.9	71.4	82.4	69.5	76.7	84.7	74.4	82.6	73.4	129.2	81.6	72.0	123.0	80.3	26.8	24.1	20.8	7714	601
ANOKA CO BLAINE	45.15N	93.20W	912	-9.1	-5.8	90.1	74.3	87.6	73.0	83.8	71.0	77.8	85.7	75.4	83.3	75.0	135.8	82.9	72.8	125.7	80.2	23.0	19.7	17.8	7536	624
CRYSTAL	45.06N	93.35W	869	-9.1	-5.8	90.5	73.1	88.1	72.0	84.2	70.1	76.6	86.3	74.4	83.9	73.0	126.6	82.5	71.9	121.7	81.0	21.3	19.0	17.2	7521	692
MINNEAPOLIS/ST.PAUL	44.88N	93.23W	837	-11.2	-6.2	90.9	72.9	88.0	71.9	84.8	70.3	76.8	87.0	74.8	84.0	73.4	128.3	83.3	71.7	120.6	81.0	24.4	20.9	19.1	7472	765
ROCHESTER MUNICIPAL	43.90N	92.49W	1319	-13.1	-8.2	88.0	73.4	84.8	71.7	82.2	70.1	76.7	84.3	74.5	81.7	74.2	134.2	81.6	72.2	125.0	79.5	28.5	25.8	23.5	7868	515
SOUTH ST PAUL MUNI	44.85N	93.03W	820	-9.1	-5.5	90.5	73.1	88.0	71.7	84.3	69.8	77.1	85.5	74.7	83.0	74.6	133.5	82.3	72.3	123.3	79.7	18.6	16.5	14.3	7401	730
ST. CLOUD MUNICIPAL	45.55N	94.05W	1024	-17.2	-11.4	89.9	72.5	86.6	70.8	83.6	69.0	76.2	85.9	74.1	83.5	73.1	127.8	82.0	70.9	118.2	79.7	23.4	19.8	17.8	8424	477
ST PAUL DOWNTOWN HO	44.93N	93.05W	712	-11.0	-6.4	90.4	73.5	87.8	72.1	84.0	70.4	76.8	86.0	74.7	83.6	73.4	127.5	82.4	72.0	121.7	80.6	23.1	20.1	18.2	7462	722
Mississippi																									*6 sites, 7 more on CD-ROM*	
HATTIESBURG LAUREL	31.47N	89.34W	299	25.1	27.8	96.6	75.8	93.2	75.0	91.2	74.8	78.5	89.7	77.7	88.9	75.3	134.1	82.8	74.7	131.2	82.4	16.1	13.2	11.7	2081	2292
JACKSON/ALLEN C. TH	32.32N	90.08W	331	23.2	26.7	96.4	76.4	94.0	76.2	92.2	76.0	79.8	90.4	78.7	88.9	77.1	142.9	83.5	76.2	138.4	82.7	18.6	16.5	14.6	2282	2294
KEESLER AFB	30.41N	88.92W	33	30.7	35.1	93.5	79.8	91.6	79.2	90.4	78.9	83.2	89.8	81.9	88.1	81.4	163.5	86.8	80.6	159.0	86.0	17.7	15.6	13.5	1447	2757
MERIDIAN/KEY FIELD	32.33N	88.75W	312	22.5	26.1	96.3	75.9	93.8	76.0	92.0	75.7	79.6	89.7	78.6	88.6	77.0	142.5	83.4	76.0	137.3	82.5	18.5	16.6	14.7	2344	2161
MERIDIAN NAS	32.55N	88.57W	318	22.5	26.7	97.4	76.7	95.3	76.6	93.1	75.7	80.3	91.6	79.0	90.5	77.3	143.6	85.9	75.7	136.3	84.2	15.7	12.7	10.9	2307	2290
TUPELO/C.D. LEMONS	34.26N	88.77W	361	19.1	23.4	96.4	76.0	93.5	75.6	91.5	75.4	79.2	89.9	78.3	88.7	76.4	139.5	83.7	75.4	134.7	82.9	18.9	17.0	15.4	2915	2003
Missouri																									*9 sites, 10 more on CD-ROM*	
CAPE GIRARDEAU RGNL	37.23N	89.57W	351	9.7	15.5	94.5	77.3	92.3	76.8	90.3	76.1	80.3	90.2	78.8	88.8	77.4	144.3	86.1	75.9	137.1	84.4	21.2	19.0	17.3	4182	1531
COLUMBIA REGIONAL	38.82N	92.22W	899	2.8	8.6	94.2	76.4	91.3	76.0	88.8	74.9	79.3	89.3	77.9	87.8	76.4	142.6	85.4	75.0	135.5	83.8	24.2	20.6	18.6	4937	1247
JEFFERSON CITY MEM	38.59N	92.16W	574	7.1	11.8	95.0	76.5	91.4	75.6	90.1	75.1	79.5	89.4	78.0	88.3	76.9	142.9	85.0	74.9	133.9	83.2	20.9	18.5	16.5	4560	1397
JOPLIN RGNL	37.15N	94.50W	984	8.5	13.9	96.6	75.7	93.4	75.6	91.0	75.1	78.6	90.3	77.7	89.5	75.3	137.5	85.4	74.1	132.1	84.2	24.9	21.7	19.3	4033	1638
CHARLES B WHEELER D	39.12N	94.59W	751	5.0	9.8	96.8	76.4	93.3	75.9	90.9	75.3	79.5	91.8	78.2	89.9	75.9	139.4	86.6	74.8	134.0	85.7	22.5	19.6	18.3	4542	1637
KANSAS CITY INTL	39.30N	94.72W	1024	2.0	7.2	95.8	76.8	92.5	76.2	89.7	75.4	79.8	90.5	78.3	88.9	76.9	145.3	86.6	75.2	137.2	85.2	25.6	23.0	20.0	5012	1372
SPRINGFIELD MUNI	37.24N	93.39W	1270	6.6	12.3	94.8	74.6	91.7	74.7	89.3	74.3	77.8	88.9	76.8	87.6	74.6	135.6	83.6	73.4	130.1	82.3	23.3	20.1	18.3	4442	1366
ST. LOUIS/LAMBERT	38.75N	90.37W	709	6.6	11.7	95.5	76.8	93.0	76.1	90.7	75.0	79.4	90.8	78.1	89.2	76.2	140.6	85.8	74.9	134.2	84.9	23.7	20.1	18.1	4436	1650
SPIRIT OF ST LOUIS	38.66N	90.66W	463	5.3	10.6	95.3	77.3	92.6	76.3	90.3	75.2	79.9	90.8	78.3	89.0	76.9	142.3	86.2	75.2	134.3	84.4	20.7	18.5	16.7	4679	1389
Montana																									*7 sites, 14 more on CD-ROM*	
BILLINGS/LOGAN INT.	45.81N	108.54W	3570	-9.4	-3.2	94.8	62.9	91.2	61.9	88.0	61.3	66.3	85.3	64.5	83.8	60.3	89.3	72.1	58.0	82.0	70.5	27.1	24.5	21.1	6705	630
GALLATIN FLD	45.79N	111.15W	4449	-15.8	-8.0	92.0	61.4	88.6	60.7	85.0	59.5	64.5	83.3	62.7	81.7	58.5	86.5	69.7	56.1	79.1	68.4	20.8	18.0	15.2	8184	233
BERT MOONEY	45.95N	112.51W	5535	-18.2	-9.5	88.0	57.5	84.4	56.5	81.6	55.8	60.4	79.1	59.0	77.5	54.7	78.2	62.9	52.3	71.7	62.1	22.0	19.0	17.2	9104	77
GREAT FALLS	47.45N	111.38W	3707	-13.5	-6.6	90.4	60.3	86.9	59.4	83.7	58.8	63.3	82.9	61.7	80.5	57.1	80.0	66.4	55.1	74.1	67.2	31.3	27.1	24.6	7733	311
GREAT FALLS INTL	47.47N	111.38W	3658	-16.3	-9.1	92.2	61.1	88.7	60.3	85.2	59.5	64.1	84.6	62.4	82.3	57.6	81.1	66.7	55.6	75.4	67.1	31.4	27.5	24.8	7470	326
MALMSTROM AFHP	47.50N	111.19W	3471	-16.3	-9.2	92.2	61.7	88.9	61.0	85.5	60.3	64.6	84.7	63.1	83.3	57.6	80.6	69.2	55.8	75.5	68.7	29.8	26.5	23.4	6886	394
MISSOULA/JOHNSON-BE	46.92N	114.09W	3189	-3.8	3.1	92.8	62.1	89.7	61.5	86.0	60.5	65.0	85.3	63.4	83.6	58.7	83.0	68.9	56.5	76.6	67.8	21.4	18.8	16.6	7372	314
Nebraska																									*5 sites, 20 more on CD-ROM*	
GRAND ISLAND COUNTY	40.96N	98.31W	1857	-4.3	1.1	95.7	74.1	92.4	73.2	89.5	72.0	77.4	89.1	75.8	87.7	74.1	136.2	84.1	72.4	128.5	82.4	28.6	25.5	22.8	6081	1037
LINCOLN MUNICIPAL	40.83N	96.76W	1188	-3.5	1.5	96.9	75.1	93.2	74.5	90.4	73.5	78.3	90.6	76.9	89.1	74.9	136.6	85.5	73.2	129.0	83.7	27.1	24.3	20.9	5917	1185
OFFUTT AFB	41.12N	95.90W	1053	-1.5	2.6	94.8	76.1	91.0	74.9	88.5	73.8	79.8	88.3	77.9	86.5	77.3	147.6	84.2	75.2	137.5	82.2	24.9	21.0	18.7	5874	1151
OMAHA/EPPLEY FIELD	41.31N	95.90W	981	-4.3	0.6	94.5	76.4	91.4	75.2	88.8	73.7	79.3	89.6	77.6	87.8	76.4	142.7	85.8	74.6	134.3	84.0	26.3	23.7	20.4	6025	1132
OMAHA	41.37N	96.02W	1332	-6.1	-0.1	94.0	75.0	90.9	74.6	88.0	73.0	77.7	89.0	76.3	87.3	74.4	135.3	84.2	72.9	128.2	83.0	23.3	19.2	17.8	5981	1093
Nevada																									*3 sites, 10 more on CD-ROM*	
LAS VEGAS/MCCARRAN	36.08N	115.16W	2182	31.0	33.8	108.4	67.8	106.3	67.0	104.1	66.5	72.6	96.7	71.1	95.1	65.7	103.0	81.7	63.2	94.2	84.6	26.3	23.3	20.0	2015	3486
NELLIS AFB	36.24N	115.03W	1867	27.7	30.9	109.2	67.4	107.1	66.9	104.7	66.2	72.2	95.2	71.0	95.5	65.8	101.8	80.8	63.0	92.4	83.7	25.8	22.5	19.3	2130	3303
RENO/CANNON INTL	39.48N	119.77W	4400	12.1	17.6	96.3	61.6	93.4	60.2	91.1	59.3	64.0	89.3	62.3	87.7	55.1	76.0	71.4	51.9	67.5	70.9	25.5	21.1	18.7	5043	791
New Hampshire																									*4 sites, 8 more on CD-ROM*	
CONCORD MUNICIPAL	43.20N	71.50W	348	-3.6	1.5	90.1	71.4	87.1	69.9	84.1	68.7	74.8	85.0	73.0	82.2	71.8	118.9	78.5	70.2	112.4	77.0	20.9	18.6	16.6	7141	469
JAFFREY ARPT SILVER	42.81N	72.00W	1040	-2.2	1.4	86.5	69.8	83.6	68.8	81.2	67.1	73.0	81.1	71.6	79.1	71.6	121.3	76.5	70.0	114.5	75.2	16.3	13.7	12.1	7323	362

Meaning of acronyms:
DB: Dry bulb temperature, °F — WB: Wet bulb temperature, °F — MCWB: Mean coincident wet bulb temperature, °F
Lat: Latitude, ° — DP: Dew point temperature, °F — MCDB: Mean coincident dry bulb temperature, °F
Long: Longitude, ° — HR: Humidity ratio, grains of moisture per lb of dry air
Elev: Elevation, ft — WS: Wind speed, mph — HDD and CDD 65: Annual heating and cooling degree-days, base 65°F, °F-day

Station	Lat	Long	Elev	Heating DB		Cooling DB/MCWB						Evaporation WB/MCDB				Dehumidification DP/HR/MCDB						Extreme Annual WS			Heat./Cool. Degree-Days	
						0.4%		1%		2%		0.4%		1%		0.4%			1%							
				99.6%	99%	DB	MCWB	DB	MCWB	DB	MCWB	WB	MCDB	WB	MCDB	DP	HR	MCDB	DP	HR	MCDB	1%	2.5%	5%	HDD	CDD 65
MANCHESTER	42.93N	71.44W	233	1.4	7.1	91.1	71.9	88.5	70.6	85.7	69.5	75.5	85.7	73.8	83.2	72.4	121.0	80.3	71.2	116.1	78.8	19.3	17.7	15.7	6214	730
PEASE INTL TRADEPOR	43.08N	70.82W	102	2.8	8.4	89.6	72.8	86.0	71.2	82.4	69.5	75.4	84.8	73.6	82.2	72.4	120.6	80.2	71.0	114.6	78.4	23.1	19.7	17.5	6418	545
New Jersey																									*7 sites, 3 more on CD-ROM*	
ATLANTIC CITY INTL	39.46N	74.58W	66	11.4	15.9	92.2	74.9	89.5	73.8	86.5	72.8	77.9	87.4	76.7	84.9	75.2	132.5	81.8	74.2	128.0	80.6	24.9	21.3	18.9	4913	1014
MONMOUTH EXECUTIVE	40.19N	74.12W	161	11.6	16.0	90.9	73.6	88.3	72.3	84.4	70.9	76.3	86.8	74.9	84.2	73.0	123.3	80.9	72.1	119.6	80.2	25.2	22.0	19.3	5105	894
MC GUIRE AFB	40.02N	74.58W	131	11.9	15.9	92.6	75.9	90.2	74.7	87.8	73.8	79.2	87.4	77.7	85.6	77.1	141.7	82.5	75.2	132.6	81.4	23.2	19.8	17.8	4864	1050
MILLVILLE MUNI	39.37N	75.08W	75	11.0	15.8	92.1	74.8	89.7	74.1	87.3	73.1	78.0	87.2	76.8	85.1	75.4	133.4	81.6	74.4	128.8	80.6	20.2	18.3	16.6	4891	1059
NEWARK INTL AIRPORT	40.68N	74.17W	30	12.3	16.6	94.2	74.6	91.1	73.1	88.4	72.0	77.7	88.7	76.3	85.8	74.7	130.0	82.1	73.4	124.4	80.8	25.0	21.8	19.3	4687	1257
TETERBORO	40.85N	74.06W	7	11.5	15.8	92.4	74.5	89.9	73.5	87.4	72.1	77.7	87.7	75.9	85.1	74.8	130.2	82.5	73.1	122.9	80.3	20.7	18.6	17.0	4996	1050
TRENTON MERCER	40.28N	74.81W	213	11.9	16.1	92.8	74.2	90.2	73.2	87.8	72.4	77.2	88.3	75.8	85.3	73.4	125.4	81.4	72.7	122.4	80.7	21.3	19.0	17.5	4982	1049
New Mexico																									*8 sites, 11 more on CD-ROM*	
ALAMOGORDO WHITE SA	32.84N	105.98W	4199	21.3	25.2	99.8	63.9	98.6	64.2	95.2	64.0	71.0	86.6	69.5	85.3	66.3	113.4	75.3	65.6	110.5	75.2	22.2	18.7	16.4	2856	1904
ALBUQUERQUE INTL	35.04N	106.62W	5315	18.2	21.6	95.3	60.1	92.9	59.8	90.6	59.7	65.3	81.3	64.4	80.4	61.6	100.0	68.0	60.4	95.6	68.6	28.2	24.7	20.6	3994	1370
CANNON AFB	34.38N	103.32W	4295	12.6	17.8	97.8	63.4	94.8	63.8	92.1	64.2	70.4	83.8	69.2	83.1	67.0	116.7	73.3	65.5	110.7	73.3	28.2	24.8	21.5	3776	1355
CLOVIS MUNI	34.43N	103.07W	4213	13.9	17.9	97.0	63.9	93.3	63.8	91.1	63.9	69.5	84.3	68.5	83.6	65.7	111.2	74.3	64.1	104.8	72.7	31.8	27.2	24.3	4084	1191
FOUR CORNERS RGNL	36.74N	108.23W	5502	7.3	11.8	95.4	59.8	92.8	59.1	90.5	59.0	65.0	81.7	64.0	80.9	61.2	99.4	67.5	59.3	92.6	67.9	24.8	21.3	18.5	5328	912
HOLLOMAN AFB	32.85N	106.10W	4094	18.9	22.2	99.4	63.0	97.0	62.9	94.5	62.7	68.8	85.7	67.9	85.0	64.4	105.6	71.9	63.4	101.7	72.2	24.0	19.7	17.0	3228	1715
ROSWELL/INDUSTRIAL	33.31N	104.54W	3668	18.0	21.4	100.1	64.9	97.8	65.0	95.5	64.9	70.9	86.8	69.8	86.0	67.0	114.0	74.1	65.9	109.4	73.8	25.9	21.2	18.5	3116	1892
WHITE SANDS	32.38N	106.48W	4081	18.4	22.5	99.0	63.7	96.5	63.9	94.2	63.8	69.8	87.4	68.9	86.1	65.9	111.2	72.1	64.6	106.4	72.3	18.7	16.2	13.3	2946	1811
New York																									*19 sites, 17 more on CD-ROM*	
ALBANY COUNTY AIRPO	42.75N	73.80W	292	-0.9	3.9	89.2	73.0	86.2	71.2	83.4	70.1	75.5	84.8	74.0	82.2	72.7	122.5	80.3	71.3	116.7	78.7	24.1	20.5	18.5	6562	619
AMBROSE LIGHT	40.45N	73.80W	69	13.8	17.8	83.9	N/A	80.8	N/A	78.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	42.3	36.9	33.3	4916	704
BINGHAMTON/BROOME C	42.21N	75.98W	1637	-0.2	4.1	85.5	70.1	82.3	68.3	80.0	67.2	72.8	80.9	71.1	78.5	70.2	118.2	76.6	68.7	112.0	74.9	20.9	18.8	17.3	7097	399
GREATER BUFFALO INT	42.94N	78.74W	705	3.6	7.4	86.4	71.3	83.9	70.1	81.6	68.8	74.8	81.9	73.2	80.1	72.4	123.1	79.0	70.7	115.9	77.6	27.4	24.5	20.8	6508	563
ELMIRA CORNING RGNL	42.16N	76.89W	955	-0.3	4.7	89.9	71.9	86.5	70.0	83.7	68.8	74.7	84.4	72.8	82.2	71.9	122.1	80.1	70.1	114.8	77.5	20.3	18.2	16.3	6766	470
GRIFFISS AIRPARK	43.23N	75.41W	518	-5.5	0.6	88.5	72.5	85.5	70.3	82.4	68.8	75.0	85.0	73.0	81.8	71.9	120.4	80.8	70.1	112.9	78.4	22.8	19.1	16.9	7054	473
LONG ISLAND MAC ART	40.79N	73.10W	98	11.5	15.7	88.5	73.4	85.7	72.2	82.7	70.9	76.6	83.5	75.3	81.2	74.6	129.8	79.7	73.3	124.2	78.3	24.0	20.4	18.6	5294	809
CHATAUQUA CO JAMESTO	42.15N	79.25W	1722	1.0	5.2	82.4	69.5	81.0	68.5	78.8	66.8	72.2	79.8	70.5	77.7	70.1	118.0	77.4	67.9	109.4	75.1	21.5	18.9	17.3	7166	295
NEW YORK/JOHN F. KE	40.66N	73.80W	23	13.8	17.8	89.8	72.9	86.5	71.8	83.7	71.1	76.7	83.8	75.4	81.6	74.6	129.4	80.1	73.4	124.2	78.6	27.2	24.6	21.6	4843	984
NEW YORK/LA GUARDIA	40.78N	73.88W	30	13.9	18.0	92.4	74.0	89.7	72.7	86.9	71.8	77.0	87.0	75.8	84.5	74.2	127.9	81.0	73.0	122.8	80.2	27.2	24.6	21.5	4555	1259
STEWART INTL	41.50N	74.10W	492	4.6	9.5	90.2	72.9	86.4	71.9	83.9	70.7	76.0	85.1	74.4	82.9	73.0	124.9	79.8	72.2	121.3	79.1	24.3	20.3	18.4	5933	722
NIAGARA FALLS INTL	43.11N	78.95W	587	3.0	7.3	88.0	72.9	85.3	71.3	82.4	69.7	75.5	83.7	73.9	81.6	72.9	124.6	80.2	71.7	119.6	78.7	26.4	23.6	20.3	6584	590
PLATTSBURGH INTL	44.65N	73.47W	233	-9.6	-5.1	86.5	71.3	83.2	69.5	80.3	68.2	74.1	82.3	72.2	80.0	71.4	117.0	79.0	69.5	109.5	76.6	20.6	18.4	16.3	7823	360
DUTCHESS CO	41.63N	73.88W	161	1.7	7.5	91.4	73.8	88.7	72.6	85.7	71.3	76.7	87.3	75.1	84.5	73.3	124.6	82.0	72.2	119.9	80.7	18.5	16.8	14.3	6149	702
REPUBLIC	40.73N	73.42W	82	12.3	17.7	90.2	73.7	86.5	71.9	83.7	71.3	76.7	84.6	75.4	82.1	74.7	130.1	79.9	73.1	123.4	78.3	24.7	21.4	19.0	5041	912
ROCHESTER-MONROE CO	43.12N	77.68W	554	2.9	6.9	88.7	73.2	85.6	71.2	82.7	69.7	75.4	84.5	73.5	81.9	72.5	122.7	80.6	70.8	115.8	78.2	25.1	21.4	18.9	6558	555
SYRACUSE/HANCOCK	43.11N	76.10W	417	-1.2	4.3	89.2	73.2	86.3	71.3	83.6	70.0	75.3	85.2	73.6	82.6	72.2	121.1	80.9	70.5	114.0	78.7	24.3	20.5	18.3	6577	594
ONEIDA CO	43.15N	75.38W	745	-5.0	1.0	87.3	72.5	84.3	70.6	81.8	69.0	75.0	83.2	73.2	80.8	72.4	123.4	79.2	70.6	115.8	77.4	20.7	18.7	17.2	7074	463
WESTCHESTER CO	41.07N	73.71W	397	9.0	12.8	89.9	73.9	86.5	72.1	83.7	70.8	76.4	84.9	74.8	82.3	73.5	126.4	79.4	72.5	122.4	78.4	21.8	18.6	16.5	5559	749
North Carolina																									*14 sites, 22 more on CD-ROM*	
ASHEVILLE MUNICIPAL	35.43N	82.54W	2169	14.7	18.9	88.3	71.2	85.9	70.6	83.8	69.8	73.9	83.1	72.8	81.6	71.4	125.8	77.4	70.3	120.8	76.3	23.1	19.5	17.5	4144	844
CHARLOTTE/DOUGLAS	35.21N	80.94W	768	21.0	25.0	94.3	74.5	92.0	74.0	89.9	73.4	77.2	88.4	76.2	86.8	74.1	130.8	81.0	73.2	126.7	80.0	18.6	16.5	14.3	3065	1713
FAYETTEVILLE RGNL G	34.99N	78.88W	197	22.2	26.4	96.5	76.3	93.2	75.1	91.1	74.8	79.2	89.8	78.2	88.2	76.7	140.0	82.5	75.4	133.9	81.5	20.2	17.8	15.8	2764	1957
FORT BRAGG/SIMMONS	35.13N	78.94W	243	21.9	25.8	97.0	76.3	94.7	75.9	92.1	75.1	79.4	90.9	78.2	89.4	76.4	138.8	84.3	75.2	133.4	83.4	17.6	14.8	12.6	2786	2071
GREENSBORO/G.-HIGH	36.10N	79.94W	886	18.4	22.2	92.6	74.3	90.4	73.7	88.3	72.9	77.0	87.8	75.8	85.9	73.7	129.6	81.1	72.8	125.7	80.0	19.9	17.7	15.8	3606	1446
HICKORY RGNL	35.74N	81.39W	1188	19.2	23.4	92.9	72.4	90.4	72.4	88.2	71.8	75.7	86.0	74.8	84.7	72.9	127.5	79.2	72.1	124.1	78.3	17.5	14.9	13.0	3509	1377
JACKSONVILLE (AWOS)	34.83N	77.61W	95	20.5	24.8	94.0	76.9	91.4	75.8	90.1	75.2	79.6	90.9	78.2	88.5	76.5	138.7	85.0	75.1	132.2	83.2	19.9	17.6	15.5	2966	1721
NEW RIVER MCAS	34.70N	77.43W	26	23.2	26.8	93.1	78.1	90.9	77.5	89.3	76.9	80.6	89.0	79.4	87.7	78.7	149.3	85.1	77.0	140.9	83.8	20.1	17.8	15.9	2547	1937
PITT GREENVILLE	35.64N	77.38W	26	20.8	24.8	95.1	76.3	93.0	75.1	91.0	74.5	79.0	91.2	77.5	88.6	75.3	132.8	83.0	74.6	129.8	82.2	18.8	16.4	14.1	2930	1923
POPE AFB	35.17N	79.03W	200	20.9	24.8	97.1	75.5	93.4	74.7	91.1	74.5	79.6	87.9	78.5	87.0	77.5	144.0	81.1	76.7	140.4	80.9	18.7	16.5	14.1	2880	1991
RALEIGH/RALEIGH-DUR	35.87N	78.79W	436	19.6	23.6	94.8	75.7	92.4	75.2	90.2	74.5	78.3	89.7	77.3	88.1	75.3	134.8	82.7	74.3	130.2	81.5	18.9	16.8	15.0	3275	1666
SEYMOUR JOHNSON AFB	35.34N	77.96W	112	22.4	26.3	96.9	76.7	94.4	75.9	91.8	75.5	80.0	89.9	78.9	88.4	77.4	143.2	83.3	76.6	139.0	82.7	18.5	16.2	14.0	2734	2053
WILMINGTON	34.27N	77.90W	33	24.6	27.7	92.6	77.0	90.2	76.3	88.2	75.6	79.2	87.9	78.3	86.1	76.9	140.4	83.1	76.1	136.5	82.4	21.3	18.9	16.8	2444	2030
SMITH REYNOLDS	36.13N	80.22W	971	18.9	23.3	92.9	73.6	90.6	73.0	88.5	72.2	76.4	87.0	75.3	85.5	73.1	127.4	80.6	72.3	124.1	79.8	18.2	15.9	13.4	3468	1481
North Dakota																									*6 sites, 7 more on CD-ROM*	
BISMARCK MUNICIPAL	46.77N	100.75W	1660	-18.5	-13.1	93.9	69.6	90.2	68.7	86.7	67.6	74.6	86.1	72.2	84.4	70.9	121.3	81.9	68.2	110.4	79.0	27.2	24.3	20.8	8396	546
FARGO/HECTOR FIELD	46.93N	96.81W	899	-19.3	-14.5	90.7	72.0	87.6	70.4	84.5	68.8	75.4	85.3	73.4	83.5	72.3	123.7	81.9	70.0	114.0	80.2	28.2	25.4	23.0	8729	555

Meaning of acronyms:
DB: Dry bulb temperature, °F *WB: Wet bulb temperature, °F* *Lat: Latitude, °* *Long: Longitude, °* *Elev: Elevation, ft*
MCWB: Mean coincident wet bulb temperature, °F *DP: Dew point temperature, °F* *HR: Humidity ratio, grains of moisture per lb of dry air* *WS: Wind speed, mph*
MCDB: Mean coincident dry bulb temperature, °F *HDD and CDD 65: Annual heating and cooling degree-days, base 65°F, °F-day*

Station	Lat	Long	Elev	Heating DB		Cooling DB/MCWB						Evaporation WB/MCDB				Dehumidification DP/HR/MCDB						Extreme Annual WS			Heat./Cool. Degree-Days	
						0.4%		1%		2%		0.4%		1%		0.4%			1%							
				99.6%	99%	DB	MCWB	DB	MCWB	DB	MCWB	WB	MCDB	WB	MCDB	DP	HR	MCDB	DP	HR	MCDB	1%	2.5%	5%	HDD	CDD 65
GRAND FORKS AFB	47.95N	97.40W	912	-18.3	-14.7	89.9	73.8	86.1	70.9	82.4	68.4	77.1	84.3	74.2	82.0	74.9	135.5	81.2	72.2	123.4	78.2	27.7	24.9	22.0	9197	406
GRAND FORKS INTL	47.95N	97.18W	833	-22.0	-17.1	89.9	71.1	86.4	69.4	83.5	68.0	74.8	84.4	72.5	82.4	71.7	120.8	81.2	69.2	110.7	78.7	26.9	24.3	20.9	9320	425
MINOT AFB	48.43N	101.36W	1667	-23.4	-17.7	93.1	68.4	89.3	67.5	85.5	66.4	73.0	86.0	70.7	83.1	69.5	115.4	79.4	66.4	103.3	76.7	28.9	25.9	22.8	9024	430
MINOT INTL	48.26N	101.28W	1713	-19.1	-13.9	91.2	68.5	87.8	68.0	84.0	66.0	73.4	84.1	70.9	81.8	70.2	118.4	79.9	67.4	107.5	77.0	27.9	24.9	21.9	8696	444
Ohio																									*13 sites, 15 more on CD-ROM*	
AKRON/AKRON-CANTON	40.92N	81.44W	1237	2.8	7.9	88.8	72.8	86.1	71.8	83.5	70.3	75.5	84.4	73.9	82.1	72.7	127.1	80.4	71.4	121.4	78.4	23.2	19.8	18.1	6054	688
CINCINNATI MUNI LUN	39.10N	84.42W	499	8.1	13.4	92.8	74.5	90.3	74.2	88.1	73.3	78.0	87.9	76.7	86.2	75.1	134.4	82.6	73.8	128.4	81.1	20.4	18.3	16.6	4744	1155
CLEVELAND	41.41N	81.85W	804	4.1	9.7	89.7	73.7	87.0	72.4	84.2	71.0	76.2	85.4	74.7	83.0	73.2	127.3	81.3	72.0	121.9	79.6	24.5	20.9	18.8	5850	774
COLUMBUS/PORT COLUM	39.99N	82.88W	817	5.0	10.4	91.1	73.6	89.0	72.9	86.5	71.7	76.8	87.0	75.3	84.5	73.6	129.1	81.3	72.4	123.8	80.2	22.3	18.9	16.9	5255	1015
DAYTON/JAMES M COX	39.91N	84.22W	1004	2.0	8.1	90.4	73.5	88.0	72.8	85.5	71.4	76.5	86.2	75.1	84.0	73.4	128.7	81.9	72.2	123.8	80.5	24.5	20.8	18.8	5512	945
FINDLAY	41.01N	83.67W	814	1.0	6.8	90.5	73.2	88.1	72.3	85.1	70.7	76.5	86.2	74.8	83.5	73.2	127.2	82.2	72.0	122.2	80.5	24.7	21.0	18.9	5930	808
FAIRFIELD CO	39.76N	82.66W	869	1.5	9.4	90.5	73.4	88.4	73.0	85.9	71.7	76.7	86.4	75.3	83.8	73.2	127.6	81.1	72.5	124.2	80.2	20.1	17.8	15.9	5459	810
MANSFIELD LAHM RGNL	40.82N	82.52W	1312	1.0	6.7	88.1	73.0	85.5	71.8	83.0	70.3	75.6	84.5	74.1	82.3	72.9	128.0	80.9	71.5	122.2	79.2	24.3	20.8	18.9	6152	659
OHIO STATE UNIVERSI	40.08N	83.08W	906	4.9	10.0	90.4	73.3	88.2	72.8	85.6	71.5	76.4	85.9	74.9	83.5	73.0	126.8	81.2	72.3	123.7	80.0	21.8	19.1	17.3	5429	911
RICKENBACKER INTL	39.80N	82.92W	745	6.6	11.7	92.7	75.2	90.5	74.5	88.3	73.5	80.5	86.8	78.5	85.6	79.1	155.3	84.2	76.5	142.2	82.5	23.7	20.0	17.7	4971	1156
TOLEDO EXPRESS	41.59N	83.80W	692	1.3	6.8	91.3	74.0	88.6	72.6	85.9	71.4	77.2	87.0	75.4	84.1	74.2	130.8	82.8	72.6	124.1	80.6	24.3	20.7	18.6	6074	798
DAYTON/WRIGHT-PATTE	39.83N	84.05W	823	3.1	9.4	90.6	73.8	88.3	73.3	86.0	72.0	77.0	85.3	75.6	83.8	74.8	134.3	80.7	73.0	126.1	79.1	21.4	18.8	16.9	5301	958
YOUNGSTOWN MUNI	41.25N	80.67W	1188	2.9	7.9	88.5	72.5	85.8	71.1	83.4	69.6	75.0	84.4	73.4	81.8	72.2	124.4	79.5	70.7	118.1	77.6	21.3	18.9	17.2	6198	583
Oklahoma																									*9 sites, 11 more on CD-ROM*	
FORT SILL	34.65N	98.40W	1188	14.3	20.2	100.8	73.1	98.6	73.1	95.5	73.4	77.5	91.0	76.5	89.8	74.1	132.8	82.5	72.9	127.6	81.6	24.7	21.3	19.3	3197	2117
LAWTON MUNICIPAL	34.57N	98.42W	1109	17.9	20.8	102.4	73.4	100.2	73.7	98.8	73.8	78.1	92.6	77.1	91.3	73.5	129.9	82.8	73.0	127.8	82.5	26.0	23.1	20.1	3168	2271
OKLAHOMA CITY/W. RO	35.39N	97.60W	1306	14.1	18.9	99.6	74.2	96.9	74.2	94.0	74.0	77.8	91.0	76.9	89.9	74.2	134.3	83.6	73.2	129.3	82.3	27.6	24.9	22.7	3438	1950
OKLAHOMA CITY/WILEY	35.53N	97.65W	1299	12.5	18.2	99.5	73.9	97.2	73.9	93.8	73.7	77.4	91.2	76.4	89.9	73.3	130.0	83.3	72.5	126.4	82.4	26.7	24.5	22.0	3487	2047
STILLWATER RGNL	36.16N	97.09W	984	13.7	18.2	101.7	75.4	99.1	75.6	95.4	75.8	79.1	93.9	78.0	92.5	75.1	136.5	86.1	73.3	128.6	84.0	24.7	22.0	19.7	3589	2001
TINKER AFB	35.42N	97.38W	1302	15.8	18.9	99.3	72.9	96.8	73.1	93.1	73.0	77.3	89.2	76.2	88.0	73.4	130.5	81.0	72.9	128.1	80.6	26.3	23.7	20.6	3383	1916
TULSA INTL ARPT(AW)	36.20N	95.89W	676	13.2	18.3	99.4	75.9	96.8	76.0	94.0	75.6	79.2	92.5	78.2	91.2	75.4	136.6	85.5	74.4	131.8	84.7	24.6	21.5	19.4	3455	2051
RICHARD LLOYD JONES	36.04N	95.98W	627	15.8	18.8	100.0	76.7	98.6	76.9	95.0	76.6	79.6	94.1	78.5	92.6	75.4	136.1	85.4	74.8	133.5	84.9	19.8	17.8	16.1	3503	2020
VANCE AFB	36.34N	97.99W	1306	10.0	15.7	100.4	73.4	98.5	73.5	95.1	73.7	77.4	91.6	76.3	90.4	73.4	130.3	82.0	72.5	126.5	81.7	27.5	24.7	21.7	3936	1864
Oregon																									*9 sites, 18 more on CD-ROM*	
AURORA STATE	45.25N	122.77W	197	26.6	28.2	91.3	66.9	88.3	66.6	83.9	65.5	70.1	86.3	68.2	84.1	63.8	89.4	75.7	62.9	86.6	73.8	18.0	15.8	12.8	4415	379
CORVALLIS MUNI	44.50N	123.29W	246	25.0	27.7	92.9	67.0	89.8	65.9	85.6	64.2	68.6	89.1	67.0	86.9	61.0	80.7	76.7	58.5	73.9	75.5	19.8	17.8	16.0	4255	397
EUGENE/MAHLON SWEET	44.13N	123.21W	374	23.4	27.3	91.7	66.5	88.0	65.6	84.1	64.5	68.8	87.4	67.1	84.7	62.2	84.8	74.6	60.4	79.5	72.2	19.6	17.5	15.9	4638	270
MC MINNVILLE MUNI	45.20N	123.13W	161	26.8	28.2	91.4	66.0	88.4	65.8	84.0	64.7	68.7	87.2	67.0	85.1	62.6	85.4	74.0	60.8	80.1	71.9	20.7	17.7	15.5	4673	287
MEDFORD-JACKSON COU	42.39N	122.87W	1329	23.1	26.1	99.2	66.9	95.6	65.8	92.2	64.6	68.8	94.3	67.4	91.5	60.3	82.2	74.1	58.3	76.4	73.7	18.3	15.4	12.4	4264	834
PORTLAND INTL ARPT	45.59N	122.60W	108	25.2	29.5	91.4	67.3	87.5	66.5	83.6	65.3	69.5	86.9	67.9	84.5	63.2	87.0	75.1	61.6	82.3	73.1	23.6	19.7	17.5	4214	433
PORTLAND/HILLSBORO	45.54N	122.95W	230	23.2	27.0	92.2	68.0	88.3	67.0	84.0	65.5	70.5	88.2	68.3	85.3	63.7	89.2	76.8	61.7	82.8	73.6	18.7	16.8	14.3	4744	283
ROBERTS FLD	44.25N	121.15W	3084	5.6	12.6	93.0	61.7	90.2	60.8	87.0	59.7	63.7	88.6	62.1	86.0	54.8	71.5	67.2	52.8	66.5	66.9	20.7	18.6	16.7	6470	237
SALEM/MCNARY	44.91N	123.00W	200	23.5	27.4	92.3	66.8	88.2	65.8	84.3	64.6	68.7	88.4	67.1	85.2	61.5	82.2	73.0	59.9	77.6	72.3	20.9	18.4	16.3	4533	313
Pennsylvania																									*14 sites, 14 more on CD-ROM*	
ALLENTOWN/A.-BETHLE	40.65N	75.45W	384	8.4	12.6	91.0	73.7	88.3	72.5	85.7	71.3	76.7	86.4	75.2	83.7	73.8	127.8	81.2	72.5	122.1	79.7	23.4	19.7	17.7	5552	838
ALTOONA BLAIR CO	40.30N	78.32W	1470	5.9	10.0	88.3	71.8	85.6	70.8	82.8	69.4	74.7	83.9	73.1	81.8	72.0	125.2	79.8	70.3	118.0	77.8	23.0	19.1	17.1	5950	612
BUTLER CO SCHOLTER F	40.78N	79.94W	1247	3.2	8.8	88.1	71.9	84.5	70.3	82.2	68.9	74.5	83.4	72.9	81.6	72.1	124.3	79.8	70.3	116.9	77.3	18.0	15.6	13.0	6089	549
ERIE INTL AIRPORT	42.08N	80.18W	738	6.8	10.4	86.7	73.0	84.2	71.8	81.8	70.5	75.3	82.7	73.9	81.1	72.8	125.2	80.5	71.4	119.1	78.7	24.5	21.3	19.4	6080	659
HARRISBURG/CAPITAL	40.22N	76.85W	348	10.7	15.4	92.5	73.8	89.9	72.6	87.5	71.8	76.6	87.1	75.3	84.6	73.4	125.8	80.5	72.5	121.8	79.5	20.6	18.4	16.5	5109	1056
HARRISBURG INTL	40.19N	76.76W	312	11.6	15.6	92.3	75.1	89.7	74.0	86.9	72.8	78.0	87.7	76.5	85.3	75.2	133.6	83.0	73.5	126.1	81.0	25.6	23.1	19.0	5046	1110
PHILADELPHIA INTL	39.87N	75.23W	30	13.8	18.0	93.4	75.1	90.8	74.4	88.3	72.9	78.3	88.6	77.0	86.4	75.4	133.4	82.5	74.3	128.2	81.4	24.7	20.9	18.7	4512	1332
NORTHEAST PHILADELPH	40.08N	75.01W	118	12.3	16.8	93.2	75.3	90.6	74.2	88.3	73.0	78.4	88.7	76.8	86.7	75.4	133.4	82.8	73.5	125.4	80.9	21.8	18.9	17.3	4754	1177
ALLEGHENY CO	40.36N	79.92W	1273	5.6	10.0	90.0	72.3	87.5	71.3	84.4	69.7	75.0	84.8	73.6	82.8	72.3	125.2	79.9	70.8	118.8	78.2	20.3	18.4	16.8	5438	851
GREATER PITTSBURGH I	40.50N	80.23W	1204	5.2	9.9	89.7	72.4	87.0	71.1	84.4	69.8	75.2	84.8	73.7	82.6	72.3	125.0	80.0	70.9	119.2	78.3	23.1	19.6	17.6	5583	782
READING RGNL CARL A	40.37N	75.96W	354	9.9	14.3	92.6	74.1	90.0	73.0	87.6	72.0	77.1	87.6	75.4	84.8	73.4	125.9	82.0	72.5	121.9	80.7	22.8	19.3	17.8	5171	997
WASHINGTON CO	40.14N	80.28W	1184	3.0	8.8	88.3	70.7	85.5	69.6	82.9	68.4	73.6	83.1	72.2	82.0	70.4	117.1	78.9	69.7	114.0	77.7	19.3	17.0	14.7	5964	539
WILKES-BARRE-SCRANT	41.34N	75.73W	961	4.4	9.1	89.3	71.9	86.2	70.3	83.5	69.0	74.9	84.0	73.2	81.6	72.1	123.0	79.1	70.5	116.6	77.3	20.2	18.0	16.3	6086	637
WILLOW GROVE NAS JR	40.20N	75.15W	361	11.7	15.7	92.6	74.7	90.1	73.4	87.6	72.2	77.6	88.5	76.1	85.9	74.3	129.9	83.2	72.9	123.7	81.6	18.8	16.5	14.1	4907	1074
Rhode Island																									*1 site, 2 more on CD-ROM*	
PROVIDENCE/GREEN ST	41.72N	71.43W	62	8.5	12.9	90.1	73.3	86.7	71.9	83.8	70.6	76.4	85.2	74.9	82.0	73.9	126.5	80.2	72.7	121.3	78.6	24.3	20.7	18.7	5562	743

Meaning of acronyms:
DB: Dry bulb temperature, °F
WB: Wet bulb temperature, °F
MCWB: Mean coincident wet bulb temperature, °F
Lat: Latitude, °
DP: Dew point temperature, °F
MCDB: Mean coincident dry bulb temperature, °F
Long: Longitude, °
HR: Humidity ratio, grains of moisture per lb of dry air
Elev: Elevation, ft
WS: Wind speed, mph
HDD and CDD 65: Annual heating and cooling degree-days, base 65°F, °F-day

Station	Lat	Long	Elev	Heating DB		Cooling DB/MCWB						Evaporation WB/MCDB				Dehumidification DP/HR/MCDB						Extreme Annual WS			Heat./Cool. Degree-Days	
				99.6%	99%	0.4%		1%		2%		0.4%		1%		0.4%			1%			1%	2.5%	5%	HDD / CDD 65	
						DB	MCWB	DB	MCWB	DB	MCWB	WB	MCDB	WB	MCDB	DP	HR	MCDB	DP	HR	MCDB				HDD	CDD
South Carolina																									*6 sites, 8 more on CD-ROM*	
CHARLESTON MUNI	32.90N	80.04W	49	27.3	30.4	94.3	78.2	92.1	77.6	90.4	77.1	80.8	89.1	79.9	87.9	78.9	150.0	84.4	77.7	144.3	83.5	20.4	18.3	16.5	1880	2357
COLUMBIA METRO	33.94N	81.12W	226	22.8	26.5	97.2	75.2	94.8	75.0	92.6	74.5	78.5	89.9	77.7	88.7	75.7	135.6	82.2	74.8	131.7	81.4	19.4	17.0	15.2	2500	2166
FLORENCE RGNL	34.19N	79.73W	151	23.8	27.1	96.2	76.7	93.4	76.0	91.3	75.5	79.3	90.5	78.3	88.9	76.6	139.4	83.6	75.4	133.8	82.2	19.4	17.7	15.8	2429	2102
FOLLY ISLAND	32.68N	79.88W	16	31.4	34.6	87.5	77.8	86.2	77.7	85.1	77.5	80.4	85.0	79.3	84.2	78.9	150.0	84.0	77.8	144.7	82.9	33.1	26.2	23.0	1923	2126
GREENVILLE/GREENVIL	34.90N	82.22W	971	21.2	25.1	94.4	73.8	91.8	73.5	89.8	72.9	77.1	88.0	76.1	86.2	74.2	132.2	80.4	73.2	127.8	79.6	19.5	17.5	15.8	3080	1630
SHAW AFB/SUMTER	33.97N	80.48W	240	24.6	27.3	95.5	75.3	93.1	75.2	90.9	74.8	79.1	90.3	78.2	88.3	76.6	139.9	82.8	75.2	133.4	81.4	19.2	17.0	15.3	2422	2080
South Dakota																									*3 sites, 16 more on CD-ROM*	
ELLSWORTH AFB	44.15N	103.10W	3278	-9.4	-3.6	95.7	65.6	91.5	65.4	88.2	64.6	70.7	85.7	68.9	84.1	66.0	108.2	78.0	63.9	100.4	75.7	34.6	28.7	25.1	6882	668
RAPID CITY/REGIONAL	44.05N	103.05W	3169	-9.2	-3.4	97.2	65.8	93.0	65.5	89.4	64.8	70.9	85.5	69.2	84.7	66.4	109.5	77.7	64.3	101.6	75.7	35.2	30.6	26.2	7000	671
SIOUX FALLS/FOSS FI	43.58N	96.75W	1427	-12.3	-7.3	92.2	73.6	88.9	73.0	86.0	71.3	77.2	87.2	75.4	85.4	74.3	135.4	83.4	72.4	126.4	81.6	27.5	24.6	21.2	7470	745
Tennessee																									*7 sites, 3 more on CD-ROM*	
TRI CITIES RGNL	36.48N	82.40W	1526	12.9	17.7	90.5	71.8	88.2	71.5	86.0	71.1	75.1	85.0	74.0	83.7	72.2	126.3	79.1	71.2	121.8	77.9	18.9	16.5	13.9	4214	1033
CHATTANOOGA/LOVELL	35.03N	85.20W	689	19.0	23.1	95.0	74.9	92.6	74.4	90.4	73.8	77.9	89.1	76.9	87.6	75.0	134.7	81.5	73.9	129.7	80.6	17.9	16.0	13.6	3145	1763
MC KELLAR SIPES RGN	35.59N	88.92W	423	15.4	19.3	94.9	76.6	92.8	76.4	90.7	75.9	79.9	90.3	78.6	88.9	77.0	142.6	85.5	75.5	135.5	84.0	19.5	17.8	16.0	3427	1746
KNOXVILLE MUNICIPAL	35.82N	83.99W	981	16.5	20.8	93.0	73.9	90.6	73.7	88.5	73.0	77.1	87.8	76.1	86.1	74.0	131.5	81.4	73.0	127.2	80.4	20.4	17.7	15.3	3594	1514
MEMPHIS INTL ARPT	35.06N	89.99W	331	18.7	22.9	96.7	77.2	94.3	76.6	92.4	76.1	80.0	91.5	79.0	90.1	76.9	141.9	85.8	75.8	136.7	84.8	20.2	18.2	16.5	2898	2253
MILLINGTON MUNI ARP	35.35N	89.87W	322	17.6	21.4	98.2	78.7	95.4	76.9	92.9	76.3	81.4	93.0	79.6	91.3	78.8	151.1	88.5	76.2	138.2	86.2	18.5	16.3	14.1	3123	2031
NASHVILLE/METROPOLI	36.12N	86.69W	604	14.8	19.3	94.8	74.9	92.4	74.7	90.3	74.1	78.2	88.9	77.2	87.9	75.2	135.0	82.9	74.0	129.8	81.8	19.4	17.3	15.6	3518	1729
Texas																									*51 sites, 34 more on CD-ROM*	
ABILENE DYESS AFB	32.43N	99.85W	1788	18.9	23.4	101.7	72.0	99.3	71.9	96.9	71.9	77.2	91.1	76.0	89.9	73.6	133.7	81.4	72.4	128.5	80.7	25.3	22.2	19.4	2507	2537
ABILENE MUNICIPAL	32.41N	99.68W	1791	20.1	24.6	99.4	70.8	97.3	70.8	95.0	70.9	75.5	88.9	74.6	87.9	72.2	127.4	80.1	71.2	123.0	79.4	26.0	23.7	20.7	2482	2389
AMARILLO INTL	35.22N	101.71W	3606	9.8	15.6	97.3	66.2	94.7	66.3	92.2	66.2	71.3	86.1	70.2	85.3	67.3	114.9	75.3	66.1	110.1	74.4	29.2	26.4	24.2	4102	1366
AUSTIN/MUELLER MUNI	30.18N	97.68W	495	26.6	29.8	99.8	74.5	98.2	74.7	96.1	75.1	79.1	89.7	78.3	88.9	76.7	141.9	81.8	75.8	137.3	81.0	21.2	19.0	17.2	1671	2962
BROWNSVILLE INTL	25.91N	97.43W	23	38.1	42.1	95.4	77.8	94.3	77.8	93.1	77.7	80.9	87.9	80.3	87.6	79.3	152.2	83.0	78.7	149.1	82.8	26.2	23.8	20.7	538	3986
AUSTIN CAMP MABRY	30.32N	97.77W	659	28.4	32.4	99.7	74.2	97.9	74.4	95.8	74.7	78.5	89.0	77.9	88.4	76.3	140.8	81.0	75.4	136.6	80.4	19.2	17.1	15.5	1498	3093
EASTERWOOD FLD	30.59N	96.36W	328	27.8	31.6	99.4	75.7	97.4	75.7	95.3	75.8	79.8	90.8	78.8	89.2	77.2	143.5	83.2	76.4	139.3	82.3	20.2	18.3	16.6	1588	3030
CORPUS CHRISTI/INT.	27.77N	97.51W	43	34.3	38.0	96.3	77.8	94.6	77.9	93.0	77.8	81.1	89.3	80.4	88.3	79.3	152.1	83.1	78.7	149.4	82.9	27.2	24.9	22.8	861	3529
CORPUS CHRISTE NAS	27.70N	97.28W	20	37.1	41.4	93.0	79.5	91.8	79.4	91.0	79.3	82.4	88.3	81.6	87.9	81.2	162.3	84.8	79.8	154.7	84.5	25.6	23.2	20.3	711	3783
DALLAS HENSLEY FIELD NAS	32.73N	96.97W	495	21.5	27.2	99.6	75.5	97.5	75.4	95.3	75.0	79.0	92.0	77.9	91.2	75.4	135.5	85.6	74.2	130.1	84.2	20.6	18.7	17.0	2171	2723
DALLAS LOVE FLD	32.85N	96.85W	489	24.4	28.2	100.2	75.5	98.7	75.4	96.7	75.3	79.5	92.6	78.3	91.2	76.1	139.0	85.1	75.0	133.5	83.8	22.4	19.9	18.4	2058	2944
DALLAS EXECUTIVE	32.68N	96.87W	673	26.6	28.1	100.2	74.9	99.0	74.8	96.8	74.7	78.3	91.9	77.5	90.8	75.0	134.6	82.4	73.4	127.5	81.4	22.8	19.5	17.7	2116	2764
DALLAS-FORT WORTH/F	32.90N	97.04W	597	23.0	27.3	100.5	74.6	98.6	74.7	96.4	75.0	78.6	91.5	77.8	90.8	75.4	136.1	83.7	74.4	131.4	82.8	26.0	23.6	20.5	2192	2784
DEL RIO INTL	29.37N	100.92W	1027	31.5	34.7	101.6	72.3	99.6	72.3	97.8	72.2	77.6	89.3	76.8	88.6	74.9	135.7	81.4	73.5	129.5	81.1	20.7	18.5	16.7	1269	3440
DRAUGHON MILLER CEN	31.15N	97.40W	682	25.0	28.1	99.7	74.2	98.0	74.2	95.9	74.3	78.2	90.9	77.4	90.0	75.0	134.7	81.8	73.7	128.6	81.0	24.9	22.4	19.9	1975	2734
EL PASO INTL ARPT	31.81N	106.38W	3917	23.9	27.5	100.7	64.5	98.5	64.0	96.2	64.0	70.2	86.0	69.3	85.2	66.8	114.3	72.9	65.5	109.2	73.0	26.5	22.3	18.7	2383	2379
ROBERT GRAY AAF	31.07N	97.83W	1014	27.1	29.9	100.1	71.9	98.8	72.2	95.7	72.5	76.8	87.2	76.0	86.9	74.9	135.6	78.3	73.3	128.6	77.7	22.8	19.7	18.0	1816	2816
FORT WORTH ALLIANCE	32.97N	97.32W	722	22.4	26.7	101.8	74.5	99.5	74.6	97.3	74.4	78.3	92.6	77.5	91.5	74.8	134.0	83.7	73.3	127.4	82.3	23.6	20.8	18.9	2363	2668
FORT WORTH MEACHAM	32.82N	97.36W	705	21.9	26.7	100.6	74.6	99.0	74.7	96.8	74.6	78.5	91.7	77.6	91.1	75.2	135.5	83.7	74.1	130.4	82.5	22.4	19.8	18.3	2253	2723
FORT WORTH NAS JRB	32.77N	97.44W	650	22.0	27.4	100.5	74.5	98.9	74.7	96.7	74.9	79.0	92.0	78.0	91.1	75.7	137.9	84.1	74.5	132.2	83.4	24.1	20.7	18.7	2149	2785
GALVESTON	29.27N	94.86W	10	36.0	39.2	91.3	79.1	90.5	79.0	89.9	78.9	81.6	87.0	81.0	86.6	80.8	159.8	84.2	79.3	152.2	84.3	25.1	22.1	19.8	1011	3242
GEORGETOWN MUNI	30.68N	97.67W	787	26.5	28.2	99.3	73.1	97.2	72.9	95.0	73.1	77.0	89.2	76.2	88.4	73.3	127.7	80.1	72.9	125.6	80.0	20.9	18.9	17.2	1957	2732
VALLEY INTL	26.23N	97.65W	36	36.7	40.8	98.8	77.6	97.2	77.6	95.5	77.7	81.3	89.8	80.4	89.0	79.4	152.9	83.1	79.0	150.6	83.0	27.8	24.9	23.3	573	4071
HOUSTON/INTERCONTIN	29.99N	95.36W	105	30.3	33.8	97.2	76.6	95.2	76.7	93.4	76.6	80.2	88.9	79.4	88.2	78.2	147.1	82.9	77.3	142.7	82.5	19.6	17.8	16.2	1371	3059
WILLIAM P HOBBY	29.65N	95.28W	46	32.9	36.4	95.3	77.6	93.4	77.3	92.0	77.1	80.4	88.9	79.9	88.2	78.7	149.3	83.2	77.7	144.4	82.7	20.8	18.8	17.2	1169	3160
HOUSTON/D.W. HOOKS	30.06N	95.55W	151	29.9	33.8	98.5	76.2	95.3	76.7	93.0	76.5	80.2	88.2	79.4	87.8	79.0	151.3	82.5	77.3	143.0	82.3	17.7	16.0	13.7	1452	2973
HOUSTON/ELLINGTON	29.61N	95.16W	33	31.9	36.0	96.1	78.2	94.5	78.3	92.9	78.2	81.2	90.0	80.4	89.4	79.2	151.6	83.9	78.5	148.1	84.0	19.5	17.7	15.9	1247	3116
LACKLAND AFB KELLY	29.38N	98.58W	692	29.0	32.8	99.9	75.0	98.1	74.8	96.0	74.7	80.1	90.4	78.9	88.4	77.4	146.3	83.5	76.8	143.3	82.9	19.9	17.7	15.7	1392	3183
KILLEEN MUNI (AWOS)	31.09N	97.69W	850	26.5	29.5	99.6	74.2	97.8	74.2	95.6	74.5	77.9	91.8	77.2	90.8	73.9	130.3	82.7	73.2	127.3	82.3	22.1	19.8	18.2	1889	2815
LAREDO INTL AIRPORT	27.55N	99.47W	509	34.4	38.6	102.3	73.4	100.4	73.5	99.1	73.5	78.4	90.7	77.7	89.8	75.7	137.0	81.4	75.0	134.0	81.1	24.5	22.0	20.1	839	4149
LAUGHLIN AFB	29.36N	100.78W	1083	30.3	34.1	104.1	72.8	101.6	73.5	99.3	73.2	78.8	91.3	77.5	90.6	75.5	138.9	83.2	74.3	133.2	82.6	22.5	19.6	17.6	1218	3518
LONGVIEW	32.39N	94.71W	374	24.9	27.9	99.3	75.5	97.0	75.7	93.5	75.3	79.1	90.7	78.3	89.6	76.1	138.4	82.7	75.3	134.5	82.0	19.9	17.8	16.0	2109	2531
LUBBOCK/LUBBOCK INT	33.67N	101.82W	3241	15.9	19.9	99.0	66.7	96.6	67.4	94.0	67.6	73.2	87.6	72.1	86.5	69.6	122.7	77.2	68.3	117.2	76.2	28.9	25.9	23.5	3275	1846
ANGELINA CO	31.23N	94.75W	315	27.1	29.8	98.7	76.4	95.7	76.8	93.4	76.4	80.0	90.4	79.2	89.5	77.4	144.2	82.8	76.9	141.6	82.5	17.8	16.1	14.3	1847	2646
MC GREGOR EXECUTIVE	31.49N	97.30W	591	25.2	28.0	100.1	74.7	99.0	74.8	97.0	74.7	78.5	91.7	77.9	91.4	75.2	135.3	83.1	74.5	132.0	82.7	23.2	20.4	18.5	2082	2721
MC ALLEN MILLER INT	26.18N	98.24W	112	37.9	42.0	100.2	76.3	99.0	76.5	97.3	76.5	80.4	91.0	79.8	89.7	78.8	150.1	82.6	77.7	144.5	82.2	24.9	22.7	20.4	546	4465
COLLIN CO RGNL	33.18N	96.59W	584	21.4	26.5	100.1	75.1	99.0	75.3	96.8	75.3	78.5	92.0	77.9	91.3	75.2	134.9	82.9	74.5	132.0	82.4	23.1	19.8	17.8	2486	2492

Meaning of acronyms:
DB: Dry bulb temperature, °F
WB: Wet bulb temperature, °F
MCWB: Mean coincident wet bulb temperature, °F
Lat: Latitude, °
DP: Dew point temperature, °F
MCDB: Mean coincident dry bulb temperature, °F
Long: Longitude, °
HR: Humidity ratio, grains of moisture per lb of dry air
HDD and CDD 65: Annual heating and cooling degree-days, base 65°F, °F-day
Elev: Elevation, ft
WS: Wind speed, mph

Station	Lat	Long	Elev	Heating DB		Cooling DB/MCWB						Evaporation WB/MCDB				Dehumidification DP/HR/MCDB						Extreme Annual WS			Heat./Cool. Degree-Days	
						0.4%		1%		2%		0.4%		1%		0.4%			1%							
				99.6%	99%	DB	MCWB	DB	MCWB	DB	MCWB	WB	MCDB	WB	MCDB	DP	HR	MCDB	DP	HR	MCDB	1%	2.5%	5%	HDD	CDD 65
MIDLAND/MIDLAND REG	31.93N	102.21W	2861	19.9	24.1	100.3	67.1	98.2	67.4	95.9	67.7	73.3	87.0	72.3	86.4	70.2	123.8	76.6	69.0	118.4	76.1	26.6	24.0	20.7	2617	2260
A L MANGHAM JR RGNL	31.58N	94.70W	354	25.2	27.8	98.5	75.8	95.3	76.0	93.0	75.7	79.1	89.6	78.3	88.9	76.8	141.3	82.3	75.3	134.4	81.5	18.3	16.1	13.7	2121	2426
PORT ARANSAS	27.83N	97.07W	20	36.8	41.1	86.1	78.0	85.4	78.1	84.9	78.0	80.4	84.0	80.1	83.8	79.4	152.4	83.1	78.7	149.1	82.9	38.4	32.2	26.7	829	3047
PORT ARTHUR/JEFFERS	29.95N	94.02W	16	31.4	34.7	94.5	78.0	92.9	78.1	91.3	78.0	81.5	88.8	80.6	87.9	79.5	153.0	84.5	78.9	149.9	83.9	21.4	19.1	17.6	1356	2899
RANDOLPH AFB	29.53N	98.28W	761	27.8	31.7	99.5	74.3	97.7	74.3	95.8	74.6	78.6	89.3	78.0	88.6	76.4	141.7	81.2	75.3	136.6	80.8	20.8	18.8	16.9	1482	3066
REESE AFB/LUBBOCK	33.60N	102.05W	3337	14.7	19.4	101.0	67.0	97.8	67.3	95.1	67.2	73.2	87.2	72.0	86.7	69.5	122.9	78.7	67.9	116.4	77.6	27.4	24.1	20.6	3182	1831
SABINE	29.67N	94.05W	20	32.2	35.9	88.6	77.3	87.3	77.5	86.4	77.5	80.9	85.4	80.2	85.0	79.7	154.1	83.9	78.6	148.3	83.6	34.9	27.5	23.8	1455	2605
SAN ANGELO/MATHIS	31.35N	100.49W	1893	21.9	25.9	100.4	70.3	98.7	70.1	96.5	70.1	75.3	88.7	74.3	87.9	72.0	126.9	79.8	70.8	121.9	79.0	24.7	21.5	19.4	2241	2509
SAN ANTONIO INTL	29.53N	98.46W	810	29.2	32.7	99.0	73.5	97.2	73.7	95.3	73.9	78.1	87.9	77.4	87.1	76.0	139.9	80.2	75.3	136.5	79.9	20.2	18.3	16.6	1418	3157
STINSON MUNI	29.34N	98.47W	577	30.4	34.1	100.1	74.2	99.0	74.2	96.9	74.0	79.0	89.2	78.2	88.3	76.7	142.2	82.1	75.4	135.8	81.1	18.9	17.1	15.8	1283	3298
SAN MARCOS MUNI	29.89N	97.85W	597	27.8	30.4	99.4	74.3	97.5	74.3	95.8	74.2	78.3	90.2	77.7	89.8	75.2	135.1	83.0	74.5	131.9	82.6	24.5	21.1	19.1	1617	3003
VICTORIA/VICTORIA R	28.86N	96.93W	118	31.0	34.5	97.1	76.6	95.2	76.7	93.4	76.7	80.3	87.8	79.7	87.3	79.0	150.9	82.3	78.1	146.5	82.0	24.3	20.9	19.1	1185	3193
WACO RGNL	31.61N	97.23W	509	24.6	28.1	100.5	75.0	99.0	75.1	96.9	75.2	78.7	91.5	78.1	90.8	75.8	137.4	82.3	75.0	133.8	81.8	24.6	21.4	19.5	2010	2856
WICHITA FALLS/SHEPS	33.98N	98.49W	1030	18.2	22.6	102.5	73.2	100.1	73.3	97.7	73.4	77.8	92.0	76.8	91.0	74.0	131.7	82.8	73.0	127.1	81.7	26.9	24.3	21.3	2811	2456
Utah																										*5 sites, 7 more on CD-ROM*
HILL AFB	41.12N	111.97W	4790	9.5	12.3	95.2	61.7	92.7	60.5	90.2	59.7	65.0	86.3	63.5	86.4	57.4	84.2	72.8	54.7	76.1	72.9	22.9	19.8	18.2	6041	1030
LOGAN CACHE	41.79N	111.85W	4455	-5.9	0.4	94.5	62.1	91.3	60.9	89.9	60.4	65.1	86.6	63.8	85.0	58.9	87.9	69.5	55.4	77.1	70.2	19.7	16.6	13.1	7264	466
PROVO MUNI	40.22N	111.72W	4498	7.2	11.5	94.7	62.4	91.3	62.2	89.9	61.9	66.4	86.7	65.1	85.2	59.8	90.8	75.3	57.2	82.5	74.8	24.1	20.1	17.4	6030	791
ST GEORGE MUNI	37.09N	113.58W	2940	26.6	28.1	106.3	66.2	103.7	65.1	100.9	64.4	69.1	94.4	68.0	93.6	62.9	95.8	76.7	59.5	84.6	79.1	26.8	23.3	19.6	2971	2735
SALT LAKE CITY INTL	40.79N	111.97W	4226	9.6	14.2	97.7	62.8	95.1	62.2	92.6	61.5	66.3	88.1	65.1	86.9	60.1	90.7	72.6	57.5	82.6	73.1	25.0	20.9	18.6	5507	1218
Vermont																										*1 site, 5 more on CD-ROM*
BURLINGTON INTL	44.47N	73.15W	341	-7.8	-2.7	88.4	71.3	85.5	69.9	82.4	68.4	74.4	84.0	72.6	81.4	71.3	117.1	78.9	69.7	110.6	77.5	23.6	20.3	18.4	7352	505
Virginia																										*17 sites, 22 more on CD-ROM*
DANVILLE RGNL	36.57N	79.34W	591	18.2	21.3	94.6	74.6	91.3	74.0	90.0	73.5	77.8	89.3	76.7	87.5	74.7	132.9	82.8	73.2	126.3	81.0	18.6	16.5	14.2	3609	1481
DINWIDDIE CO	37.18N	77.50W	194	16.1	19.3	97.3	77.3	94.6	76.4	91.5	74.9	80.7	91.9	79.2	90.8	77.5	144.0	86.2	75.4	133.9	84.0	18.1	15.8	13.0	3732	1555
DAVISON AAF	38.72N	77.32W	75	13.5	18.1	96.9	76.0	93.7	75.1	91.1	74.3	79.6	91.1	78.1	89.0	76.3	137.9	85.4	74.9	131.4	83.9	21.0	17.6	14.2	4304	1436
LANGLEY AFB/HAMPTON	37.08N	76.35W	20	20.7	24.8	91.4	76.1	90.2	76.0	88.1	75.3	80.4	86.4	79.0	85.2	79.0	150.8	83.3	77.2	141.8	82.1	23.8	20.2	18.3	3449	1555
LEESBURG EXECUTIVE	39.08N	77.55W	390	14.5	18.1	95.1	75.8	92.6	75.1	90.4	74.0	79.1	90.6	77.7	88.4	75.4	135.0	83.1	74.7	132.0	82.5	22.7	18.8	16.3	4433	1350
LYNCHBURG/MUN. P. G	37.34N	79.21W	938	15.3	19.0	92.2	73.8	89.9	73.0	87.6	72.3	76.5	87.0	75.3	85.4	73.4	128.4	80.5	72.4	124.1	79.5	17.9	15.9	13.5	4228	1132
MANASSAS RGNL DAVIS	38.72N	77.50W	194	11.8	16.4	93.0	74.1	90.7	73.8	88.4	72.8	77.2	88.7	75.8	86.6	73.3	124.8	82.2	72.5	121.2	81.3	21.6	18.6	16.3	4774	1073
NEWPORT NEWS WILLIA	37.13N	76.49W	52	19.2	23.2	94.6	77.1	91.6	76.1	90.0	75.4	79.5	90.3	78.3	88.1	76.8	140.0	83.9	75.4	133.2	82.5	20.0	18.3	16.8	3527	1589
NORFOLK INTL ARPT	36.90N	76.19W	30	22.5	26.2	93.7	76.7	91.3	76.0	89.2	75.2	79.1	88.7	78.0	87.1	76.7	139.2	83.0	75.6	133.9	81.6	24.8	21.0	19.1	3230	1700
NORFOLK NS	36.93N	76.28W	16	23.8	27.3	94.1	77.2	91.4	76.2	89.9	75.8	80.0	89.4	78.6	87.7	77.4	142.5	84.1	76.1	136.2	83.0	25.4	22.0	19.2	3059	1843
OCEANA NAS	36.82N	76.03W	23	21.5	25.5	92.9	77.2	90.5	76.3	88.3	75.4	79.4	88.8	78.1	86.9	76.9	140.1	83.9	75.4	133.1	82.4	24.5	20.7	18.6	3308	1569
QUANTICO MCAF	38.50N	77.30W	13	16.3	19.6	92.6	76.4	90.3	75.7	88.1	74.7	79.4	89.0	77.9	87.3	76.7	139.1	85.0	75.0	131.4	83.1	19.5	17.0	15.1	4180	1363
RICHMOND/BYRD FIELD	37.51N	77.32W	164	17.8	21.2	95.1	75.9	92.6	75.0	90.2	74.1	78.4	89.3	77.4	87.7	75.7	135.2	82.8	74.6	130.1	81.5	20.8	18.6	16.8	3729	1532
ROANOKE MUNICIPAL	37.32N	79.97W	1175	15.7	19.6	92.3	72.8	90.0	72.2	87.7	71.5	75.4	86.5	74.5	85.1	72.4	125.3	79.6	71.5	121.3	78.5	22.9	19.0	16.8	4044	1230
SHENANDOAH VALLEY RG	38.26N	78.88W	1201	11.8	16.3	93.3	74.0	91.1	73.8	89.7	73.2	78.4	87.4	77.1	86.1	75.4	139.3	82.6	74.7	135.7	81.7	17.6	15.2	12.6	4422	1182
VIRGINIA TECH ARPT	37.21N	80.40W	2133	10.4	15.8	89.8	72.6	87.6	71.2	84.0	70.2	75.6	83.5	74.1	82.0	73.1	133.2	79.0	72.0	128.4	78.3	20.4	18.0	15.8	4823	789
WASHINGTON/DULLES	38.94N	77.45W	325	12.1	16.5	93.5	74.7	91.0	73.9	88.6	72.8	77.6	89.0	76.4	86.7	74.4	130.1	81.9	73.3	125.4	80.6	20.8	18.4	16.5	4675	1183
WASHINGTON/NATIONAL	38.87N	77.03W	66	17.3	20.7	94.5	75.7	91.8	74.8	89.5	73.7	78.5	88.9	77.4	87.2	75.9	135.6	83.1	74.7	130.3	82.0	23.4	20.0	18.1	3996	1555
Washington																										*20 sites, 18 more on CD-ROM*
ARLINGTON MUNI	48.16N	122.15W	138	20.6	24.7	82.2	66.0	79.3	64.3	75.3	62.9	67.3	80.7	65.4	77.5	62.3	84.3	73.0	60.7	79.8	71.1	20.9	18.1	15.6	5371	60
BELLINGHAM INTL	48.79N	122.54W	151	19.0	23.9	79.5	65.2	76.0	63.8	73.0	62.1	66.7	77.7	64.8	74.5	62.2	84.1	71.7	60.7	79.8	69.3	25.4	20.7	18.4	5338	53
BREMERTON NATIONAL	47.49N	122.76W	440	22.6	26.6	85.9	65.1	81.8	63.5	78.7	62.1	66.4	83.1	64.5	80.0	59.1	76.1	71.5	57.3	71.2	68.8	18.9	16.8	14.6	5615	101
FAIRCHILD AFB	47.62N	117.65W	2461	6.8	11.7	92.9	62.1	90.1	61.3	86.2	60.4	64.5	86.5	63.0	84.1	57.3	76.6	66.0	55.1	70.8	65.5	24.7	20.7	18.3	6776	462
FELTS FLD	47.68N	117.32W	1969	7.6	13.8	94.3	65.1	90.8	63.6	87.9	62.6	67.4	89.6	65.4	86.7	60.0	83.2	71.3	57.4	75.5	71.2	19.9	17.5	15.1	6130	439
FORT LEWIS/GRAY AAF	47.12N	122.55W	302	19.8	24.8	87.7	65.4	83.3	64.0	79.7	62.6	67.0	83.9	65.3	80.3	61.3	81.8	69.2	59.4	76.5	68.8	18.2	15.7	12.9	5111	147
KELSO LONGVIEW	46.12N	122.89W	20	21.3	26.2	88.1	67.7	82.5	65.7	79.4	64.0	68.9	84.6	66.8	81.2	63.0	86.2	75.5	61.1	80.6	72.5	17.5	15.0	12.8	4825	185
TACOMA/MC CHORD AFB	47.15N	122.48W	285	21.3	25.0	86.3	64.4	82.2	63.2	79.2	61.9	66.2	82.7	64.4	79.2	60.8	80.3	69.3	58.9	75.0	68.2	20.3	17.7	15.6	5288	123
OLYMPIA	46.97N	122.90W	200	20.1	24.5	87.6	66.0	83.4	64.8	79.9	63.3	67.8	84.8	65.8	81.2	61.4	81.9	71.0	59.9	77.6	69.5	18.8	16.6	14.6	5372	106
TRI CITIES	46.27N	119.12W	404	7.4	15.6	99.4	69.0	96.6	68.0	92.5	66.5	71.7	93.9	69.7	91.5	64.0	90.6	79.1	62.5	85.9	77.5	24.6	20.7	18.3	4936	805
PEARSON FLD	45.62N	122.66W	20	24.9	27.6	90.9	66.0	87.8	65.8	82.4	64.6	69.2	85.6	67.4	83.8	63.1	86.6	74.4	61.3	81.1	72.4	16.6	13.8	12.1	4415	374
BOEING FLD KING CO	47.53N	122.30W	30	24.8	28.4	86.0	65.7	82.1	63.9	79.2	62.7	66.9	83.2	65.3	79.5	61.2	80.8	69.5	59.5	75.9	69.3	18.6	16.8	14.5	4320	264
SEATTLE-TACOMA INTL	47.46N	122.31W	433	25.2	29.6	85.3	65.2	81.6	63.7	78.3	62.6	66.8	82.6	65.0	79.0	61.0	81.4	70.0	59.4	76.8	68.0	20.3	18.2	16.4	4705	188
SANDERSON FLD	47.24N	123.15W	269	23.1	26.7	87.9	65.1	82.7	64.3	79.2	62.8	67.2	83.8	65.3	80.5	61.2	81.5	69.9	59.4	76.3	68.1	20.4	18.2	16.4	5465	103
SNOHOMISH CO	47.91N	122.28W	607	25.5	29.6	80.8	63.8	75.5	62.0	72.9	60.9	65.4	77.0	63.5	74.0	61.1	82.4	68.4	59.1	76.4	67.2	24.4	20.1	17.5	5208	79

Meaning of acronyms:
DB: Dry bulb temperature, °F *WB: Wet bulb temperature, °F*
MCWB: Mean coincident wet bulb temperature, °F
Lat: Latitude, °
DP: Dew point temperature, °F
MCDB: Mean coincident dry bulb temperature, °F
Long: Longitude, °
HR: Humidity ratio, grains of moisture per lb of dry air
HDD and CDD 65: Annual heating and cooling degree-days, base 65°F, °F-day
Elev: Elevation, ft
WS: Wind speed, mph

Station	Lat	Long	Elev	Heating DB		Cooling DB/MCWB						Evaporation WB/MCDB				Dehumidification DP/HR/MCDB						Extreme Annual WS			Heat./Cool. Degree-Days	
						0.4%		1%		2%		0.4%		1%		0.4%			1%							
				99.6%	99%	DB	MCWB	DB	MCWB	DB	MCWB	WB	MCDB	WB	MCDB	DP	HR	MCDB	DP	HR	MCDB	1%	2.5%	5%	HDD	CDD 65
SPOKANE INTL ARPT	47.62N	117.53W	2365	4.7	11.0	92.8	63.0	89.6	61.7	86.0	60.5	65.0	87.2	63.4	84.9	57.6	77.3	67.4	55.5	71.6	67.5	25.6	22.0	19.1	6627	434
TACOMA NARROWS	47.27N	122.58W	315	27.4	31.2	83.8	64.5	80.8	63.0	76.8	61.6	66.0	80.9	64.2	77.3	61.0	81.2	68.4	59.1	75.8	66.9	19.5	17.4	15.5	4771	145
WALLA WALLA RGNL	46.10N	118.29W	1204	10.4	18.0	98.7	66.2	94.6	65.1	90.9	63.8	68.4	92.7	66.6	90.4	60.7	82.8	73.5	57.6	74.0	72.4	24.0	19.9	17.8	4825	910
WEST POINT (LS)	47.67N	122.43W	30	29.7	33.4	70.5	60.7	68.1	60.0	66.1	59.3	62.1	67.5	60.9	65.7	59.8	77.0	64.0	58.9	74.3	62.9	36.7	30.9	26.0	4906	8
YAKIMA AIR TERMINAL	46.56N	120.53W	1066	7.8	13.7	96.0	66.4	92.7	65.3	89.5	63.8	68.4	91.0	66.6	88.8	60.4	81.4	76.0	57.8	74.3	74.5	23.2	19.1	16.4	5898	509
West Virginia																									*3 sites, 8 more on CD-ROM*	
YEAGER	38.38N	81.59W	981	10.1	15.5	91.3	72.9	89.1	72.7	86.6	72.1	76.7	86.0	75.3	84.1	74.0	131.5	80.7	72.8	126.0	79.3	17.2	14.8	12.3	4444	1076
HUNTINGTON/TRI STAT	38.38N	82.56W	837	10.1	15.5	91.9	73.5	89.6	73.2	87.2	72.6	77.3	86.6	75.9	84.8	74.5	133.1	81.4	73.2	127.4	80.1	16.8	14.8	12.7	4426	1156
MID OHIO VALLEY RGN	39.35N	81.44W	863	7.3	12.3	90.9	73.6	88.4	72.9	86.0	72.0	76.9	86.5	75.4	84.0	73.9	130.5	81.2	72.7	125.1	79.7	18.2	16.0	13.9	4940	949
Wisconsin																									*14 sites, 31 more on CD-ROM*	
OUTAGAMIE CO RGNL	44.26N	88.52W	919	-6.3	-0.9	88.2	74.3	84.4	72.2	82.1	70.3	76.9	84.8	74.9	82.0	74.6	134.0	81.2	72.5	124.7	79.3	24.7	21.2	18.9	7273	587
CHIPPEWA VALLEY RGN	44.87N	91.49W	896	-13.5	-8.3	90.5	73.0	87.2	71.1	84.1	69.2	75.8	85.7	73.9	83.4	72.7	125.3	81.8	70.7	117.0	79.5	19.9	17.9	16.3	7801	600
FOND DU LAC CO	43.77N	88.49W	807	-5.7	-0.1	88.3	73.8	84.4	71.4	82.2	69.8	76.2	84.6	74.3	82.1	73.0	126.4	81.9	72.1	122.1	80.2	23.5	20.1	18.2	7071	588
GREEN BAY/A.-STRAUB	44.51N	88.12W	702	-8.2	-3.0	88.5	73.5	85.3	71.9	82.5	70.1	76.3	85.0	74.3	82.2	73.5	127.8	81.3	71.7	120.0	79.5	23.5	20.0	18.1	7599	479
KENOSHA RGNL	42.60N	87.94W	745	-1.7	2.8	89.9	74.7	87.0	73.3	83.7	71.8	76.9	86.3	75.1	83.5	73.3	127.2	81.6	72.4	123.3	80.5	24.9	21.7	19.2	6681	614
LA CROSSE MUNICIPAL	43.88N	91.25W	656	-9.3	-4.5	91.7	74.8	88.8	73.2	85.9	71.5	77.9	87.8	75.7	84.9	74.9	134.1	83.9	72.8	124.5	81.3	23.1	19.6	18.0	7010	818
MADISON/DANE COUNTY	43.14N	89.35W	866	-7.0	-1.6	89.6	74.2	86.6	72.6	83.8	71.0	77.0	86.1	75.0	83.3	73.9	130.4	82.9	72.2	123.1	80.5	22.6	19.6	17.9	7104	620
MANITOWOC CO	44.13N	87.67W	650	-4.2	0.5	84.4	71.6	81.7	70.1	79.3	68.3	74.7	82.1	72.5	79.2	72.3	122.5	79.8	70.3	114.2	77.2	24.1	20.7	18.8	7541	344
MILWAUKEE/GEN. MITC	42.95N	87.90W	692	-1.4	3.2	90.0	74.3	86.5	72.4	83.5	70.8	76.8	86.5	74.9	83.3	73.6	128.4	82.2	72.1	121.8	80.4	25.2	22.3	19.8	6684	690
CENTRAL WISCONSIN	44.78N	89.67W	1276	-10.8	-6.5	86.4	71.8	83.0	69.6	81.2	68.0	74.0	82.6	72.0	80.0	71.8	123.4	79.3	69.8	115.0	77.6	23.0	19.6	17.6	8223	363
SHEBOYGAN CO MEM	43.77N	87.85W	748	-3.7	0.6	88.1	73.6	84.0	71.5	81.6	69.7	75.6	83.9	73.8	81.8	72.8	124.9	81.1	71.8	120.9	79.4	24.3	20.7	18.6	7375	423
SHEBOYGAN	43.75N	87.68W	620	-2.2	2.8	83.0	71.2	79.3	70.2	76.5	69.7	76.2	79.0	74.1	76.8	75.3	135.9	77.3	73.3	126.6	75.7	40.7	33.3	28.0	7272	322
WAUSAU DOWNTOWN	44.93N	89.63W	1198	-11.8	-6.9	88.1	71.6	84.5	69.5	81.9	67.6	74.3	83.2	72.5	81.0	71.8	122.9	79.0	69.8	114.7	77.4	20.0	17.7	15.9	7973	462
WITTMAN RGNL	43.98N	88.56W	840	-6.0	-0.4	88.2	73.7	84.3	71.8	82.0	69.9	76.1	84.3	74.2	82.0	73.1	126.6	81.2	72.0	122.1	79.8	23.1	20.0	18.0	7286	548
Wyoming																									*2 sites, 16 more on CD-ROM*	
CASPER/NATRONA COUN	42.90N	106.47W	5289	-8.3	-0.7	93.8	59.7	91.1	59.0	88.3	58.4	63.2	83.2	61.8	82.2	57.4	85.9	66.3	55.2	79.1	66.2	32.1	28.1	25.5	7285	461
CHEYENNE/WARREN AFB	41.16N	104.81W	6142	-3.7	2.9	89.7	58.3	86.8	57.7	83.8	57.2	62.6	77.3	61.5	76.9	58.8	93.1	65.6	56.9	86.9	65.2	33.6	28.9	25.9	7050	338
Canada																									*100 sites, 462 more on CD-ROM*	
Alberta																									*13 sites, 50 more on CD-ROM*	
CALGARY INT'L A	51.11N	114.02W	3556	-19.8	-13.1	83.5	60.7	79.9	59.7	76.4	58.4	63.6	78.0	61.7	75.6	58.3	83.1	69.3	56.2	76.8	66.8	27.0	23.1	20.3	9093	64
COP UPPER	51.08N	114.22W	4052	-17.8	-12.0	82.7	58.8	78.8	57.7	75.2	56.7	62.9	75.0	60.7	73.2	58.7	85.7	67.2	56.2	78.2	64.7	23.1	20.0	17.5	9048	73
EDMONTON CITY CENTRE AWOS	53.57N	113.52W	2201	-20.5	-14.8	83.0	64.4	79.6	62.7	76.5	60.8	66.5	79.3	64.5	76.3	61.9	89.7	72.3	59.9	83.4	69.8	22.0	18.8	16.5	9356	121
EDMONTON INT'L A	53.32N	113.58W	2372	-26.7	-20.6	82.0	63.9	78.5	62.3	75.6	60.6	66.5	78.5	64.4	75.6	61.9	90.5	73.1	59.9	84.0	70.5	22.9	19.7	17.1	10321	42
EDMONTON NAMAO A	53.67N	113.47W	2257	-22.7	-16.7	82.1	64.0	78.7	62.2	75.5	60.2	66.0	78.5	64.1	75.6	61.4	88.6	71.3	59.4	82.1	69.2	23.1	20.0	17.4	9893	68
FORT MCMURRAY CS	56.65N	111.21W	1211	-33.4	-28.3	84.1	63.9	80.5	61.8	77.0	60.3	66.0	79.7	64.1	76.7	61.2	84.5	70.4	59.2	78.5	68.5	18.6	16.2	14.1	11405	82
GRANDE PRAIRIE A	55.18N	118.88W	2195	-32.8	-24.5	81.4	61.9	78.0	60.2	75.0	58.7	64.3	77.3	62.2	74.5	59.7	82.8	68.9	57.5	76.5	66.2	24.8	21.6	18.7	10552	45
LACOMBE CDA 2	52.45N	113.76W	2822	-26.5	-19.4	83.0	64.9	79.2	62.8	76.0	61.0	66.9	79.3	64.7	76.5	62.2	92.9	73.9	59.9	85.5	71.2	21.2	18.2	15.6	10304	43
LETHBRIDGE AWOS A	49.63N	112.80W	3048	-21.1	-14.5	88.7	62.2	85.0	61.2	81.4	60.4	65.7	81.4	63.7	79.5	60.0	86.6	72.7	57.9	80.1	69.6	35.6	30.5	27.0	8320	153
LETHBRIDGE CDA	49.70N	112.77W	2986	-18.5	-12.5	89.4	62.3	85.5	61.3	81.9	60.5	65.8	81.5	64.0	79.6	60.4	87.6	72.1	58.2	80.8	69.7	29.8	26.5	23.4	8108	205
MEDICINE HAT RCS	50.03N	110.72W	2346	-23.0	-16.4	90.8	64.0	87.3	62.8	83.8	61.5	66.2	84.7	64.5	82.6	60.0	84.3	72.2	58.0	78.4	70.4	25.1	21.6	18.9	8354	301
RED DEER A	52.18N	113.89W	2969	-26.0	-18.9	82.4	63.1	78.9	61.3	75.7	59.8	65.4	78.6	63.3	75.6	60.3	87.4	71.8	58.3	81.1	69.2	20.3	18.2	16.4	10196	42
SPRINGBANK A	51.10N	114.37W	3940	-25.0	-18.3	80.3	60.0	76.7	58.3	73.6	57.3	62.3	75.5	60.4	73.2	57.1	80.6	68.0	55.2	75.1	65.3	24.8	21.2	18.6	10293	8
British Columbia																									*27 sites, 52 more on CD-ROM*	
ABBOTSFORD A	49.03N	122.36W	194	17.9	22.9	85.7	67.2	82.0	65.9	78.4	64.2	68.7	83.4	66.7	79.9	62.6	85.5	77.2	60.9	80.3	73.4	19.8	16.7	14.3	5256	134
AGASSIZ CS	49.24N	121.76W	62	18.8	23.3	86.6	68.7	83.1	67.4	79.7	66.3	71.0	82.8	68.9	80.2	66.5	97.9	77.8	64.5	91.2	75.0	22.9	17.9	14.2	5150	203
BALLENAS ISLAND	49.35N	124.16W	43	30.8	33.6	74.8	66.8	72.5	65.7	70.5	64.5	68.3	73.3	66.6	71.3	66.3	96.9	71.7	64.6	91.4	69.9	35.7	30.9	27.2	4627	109
COMOX A	49.72N	124.90W	85	23.4	27.1	80.3	63.9	76.5	62.6	73.4	61.4	65.2	76.8	63.8	73.9	60.8	79.9	68.9	59.6	76.3	67.4	30.2	25.9	21.9	5541	94
DISCOVERY ISLAND	48.42N	123.23W	49	30.6	34.8	73.5	N/A	69.8	N/A	66.8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	36.5	29.1	22.5	4802	23
ENTRANCE ISLAND CS	49.22N	123.80W	16	28.9	32.1	75.1	N/A	72.2	N/A	70.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	32.0	28.1	25.2	4814	108
ESQUIMALT HARBOUR	48.43N	123.44W	10	27.1	30.9	72.1	60.8	69.0	59.7	66.4	58.8	62.3	69.1	61.0	66.8	59.4	75.7	64.4	58.4	72.8	63.1	21.7	18.8	16.5	5403	12
HOWE SOUND - PAM ROCKS	49.49N	123.30W	16	26.9	30.4	76.9	66.3	73.8	64.7	71.5	63.8	68.0	74.0	66.2	71.9	65.5	94.1	72.3	63.7	88.4	70.2	40.4	35.5	30.2	4781	142
KAMLOOPS AUT	50.70N	120.44W	1132	-3.4	4.0	93.0	64.7	89.2	63.7	85.3	62.3	66.5	88.3	64.8	85.0	59.4	78.7	70.6	57.4	73.3	69.6	22.6	19.8	17.9	6329	482
KELOWNA A	49.96N	119.38W	1411	-0.2	6.9	91.4	64.8	87.9	63.7	84.1	62.0	66.6	86.4	64.8	83.8	59.8	80.9	70.7	57.9	75.6	69.6	17.2	14.3	11.9	7014	236
MALAHAT	48.57N	123.53W	1201	22.0	26.5	81.9	62.7	78.3	61.9	75.3	60.7	65.9	77.4	64.1	74.6	61.1	84.0	73.1	59.4	79.0	70.6	14.9	12.8	11.0	5852	174
PENTICTON A	49.46N	119.60W	1129	7.4	12.5	91.0	65.4	87.4	64.2	84.3	62.8	67.0	86.9	65.3	84.3	59.6	79.5	72.4	57.9	74.7	72.0	23.1	20.1	18.0	6161	391
PITT MEADOWS CS	49.21N	122.69W	16	18.7	23.3	86.9	68.1	83.1	66.8	79.6	65.4	69.7	83.2	67.6	80.2	64.5	90.9	75.8	62.7	85.1	72.7	12.2	10.3	8.9	5367	141
POINT ATKINSON	49.33N	123.26W	115	29.1	32.5	76.7	N/A	74.3	N/A	72.4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	30.5	26.0	22.2	4173	214

Meaning of acronyms:
DB: Dry bulb temperature, °F — *WB: Wet bulb temperature, °F* — *MCWB: Mean coincident wet bulb temperature, °F*
Lat: Latitude, ° — *DP: Dew point temperature, °F* — *MCDB: Mean coincident dry bulb temperature, °F*
Long: Longitude, ° — *HR: Humidity ratio, grains of moisture per lb of dry air* — *HDD and CDD 65: Annual heating and cooling degree-days, base 65°F, °F-day*
Elev: Elevation, ft — *WS: Wind speed, mph*

Station	Lat	Long	Elev	Heating DB		Cooling DB/MCWB 0.4%		Cooling DB/MCWB 1%		Cooling DB/MCWB 2%		Evaporation WB/MCDB 0.4%		Evaporation WB/MCDB 1%		Dehumidification DP/HR/MCDB 0.4%			Dehumidification DP/HR/MCDB 1%			Extreme Annual WS			Heat./Cool. Degree-Days	
				99.6%	99%	DB	MCWB	DB	MCWB	DB	MCWB	WB	MCDB	WB	MCDB	DP	HR	MCDB	DP	HR	MCDB	1%	2.5%	5%	HDD	CDD 65
PRINCE GEORGE AIRPORT AUTO	53.89N	122.67W	2231	-22.4	-14.0	82.1	61.3	78.3	59.7	74.9	58.1	62.9	78.3	61.0	75.1	57.1	75.6	66.2	55.4	70.9	64.6	21.3	18.6	16.4	9174	38
SANDHEADS CS	49.11N	123.30W	36	25.5	29.8	72.3	N/A	70.3	N/A	68.4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	30.6	27.0	24.1	4951	55
SUMMERLAND CS	49.56N	119.64W	1490	6.0	12.4	91.5	63.9	88.1	63.1	84.7	62.0	66.8	85.3	65.0	82.8	60.5	83.0	72.5	58.3	76.8	71.5	18.6	14.8	12.0	6311	466
VANCOUVER HARBOUR CS	49.30N	123.12W	10	26.5	30.5	78.6	N/A	75.9	N/A	73.4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	4807	124
VANCOUVER INT'L A	49.20N	123.18W	13	20.9	26.0	77.3	65.1	74.5	64.0	72.2	62.8	66.3	75.2	64.8	73.1	62.4	84.4	71.6	61.1	80.5	69.6	23.6	20.2	17.5	5225	80
VERNON AUTO	50.22N	119.19W	1581	3.2	9.3	91.7	65.4	87.9	64.3	83.9	62.9	67.5	85.6	65.7	83.3	62.1	88.5	70.6	60.1	82.3	69.3	14.2	11.8	10.0	6790	370
VICTORIA GONZALES CS	48.41N	123.33W	230	26.9	31.1	76.4	62.6	72.1	61.0	68.9	59.7	63.9	73.3	62.2	69.8	60.3	78.7	65.9	59.1	75.3	64.8	27.3	23.3	20.5	5146	42
VICTORIA HARTLAND CS	48.53N	123.46W	505	25.5	29.3	83.4	65.8	80.0	64.4	76.9	63.2	68.0	79.8	66.3	77.0	63.8	90.2	72.5	62.2	85.2	70.3	21.0	18.2	15.6	5055	177
VICTORIA INT'L A	48.65N	123.43W	66	24.4	27.9	80.2	63.7	76.4	62.4	73.3	61.1	64.6	78.0	63.0	74.7	59.0	74.6	68.4	57.7	71.2	67.3	19.9	16.6	14.2	5417	44
ESQUIMALT HARBOUR	48.43N	123.44W	10	27.1	30.9	72.1	60.8	69.0	59.7	66.4	58.8	62.3	69.1	61.0	66.8	59.4	75.7	64.4	58.4	72.8	63.1	21.7	18.8	16.5	5403	12
VICTORIA UNIVERSITY CS	48.46N	123.30W	197	27.4	31.6	80.8	65.1	77.4	63.9	74.3	62.8	67.1	77.6	65.4	74.8	63.3	87.8	70.5	61.8	83.0	68.6	12.8	11.1	9.7	4901	70
WEST VANCOUVER AUT	49.35N	123.19W	551	21.6	26.3	81.0	65.6	77.6	64.8	74.6	63.5	67.6	78.0	66.0	75.4	63.6	89.8	73.3	62.0	84.9	71.3	11.1	9.5	7.8	5408	135
WHITE ROCK CAMPBELL SCIENTIFI	49.02N	122.78W	43	22.3	26.6	76.8	65.9	73.9	64.6	71.6	63.5	67.6	74.4	65.8	72.2	64.9	92.4	71.5	63.2	86.8	69.2	14.1	11.6	9.4	5020	55
Manitoba																										*1 site, 38 more on CD-ROM*
WINNIPEG RICHARDSON INT'L A	49.92N	97.23W	784	-25.9	-21.5	87.1	70.0	83.8	68.6	80.8	67.0	73.3	83.0	70.9	80.6	70.1	114.0	79.5	67.5	104.0	76.5	28.0	24.7	22.0	10309	292
New Brunswick																										*3 sites, 10 more on CD-ROM*
FREDERICTON A	45.87N	66.53W	69	-10.3	-5.6	85.6	69.9	82.2	67.6	79.2	66.0	72.1	82.0	70.2	78.8	68.7	105.7	77.0	67.1	99.8	74.8	22.1	19.2	17.3	8399	242
MONCTON A	46.10N	64.69W	233	-8.5	-4.2	83.3	69.4	80.3	67.4	77.4	65.8	71.8	79.8	70.0	77.0	69.1	107.9	76.0	67.4	101.7	74.1	28.1	24.4	21.4	8556	182
SAINT JOHN A	45.32N	65.89W	358	-8.3	-3.5	79.0	65.5	75.9	63.9	73.1	62.3	68.1	75.2	66.2	72.7	65.4	95.0	71.1	63.8	89.7	68.9	27.3	23.5	20.8	8554	55
Newfoundland and Labrador																										*1 site, 37 more on CD-ROM*
ST JOHN'S A	47.62N	52.74W	463	4.3	8.1	76.3	66.1	73.5	64.5	71.0	63.2	68.7	73.7	66.8	71.2	66.8	100.1	71.5	65.0	94.1	69.5	35.5	30.1	27.0	8727	54
Northwest Territories																										*1 site, 38 more on CD-ROM*
YELLOWKNIFE A	62.46N	114.44W	676	-41.2	-37.2	77.4	60.7	74.4	59.2	71.5	58.1	62.9	72.8	61.2	71.1	59.1	76.6	67.1	56.9	70.8	65.2	21.0	18.7	16.8	14741	62
Nova Scotia																										*3 sites, 16 more on CD-ROM*
HALIFAX STANFIELD INT'L A	44.88N	63.52W	476	-1.1	2.6	82.0	68.7	78.8	66.7	76.0	65.1	71.1	78.2	69.3	75.4	68.9	107.9	74.4	67.2	101.9	72.1	27.6	23.6	20.9	7794	185
SHEARWATER RCS	44.63N	63.51W	79	2.0	5.9	79.0	67.3	76.0	65.4	73.3	64.2	69.9	75.2	68.2	72.9	68.1	103.5	72.0	66.4	97.6	70.1	26.8	23.2	20.7	7514	124
SYDNEY A	46.17N	60.05W	203	-0.2	4.1	81.4	68.5	78.4	67.1	75.3	65.3	70.8	78.6	68.8	75.5	68.0	103.7	74.7	66.4	97.8	72.4	28.0	24.6	21.8	8245	145
Nunavut																										*1 site, 41 more on CD-ROM*
IQALUIT CLIMATE	63.75N	68.54W	112	-39.0	-35.6	62.7	52.7	57.6	50.0	54.0	48.0	53.6	61.0	50.8	56.9	48.9	51.4	56.1	46.7	47.3	53.0	34.4	28.9	25.2	17863	0
Ontario																										*20 sites, 49 more on CD-ROM*
BEAUSOLEIL	44.85N	79.87W	600	-10.8	-4.7	85.9	74.0	82.6	71.7	79.7	70.3	75.9	82.6	73.9	79.9	73.9	129.2	79.5	71.9	120.8	77.2	14.0	12.1	10.7	7850	382
BELLE RIVER	42.30N	82.70W	604	5.7	10.1	88.9	75.6	86.0	74.6	83.3	73.0	78.6	85.3	76.8	83.1	76.7	142.5	83.0	74.9	133.8	80.6	29.0	25.3	22.2	5983	810
BURLINGTON PIERS (AUT)	43.30N	79.80W	253	5.0	9.1	86.4	70.3	83.5	69.2	80.6	67.9	73.7	80.8	72.0	79.4	71.6	117.6	77.5	69.6	110.0	75.7	23.4	20.2	17.6	6408	557
ERIEAU (AUT)	42.25N	81.90W	584	5.7	9.8	80.2	73.0	78.4	71.9	76.9	71.1	76.2	77.8	74.6	76.7	75.6	137.1	77.2	73.9	129.3	75.9	28.5	25.0	22.0	6470	502
LAGOON CITY	44.55N	79.22W	725	-10.4	-4.5	81.4	73.4	79.1	71.9	77.0	70.5	75.6	79.2	73.8	77.3	74.6	132.8	78.0	72.6	124.2	76.4	28.3	24.9	21.9	7940	340
LONDON CS	43.03N	81.15W	912	0.0	4.2	86.4	72.2	83.6	70.9	81.0	69.2	74.5	82.9	72.8	80.7	71.9	122.0	79.2	70.2	115.0	77.3	23.5	21.0	18.7	7117	433
NORTH BAY A	46.36N	79.42W	1214	-17.2	-12.2	82.2	68.2	79.2	66.5	76.6	65.0	71.2	78.7	69.3	75.3	68.8	110.9	74.5	67.1	104.4	72.8	21.6	18.9	17.0	9345	221
OTTAWA MACDONALD-CARTIER INT'	45.32N	75.67W	374	-11.5	-6.6	87.1	71.3	84.1	69.5	81.1	68.0	73.8	83.0	71.9	80.3	71.0	115.7	78.6	69.2	108.8	76.6	22.3	19.6	17.4	8142	428
PETERBOROUGH AWOS	44.23N	78.37W	627	-10.1	-3.8	86.1	72.1	83.1	70.2	80.5	68.8	74.5	82.7	72.6	80.1	72.0	121.0	79.1	70.1	113.2	76.5	20.2	17.6	15.4	7866	269
PORT WELLER (AUT)	43.25N	79.22W	259	8.6	12.2	84.4	73.5	81.7	72.2	79.2	70.9	76.2	80.9	74.4	78.9	74.7	131.3	79.1	73.1	124.2	77.2	32.2	28.4	25.0	6328	562
SAULT STE MARIE A	46.48N	84.51W	630	-12.3	-6.7	83.4	70.1	80.0	67.9	77.1	66.3	72.2	79.9	70.0	77.1	69.6	111.4	76.6	67.6	103.8	74.2	23.1	20.0	17.7	8910	165
SUDBURY A	46.62N	80.80W	1142	-17.8	-12.5	84.7	68.4	81.3	66.3	78.3	64.6	70.9	80.6	69.0	77.3	67.9	106.8	74.4	66.0	100.1	73.0	22.7	20.1	18.0	9433	238
THUNDER BAY CS	48.37N	89.33W	653	-20.7	-15.9	84.2	68.9	80.6	66.6	77.4	64.8	71.3	80.7	68.9	77.2	68.0	105.5	76.6	65.8	97.6	73.6	21.8	18.9	16.6	10069	123
TIMMINS VICTOR POWER A	48.57N	81.38W	968	-27.5	-21.8	85.2	67.8	81.6	65.3	78.4	64.0	70.5	81.2	68.3	77.7	66.9	102.5	75.3	64.9	95.4	73.3	18.7	17.4	14.7	10830	157
TORONTO BUTTONVILLE A	43.86N	79.37W	650	-3.6	1.5	88.9	72.3	85.5	70.4	82.4	68.9	74.5	85.0	72.5	82.2	71.2	118.0	80.0	69.3	110.4	77.8	21.5	18.8	17.2	7352	456
TORONTO CITY CENTRE	43.63N	79.40W	253	3.0	8.1	83.3	71.2	80.2	70.5	77.5	69.5	74.4	79.3	72.8	77.5	72.8	122.8	77.2	71.2	116.0	75.6	29.7	26.5	23.4	6698	427
TORONTO LESTER B. PEARSON INT	43.68N	79.63W	568	-0.5	4.0	88.5	72.3	85.2	70.6	82.2	69.1	74.7	84.4	72.9	82.1	71.7	119.7	80.1	69.9	112.1	78.1	27.1	23.4	20.7	7006	526
TRENTON A	44.12N	77.53W	282	-6.5	-1.2	84.7	71.9	82.1	70.5	79.6	69.1	74.4	81.6	72.7	79.4	72.0	119.5	78.8	70.3	112.8	77.0	23.5	20.6	18.1	7455	380
WELCOME ISLAND (AUT)	48.37N	89.12W	692	-14.4	-10.2	75.5	65.5	72.6	63.9	70.1	63.1	68.2	72.1	66.1	70.3	66.8	101.3	70.5	64.5	93.4	68.1	34.6	29.4	26.1	9664	68
WINDSOR A	42.28N	82.96W	623	4.0	8.4	89.7	73.2	86.8	72.0	84.2	70.7	76.0	85.8	74.2	83.2	73.0	125.4	81.7	71.4	118.5	79.3	25.4	22.4	20.0	6200	781
Prince Edward Island																										*1 site, 4 more on CD-ROM*
CHARLOTTETOWN A	46.29N	63.13W	161	-4.7	-0.3	80.1	69.2	77.5	67.3	75.0	65.8	71.1	77.6	69.3	75.1	68.8	106.5	75.2	67.1	100.3	73.3	26.1	22.5	19.8	8389	181
Québec																										*23 sites, 71 more on CD-ROM*
BAGOTVILLE A	48.33N	71.00W	522	-21.7	-17.2	84.7	67.0	81.1	65.4	77.8	64.0	70.2	79.6	68.2	77.1	67.0	101.3	74.2	65.1	94.7	72.3	26.9	23.5	21.0	10247	176
JONQUIERE	48.42N	71.15W	420	-20.0	-15.6	84.3	67.9	80.8	66.0	77.6	64.8	71.4	79.6	69.4	76.7	68.7	107.0	75.4	66.7	99.9	73.1	23.6	21.1	19.0	9893	175
LA BAIE	48.30N	70.92W	499	-22.4	-17.9	84.4	67.5	80.7	66.1	77.4	64.8	71.1	79.5	69.1	76.6	68.4	106.3	75.2	66.5	99.2	72.8	23.0	20.4	18.1	10285	126
LAC SAINT-PIERRE	46.18N	72.92W	52	-12.5	-7.0	81.9	69.8	79.2	68.0	77.0	67.0	72.6	78.6	70.9	76.6	70.4	112.0	76.4	68.7	105.7	74.8	29.8	26.5	23.6	8375	325

Meaning of acronyms:
DB: Dry bulb temperature, °F *WB: Wet bulb temperature, °F*
MCWB: Mean coincident wet bulb temperature, °F
Lat: Latitude, °
DP: Dew point temperature, °F
MCDB: Mean coincident dry bulb temperature, °F
Long: Longitude, °
HR: Humidity ratio, grains of moisture per lb of dry air
HDD and CDD 65: Annual heating and cooling degree-days, base 65°F, °F-day
Elev: Elevation, ft
WS: Wind speed, mph

Station	Lat	Long	Elev	Heating DB		Cooling DB/MCWB						Evaporation WB/MCDB				Dehumidification DP/HR/MCDB						Extreme Annual WS			Heat./Cool. Degree-Days	
						0.4%		1%		2%		0.4%		1%		0.4%			1%							
				99.6%	99%	DB	MCWB	DB	MCWB	DB	MCWB	WB	MCDB	WB	MCDB	DP	HR	MCDB	DP	HR	MCDB	1%	2.5%	5%	HDD	CDD 65
L'ACADIE	45.29N	73.35W	144	-10.9	-6.4	86.2	71.1	83.4	70.0	80.8	68.7	74.7	82.3	72.7	79.4	72.1	119.6	79.2	70.5	112.8	77.0	22.8	19.6	16.9	7926	404
L'ASSOMPTION	45.81N	73.43W	69	-14.1	-8.6	86.7	71.4	83.7	69.6	80.9	68.2	74.2	82.7	72.2	79.8	71.4	116.3	78.4	69.7	109.4	76.6	18.9	16.5	14.4	8309	366
LENNOXVILLE	45.37N	71.82W	594	-14.1	-8.1	85.0	70.8	82.3	69.4	79.7	67.9	73.8	81.2	71.9	79.0	71.5	119.1	77.8	69.6	111.2	75.9	20.2	17.7	15.7	8291	266
MCTAVISH	45.50N	73.58W	240	-7.1	-2.4	86.2	71.6	83.4	69.7	81.0	68.2	74.0	82.9	72.1	79.8	71.0	115.3	79.0	69.4	109.1	77.3	11.3	9.8	8.9	7460	533
MONT-JOLI A	48.60N	68.22W	171	-10.8	-6.8	80.2	67.6	77.0	65.6	74.3	64.1	69.3	77.5	67.3	74.9	66.1	96.9	75.1	64.1	90.2	72.3	28.1	24.8	22.1	9623	123
MONT-ORFORD	45.31N	72.24W	2776	-19.0	-13.2	77.2	65.3	74.3	63.9	71.6	62.8	69.0	73.6	66.7	70.7	67.4	111.8	71.2	65.4	104.2	69.0	35.1	30.3	27.2	10169	96
MONTREAL/MIRABEL INT'L A	45.67N	74.03W	269	-14.9	-9.6	85.2	71.6	82.3	69.4	79.5	67.9	73.4	82.3	71.4	79.4	70.4	113.1	79.0	68.5	105.9	76.4	18.9	16.4	14.2	8630	307
MONTREAL/PIERRE ELLIOTT TRUDE	45.47N	73.74W	105	-9.8	-5.3	86.1	71.9	83.3	70.0	80.8	68.5	73.9	82.9	72.2	80.1	71.0	114.5	79.0	69.3	108.3	77.5	25.2	22.0	19.5	7885	470
MONTREAL/ST-HUBERT A	45.52N	73.42W	89	-10.9	-6.1	86.2	71.8	83.4	70.1	80.8	68.7	74.4	82.8	72.4	80.2	71.6	117.3	79.1	69.8	109.8	77.1	25.1	22.0	19.6	8111	397
MONTREAL-EST	45.63N	73.55W	164	-9.4	-4.4	86.9	69.8	84.2	68.1	81.7	66.9	72.9	81.9	71.1	79.1	70.1	111.4	76.6	68.4	104.9	75.7	19.3	17.0	15.2	7765	511
NICOLET	46.23N	72.66W	26	-13.7	-8.4	83.8	72.5	80.9	70.4	78.4	68.9	74.4	81.1	72.4	78.5	72.1	118.9	78.5	70.2	111.4	76.2	21.2	18.3	15.9	8425	292
POINTE-AU-PERE (INRS)	48.51N	68.47W	16	-7.5	-2.8	73.3	65.4	70.5	63.6	68.1	62.0	67.4	71.7	65.0	69.2	65.5	94.1	70.6	63.1	86.4	68.2	29.0	25.5	22.6	9584	20
QUEBEC/JEAN LESAGE INTL	46.79N	71.38W	243	-14.9	-9.9	84.0	70.3	81.0	68.4	78.2	66.4	72.8	80.8	70.6	77.9	70.0	111.5	77.5	68.0	103.9	75.3	25.2	22.0	19.6	9104	238
SHERBROOKE A	45.43N	71.68W	791	-18.1	-12.4	83.8	70.0	81.0	68.5	78.5	66.8	72.6	80.8	70.5	78.2	69.8	112.7	77.5	67.8	105.2	75.1	20.2	17.6	15.4	9011	178
ST-ANICET 1	45.12N	74.29W	161	-12.3	-7.1	86.6	72.8	83.8	71.1	81.3	69.5	75.5	83.4	73.6	81.0	72.9	123.0	80.4	71.2	115.6	77.9	20.8	18.2	16.1	8022	361
STE-ANNE-DE-BELLEVUE 1	45.43N	73.93W	128	-10.7	-5.5	86.0	71.4	83.2	69.9	80.6	68.5	74.3	82.3	72.5	79.7	71.8	117.9	78.6	70.1	111.2	76.4	20.0	17.7	15.8	7963	405
STE-FOY (U. LAVAL)	46.78N	71.29W	299	-12.2	-7.3	84.4	69.4	81.5	67.5	78.6	65.6	72.6	80.7	70.6	77.7	69.9	111.1	76.8	68.2	104.6	74.5	21.0	18.0	15.3	8717	259
TROIS-RIVIERES	46.35N	72.52W	20	-10.8	-6.0	81.3	70.5	79.1	69.7	77.0	68.5	73.3	78.4	71.8	76.8	71.6	116.6	76.7	70.0	110.2	75.2	23.8	20.9	18.5	8229	330
VARENNES	45.72N	73.38W	59	-10.3	-5.7	86.6	71.3	83.5	69.7	80.8	68.2	74.3	82.5	72.4	80.0	71.7	117.1	78.8	69.9	110.2	76.9	24.5	21.2	18.8	8085	367
Saskatchewan																										*5 sites, 41 more on CD-ROM*
MOOSE JAW CS	50.33N	105.54W	1893	-25.2	-19.5	89.9	65.5	86.1	64.4	82.3	63.0	69.6	82.4	67.3	80.2	65.7	101.6	74.3	63.0	92.4	72.0	28.3	25.1	22.4	9482	254
PRINCE ALBERT A	53.22N	105.67W	1404	-32.8	-26.7	84.6	65.6	81.0	64.0	77.9	62.1	68.1	80.3	66.1	77.5	63.8	93.2	73.5	61.7	86.6	71.2	21.0	18.6	16.8	11090	123
REGINA RCS	50.43N	104.67W	1893	-28.5	-22.9	88.2	65.9	84.5	65.0	81.1	63.3	70.0	82.2	67.5	79.6	66.1	103.1	76.0	63.2	93.1	73.5	29.8	26.3	23.4	10244	211
SASKATOON RCS	52.17N	106.72W	1654	-30.3	-24.7	87.2	65.6	83.5	64.3	79.9	62.9	69.1	81.8	66.8	78.9	64.8	97.8	74.6	62.6	90.2	72.0	25.0	22.0	19.5	10508	180
SASKATOON KERNEN FARM	52.15N	106.55W	1673	-28.3	-23.0	87.2	63.8	83.4	62.4	80.2	61.0	68.9	80.5	66.5	76.9	65.1	98.8	74.6	62.6	90.3	71.6	24.0	21.2	19.0	10626	182
Yukon Territory																										*1 site, 15 more on CD-ROM*
WHITEHORSE A	60.71N	135.07W	2316	-39.5	-30.3	78.2	57.5	74.1	55.9	70.3	54.2	58.7	74.5	57.0	71.4	52.2	63.2	61.1	50.5	59.4	60.3	23.0	20.8	18.7	12155	12

Codes, Standards, and Rating Systems

Overview

Numerous codes, standards, and rating systems from various organizations govern and surround the building industry, intertwining and sometimes cross referencing themselves. This section defines and differentiates between the primary ones while highlighting the organizations that create, reference, or enforce them.

First, it is important to differentiate between a code, a standard, and a rating system.

A building code establishes the minimum requirements for buildings within a given area/jurisdiction and is enforceable by local authorities. Adoption and implementation can vary. Some states adopt statewide codes, while others leave code adoption up to local agencies, councils, or boards.

A standard is a "how-to" guideline of suggested best practices and minimum requirements that is supplied by an industry or professional organization. Standards are often referenced within codes, but by themselves, standards are not enforced.

A rating system is a voluntary program that goes beyond the industry minimums set forth in the standards and codes. Qualified buildings attain certification at different levels after they are evaluated by inspectors representing the rating system.

ASHRAE Standards

The American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) is an international organization that works towards advancing the fields of heating, ventilation, air conditioning, and refrigeration. Founded in 1894, ASHRAE has spent over 100 years serving and promoting a sustainable world through research, standards writing, publishing, and continuing education. ASHRAE encourages interaction from its constituents through membership in ASHRAE Technical Committees, Task Groups, and Technical Resource Groups. These groups are responsible for preparing the applicative text for the annual ASHRAE Handbook, presenting at ASHRAE meetings, reviewing technical papers, evaluating the need for standards, and advising the general membership on all aspects of the technology in which it specializes.

ASHRAE guides the industry with written standards. These standards are created to establish consensus for test methods and performance criteria within the heating, ventilation, air conditioning, and refrigeration industries. Consensus standards are developed and published to define minimum values of acceptable performance. Within the HVAC industry, two of ASHRAE's most referenced standards are Standard 90.1 and Standard 189.1.

STANDARD 90.1- 2013

ASHRAE Standard 90.1, entitled *Energy Standard for Buildings Except Low-Rise Residential Buildings*, provides minimum requirements for energy efficient designs for buildings, including both new construction and renovation projects. Standard 90.1 is continually maintained and updated due to rapid changes in technology and energy prices with the most recent version published in 2013. Federal law requires that all states adopt Standard 90.1 as a base energy code or have an energy code that is at least as stringent as Standard 90.1. **Table 1** shows the USGPM/HP ratings for cooling towers and closed circuit cooling towers and btu/h·hp for condensers according to Standard 90.1.

Equipment Type	Total System Heat Rejection Capacity at Rated Conditions	Subcategory or Rating Condition[h]	Performance Required [a,b,c,d,f,g]	Test Procedure[e]
Propeller or Axial Fan Open Circuit Cooling Towers	All	95°F entering water 85°F leaving water 75°F entering wet-bulb	≥40.2 gpm/hp	CTI ATC-105 and CTI STD-201
Centrifugal Fan Open Circuit Cooling Towers	All	95°F entering water 85°F leaving water 75°F entering wet-bulb	≥20.0 gpm/hp	CTI ATC-105 and CTI STD-201
Propeller or Axial Fan Closed Circuit Cooling Towers	All	102°F entering water 90°F leaving water 75°F entering wet-bulb	≥14.0 gpm/hp	CTI ATC-105 and CTI STD-201
Centrifugal Closed Circuit Cooling Towers	All	102°F entering water 90°F leaving water 75°F entering wet-bulb	≥7.0 gpm/hp	CTI ATC-105 and CTI STD-201
Propeller or Axial Fan Evaporative Condensers	All	R-507A test fluid 165°F entering gas temperature 105°F condensing temperature 75°F entering wet-bulb	≥157,000 Btu/h·hp	CTI ATC-106
Propeller or Axial Fan Evaporative Condensers	All	Ammonia test fluid 140°F entering gas temperature 96.3°F condensing temperature 75°F entering wet-bulb	≥134,000 Btu/h·hp	CTI ATC-106
Centrifugal Fan Evaporative Condensers	All	R-507A test fluid 165°F entering gas temperature 105°F condensing temperature 75°F entering wet-bulb	≥135,000 Btu/h·hp	CTI ATC-106
Centrifugal Fan Evaporative Condensers	All	Ammonia test fluid 140°F entering gas temperature 96.3°F condensing temperature 75°F entering wet-bulb	≥110,000 Btu/h·hp	CTI ATC-106
Air-Cooled Condensers	All	125°F condensing temperature 190°F entering gas temperature 15°F sub-cooling 95°F entering dry-bulb	≥176,000 Btu/h·hp	AHRI 460

Table 1. ASHRAE Standard 90.1 Table 6.8.1-7: Performance Requirements for Heat Rejection

NOTES: For **Table 1** notes, see **page J24**.

Codes, Standards, and Rating Systems

NOTES FOR TABLE 1 (PAGE J23):

a. For purposes of this table, open circuit cooling tower performance is defined by ASHRAE as the water flow rating of the tower at the thermal rating condition listed in Table 6.8.1-7 of ASHRAE Standard 90.1 divided by the fan motor nameplate power.

b. For purposes of this table, closed circuit cooling tower performance is defined by ASHRAE as the process water flow rating of the tower at the thermal rating condition listed in Table 6.8.1-7 of ASHRAE Standard 90.1 divided by the sum of the fan motor nameplate power and the integral spray pump motor nameplate power.

c. For purposes of this table, air-cooled condenser performance is defined as the heat rejected from the refrigerant divided by the fan motor nameplate power.

d. Section 12 [of ASHRAE Standard 90.1] contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.

e. The efficiencies and test procedures for both open and closed circuit cooling towers are not applicable to hybrid cooling towers that contain a combination of separate wet and dry heat exchange sections.

f. All cooling towers shall comply with the minimum efficiency listed in the table for that specific type of tower with the capacity effect of any project-specific accessories and/or options included in the capacity of the cooling tower.

g. For the purposes of this table, evaporative condenser performance is defined as the heat rejected at the specific rating condition in the table, divided by the sum of the fan motor nameplate power and the integral spray pump nameplate power.

h. Requirements for evaporative condensers are listed with ammonia (R-717) and R-507A as test fluids in the table. Evaporative condensers intended for use with halocarbon refrigerants other than R-507A must meet the minimum efficiency requirements listed above with R-507A as the test fluid.

An important point to note in Standard 90.1 pertaining to cooling towers is that centrifugal fan open circuit cooling towers with a combined rated capacity of 1,100 USGPM or greater at 95°F (35°C) condenser water return, 85°F (29.4°C) condenser water supply, and 75°F (23.9°C) entering wet-bulb temperature shall meet the energy efficiency requirement for axial fan open circuit cooling towers listed in ASHRAE table 6.8.1G (**Table 1**). The exception to this rule is when the centrifugal open circuit cooling towers are ducted with inlet or discharge ducting or require external sound attenuation.

Standard 90.1 also makes a specific exception for applications with cooling towers or closed circuit cooling towers that work with hydronic heat pumps. When hydronic heat pumps are connected to a common heat pump water loop, which has central devices for heat rejection and heat addition (e.g. cooling tower and boiler), the following applies according to Standard 90.1 section 6.5.2.2.3 part b:

> "For climate zones 3 through 8, if a closed-circuit tower (fluid cooler) is used, either an automatic valve shall be installed to bypass all but a minimal flow of water around the tower (for freeze protection) or low-leakage positive closure dampers shall be provided. If an open circuit tower is used directly in the heat pump loop, an automatic valve shall be installed to bypass all heat pump water flow around the tower. If an open-circuit tower is used in conjunction with a separate heat exchanger to isolate the tower from the heat pump loop, then heat loss shall be controlled by shutting down the circulation pump on the cooling tower loop."

For zoning information please see Standard 90.1, Table 3.1.

STANDARD 189.1

Introduced in 2009, Standard 189.1, *Standard for the Design of High-Performance, Green Buildings Except Low-Rise Residential Buildings*, was the first code intended for commercial green building standard in the United States. It provides a total building sustainability package for those who strive to design, build, and operate green buildings. From site location, to energy use to recycling, this standard sets the foundation for green buildings by addressing site sustainability, water use efficiency, energy efficiency, indoor environmental quality, and the building's impact on the atmosphere, materials, and resources. Standard 189.1 applies to new construction, additions, and renovations.

Standard 189.1 provides a minimum requirement for sustainability, while LEED® (for more about LEED, see **page J34**), which it is sometimes compared to, provides an increased voluntary effort at sustainability measures. When a government or group accepts Standard 189.1, there are mandatory minimums that must be met, while LEED, as a rating system, continues to be optional. Of particular note, the US Army issued their new sustainable design and development initiatives in December 2010 and incorporated Standard 189.1.

Compared to ASHRAE Standard 90.1, which only addresses energy efficiency, Standard 189.1 also provides minimum requirements for the siting, design, and construction of high performance, green buildings. **Table 2** lists the energy efficiency performance requirements for cooling towers and closed circuit cooling towers according to Standard 189.1.

Equipment Type	Total System Heat Rejection Capacity at Rated Conditions	Rating Condition	Performance Required [a,b]	Rating Standard
Open Loop Propeller or Axial Fan Cooling Towers[a]	All	95°F entering water, 85°F leaving water 75°F entering wet-bulb	≥40.2 gpm/hp	CTI ATC-105 and CTI STD-201
Open Loop Centrifugal Fan Cooling Towers[a]	All	95°F entering water, 85°F leaving water 75°F entering wet-bulb	≥22.0 gpm/hp	CTI ATC-105 and CTI STD-201
Closed Loop Propeller or Axial Fan Cooling Towers[b]	All	102°F entering water, 90°F leaving water 75°F entering wet-bulb	≥15.0 gpm/hp	CTI ATC-105 and CTI STD-201
Closed Loop Centrifugal Fan Cooling Towers[b]	All	102°F entering water, 90°F leaving water 75°F entering wet-bulb	≥8.0 gpm/hp	CTI ATC-105 and CTI STD-201
Propeller or Axial Fan Evaporative Condensers	All	R-507A test fluid, 165°F entering gas temperature 105°F condensing temperature, 75°F entering wet-bulb	≥157,000 Btu/h·hp	CTI ATC-106
Propeller or Axial Fan Evaporative Condensers	All	Ammonia test fluid, 140°F entering gas temperature 96.3°F condensing temperature, 75°F entering wet-bulb	≥134,000 Btu/h·hp	CTI ATC-106
Centrifugal Fan Evaporative Condensers	All	R-507A test fluid, 165°F entering gas temperature 105°F condensing temperature, 75°F entering wet-bulb	≥135,000 Btu/h·hp	CTI ATC-106
Centrifugal Fan Evaporative Condensers	All	Ammonia test fluid, 140°F entering gas temperature 96.3°F condensing temperature,75°F entering wet-bulb	≥110,000 Btu/h·hp	CTI ATC-106

Table 2. ASHRAE Standard 189.1 Table C-8: Performance Requirements for Heat Rejection Equipment
(Supersedes Table 1: 6.8.1G in AHSRAE Standard 90.1)

NOTES: For **Table 2** notes, see **page J26**.

Codes, Standards, and Rating Systems

NOTES FOR TABLE 2 (PAGE J25):

a. For purposes of this table, open circuit cooling tower performance is defined by ASHRAE as the water flow rating of the tower at the thermal rating condition listed in C-15 of ASHRAE Standard 189.1 divided by the fan motor nameplate power.

b. For purposes of this table, closed circuit cooling tower performance is defined by AHSRAE as the process water flow rating of the tower at the thermal rating condition listed in C-15 ASHRAE Standard 189.1 divided by the sum of the fan motor nameplate power and the integral spray pump motor nameplate power.

As Standard 189.1 addresses issues beyond just energy consumption, there are water restrictions that may impact the HVAC industry. Measurement devices with remote capabilities should be provided to collect water use data of each water supply source for the building project if the measurement total is to exceed the threshold listed in **Table 3** below**.**

Water Source	Main Measurement Threshold
Potable water	1,000 gal/day (3,800 L/day)
Municipally reclaimed water	1,000 gal/day (3,800 L/day)
Alternate sources of water	500 gal/day (1,900 L/day)

Table 3. ASHRAE Standard 189.1 Table 6.3.3-1 – Water Supply Source Measurement Thresholds

Sub-metering remote communication measurement systems must then also be provided to collect water use data for each of the following building subsystems, if the subsystems have been sized above the threshold levels listed in **Table 4.**

Subsystem	Sub-Metering Threshold
Cooling towers (meter on make-up water and blowdown)	Cooling tower flow through tower > 500 gpm (30 L/s)
Evaporative coolers	Makeup water > 0.6 gpm (0.04 L/s)
Steam and hot-water boilers	> 500,000 BTU/h (50 kW) input
Total irrigated landscape area with controllers	> 25,000 ft^2 (2,500m^2)
Separate campus or project buildings	Consumption > 1,000 gal/day (3,800 L/day)
Separately leased or rental space	Consumption > 1,000 gal/day (3,800 L/day)
Any large water using process	Consumption > 1,000 gal/day (3,800 L/day)

Table 4. ASHRAE Standard 189.1 Table 6.3.3-2 Subsystem Measurement Thresholds

Standard 189.1 goes on to address cycles of concentration requirements for cooling towers. For more information on cycles of concentration and how to address the standard, contact your local water quality expert.

Also involving water in the tower, Standard 189.1 requires that cooling towers be equipped with efficient drift eliminators, reducing drift rates to 0.005% in a crossflow tower and 0.002% in a counterflow tower.

BAC and ASHRAE Standards

BAC's products meet or exceed Standard 90.1 energy efficiency requirements. BAC also continues to move forward with research and development of new products that continue to be more energy efficient. BAC is active on the committee of Standard 90.1, and continues to support the committee efforts for both ASHRAE Standards 90.1 and 189.1. BAC's Extreme Efficiency (XE) Models are at least 2 times more efficient than the minimum requirements established in ASHRAE Standard 90.1 - 2013. BAC's CXVT Evaporative Condenser XE Models are at least 3 times more efficient than the minimum requirements.

ASME B31.5 and U Designator

The American Society of Mechanical Engineers (ASME) publishes two important codes that apply to the industrial and refrigeration industries: ASME B31.5 and ASME Pressure Vessel Code.

ASME B31.5

ASME B31 sets standards for pressure piping, and ASME B31.5 specifically applies to refrigerant heat transfer components and secondary coolant piping for temperatures down to -320°F (-195.6°C).

The code applies to:

- Refrigerant and secondary cooling piping for temperatures as low as -320°F (-195.6°C)
- Factory assembled and field erected piping
- Heat transfer components

The code does not apply to:

- Self-contained equipment subject to the requirements of nationally recognized laboratories
- Water piping
- Internal or external low pressure piping (less than 15 psig)
- Pumps, pressure vessels and compressors, but does apply to primary and secondary refrigerant piping connected after the first joint adjacent to the equipment

BAC and ASME B31.5

BAC designs coils that comply with ASME B31.5 for all condensers and closed circuit cooling towers. Compliance with ASME B31.5 assures the highest quality coil design, materials, and manufacturing processes, providing the customer a safe and superior product. Coils for condensers and closed circuit cooling towers are rated at 300 psig maximum allowable working pressure, and they are pneumatically tested at 375 psig.

BAC and the ASME U Designator

BAC offers coils that are certified in accordance with the ASME Boiler and Pressure Vessel Code, Section VIII, Division I. These coils bear the U designator and are available for evaporative condensers and closed circuit cooling towers. ASME U designated coils are available for projects requiring ASME certified pressure vessels and involve 3rd party inspection and certification. ASME U designated coils are rated at 340 psig maximum allowable working pressure, and they are pneumatically tested at 375 psig The ASME code only governs the coil and does not affect the design of the coil casing, cold water basin, or any other closed circuit cooling tower or evaporative condenser component.

Codes, Standards, and Rating Systems

IBC and ASCE 7

The International Building Code® (IBC) is a model code developed by the International Code Council® (ICC) and available for adoption by jurisdictions internationally. The IBC was first issued in 2000 and is updated triennially. The latest edition is 2015.

Up to six editions of the IBC (2000, 2003, 2006, 2009, 2012, and 2015) have been adopted and are effective at the local or state level in all 50 states and the District of Columbia. Once adopted, the IBC provisions become enforceable regulations governing the design of buildings and structures.

The IBC defines design requirements for buildings, structures, and parts thereof. Contained within the structural design provisions of the IBC are requirements for cooling towers that may be subjected to various types of environmental factors, such as wind loads and seismic loads. For the seismic load design requirements, the IBC refers extensively to and incorporates many provisions of ASCE/SEI 7, the consensus standard published by the American Society of Civil Engineers (ASCE).

BAC, IBC, and ASCE 7

BAC supports both IBC and ASCE. When it comes to seismic certification, the most reliable form of testing is shake table testing. BAC goes beyond calculations by shake table testing its products for certification, proving functionality after a seismic event. To see the shake table ratings for BAC's products, please see each product's introduction section.

NOTE: For more information on seismic certification please refer to "Seismic Design and Qualification Methods" on **page J38**.

California's Title 24 and OSHPD

Title 24 is the California Building Standards Code and is part of the larger California Code of Regulations. It applies to all occupancies that submit for a building permit in California, and the most recent edition is dated 2013. Title 24 has twelve parts, each outlining a specific section of the building standards code, and includes regulations for energy efficiency and specific building requirements. Of particular interest to the evaporative cooling industry are the seismic regulations included in Title 24, Part 2: The California Building Code.

The California Building Code is based on IBC 2012 and ASCE 7-10 (see **page J38** for "Seismic Design and Qualification Methods"). It is important to note how California interprets these two standards. For critical facilities, including essential care, hospitals, and mission critical entities, California requires shake table testing to prove mechanical operation following a seismic event. Calculations are not accepted. While most states have the same requirements, very few enforce it. For its most critical of facilities, heath facilities, California designates this enforcement to its Office of Statewide Health Planning and Development (OSHPD). In addition to enforcement, OSHPD also has the authority to amend Title 24 when necessary. To help make the building and submittal process easier for contractors, OSHPD provides a pre-approved list of mechanical and electrical components available for use on hospitals. If outside components are selected for use on a facility, those individual components must be shake table tested.

BAC and State Building Codes

BAC takes seismic certification, wind load certification, and energy efficiency very seriously and is committed to having the best product line in the market. BAC's PT2 was the first cooling tower to qualify for the OSHPD pre-approved list, and it, along with BAC's Series 3000 and Series 1500 are still on the list, continuing to be frequently used on healthcare facilities in California. As states continue to make changes to and upgrade their building and energy codes, BAC will also continue to update product lines to meet all applicable codes.

California Title 24 Code - Building Energy Efficiency Standards

California Title 24, created by the California Energy Commission, has an energy efficiency standard for both residential and nonresidential buildings. The standard covers all aspects of building energy use in order to: reduce energy use and create more efficient operation, increase electricity reliability and reduce demand, increase comfort of building inhabitants, and promote environmental conservation.

For applications with open and closed circuit cooling towers greater than 150 tons, California Title 24 has requirements for both energy and water efficiency.

The energy efficiency requirements are applicable for all products are stated in **Table 5** and **Table 6**.

Equipment Type	Total System Heat Rejection Capacity at Rated Conditions	Subcategory or Rating Condition	Performance Required [a,b,c,d]	Test Procedure
Propeller or Axial Fan Open Circuit Cooling Towers	All	95°F entering water, 85°F leaving water 75°F entering wet-bulb	= 42.1 gpm/hp	CTI ATC-105 and CTI STD-201
Centrifugal Fan Open Circuit Cooling Towers	All	95°F entering water, 85°F leaving water 75°F entering wet-bulb	= 20.0 gpm/hp	CTI ATC-105 and CTI STD-201
Propeller or Axial Fan Closed Circuit Cooling Towers	All	102°F entering water, 90°F leaving water 75°F entering wet-bulb	= 14.0 gpm/hp	CTI ATC-105S and CTI STD-201
Centrifugal Fan Closed Circuit Cooling Towers	All	102°F entering water, 90°F leaving water 75°F entering wet-bulb	= 7.0 gpm/hp	CTI ATC-105S and CTI STD-201
Air-Cooled Condensers	All	125°F condensing temperature, R-22 test fluid 190°F entering gas temperature, 15°F sub-cooling 95°F entering dry-bulb	= 176,000 Btu/h·hp	ANSI/AHRI 460

Table 5. California Title 24 Building Energy Efficiency Standards Table 110.2-G: Performance Requirements for Heat Rejection Equipment

NOTES: For Table 5 notes, see **page J30**.

Codes, Standards, and Rating Systems

NOTES FOR TABLE 5 (PAGE J29):

a. For purposes of this table, open circuit cooling tower performance is defined as the water flow rating of the tower at the thermal rating conditions divided by the fan motor nameplate power.

b. For purposes of this table, closed circuit cooling tower performance is defined as the process water flow rating of the tower at the thermal rating condition divided by the sum of the fan motor nameplate power and the integral spray pump motor nameplate power.

c. For purposes of this table, air-cooled condenser performance is defined as the heat rejected from the refrigerant divided by the fan motor nameplate power.

d. Open cooling towers shall be tested using the test procedures in CTI ATC-105. Performance of factory assembled open cooling towers shall be either certified as base models as specified in CTI STD-201 or verified by testing in the field by a CTI approved testing agency. Open factory assembled cooling towers with custom options added to a CTI certified base model for the purpose of safe maintenance or to reduce environmental or noise impact shall be rated at 90 percent of the CTI certified performance of the associated base model or at the manufacturer's stated performance, whichever is less. Base models of open factory assembled cooling towers configured in exact accordance with the Data of Record submitted to CTI as specified by CTI STD-201.

e. Applicable test procedure and reference year are provided under the definitions.

For Industrial Refrigeration Applications, California Title 24 applies to:

Refrigerated spaces greater than or equal to 3,000 ft^2 and are served by the same refrigeration compressor(s) and condenser(s). Exempt are systems for which more than 20% of the total design refrigeration load is for quick chilling or freezing or process refrigeration cooling for other than a refrigerated space.

Code Required Design Criteria:

- Design saturated condensing temperatures (SCT) for evaporative-cooled condensers and water-cooled condensers served by fluid coolers or cooling towers shall be less than or equal to:
  - Wet Bulb ≤76°F ; SCT ≤20°F + Design WBT
  - 78°F ≤ Wet Bulb ≤ 76°F ; SCT≤ 19°F + Design WBT
  - 78°F ≥ Wet Bulb; SCT≤ 18°F + Design WBT
- All condenser fans for evaporative-cooled condensers or fans on cooling towers or fluid coolers shall be continuously variable speed, and the condensing temperature control system shall control the speed of all fans serving a common condenser high side in unison.
- The minimum condensing temperature set point shall be less than or equal to 70°F.

DID YOU KNOW?

- Title 24 standards took effect **July 1, 2014** increasing the minimum energy efficiency requirements on all air-cooled and water-cooled products.
- BAC's XE Models have an efficiency of at least 2 times the minimum requirements.
- For additional information on commercial refrigeration applications, see **page J32**.

Condenser Type	Refrigerant Type	Minimum Efficiency	Rating Condition
Outdoor Evaporative-Cooled with THR Capacity > 8,000 MBH	All	350 Btuh/Watt	100°F Saturated Condensing Temperature (SCT), 70°F Outdoor Wetbulb Temperature
Outdoor Evaporative-Cooled with THR Capacity < 8,000 MBH and Indoor Evaporative-Cooled	All	160 Btuh/Watt	
Outdoor Air-Cooled	Ammonia	75 Btuh/Watt	105°F Saturated Condensing Temperature (SCT), 95°F Outdoor Drybulb Temperature
	Halocarbon	65 Btuh/Watt	

Table 6. Reference 2013 Title 24 - Table 120.6-B: Fan-Powered Condensers – Minimum Efficiency Requirements

In addition to meeting the minimum the efficiency, Title 24 requires fan speed control, tower flow turndown, fan operating recommendations and limitations on centrifugal fan cooling towers.

Fan Speed Controls: Each fan powered by a motor of 7.5 hp (5.6 kW) or larger shall have the capability to operate that fan at 2/3 of full speed or less, and shall have controls that automatically change the fan speed to control the leaving fluid temperature or condensing temperature or pressure of the heat rejection device.

Tower Flow Turndown: Open cooling towers configured with multiple condenser water pumps shall be designed so that all cells can be run in parallel with the larger of:

- The flow that is produced by the smallest pump; or
- 50 percent of the design flow for the cell.

Operating Recommendations: Multiple cell heat rejection equipment with variable speed fan drives shall:

- Operate the maximum number of fans allowed that comply with the manufacturer's requirements for all system components, and
- Control all operating fans to the same speed. Minimum fan speed shall comply with the minimum allowable speed of the fan drive per the manufactures recommendation. Staging of fans is allowed once the fans are at their minimum operating speed.

Limitation on Centrifugal Fan Cooling Towers: Open cooling towers with a combined rated capacity of 900 gpm and greater at 95°F condenser water return, 85°F condenser water supply, and 75°F outdoor wetbulb temperature, shall use propeller fans and shall not use centrifugal fans. The exception to this if the cooling towers are ducted, or have sound attenuation requiring external static pressure.

California Title 24 includes water efficiency requirements including:

1. **Conductivity or Flow-based Controls** that maximize cycles of concentration based on local water quality conditions.
2. **Documentation of Maximum Achievable Cycles of Concentration** based on local water supply as reported annually by the local water supplier, and using the calculator approved by the Energy Commission.
3. **Flow Meter** with an analog output on the makeup water line.
4. **Overflow Alarm** to prevent overflow of the sump in case of makeup water valve failure.
5. **Efficient Drift Eliminators** that achieve drift reduction to 0.002 percent of the circulated water volume for counter-flow towers and 0.005 percent for crossflow towers.

Codes, Standards, and Rating Systems

California Title 24 Code - Building Energy Efficiency Standards - Commercial Refrigeration

The following table summarizes some of the code requirements, how the code effects the refrigeration system, and how the TrilliumSeries™ Condenser can be an ideal solution for commercial refrigeration applications..

Title 24 Code Requirements (§120.6(b))	Effects to the Commercial Refrigeration System	The Solution
Title 24 applies to retail food stores that have: • Air-cooled or evaporatively-cooled condensers • > 8,000 ft² of conditioned space • Condensers with THR capacity > 150,000 Btu/h at 100°F CT / 70°F WBT • New condensers replacing existing units, if the system THR is increased and > 25% of attached compressors and display cases are new	Higher installed cost due to larger and higher first cost of equipment.	TrilliumSeries™ Condenser is exempt from Btu/h/W requirements, but is designed to maximize energy efficiency and meets all of the requirements from Title 24.
All condenser fans must be continuously variable speed.	Staged fans are no longer acceptable.	The TrilliumSeries™ Condenser has high efficiency variable speed electronically commutated (VSEC) motors as standard.
The refrigeration system controls must reset the condensing temperature based on the ambient dry bulb temperature for air-cooled condensers and on the ambient wet bulb temperature for evaporative condensers. The minimum condensing setpoint shall be ≤ 70°F.	Maintaining the constant design condensing temperature, irrespective of the outside temperature, is not acceptable. Lowering the condensing temperature allows the compressors and the overall refrigeration system, to run more efficiently and save energy.	Each TrilliumSeries™ Condenser is offered with custom controls logic which can reduce the condensing temperature on non-design days to maximize system energy savings.
Air-cooled condensers must have a fin density ≤ 10 fins per inch. Microchannel coils are exempt.	Some air cooled manufacturers provide selections using 12+ fpi to reduce footprint.	The TrilliumSeries™ Condenser is supplied with a microchannel coil for high heat transfer efficiency.
Air-cooled condensers must have efficiency ≥ 65 Btu/h/W at 105°F CT / 95°F DBT. Evaporative condensers must have efficiency ≥ 160 Btu/h/W at 100°F CT / 70°F.	Failure to meet the threshold may mean that the city inspector will refuse to provide a passing inspection.	The minimum efficiency of the product line is 205 Btu/h/W at 105°F CT / 95°F DBT / 70°F WBT.

Table 7. The TrilliumSeries™ Condenser Provides a Peace of Mind Solution when Meeting Title 24 Condenser Requirements

For questions on how BAC can best meet your condenser needs, including payback and total cost of ownership analyses, contact Baltimore Aircoil Company. For the full Title 24 text, go to www.energy.ca.gov/Title24.

CTI STD-201

The Cooling Technology Institute (CTI) has been certifying cooling tower thermal performance for over sixty years. CTI Standard STD-201 provides independent assurance, prior to shipment and installation, that a specific cooling tower will perform in accordance with the manufacturer's published thermal performance data. Having CTI certification eliminates the need for costly onsite field tests and ensures system performance will meet design objectives. ASHRAE Standards 90.1 and 189.1 both cite CTI's STD-201 as the required test methods when evaluating cooling towers.

CTI certification is important to many different groups involved in the cooling tower life cycle:

Equipment Owners and Operators: Independent certification of cooling tower thermal performance assures owners and operators that they will receive full value from their investment. It eliminates the potential for years of excessive operating costs due to deficient equipment and provides this benefit at no additional cost to the project. In fact, performance certification can actually reduce first cost by eliminating the need for "safety factors" when sizing the equipment and the cost of a field acceptance test to verify performance.

Design Engineers: By specifying CTI Certification of thermal performance, a design engineer can protect the owner and ensure that the client receives the specified performance. CTI performance certification provides a responsible basis for design and complements codes and standards used to control other systems and products. Many industry organizations are working to include certification in their codes and standards.

Installing Contractors: Independent certification of cooling tower thermal performance assures the installing contractor that all certified cooling tower proposals are based on the same level of thermal performance. This not only eliminates the potential for costly callbacks due to deficient thermal performance, but also maintains a responsible basis of design for design/build, design/assist, or value-engineered projects.

The Cost of Cooling Tower Deficiency

While sometimes hard to detect, a deficient cooling tower forces other system components to work harder to make up for its shortcomings. In an air conditioning application, this burden is imposed upon the chiller. If the cooling tower cannot reject the required load at the lowest possible temperatures, the chiller is forced to operate against a condensing pressure higher than necessary, thereby consuming considerably more energy. This may not affect building comfort levels except at peak conditions, but it will increase operating costs year-round. A tower that is 20% underrated will cost the owner three to four times the original price of the tower in added system energy costs.

Codes, Standards, and Rating Systems

BAC and CTI

BAC is committed to providing independent thermal performance verification for all its products. Every BAC cooling tower has been certified, starting with the FXT Cooling Tower line in 1981. Since then, every factory-assembled BAC cooling tower line has been CTI Certified.

In 1998, CTI Standard STD-201 was expanded to include closed circuit cooling towers, and BAC again led the industry, being the first to achieve certification, with the FXV Closed Circuit Cooling Tower line. Since 1998 all BAC closed circuit cooling towers have been certified, and most notably in 2003 the Dual Air Inlet FXV Closed Circuit Cooling Tower was certified with the largest capacity of any factory-assembled closed circuit cooling tower cell in the industry. In 2009, BAC was the first company to offer certification with water, and ethylene or propylene glycol as the process fluid.

As the certification landscape continues to change, BAC remains committed to providing independent thermal performance, and it is important that contractors and engineers require the same. The equipment sections of this handbook include suggested specifications for each product. When adding verbiage to an existing specification, suggested wording is as follows:

> "The thermal performance shall be certified by the Cooling Technology Institute in accordance with CTI Standard STD-201 or, lacking such certification, a field acceptance test shall be conducted within the warranty period in accordance with CTI Acceptance Test Code ATC-105, by the Cooling Technology Institute, or other qualified independent third-party testing agency, licensed by CTI. Tests performed by the manufacturer's personnel are not acceptable."

USGBC and LEED®

The US Green Building Council (USGBC) is a non-government organization comprised of leaders from the building industry, brought together to promote buildings that are environmentally responsible, profitable, and healthy places to live and work. Members of the USGBC represent all segments of the building industry including: manufacturers, municipalities, architects, interior designers, builders, and several branches of the military. USGBC conceived and now administers the development and ongoing improvement of the Leadership and Energy and Environmental Design (LEED) Green Building Rating Systems.

LEED

LEED rating systems are voluntary, internationally recognized, certification systems that provide third party verification that a building or community was designed, constructed, and will be operated using strategies intended to improve energy efficiency, water savings, CO_2 emissions reduction, indoor environmental air quality, and resource utilization. In its third iteration, LEED is now administered by the Green Building Certification Institute (GBCI).

LEED® standards are available or under development for:

- Building Design and Construction (BD+C)
- Interior Design and Construction (ID+C)
- Building Operations and Maintenance (O+M)
- Neighborhood Development (LEED-ND)
- Homes

LEED was created to define the "green building" by establishing a common standard of measurement, all while raising consumer awareness of green building benefits. A voluntary system, LEED promotes whole-building design practices as it recognizes environmental leadership in the building industry. Points are given for various sustainable features in eight categories:

- Sustainable Sites
- Water Efficiency
- Energy and Atmosphere
- Materials and Resources
- Indoor Environmental Quality
- Location and Transportation
- Innovation
- Regional Priority Credits

LEED for Neighborhood development has the following additional credit categories:

- Smart Location and Linkage
- Neighborhood Pattern and Design
- Green Infastructure and Buildings

A project must satisfy all prerequisites and earn a minimum number of points to be certified.

Depending on the number of points, the project can be classified at the following levels:

Certified: 40–49 points

Silver: 50–59 points

Gold: 60–79 points

Platinum: 80 points and above

More than 60,000 projects are participating in LEED across 150+ countries and territories, comprising over 11 billion square feet. Over 450 state and local governments across the country have adopted green building policies, and fourteen federal agencies have adopted department-wide LEED initiatives, including the Department of Defense, the Department of Energy, and the Department of State. LEED buildings and the concept of building "green" will become the voluntary norm worldwide as the price of energy increases and our natural resources decline.

Codes, Standards, and Rating Systems

BAC, USGBC, and LEED®

BAC is a member of USGBC and is active in both local chapters and on a national basis. BAC is an active participant at GREENBUILD, USGBC's Annual Conference, and additionally, BAC has a number of LEED certified employees who have become leaders in providing green products.

BAC is a leader in Ice Thermal Storage Systems that currently qualify for LEED credits under the Energy and Atmosphere category, saving 20-40% on cooling energy costs. For more information on BAC's Ice Thermal Storage Systems, please see **page G1**.

CRN

The Canadian Registration Number (CRN) is a number issued by each Canadian province or territory to certify the design of a boiler, pressure vessel, or fitting. The CRN identifies that the design has been accepted and registered for use in that particular province or territory. Canadian provinces and territories are each individually represented by numeric digits following the decimal point within the CRN. For a CRN that is registered across the Canada, "C" follows the designation of the province of first registration (e.g., M 4156.5C shows the design as first registered in Ontario, then across Canada). For more information and individual province listings please visit http://www.tssa.org.

BAC and CRN

BAC is committed to developing products that can be utilized in Canada. Currently, BAC has a CRN in all Canadian provinces for closed circuit cooling towers, evaporative condensers, and ice thermal storage units with standard galvanized, dual row coil design, with a maximum allowable working pressure of up to 300 psig at 350°F (176.7°C). BAC also has a CRN in all Canadian provinces for units with TriCoil galvanized coils, a three-row design, with a maximum allowable working pressure of 300 psig at 350°F (176.7°C).

FM Approval

Factory Mutual Approvals (FM) is not a code, standard, or rating system. It is a recommendation from an independent insurance company, FM Global, to their clients. FM Global specializes in loss protection for large corporations in the Highly Protected Risk insurance sector. They have created guidelines for building materials and products in order "to develop cost-effective insurance and risk financing solutions that protect the value created by [their] clients' businesses" (www.fmglobal.com). Meaning, FM Approved products are used by FM Global and their customers to manage risk.

FM Approvals®

Member of the FM Global Group

When specifying or purchasing a new unit, it is best to verify the need for an FM Approved product. Since most facility owners are not FM Global customers, most facilities do not require FM Approved products.

For FM Global customers, it is possible to use products that are not FM Approved. Your local FM insurance underwriter can grant job specific approval for non-listed products.

BAC and FM

BAC offers two factory assembled product lines that comply with FM Approval in multi-cell installations: the 3000C and the PT2. BAC is committed to working with FM Global in the development of equipment and product specifications that support the needs of our mutual customers. If you have questions about product recommendations or specifications, please contact your local BAC Representative.

Series 3000 Cooling Tower

PT2 Cooling Tower

Seismic Design and Qualification Methods:

An Interpretation of the IBC 2015 & ASC 7 Codes

Introduction

Historically, the seismic design of mechanical equipment was primarily focused on the equipment supports, and the attachments. The intent of the seismic design provisions in building codes was to reduce the hazard to life by sliding or falling equipment during an earthquake.

Today, mechanical systems often serve vital functions in critical building facilities such as hospitals, communication centers, and emergency response centers. The mechanical systems serving these types of facilities must be operational after an event, as non-functioning equipment could constitute a hazard to life. Therefore, the seismic design for this higher level of earthquake safety must assure functionality as well as position retention.

As a result, the 2015 International Building Code® (IBC) incorporates both functionality and position retention within the structural design requirements.

Factory assembled cooling towers are considered nonstructural components that are permanently attached to building structures for their support and attachment. Therefore, the cooling tower structural design falls within the scope of building codes.

This section will discuss the basis of seismic design requirements, define the seismic variables, discuss the seismic qualifications methods, and provide an example with a suggested specification.

Basis of Seismic Design Requirements

The International Building Code® (IBC) is a model code developed by the International Code Council® (ICC) and available for adoption by jurisdictions internationally. The IBC was first issued in 2000 and is updated triennially. The latest edition is 2015.

Up to six editions of the IBC (2000, 2003, 2006, 2009, 2012, or 2015) have been adopted and are effective at the local or state level in all 50 states and the District of Columbia. Once adopted, the IBC provisions become enforceable regulations governing the design of buildings and structures.

The IBC defines design requirements for buildings, structures, and parts thereof. Contained within the structural design provisions of the IBC are requirements for cooling towers that may be subjected to various types of environmental factors, such as wind loads and seismic loads. The 2014 IBC refers extensively to and incorporates many provisions of ASCE/SEI 7-10, the consensus standard published by the American Society of Civil Engineers (ASCE).

Seismic Design Requirements for Factory Assembled Cooling Towers

As noted above, factory assembled cooling towers typically are permanently attached to buildings. This means cooling towers are subject to the seismic design requirements for “nonstructural components,” which are defined as elements of mechanical, electrical, or architectural systems within buildings.

Several key variables must be looked at to determine the seismic design requirements for cooling towers. These variables are unique for a given project and independent of the cooling tower type. Per the IBC, the variables should be provided in the project structural documents and filtered into the cooling tower specification by the engineer of record.

Determining if a Seismic Resistant Cooling Tower is Required

The following 7 step procedure can be used to determine seismic design requirements for a building (therefore the cooling tower), select the appropriate cooling tower, and provide a suggested specification.

As the paper outlines the procedure, the sidebar follows the procedure for a specific application and provides a sample specification for the cooling tower.

Step 1: Determine the Risk Category of the Building

Risk Category is a classification ranging from I to IV for buildings and other structures based on the level of risk and the nature of use. Category I buildings represent a low hazard to life in the event of failure while Category IV buildings are considered essential facilities.

Important Note: Risk category classifications are not consistent in the three editions of the IBC, and thus may vary from jurisdiction to jurisdiction depending on the edition adopted. It is important that design professionals include the edition of the IBC in project specifications.

The 2015 edition of the IBC defines the Risk Category in **Table 1604.5** which has been reproduced on the following page.

Example:

The example throughout this document illustrates the process to determine whether a seismic resistant cooling tower is required for an application and how to select the tower.

A 400 ton cooling tower is required for a 5-story hospital with emergency treatment facilities located in Glenrock, Wyoming (zip code 82637). The cooling tower will be installed on the roof of the 5-story hospital. Determine the seismic requirements that must be included in the cooling tower specification for this project.

Step 1: Determine the Risk Category of the facility

From **Table 1604.5** on the following page: Risk Category of Buildings and Other Structures, a hospital with emergency treatment services is Risk Category IV.

NOTES:

1. Steps 1 through 4 are shown to illustrate the use of seismic design provisions contained in the IBC. In application, the seismic design criteria including the Risk Category, Importance Factor, SDS, SD1, and Seismic Design Category should be provided by the Engineer of Record.
2. The figures, tables and sections referred in the analysis can be found in the 2009 IBC.

Seismic Design and Qualification Methods:

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Risk Category	Nature of Occupancy
I	Buildings and other structures that represent a low hazard to human life in the event of failure, including but not limited to: • Agricultural facilities • Certain temporary facilities • Minor Storage facilities
II	Buildings and other structures except those listed in Risk Categories I, III or IV
III	Buildings and other structures that represent a substantial hazard to human life in the event of failure, including but not limited to: • Building and other structures whose primary occupancy is public assembly with an occupant load greater than 300. • Buildings and other structures containing Group E with an occupant load greater than 250. • Building and other structures containing educational occupancies for students above the 12th grade with an occupant load greater than 500. • Group I-2 occupancies with an occupant load of 50 or more resident care recipients but not having surgery or emergency treatment facilities. • Group I-3 occupancies. • Any other occupancy with an occupant load greater than 5000[a]. • Power-generating stations, water treatment facilities for potable water, waste water treatment facilities and other public utility facilities not included in Risk Category IV. • Buildings and other structures not included in Risk Category IV containing sufficient quantities of toxic or explosive materials that: Exceed maximum allowable quantities per control area as given in Table 307.1 (1) or 307.1(2) or per outdoor control area in accordance with the *International Fire Code*; are sufficient to pose a threat to the public if released[b].
IV	Buildings and other structures designated as essential facilities, including but not limited to: • Group I-2 occupancies having surgery or emergency treatment facilities. • Fire, rescue, ambulance and police stations and emergency vehicle garages. • Designated earthquake, hurricane or other emergency shelters. • Designated emergency preparedness, communications and operations centers and other facilities required for emergency response. • Power-generating stations and other public utility facilities required as emergency backup facilities for Risk Category IV structures. • Buildings and other structures containing quantities of highly toxic materials that: Exceed maximum allowable quantities per control area as given in 307.1(2) or per outdoor control area in accordance with the *International Fire Code*; and are sufficient to pose a threat to the public if released[b]. • Aviation control towers, air traffic control centers and emergency aircraft hangers. • Buildings and other structures having critical national defense functions. • Water storage facilities and pump structures required to maintain water pressure for fire suppression.

Table 1604.5: Risk Category of Buildings and Other Structures

NOTES:

a. For purposes of occupant load calculation, occupancies required by **Table 1004.1.3** to use gross floor area calculations shall be permitted to use net floor areas to determine the total occupant load.

b. Where approved by the building official, the classification of buildings and other structures as Rick Category III or IV based on their quantities of toxic, highly toxic or explosive materials is permitted to be reduced to Category II, provided it can be demonstrated by a hazard assessment in accordance with Section 1.5.3 of ASCE 7 that a release of the toxic, highly toxic or explosive materials is not sufficient to pose a threat to the public.

Step 2: Determine the Importance Factor

All cooling towers are assigned a component importance factor, I_p, equal to 1.0 or 1.5. Towers that are needed for continued operation of an essential facility (a building with an Risk Category IV) or are required to function after an earthquake are assigned an importance factor of 1.5. All other towers receive a factor of 1.0.

Towers with an importance factor of 1.5 are further classified as “designated seismic system” components and may require certification that the unit will fully function following a seismic event.

Step 2: Determine the Component Importance Factor Required

Since the building is an essential facility (Risk Category IV) and the cooling towers are required to function after an earthquake, the importance factor is equal to 1.5.

Step 3a: Calculate the S_{DS} and S_{D1}

To determine the Design Spectral Accelerations, the Spectral Acceleration for short period and 1-second period (S_S and S_1), Site coefficient for short period and 1-second period (F_a and F_v) are required. Below are examples of the short period and 1 second period hazard maps provided by the USGS.

Step 3: Determine the Seismic Design Category

The Seismic Design Category (SDC) is a structure classification ranging from A to F that is based on the following factors:

- Risk Category
- Design Spectral Accelerations (S_{DS} & S_{D1}) – Defined below.

The most severe of the S_{DS} and the S_{D1} is used to determine the SDC.

Step 3a: Calculate the S_{DS} and S_{D1}

The design spectral accelerations (at short periods, S_{DS}, and at 1-second period, S_{D1}) are dependent on site class (defined below) and maximum ground shaking intensity (defined below) at a given location.

Site Class is based on the site soil properties, which can range from Hard Rock (Site Class A) to Peat and Clays (Site Class F). To determine site class, refer to Chapter 20 of the ASCE/SEI 7-10. The 2015 IBC states: “Where the soil properties are not known in sufficient detail to determine the site class, Site Class D shall be used unless the building official or geotechnical data determine that Site Class E or F soil is likely to be present at the site.”

Ground Shaking Intensity can be obtained from probabilistic seismic hazard maps provided in the IBC. However, due to the fine gradation of acceleration values in some regions, such as the West Coast of the United States, it is more expedient and accurate to use software tools provided by the U.S. Geological Survey (USGS). The link to the USGS software is http://earthquake.usgs.gov/designmaps.

Input values for the U.S. Seismic Design Maps Application are map coordinates for the project site.

Seismic Design and Qualification Methods:

An Interpretation of the IBC 2015 & ASC 7 Codes

To calculate the Design Spectral Accelerations, the following equations are used:

Design Spectral Acceleration - At short periods (0.2 second)

The design spectral acceleration, S_{DS}, is determined using the following equations:

$S_{DS} = 2/3 * S_{MS}$

Where S_{MS} is the maximum considered earthquake spectral response acceleration for short period as determined in the following equation:

$S_{MS} = F_a * S_s$

Combining both equations results in:

$\mathbf{S_{DS} = 2/3 * F_a * S_s}$

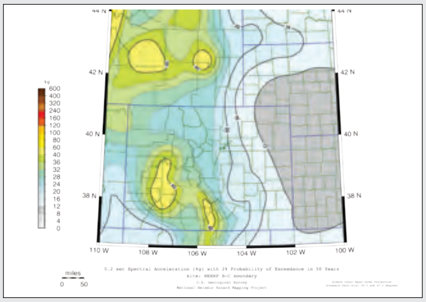
Where:

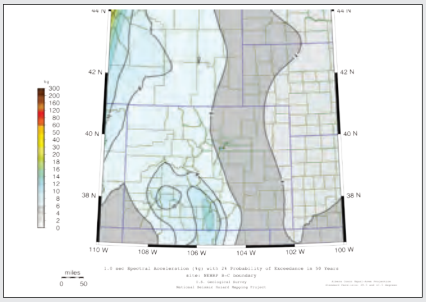
S_s is the mapped spectral accelerations for short periods as determined in Section 1613.3.1 of the Code or using the USGS software.

F_a is the site coefficient defined in **Table 1613.3.3(1)** of the 2015 IBC which is reproduced below (The tables are identical in the 2012, 2009, 2006, and 2003 versions of the code; it varies slightly in the 2000 version). Reference **Table 1613.3.3(1)** from the 2015 IBC is reproduced below.

Site Class	Mapped Spectral Response Acceleration at Short Period				
	$S_s \leq 0.25$	$S_s = 0.50$	$S_s = 0.75$	$S_s = 1.00$	$S_s \geq 1.25$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.2	1.2	1.1	1.0	1.0
D	1.6	1.4	1.2	1.1	1.0
E	2.5	1.7	1.2	0.9	0.9
F	Note b	Note b	Note b	Note b	Note b

Table 1613.3.3(1). Values of Site Coefficient F_a [a]





These values can also be found using the web tool at the following website: http://earthquake.usgs.gov/designmaps/us/application.php

NOTES:

a. Use straight-line interpolation for intermediate values of mapped spectral response acceleration for short period, S_S.

b. Values shall be determined in accordance with Section 11.4.7 of ASCE 7.

Design Spectral Acceleration At 1-Second Periods

The design spectral acceleration, S_{D1}, is determined using the following equations:

$S_{D1} = 2/3 * S_{M1}$

Where S_{M1} is the maximum considered earthquake spectral response acceleration for 1-second period as determined in the following equation:

$S_{M1}=F_V * S_1$

Combining both equations results in:

$\mathbf{S_{D1} = 2/3*F_v*S_1}$

Where:

S_1 is the mapped spectral accelerations for 1-second period as determined in Section 1613.3.1 of the Code or using the USGS software.

F_v is the site coefficient defined in **Table 1613.3.3(2)** of the 2015 IBC. (The tables are identical in the 2012, 2009, 2006, and 2003 versions of the code; it varies slightly in the 2000 version.) Reference **Table 1613.3.3(2)** from the 2015 IBC is reproduced below.

Site Class	Mapped Spectral Response Acceleration at 1-Second Period(s)				
	$S_1 \leq 0.1$	$S_1 = 0.20$	$S_1 = 0.30$	$S_1 = 0.40$	$S_1 \geq 0.50$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.7	1.6	1.5	1.4	1.3
D	2.4	2.0	1.8	1.6	1.5
E	3.5	3.2	2.8	2.4	2.4
F	Note b	Note b	Note b	Note b	Note b

Table 1613.3.3(2). Values of Site Coefficient F_v[a]

NOTES:

a. Use straight-line interpolation for intermediate values of mapped spectral response acceleration for 1-second period, S_1

b. Values shall be determined in accordance with Section 11.4.7 of ASCE 7.

Go to http://earthquake.usgs.gov/designmaps/us/application.php to use the web tool:

- Under Design Code Reference Document, select 2012 IBC.
- Select the site's soil classification.
- Select the Risk Category. For this example, IV was selected.
- Enter the site's Longitude and Latitude or enter an address.
- The web tool returns the S_S, S_1, and calculates the S_{MS}, S_{M1}, S_{DS}, and S_{D1}. For this example:

$S_S = 0.481$ g
$S_1 = 0.163$ g

$S_{MS} = 0.577$ g
$S_{M1} = 0.267$ g

$S_{DS} = 0.385$ g
$S_{D1} = 0.178$ g

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Step 3b: Determine the assigned Seismic Design Category (SDC)

Risk Category I, II or III structures located where the mapped spectral response acceleration parameter at 1-second period, S_1, is greater than or equal to 0.75 shall be assigned to Seismic Design Category E.

Risk Category IV structures located where the mapped spectral response acceleration parameter at 1-second period, S_1, is greater than or equal to 0.75 shall be assigned to Seismic Design Category F.

For all other structures, knowing the S_{DS}, S_{D1}, and Risk Category, the SDC can be determined using the following tables (The tables are identical in the 2012, 2009, 2006, and 2003 versions of the code; it varies slightly in the 2000 version). According to Section 1613.3.5, the Seismic Design Category is based on the most severe as defined from the short-period and 1-second response tables. The 2015 version of the tables is reproduced below.

Value of S_{DS}	Risk Category		
	I or II	III	IV
S_{DS}<0.167g	A	A	A
0.167g <= S_{DS} <0.33g	B	B	C
0.33g <=S_{DS} <0.50g	C	C	D
0.50g <=S_{DS}	D	D	D

Table 1613.3.5(1). Seismic Design Category Based on Short Period Response Accelerations

Value of S_{D1}	Risk Category		
	I or II	III	IV
S_{D1}<0.067g	A	A	A
0.067g ≤ S_{D1} <0.133g	B	B	C
0.133g ≤S_{D1} <0.20g	C	C	D
0.20g ≤ S_{D1}	D	D	D

Table 1613.3.5(2). Seismic Design Category Based on 1-Second Period Response Accelerations

Step 3b: Determine the Seismic Design Category.

From, **Table 1613.3.5(1)**: Seismic Design Category Based on Short-Period Response Accelerations, the Seismic Design Category is D.

From, **Table 1613.3.5(2)**: Seismic Design Category Based on 1-Second Response Accelerations, the Seismic Design Category is D.

According to Section 1613.3.5, the Seismic Design Category is based on the most severe category. In this example, the seismic design category is D.

Step 4: Determine if the Cooling Tower is Exempt from IBC Seismic Requirements

Cooling towers that meet the following conditions are exempt from seismic design requirements of the IBC.

1. All towers in Seismic Design Categories A and B.
2. Towers in Seismic Design Category C provided I_p is equal to 1.0.

All other cooling towers require seismic certification per IBC.

Step 5: Determine the Location of the Cooling Tower

The elevation of the cooling tower structure within a building has an impact on the design seismic acceleration. As the installed elevation of the cooling tower increases relative to the building height, the ground seismic accelerations are amplified. This amplification is determined utilizing a ratio of the installation elevation to total building height (z/h).

It is an accepted industry practice for equipment manufacturers to state seismic qualification using the terms, "restricted" and "unrestricted". For cooling tower installations, a restricted seismic qualification means the cooling tower is qualified for installation on grade (z/h=0). On the other hand, an unrestricted seismic qualification means the tower is qualified as if the unit is installed on top of a building (z/h=1). In other words, for projects with restricted seismic qualification, the cooling tower must be installed on the ground. With an unrestricted seismic qualification, the cooling tower can be installed in any building location, from the roof to the ground level. These will normally be expressed as an S_{DS} for a restricted (z/h=0) or unrestricted (z/h=1) application.

Step 4: Determine if the Cooling Tower is Exempt from IBC Seismic Requirement

Since the Seismic Design Category is D and the Importance Factor is 1.5, the cooling tower is not exempt from the structural requirements of the IBC.

Step 5: Determine the Location of the Cooling Tower.

Since the cooling tower will be installed on the roof of the hospital, the S_{DS} determined in Step 3a would be compared to the unrestricted (z/h=1) S_{DS} for the desired product.

Seismic Design and Qualification Methods:

An Interpretation of the IBC 2015 & ASC 7 Codes

Step 6: Select an Independently Certified Cooling Tower - Seismic Qualification Methods & Independent Certification

As mentioned earlier, the IBC refers extensively to ASCE/SEI 7, the consensus standard published by the American Society of Civil Engineers. The seismic design requirements for nonstructural components including mechanical equipment are contained in Chapter 13 of ASCE 7 Code. Specifically Section 13.2.1 requires mechanical equipment to be qualified using one of the following methods:

a. Analysis
b. Testing
c. Experience data

A summary of each method follows:

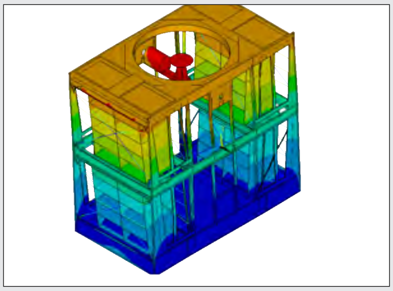
1. Analysis – A cooling tower is mathematically evaluated to determine if it can resist the code-prescribed, seismic design forces. Typically, an analysis of this type focuses on the anchorage only or on the anchorage and main structural components, depending on the component importance factor. Analysis cannot effectively address the non structural portions of a tower that affect functionality, such as the drive system, water distribution system, and heat transfer system. The analysis method is also more difficult for code bodies to review and accept/reject. It takes a great deal of time to examine the analysis and understand all the assumptions made and their validity.

2. Testing – A full-scale cooling tower is subjected to a simulated seismic event in a test laboratory. Typically, the test method is a shake-table test conducted in accordance with a code-recognized test procedure, such as the "Acceptance Criteria for Seismic Qualification by Shake Table Testing of Non-Structural Components and Systems" (AC156), published by ICC Evaluation Service (ICC ES), Inc. The standard is applicable to all types of equipment including mechanical and electrical equipment. This requires a test plan be developed for all the pre- and post-seismic test verification activities. Test results are unequivocal and much easier for a code body to review and accept/reject.

Step 6: Select the Cooling Tower

The cooling tower should have an unrestricted (z/h=1) S_{DS} of at least 0.385 based on an importance factor of 1.5 or higher based on shake table testing.

Since the towers need to be operational after an event, the best method to qualify the tower is independently certified shake table testing. Therefore the S_{DS}, I_p, and location of the tower should be compared to the same values in the equipment selected.



3. Experience Data – A cooling tower is qualified using actual earthquake performance data collected in accordance with a nationally recognized procedure. Though this method is used to some extent in the nuclear power industry, it is not used in commercial mechanical equipment applications due to the following limitations:

a. Lack of a recognized data collection procedure and a national database with widespread access.

b. Infrequency of strong motion earthquakes.

c. Low probability of data being applicable to the current generation of products.

d. Low probability that the actual seismic accelerations experienced by a unit in the field can be translated to current levels of seismic demand.

Based on the preceding limitations, experience data is excluded as a viable qualification method. The remaining methods are not equally suitable for verification of all aspects of cooling tower seismic performance. For example, mathematical analysis is well suited for verification of anchorage resistance, but not reliable for verification of cooling tower functionality after a seismic event. The applicability of Analysis, Testing, and Experience Data for equipment is shown in the following table:

Seismic Design Category	Ip = 1.0	Ip = 1.5
A and B	Exempt	Exempt
C	Exempt	Testing Experience Data
D, E, and F	Analysis Testing Experience Data	Testing Experience Data

Applicable Methods of Seismic Qualification for Cooling Towers

Seismic Design and Qualification Methods:

An Interpretation of the IBC 2015 & ASC 7 Codes

Step 7: Recommended Specification

In light of the IBC code requirements discussed previously, BAC suggests using the following specification.

"Seismic Specification: The cooling tower unit shall be designed, tested, and certified in accordance with the 2015 IBC and ASCE/SEI 7-10. The unit shall be suitable for application with Design Spectral Acceleration at Short Period (S_{DS}) for z/h=1.0 up to ___g with a Component Importance Factor (I_p) of 1.0 and 1.5. The unit shall be certified by the manufacturer as functional following an earthquake. The certification shall be based on full-scale, shake table testing conducted in accordance with ICC-ES Acceptance Criteria AC156, and shall be reviewed and approved by a licensed professional engineer independent of the manufacturer. Experience data or analysis is not acceptable to verify post-earthquake functionality for I_p = 1.5. Units not provided with evidence of shake table testing shall not be an acceptable alternative."

Note that the specification covers an importance factor of 1.5 and defaults to an unrestricted (z/h=1.0) installation. This eliminates the concern of having to determine risk category, if compliance is required, or the installation location.

Step 7: Recommended Specification

Seismic Specification: The cooling tower unit shall be designed, tested, and certified in accordance with the 2015 IBC and ASCE/SEI 7-10. The unit shall be suitable for application with Design Spectral Acceleration at Short Period (S_{DS}) for z/h=1.0 up to 0.384g with a Component Importance Factor (I_p) of 1.5. The unit shall be certified by the manufacturer as functional following an earthquake. The certification shall be based on full-scale, shake table testing conducted in accordance with ICC-ES Acceptance Criteria AC156, and shall be reviewed and approved by a licensed professional engineer independent of the manufacturer. Experience data or analysis is not acceptable to verify post-earthquake functionality for Ip = 1.5. Units not provided with evidence of shake table testing shall not be an acceptable alternative.

Conclusion

The IBC sets forth criteria to identify facilities that are critical for the protection of human life during and immediately following a seismic event and prescribe structural design requirements to ensure the safe and continued operation of such facilities.

Mechanical systems often serve vital functions in critical facilities such as emergency response centers, communication centers, and hospitals. Following an earthquake, the continued operation of these facilities could be dependent on the ability of the mechanical systems to remain operable. Failure of equipment to function in these applications could constitute a hazard to life.

The most reliable method to assure post-event functionality of the equipment is shake table testing in accordance with AC 156. The Series 3000, Series 1500, PT2, FXV, VCA, CXVB, PFi, and PCC have been tested in accordance with AC 156. All are certified in accordance with ASCE 7 to withstand the seismic forces prescribed for the continued operation of essential facilities.

If seismic certification is required, the engineer should be able to provide the information listed on the following page. To learn more about BAC's comprehensive seismic design and qualification approach, please contact your local BAC representative.

Attachment 1: Site Specific Seismic Requirements

Per the IBC, these variables should be provided in the project structural documents and filtered into the cooling tower specification by the engineer of record.

Requirement	
Site Location (Latitude and Longitude)	
Equipment Importance Factor (I_p)	
Seismic Design Category (A-F)	
Acceleration at Short Period (S_{DS})	
Installation elevation ratio to structure height (z/h)	
Rigid or Flexible Support (i.e. on vibration isolators)	
IBC Edition	

Minimizing Energy Costs with Free Cooling

Free cooling reduces refrigeration energy consumption by using evaporative cooling equipment to produce chilled water in cool weather. This section provides general guidelines for optimizing the selection and application of free cooling systems.

Overview

Many air conditioning and industrial cooling systems require chilled water throughout the year. During fall, winter, and spring, a system's cooling tower or closed circuit cooling tower can produce water cool enough to eliminate the need to operate a chiller. This is known as free cooling or evaporative chilling. There are too many variations among buildings and systems for these guidelines to be all inclusive. Therefore, it is important to contact your local BAC Representative to ensure that the system is properly sized and that all guidelines have been followed.

Free cooling can be designed into new chilled water systems or retrofitted into existing systems. Even in warm climates, this process can produce energy savings. Money is saved by operating a cooling tower fan motor, which consumes about 0.2 kW/ton, rather than a chiller compressor motor, consuming about 0.6 to 0.8 kW/ton.

Chilled Water Load and Temperatures

An exact load calculation is not necessary to select a free cooling system, but a load estimate is required to closely predict a system's number of hours of operation and its annual energy savings.

For industrial process, computer, and other constant load systems, winter cooling load is known. For air conditioning systems, winter cooling load is always less than summer cooling load and represents mostly internal heat gains, which are fairly constant, although winter solar heat gain can be significant.

Little or no dehumidification is required during cool weather, so water temperatures can be higher than normal, extending the number of hours during which the energy savings benefits of free cooling can be utilized. Typical winter chilled water supply and return temperatures can be as low as 50°F (10°C) and 55°F (12.8°C), respectively, in colder climates. The minimum practical leaving water temperature is 42°F (5.6°C) for cooling towers and 45°F (7.2°C) for closed circuit cooling towers.

Optimizing system water temperature should always be considered when designing a free cooling system. For example, during the summer in the Baltimore area, a 500 nominal ton cooling tower provides 1,500 gpm of water cooled from 95°F (35°C) to 85°F (29.4°C) at a 78°F (25.6°C) entering wet bulb temperature. If the same cooling tower were used for free cooling assuming 60% of the peak load, maintaining a 43°F (6.1°C) leaving water temperature would provide approximately 1,900 hours of free cooling operation. Increasing the leaving water temperature to 50°F (10°C) would increase free cooling operation to 2,900 hours. This process can achieve a 10% energy savings because the chiller can be shut off at the higher temperature. Therefore optimizing system water temperature should be considered when designing a free cooling system.

Flow Rate, Pumps, and Piping

Condenser water and chilled water pumps represent a significant part of total system energy consumption. At reduced winter loads, it may not be necessary to maintain the design flow rate, and energy can be saved by reducing pump motor speed, operating smaller pumps, or using two-speed pumps. If chilled water piping extends above the level of cooling tower overflow (for example, a tower at grade level) an open system is not practical unless the water can be prevented from draining through the tower at shutdown.

Size of Cooling Tower

The cooling tower or closed circuit cooling tower required depends on the load, ambient wet-bulb temperature, and leaving water temperature (**Figure 1**). For low leaving water temperatures, the unit size may be larger for winter duty than summer duty, even though the load is reduced during the winter. Operating more cooling tower capacity during winter may be justified to achieve the required chilled water temperature for the longest period of time. Because each ton of cooling tower capacity with energy consumption of about 0.2 kW/ton replaces a ton of chiller capacity with energy consumption of about 0.6 to 0.8 kW/ton, it makes sense to install and operate at the greatest practical free cooling capacity.

If the optimum summer and winter cooling capacities or flows are very different, it would be impractical to operate a single unit for both purposes. Acceptable water loading of cooling towers is limited by nozzle size and water/air ratio, which can vary considerably among manufacturers. If either summer or winter conditions fall outside the limits of a particularly sized unit, separate or multi-cell units are recommended. The sizes may be selected so that both operate during one season and only one operates during another season.

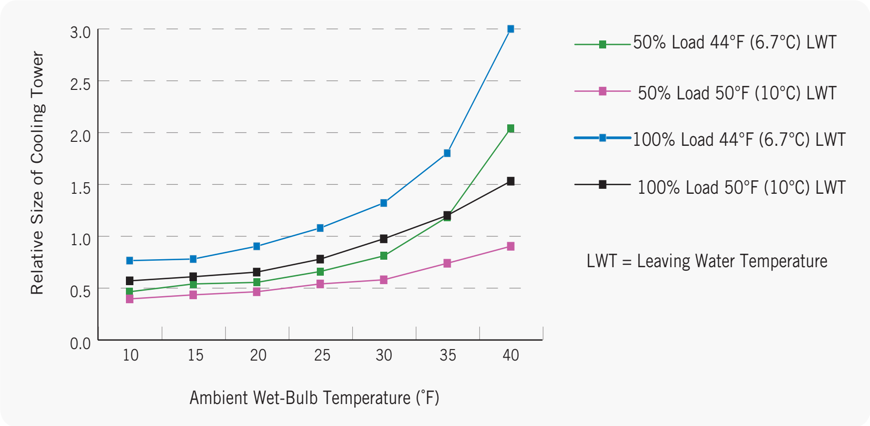


Figure 1. The Required Size of a Cooling Tower or Closed Circuit Cooling Tower Depends on the Load, Ambient Wet-Bulb Temperature, and Leaving Water Temperature

For example, if the peak summer load requires a nominal capacity of 400 tons of cooling, while the winter load requires only 150 tons of cooling, providing a single 400 ton cooling tower is not feasible, because the water loading on the tower will be less than half during winter operation. Decreased flow to the cooling tower may promote scale buildup in the fill because of wet and dry patches, drift, and, especially during the winter, freezing in the fill. Therefore, providing two of the 200 ton towers would be more practical. For the summer load, both 200 ton towers would operate, while during winter, only one would operate.

Heat Exchangers

The capacity/size and cost of heat exchangers depends on the temperature difference between the two circuits and on allowable pressure drop. The lowest possible temperature difference between circuits—about 5°F (2.8°C) or less—is desired in evaporative chilling systems. The lower the differential temperature, the higher the cost and the larger the heat exchanger.

Minimizing Energy Costs with Free Cooling

Type of System

The majority of free cooling systems fall into the following three main categories with a few variations:

1. **Cooling Tower and Heat Exchanger** (**Figure 2**):
   During the summer, the system operates as a conventional cooling tower/chiller system. During the winter, the chiller is bypassed, and the cold water produced by the cooling tower cools the chilled water serving the load through a heat exchanger. Systems of this type have been operated successfully in colder climates and are economical in warmer climates as well.

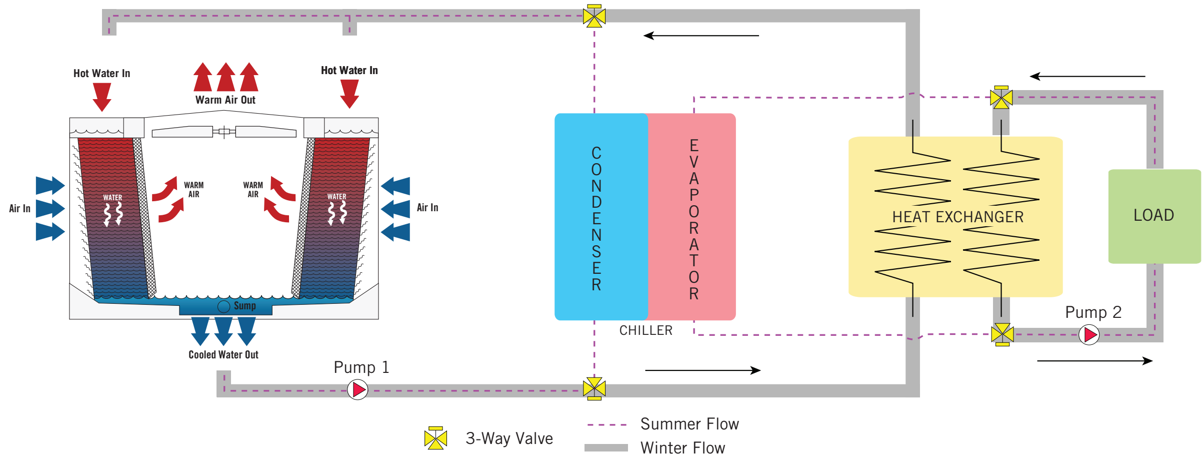


Figure 2. Cooling Tower and Heat Exchanger Free Cooling System

- *Variation 1 - Summer Tower and Winter Tower with a Heat Exchanger System* (**Figure 2a**): One cooling tower is sized and exclusively used for the condenser load and it is not winterized, so it must be shut down and drained for the winter. A second cooling tower is sized and exclusively used for the free cooling load. This system offers the most flexibility in optimizing the tower and heat exchanger selections.

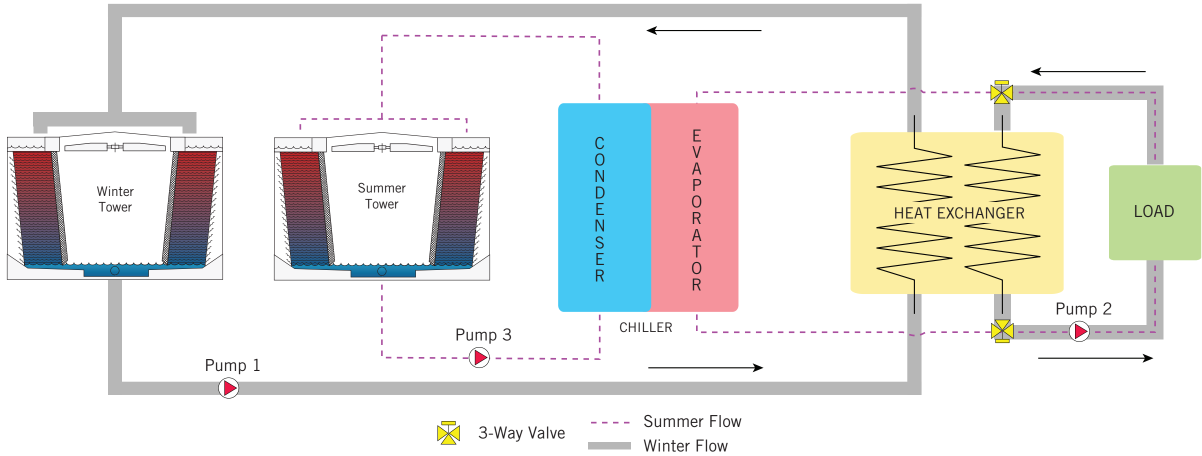


Figure 2a. Variation 1 - Summer and Winter Tower with a Heat Exchanger System

- *Variation 2 - Summer Tower and Winter/Summer Tower with a Heat Exchanger System* (**Figure 2b**): One cooling tower is sized for the free cooling load but is also used for the condenser load which is greater than the free cooling load. A second cooling tower is sized and exclusively used for the balance of the condenser load, and it is not winterized.

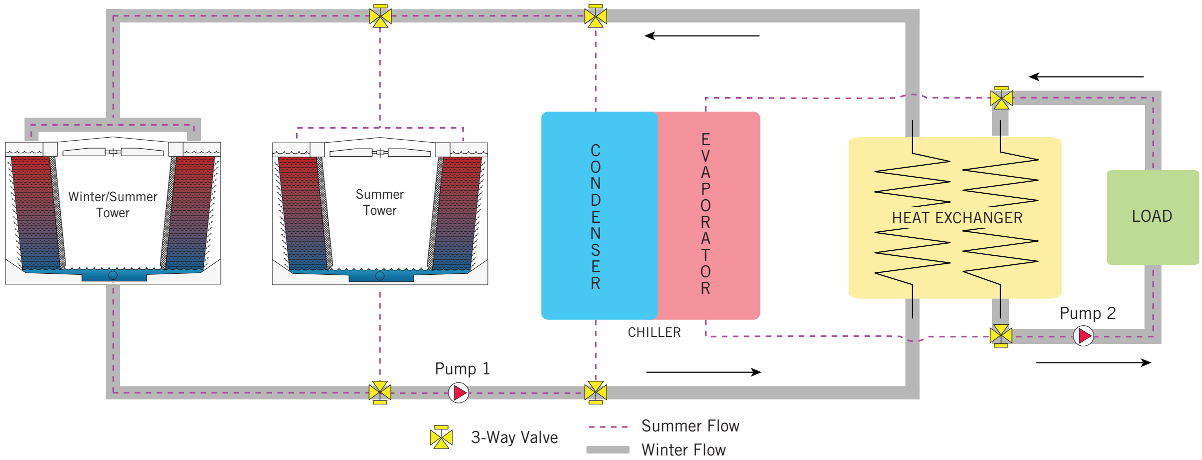


Figure 2b. Variation 2 - Summer and Winter/Summer Tower with a Heat Exchanger System

- *Variation 3 - Summer Tower and Winter Tower with a Heat Exchanger System with Load Shaving* (**Figure 2c**): The summer cooling tower is sized for the summer condenser load and then used for that summer condenser load and the reduced condenser load when load shaving. The cooling tower and heat exchanger begin to shave the load at a predetermined wet-bulb temperature by handling a portion of the chilled water load. As the wet-bulb temperature drops, the tower and heat exchanger handle an increased share of the load until the compressor finally can be turned off.

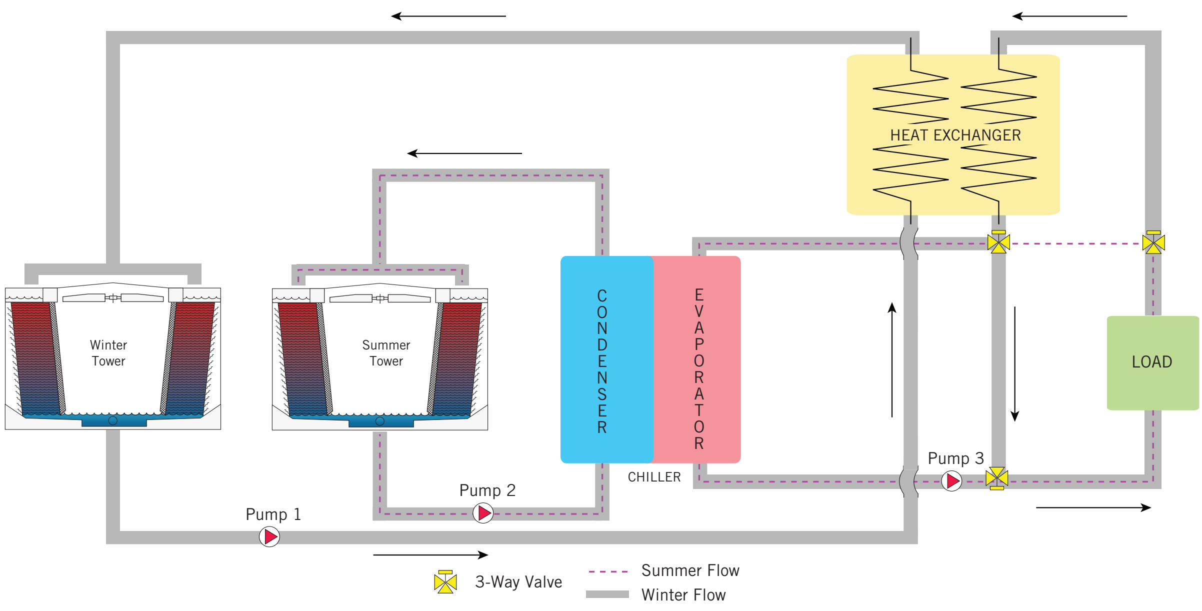


Figure 2c. Variation 3 - Summer and Winter Tower with a Heat Exchanger System with Load Shaving

Minimizing Energy Costs with Free Cooling

2. **Closed Circuit Cooling Tower** (**Figure 3**):

In this system, a closed circuit cooling tower replaces the cooling tower and heat exchanger in the condenser water loop. During the summer, water from the tower is circulated in a closed loop through the condenser of the chiller. During the winter, cold water from the tower is circulated in a closed loop directly through the chilled water circuit. This system is the only one combining the operating simplicity of a single circuit with the reliability of a closed, chilled water loop. This type of application is feasible with closed circuit cooling towers because contaminants in the recirculating water are never in direct contact with the system water.

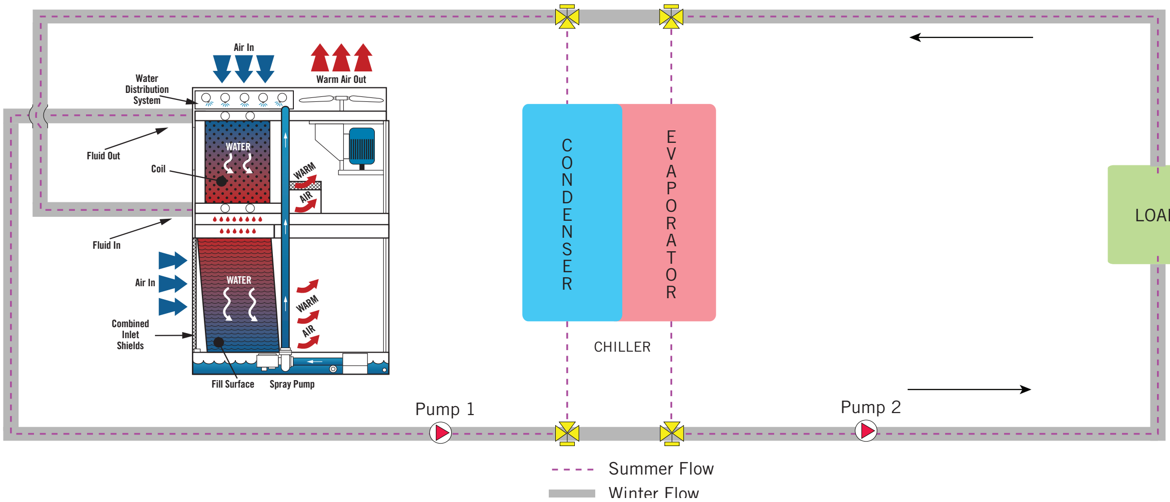


Figure 3. Closed Circuit Cooling Tower Free Cooling System

- *Variation 1 - Closed Circuit Cooling Tower System with a Summer Cooling Tower* (**Figure 3a**): The closed circuit cooling tower is sized and exclusively used for the free cooling load. An open cooling tower is sized for and exclusively used for the condenser load and is not winterized. This system variation offers the best year round energy savings of the four closed circuit cooling tower variations because the condenser load is handled by an open cooling tower which requires less energy than a closed circuit cooling tower.

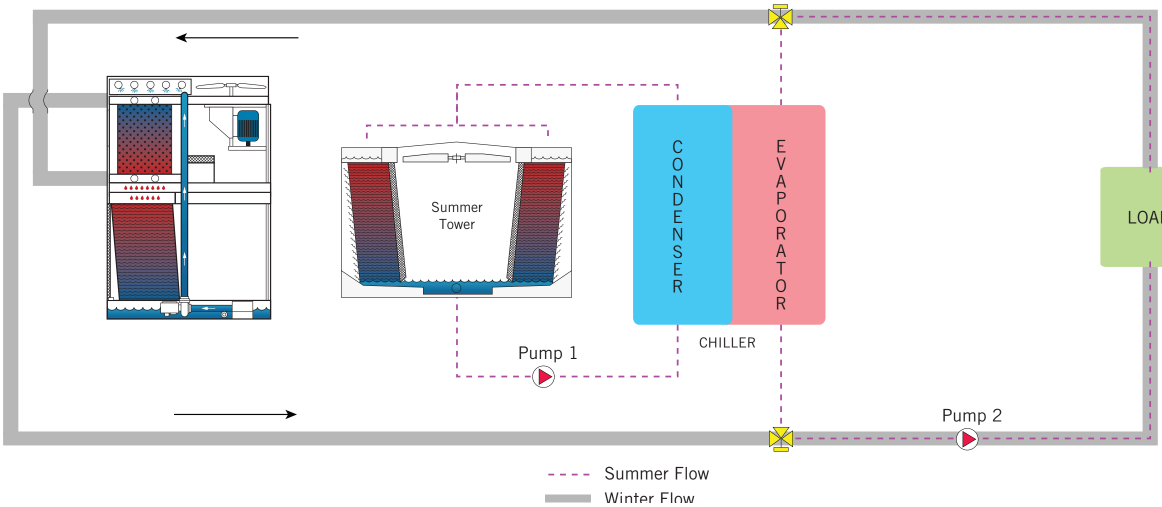


Figure 3a. Variation 1 - Closed Circuit Cooling Tower Free Cooling System with a Summer Cooling Tower

- *Variation 2 - Closed Circuit Cooling Tower System with a Summer Cooling Tower for Multiple Chillers* (**Figure 3b**)*:* For systems with multiple chillers, the closed circuit cooling tower is sized for the free cooling load, but also is used for a portion of the total condenser load. An open cooling tower is sized and exclusively used for the balance of the condenser load, and it is not winterized. This system variation offers the flexibility of using the open cooling tower for the condenser load during the majority for the summer with the benefit of low horsepower and lower first cost than the previous two closed circuit cooling tower system variations.

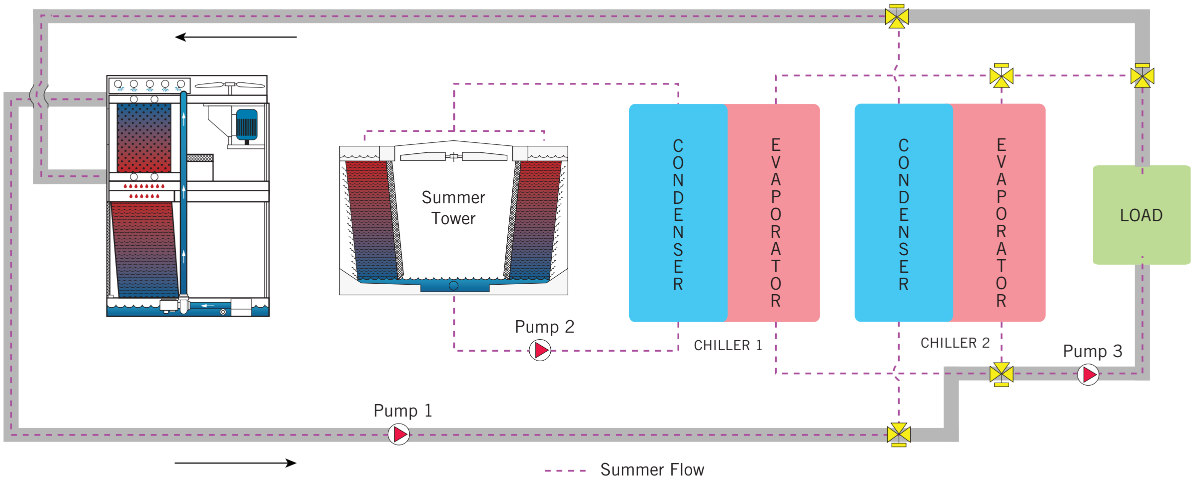


Figure 3b. Variation 2 - Closed Circuit Cooling Tower Free Cooling System with a Summer Cooling Tower for Multiple Chillers

- *Variation 3 - Closed Circuit Cooling Tower System with a Summer Cooling Tower and Load Shaving* (**Figure 3c**)*:* The closed circuit cooling tower is sized for the free cooling load and also is used in series with the chiller to reduce or shave the chiller load. An open cooling tower is sized and exclusively used for the condenser load, and it is not winterized. The closed circuit cooling tower begins to shave the load at a predetermined wet-bulb temperature by handling a portion of the chilled water load. As the wet-bulb temperature drops, the closed circuit cooling tower handles an increasing share of the load until the compressor finally can be turned off.

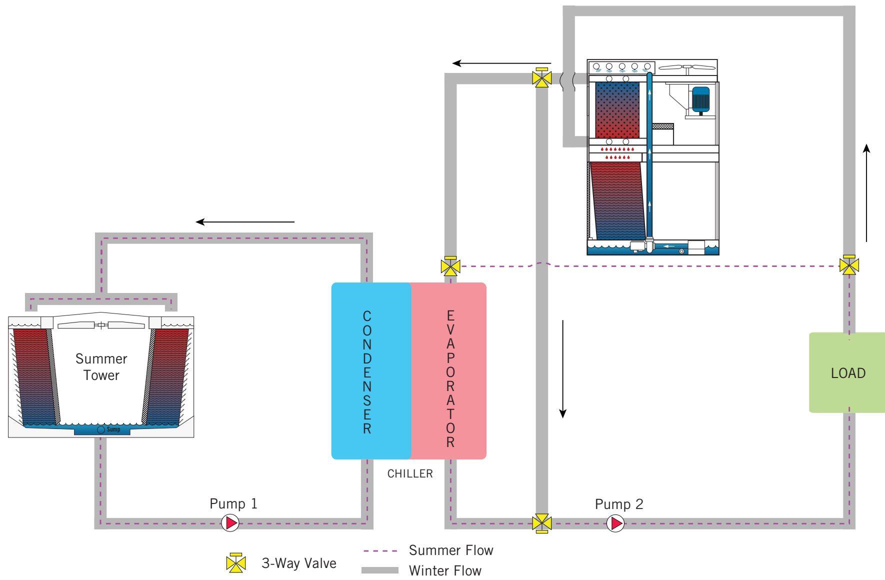


Figure 3c. Variation 3 - Closed Circuit Cooling Tower Free Cooling System with a Summer Cooling Tower and Load Shaving

Minimizing Energy Costs with Free Cooling

3. **Refrigerant Migration** (**Figure 4**):
   In this system, valves are open between the condenser and evaporator of the chiller when the compressor is off. This allows free migration of refrigerant vapor from the evaporator to the compressor and of liquid refrigerant from the condenser to the evaporator. This system is limited to the phase change and requires the coldest possible water from the open tower or closed circuit cooling tower.

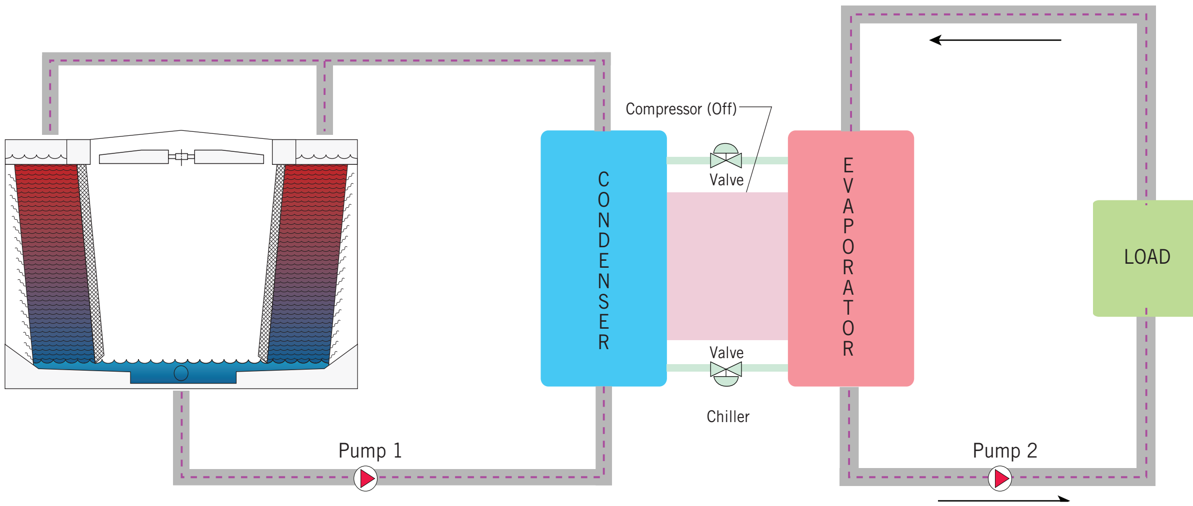


Figure 4. Refrigerant Migration Free Cooling System

Cooling load, climate, duty cycle, available space, operator skill, water and air quality, power and investment costs, maintenance, and other factors must be considered for the best system to be selected. Please contact your local BAC Representative for assistance with your system selection and sizing.

Equipment Application

The common element in all free cooling systems is the cooling tower, which can reliably produce cold water at low ambient temperatures. While most evaporative cooling equipment can operate successfully in cold weather when the leaving water temperature is high (around 85°F/29.4°C), operation at low water temperatures of 45°F (7.2°C) to 50°F (10°C) in subfreezing weather is more difficult for cooling towers. Proper winterization of the unit is critical to prevent ice formation, which may affect free cooling operation or damage the unit. For winterization guidelines and alternatives, consult your local BAC Representative.

The reliability of any unit at low temperature operation depends on the following criteria:

- Layout
- Capacity control
- Freeze protection
- Routine maintenance program

Layout

The primary consideration in locating cooling towers for cold weather operation involves recirculation. Recirculation is when warm discharge air from a unit is reintroduced into air intakes. Recirculation during warm weather means some loss in tower capacity, which sometimes can be tolerated or even allowed for in the selection process. During cold weather, recirculation of this warm moist air can cause icing of the air inlets, which eventually can restrict airflow into the unit and damage the unit.

If units are selected/located in accordance with the manufacturer's guidelines, they can offer significant energy savings during cold weather while still meeting the needs of the overall system.

Capacity Control

Performance is a function of many variables, including airflow rate, temperature difference between air and water, and heat transfer surface area. An increase in any of these variables will increase the heat transfer rate and can possibly lead to cooling some of the water to the freezing point. The closer the leaving water temperature is to approaching freezing point, the greater the concern for icing. Therefore, the recommended minimum leaving fluid temperature is 42°F (5.6°C) for cooling towers and 45°F (7.2°C) for closed circuit cooling towers.

There are three operational methods that can balance a system's required cooling while limiting ice formation:

- Temperature settings
- Fan control
- Water flow control in open cooling towers

Combinations of controls depend on expected climatic extremes and variations in heat load.

Temperature Settings: When operating at subfreezing temperatures, an evaporative cooling unit produces leaving water temperatures appreciably below winter design temperature. While this may be acceptable to the system served, it tends to promote icing and should be avoided.

Higher leaving water temperatures improve ice control capabilities because more heat must be removed from water before ice will form. Therefore it is recommended that during subfreezing temperatures, a tower be operated at the highest possible leaving water temperature consistent with efficient system performance.

Fan Control: When ambient temperatures fall below freezing, the leaving water temperature falls below the winter design temperature. Full airflow through all cells is not required. Fan speeds can be reduced with the use of variable frequency drives, pony motor systems, or two speed motors, or by cycling off fans in some cells. Varying fan speed provides the most common and direct form of capacity control.

Water Flow Control in Open Cooling Towers: Water flow rate is an important consideration when operating in subfreezing temperatures. There are two flow conditions that must be avoided under these conditions: excessive flow and minimal flow.

If actual water flow is appreciably greater than design water flow, the water distribution basins may overflow. This splash out/overflow can cause ice buildup on the exterior of a unit, a roof, or the supporting structure.

Minimizing Energy Costs with Free Cooling

A less obvious, but potentially greater problem, is that of flow rates below the minimum water distribution system design level, because this may cause water starvation within certain areas of the fill. Such areas are susceptible to icing, which easily can go unnoticed until a tower is damaged. Low flow conditions usually are encountered when pumps are taken out of service because of reduced plant load or when automatic bypass systems are used to maintain design water temperatures. When such conditions are combined with below freezing ambient temperatures, cells must be taken out of service so that the load is distributed over as few cells as practical. This means the complete shutoff of water flow to a cell, not just fan control. When cells are taken out of service, always maintain operation of the tower furthest downstream to prevent freezing at the end of the distribution header pipe.

A bypass around the tower is desirable for tower start-up and shutdown during subfreezing temperatures, but great care must be taken when employing automatic bypass valves for capacity control. Automatic bypasses can be useful in maintaining high leaving water temperature and should be considered on jobs on which wide variations in load are anticipated. However, the control sequence is critical. Under subfreezing conditions, valves should not bypass more than 20% of the design water flow when fans are running or more than 50% of design water flow when fans are off. Units used in free cooling applications should have full bypass only (i.e., no system fluid should flow over the heat transfer surface) as a final step of control after fans are cycled off.

Freeze Protection

Basin Water Protection: All units operating at subfreezing temperature, except those located indoors in a heated space, must be equipped to prevent the basin water from freezing when the unit is idle. Common forms of protection include remote sumps and electric heaters.

Reverse Fan Operation (Induced Draft Crossflow Axial Fan Cooling Towers): In extreme climates or on free cooling applications, regardless of safeguards, ice may form on the louvers and/or fill of a cooling tower. In this case, with a heat load on the tower, the fan is operated in reverse to remove ice that has built up on the air inlet louvers or fill during normal operation. By reversing the airflow through the tower, heated air is supplied to the face of the fill and air inlet louvers, providing better ice removal capabilities than can be obtained by fan control alone.

Under severe operating conditions (below 0°F/-17.8°C ambient), the suggested procedure is to operate a fan in reverse for no more than 30 minutes every two or three hours or as needed. The actual frequency of reverse fan operation can be determined only by continued observation of the installation under varying operating conditions.

Although reverse fan operation can be automatic, manual operation with frequent inspection of the towers is preferred. In either case, a time delay of at least 40 seconds between forward and reverse must be incorporated into the controls. Automatic systems should include a provision for manual reversal of fans.

Fans should not be operated in reverse for extended periods because of the risk of fan failure and personal injury from ice formation on fan blades, fan stacks, and eliminators. Therefore, reverse operation should be limited and monitored.

Fans, drives, and motors furnished on cooling towers should be designed to operate in reverse without creating mechanical or electrical overloads. Also, it is necessary that cooling towers operated in subfreezing weather be equipped with fan vibration cutout switches as a safety precaution. This accessory is mandatory on units that will use reverse fan operation for ice control.

Start-up and Shutdown: The most critical periods of operation at subfreezing temperatures are tower start-up and shutdown, because the heat input is usually minimal at these times. It is recommended that systems be installed with a full flow water bypass so water can be circulated through the system without going over the cooling tower. On start-up the bypass is used until the temperature of water entering the tower rises to within 5°F (2.8°C) of the maximum tolerable temperature for the system. Once this level is reached, the bypass is closed and the full water flow is directed over the tower while the fans remain off.

If a provision for bypass is not included in the system design, circulating pumps should not be started until the last possible moment consistent with plant operation. Tower fans should not be turned on until the temperature of the circulating water leaving the tower reaches approximately 5°F (2.8°C) below the maximum tolerable temperature for the system. At this point, fans can be cycled on low speed. On start-up, it is important that heat load be increased as rapidly as possible until the minimum recommended leaving water temperature is achieved.

The recommended shutdown procedure essentially is the reverse of the start-up procedure. As load drops, fans are cycled simultaneously to maintain the recommended tower leaving water temperature. Once all fans are off, a bypass is employed to go to full bypass without water passing over the tower at the earliest possible moment. In systems without bypass provision, tower pumps should be stopped as soon as temperatures in the tower drop below the recommended minimum or as soon as possible thereafter consistent with the cooling needs of the system.

In subfreezing weather, under no circumstances should a cooling tower operate for extended periods without a heat load or flow.

Freeze Protection in Closed Circuit Cooling Towers: At below freezing ambient temperatures, heat loss from a closed circuit cooling tower located outdoors can be substantial, even without flow through the unit and operating fans. Without a heat load on the circulating fluid, coil freezing can occur, even with full fluid flow. The use of an inhibited antifreeze solution in the coils is recommended. Two factors need to be addressed during design: (1) the increase in required pump head because of the increased viscosity of the antifreeze solution and (2) the minimal decrease in capacity. Pump head requirements and capacity reductions depend on the type of antifreeze and the concentration of the solution. Contact your local BAC Representative for selection assistance.

Theoretically, damage from freezing is prevented because antifreeze solution forms a slush solution as it begins to freeze. Most of the fluid expansion takes place during the slush forming stage. If there is a tank to accommodate the expansion, the equipment will be protected from the high pressure in the system piping.

If the use of an antifreeze solution is not practical, the system must be designed to meet both minimum flow and leaving fluid temperature requirements.

Routine Maintenance Program

Maintenance is particularly important for cooling towers operated in subfreezing weather to protect against problems that can cause icing.

First, visual inspections of a tower must be performed on a regular and frequent basis to:

- Ensure that the method of ice control is effective.
- Ensure that all controls are set properly and functioning normally.
- Discover icing conditions before the unit or supports are damaged or system performance is impaired.

Minimizing Energy Costs with Free Cooling

Additionally, a regular preventative maintenance schedule must be established and carried out, despite adverse weather conditions. Items covered should include:

- Regular lubrication of bearings with the proper type of grease as indicated in the Operation and Maintenance manual.
- Regular cleaning of strainer screens to prevent excessively high water levels in the cold water basin.
- Regular checking and adjustment of the makeup water float valve to ensure correct water levels in the cold water basin.

Example Payback Period

To better understand how much, in terms of dollars, free cooling can actually save in the long run through energy conservation, the example below shows the payback period using free cooling as opposed to a standard system.

Design Conditions

1. Summer Condenser Load: 1155 gpm cooled at 95/85/77° EWB.
2. Winter Cooling Tower Load: 1155 gpm 44.4/42/28°F EWB.
3. Winter Chilling Load: 927 gpm 49.7 to 47.2°F
4. Ambient Wet-bulb Switchpoint over 28°F, Annual Operating hours at or below switch point = 2097
5. Energy Cost = 0.12 $/kwh. Motor Power Factor = 0.90 Motor Efficiency = 0.95

				Operating HP	
System Component	Selection Conditions	Model Number	Purchase	Standard System	Free Cooling
Chiller		400 Ton Centrifugal		155	
Cooling Tower		3412C			
Heat Exchanger		Plate and Frame	36,600	25	25
Chilled Water Pump		End suction			
Condenser Water Pump				15	15
Additional Piping			5200	20	20
Total			41,800	215 (B)	60 (C)

Cost Calculations

Additional First Cost = $41,800

Annual Operating Cost Savings = (Operating HP at Std – Operating HP at Free Cooling) (KW/HP)* (PF * Eff) * Energy Cost * Operating Hours.
= (215-60) *0.746 * (0.90*0.95) * 0.12 * 2097
= $24,878 Annual Operating Cost Savings

Payback = $\dfrac{\textbf{Additional First Cost}}{\textbf{Annual Operating Cost Savings}} = \dfrac{\$41{,}800}{\$24{,}878}$ **= 1.68 years**

Summary

Free cooling is a straight forward concept that can be applied to new and existing water cooled projects with relative ease. The cooling provided, of course, is not completely "free" because the tower, chilled water pumps, and tower fans still must be operated. Nonetheless, it allows cost conscious building or process owners and operators to take advantage of naturally occurring climate conditions to save system operating costs. The concept has been applied successfully for many years to the delight of many system owners. Free cooling can be used to save energy whenever outside wet bulb temperature drops below the required chilled water set point and can save enough compressor electric power to pay for the cost. Please contact your local BAC Representative for assistance with system selection and sizing.

Fundamentals of Sound

Introduction

Sound is a form of energy transmitted from a vibrating source. The vibrating matter creates small, repetitive pressure disturbances that are imparted to the air along a path and reach a receiver, the ear. Ear drums sense these small changes in the barometric pressure of the air, distinguishing sounds based on amplitude and pitch. Amplitude refers to the level of energy that reaches the ear which corresponds to how loud we perceive sound. Pitch is the relative quality or the frequency of the sound that reaches the ear, helping a person to identify the source of the sound.

In HVAC systems, the source of sound is a combination of different processes, such as turbulence from the fan(s) and mechanical sounds from the motor(s), etc. Frequency, measured in Hertz (Hz), is the number of oscillations (cycles) completed per second by a vibrating object. The sound that humans hear covers a frequency range of about 20 Hz to about 20,000 Hz. Sounds at different frequencies behave differently, causing humans ears to react to them differently as well. This audible range of frequencies is divided into eight octave bands, reproduced below in **Table 1**.

Band Number	Identifying Frequency (Hz)	Approximate Frequency Range (Hz)
1	63	44 - 88
2	125	88 - 176
3	250	176 - 353
4	500	353 - 707
5	1,000	707 - 1,414
6	2,000	1,414 - 2,828
7	4,000	2,828 - 5,656
8	8,000	5,656 - 11,312

Table 1. Octave Band Frequencies

Creating Sound Ratings

The human ear responds to a large range of sound pressures. Sound pressure is typically measured in Pascals (Pa), which creates a range of pressure values so wide that it is more convenient to use a logarithmic scale. Therefore, the decibel (dB) scale is preferred because it collapses a large range of pressure values to a more manageable, easier to analyze range. The sound pressure level is measured in dB above a standard reference level and given by:

$$L_p = 10 \log (p/p_{ref})^2 = 20 \log (p/p_{ref})$$

Here “p” represents the sound pressure being measured and “p_{ref}” is the reference sound pressure, typically 20 μPa, which is generally considered the threshold of human hearing.

Sound ratings are typically provided in terms of the sound power of a source, which is its rate of emission of acoustical energy and is expressed in watts. Sound power does not depend on the distance of observation location from the source but it does depend on operating conditions. The sound power level, L_w, is defined by:

$$L_w = 10 \log(w/10^{-12}) \text{ dB}$$

Here “w” is the sound power emitted by the source in watts and 10^{-12} is the reference power.

Mechanical equipment is rated in terms of sound power level in order to provide a common reference measurement that is independent of distance and the acoustical conditions of the environment. When attempting to measure sound power level ratings, an engineer will find that he cannot measure these ratings directly. Instead, sound power level ratings are calculated from several sound pressure measurements created by a source in a particular test environment using one of four common methods: free-field, reverberation room, progressive wave (in-duct), and sound intensity. Once the sound pressure level is measured, the sound power level can then be determined mathematically; this calculation is treated in greater detail in **Appendix A**. The sound pressure level can also be derived from published sound power levels, again using a complex mathematical process that can be studied using **Appendix B**.

Due to the logarithmic properties of sound levels, adding two equal noise sources yields a level 3 dB higher. The addition of decibels is mentioned in greater detail in **Appendix C**.

Analyzing Sound Ratings

The purpose of developing sound ratings is to help determine whether or not the evaporative cooling equipment will cause a sound problem. Sound becomes noise when it is too loud, unexpected, contains unwanted tones (e.g. a whine, whistle, or hum), or is unpleasant. Sound only has to be unwanted for it to be noise, not necessarily just loud. Humans respond differently to each particular frequency of sound, making the ear more receptive to certain frequencies than others. As mentioned before, sound is a combination of frequencies. This creates a problem for measuring the impact of each sound on human hearing since each frequency will be perceived differently by the ear. This has resulted in the development of the A-weighting factor, which simulates human response to sound at low sound levels by de-emphasizing low frequencies within the sound spectrum. The A-weighting factor accounts for the ear's reduced sensitivity to low frequency sounds and thus allows for a better comparison of sounds emanating from two different sources. Defining a noise problem is typically in terms of dBA, which is the A-weighting corrected value of a decibel. This weighting factor, reproduced in **Table 2** below, allows for a more accurate determination of when a sound becomes a noise. Other weighting factors exist for higher sound levels, but are not commonly used.

Band Number	1	2	3	4	5	6	7	8
A- Weighting Factor	-25	-15	-8	-3	0	+1	+1	-1

Table 2. A- Weighting Factors

Fundamentals of Sound

HVAC Acoustical Design Goals

For any specific project, it is important how the design engineer decides to rate the background sound. This is not to say that all evaporative cooling equipment have a sound problem; in fact, most do not. The most common rating methods include the A-weighted sound level (dBA), noise criteria (NC) method, and room criterion (RC) method. Each method highlights different characteristics of sound. When selecting a rating method it is important to consider how the rating will be used. A-weighted sound levels are excellent predictors of human judgments of sound, but do not reveal the spectral balance of sound. Thus, a limitation of A-weighted sound levels is that the measurements do not correlate well with the annoyance caused by noises. Different sounds can receive the same rating but retain dissimilar subjective qualities. A-weighted sounds are best for a comparison between sounds that are similar but differ in level, such as comparing the loudness between two different makes of a fan. Therefore, the A-weighted sound level is not the best tool for measuring HVAC systems as a whole, but it is better used for measuring a single component like a fan.

When measuring evaporative cooling equipment as a whole, the NC or RC methods work best. These methods account for environmental noise, unlike the A-weighted sound level. The key difference between RC and NC methods is the emphasis on the lower frequencies (16 Hz, 31.5 Hz) and the higher frequencies (8 KHz), respectively. As of this publication, the predominant design criterion that HVAC engineers utilize is the NC method, chosen for its ease of use and widespread publication in HVAC resources. The RC method, considered to be the better measure of sound between the two methods, is slowly replacing the NC method as a means of analyzing sound.

The NC method plots sound pressure levels in the eight octave band levels. The method is composed of a family of criterion curves extending from 63 to 8000 Hz from which values are tangentially chosen. **Figure 1** illustrates an NC chart below.

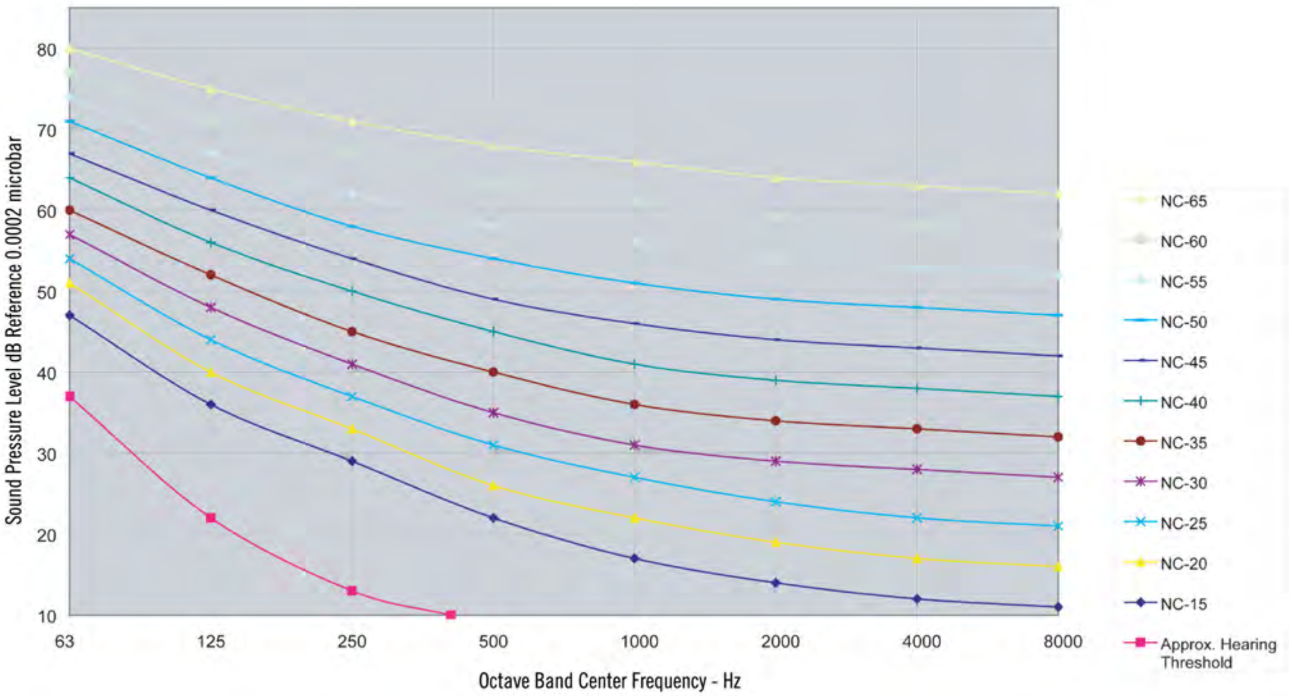


Figure 1. Noise Criterion (NC) Curves

Determining Sound Attenuation Requirements

The following thirteen step procedure can be used to determine the sound attenuation requirement for an evaporative cooling tower. The sidebar follows the procedure for a specific application.

Steps 1 and 2: Select NC Values and the Corresponding Sound Pressure Levels

The first step in the development of the evaporative cooling equipment's noise criterion is to select the particular activity that best describes what the indoor "neighbors" in the vicinity of the equipment will be doing when the equipment is operating as shown in **Table 3** on the following page. Where two or more neighbor conditions may be applicable, the one having the lowest NC value should be selected. The corresponding NC values of **Figure 1,** shown previously, or in **Table 4** on the following page give the eight octave band sound pressure levels, in decibels, for that selection. The goal is to keep the sound heard by the neighbor, inside his home or building, at or below these sound pressure levels.

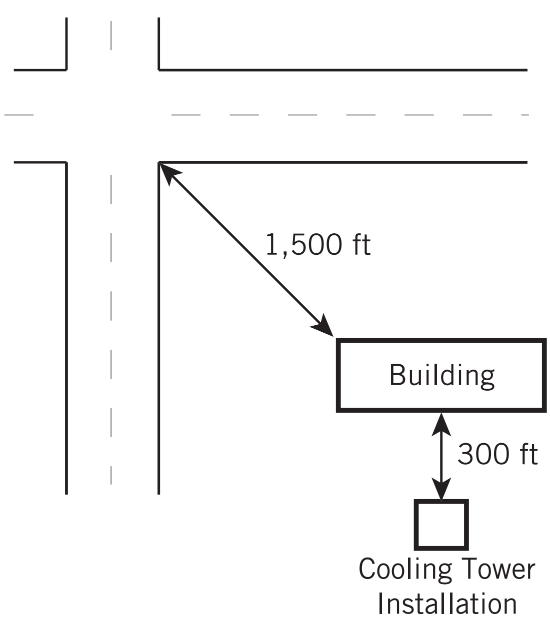


Figure 2. Example Scenario

Determining Sound Attenuation Requirements Example

The following example illustrates the process of choosing sound criteria for an application of a cooling tower. Once finished, an HVAC engineer will be able to determine what level of sound attenuation, if any, is necessary. The example refers to different "items" which are found in the BAC Sound Evaluation Worksheet (**Appendix F** on **page J86**). **Appendix F1** is a worksheet that follows the running example on the sidebar in this document. **Appendix F2** is left blank for your own use.

Example:

Consider a cooling tower installation located near the edge of a college campus, approximately 300 ft (91.4 m) from a classroom building. The college is located within a large city, and two main streets pass by one corner of the campus about 1,500 ft (457.2 m) from the classroom building. The cooling tower will be used both day and night during warm weather. The classroom must rely on open windows for air circulation (See **Figure 2)**. Determine the noise criterion for the unit.

Step 1: **Determine the Neighbor Activity Condition.** Refer to **Table 3** on the following page**.** For "good listening conditions" inside a typical classroom, select NC-30 as the noise criterion.

Step 2: **List the Sound Pressure Levels.** In the indicated spaces under Item 2 of the Sound Evaluation Work Sheet, **Appendix F**, enter the sound pressure levels from **Table 4** on the following page for the octave frequency bands that correspond to the chosen NC-30 curve.

Fundamentals of Sound

Activity	Suggested Range of Noise Criteria
Sleeping, Resting, Relaxing	
Homes, Apartments, Hotels, Hospitals, etc.	NC-20 to NC-25
Suburban and Rural areas	NC-25 to NC-30
Excellent Listening Conditions Required	
Concert Halls, Recording Studios, etc.	NC-15 to NC-20
Very Good Listening Conditions Required	
Auditoriums, Theatres	NC-20 to NC-25
Large Meeting and Conference Rooms	NC-25 to NC-30
Good Listening Conditions Required	
Private Offices, School Classrooms, Libraries, Small Conference Rooms, Radio and Television Listening in the Home, etc.	NC-30 to NC-35
Fair Listening Conditions Desired	
Large Offices, Restaurants, Retail Shops and Stores, etc.	NC-35 to NC-40
Moderately Fair Listening Conditions Acceptable	
Business Machine Areas, Lobbies, Cafeterias, Laboratory Work Areas, Drafting Rooms, Satisfactory Telephone Use, etc.	NC-40 to NC-45
Acceptable Working Conditions with Minimum Speech Interference	
Light to heavy Machinery Spaces, Industrial Areas, Commercial Area such as Garages, Kitchens, Laundries, etc.	NC-45 to NC-55

Table 3. Suggested Range of Noise Criteria for Indoor Neighbor Activities

Noise Criterion	Octave Band Center Frequency in Hz							
	63	125	250	500	1000	2000	4000	8000
NC-15	47	36	29	22	17	14	12	11
NC-20	51	40	33	26	22	19	17	16
NC-25	54	44	37	31	27	24	22	21
NC-30	57	48	41	35	31	29	28	27
NC-35	60	52	45	40	36	34	33	32
NC-40	64	56	50	45	41	39	38	37
NC-45	67	60	54	49	46	44	43	42
NC-50	71	64	58	54	51	49	48	47
NC-55	74	67	62	58	56	54	53	52
NC-60	77	71	67	63	61	59	58	57
NC-65	80	75	71	68	66	64	63	62

Table 4. Octave Band Sound Pressure Levels (dB reference 0.0002 microbar) of Indoor Noise Criterion (NC) Curves in **Figure 1**

Steps 3 through 6: Determine Environmental Sound Effects

Neighbors who are either indoors in their own building or outdoors on their property may hear sound from outdoor equipment. When outdoor sound passes into a building, it reduces, even if the building has open windows. The approximate sound reduction values provided by several typical building constructions are given in **Table 5**; the listed wall constructions are labeled with letters A through G and are described in the notes under **Table 5**. Adding these amounts of sound reduction to the indoor NC curves, band-by-band, provides a "tentative outdoor noise criterion" based on hearing the sound indoors in the neighbor's building.

Octave Frequency Band in Hz	Wall Type (See Notes Below)						
	A	B	C	D	E	F	G
63	0	10	13	19	14	24	32
125	0	10	14	20	20	25	34
250	0	10	15	22	26	27	36
500	0	10	16	24	28	30	38
1000	0	10	17	26	29	33	42
2000	0	10	18	28	30	38	48
4000	0	10	19	30	31	43	53
8000	0	10	20	30	33	48	58

Table 5. Approximate Sound Reduction (dB) Provided by Typical Exterior Wall Construction

NOTES:

A: No wall; outside conditions.

B: Any typical wall construction, with open windows covering about 5% of exterior wall area.

C: Any typical wall construction, with small open-air vents of about 1% of exterior wall area, all windows closed.

D: Any typical wall construction, with closed but operable windows covering about 10%-20% of exterior wall area.

E: Sealed glass wall construction, 1/4 inch thickness over approximately 50% of exterior wall area.

F: Approximately 20 lb/sq ft solid wall construction with no windows and no cracks or openings.

G: Approximately 50 lb/sq ft solid wall construction with no windows and no cracks or openings.

Determining Sound Attenuation Requirements Example Continued

Step 3: Analyze Sound Reduction Due to the Building. Determine the wall construction of **Table 5** that best describes the exterior wall of the classroom. Wall B can be selected for normally open windows during the summer time. Insert the Wall B values in the Item 3 spaces of **Appendix F** on **page J86**.

Step 4: Determine Tentative Outdoor Noise Criterion. Still in **Appendix F1** Add the values of Steps 2 and 3 together and insert these sums in the Item 4 spaces. This is the "tentative outdoor noise criterion." See **Appendix F** for Item 4.

In a relatively noisy outdoor area, it is possible that the outdoor background sound is even higher than the "tentative outdoor noise criterion." In this case, the steady background sound in the area may mask the sound from the evaporative cooling equipment and take over as the controlling outdoor sound criterion.

The best way to judge this is to take a few sound pressure level measurements to get the average minimum background level during the quietest intervals in which the equipment is expected to operate, or during the intervals when noise complaints are most likely to be caused. For example, test at night in residential areas where cooling equipment is operating at night, or during the day in office areas exposed to daytime cooling equipment sound.

Fundamentals of Sound

In the event that background sound measurements cannot be made, **Figure 3** and **Tables 6** and **7**, may be used to estimate the approximate outdoor background noise. **Table 6** on the following page also lists the approximations as numbers.

These estimates should be used only as approximations of background sounds, because local conditions can give rise to a wide range of actual sound levels.

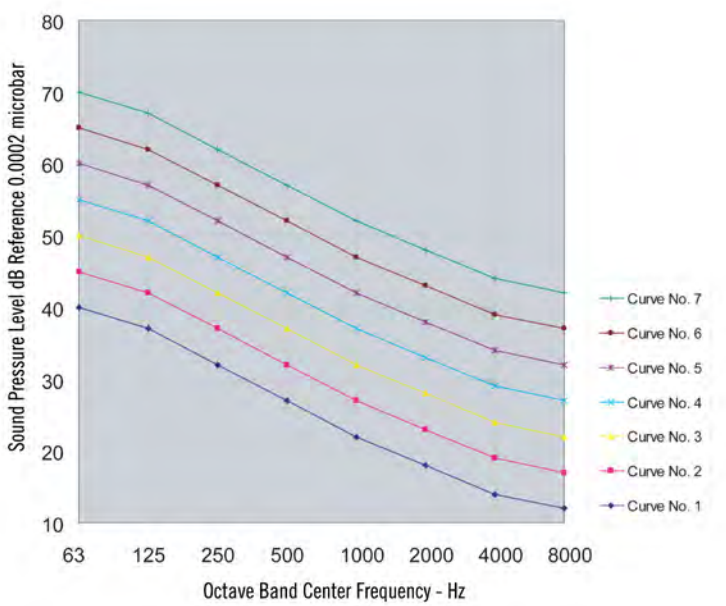


Figure 3. Approximate Average Minimum Outdoor Background Sound Pressure Levels Associated with the Conditions in **Table 6**

Determining Sound Attenuation Requirements Example

Step 5: Determine Outdoor Background Sound. In the Item 5 spaces, enter either the measured average minimum background sound pressure levels or the estimated background levels obtained from the use of **Figure 3** and **Tables 6** and **7**. See **Appendix F** on **page J86** for Item 5. In this example, we estimate that the traffic activity is best represented by "1000-2000 ft (304.8-609.6 m) from continuous heavy-density traffic." This leads to line 22 in **Table 6** which points to curve 5 in **Figure 3**. The same curve 5 information is used to discern the octave band center frequency in **Table 7 on the following page**. These numbers are shown for you in **Appendix F1**.

Condition	Curve Number In Figure 3	Condition	Curve Number In Figure 3
1. Nighttime, rural; no nearby traffic of concern	1	13. Within 300 ft of continuous medium-density traffic	6
2. Daytime, rural; no nearby traffic of concern	2	14. Within 300 ft of continuous heavy-density traffic	7
3. Nighttime, suburban, no nearby traffic of concern	2	15. 300 to 1000 ft from intermittent light traffic	3
4. Daytime, suburban; no nearby traffic of concern	3	16. 300 to 1000 ft from continuous light traffic	4
5. Nighttime, urban; no nearby traffic of concern	3	17. 300 to 1000 ft from continuous medium-density traffic	5
6. Daytime, urban; no nearby traffic of concern	4	18. 300 to 1000 ft from continuous heavy-density traffic	6
7. Nighttime, business or commercial area	4	19. 1000 to 2000 ft from intermittent light traffic	2
8. Daytime, business or commercial area	5	20. 1000 to 2000 ft from continuous light traffic	3
9. Nighttime, industrial or manufacturing area	5	21. 1000 to 2000 ft from continuous medium-density traffic	4
10. Daytime, industrial or manufacturing area	6	22. 1000 to 2000 ft from continuous heavy-density traffic	5
11. Within 300 ft of intermittent light traffic	4	23. 2000 to 4000 ft from intermittent light traffic	1
12. Within 300 ft of continuous light traffic	5	24. 2000 to 4000 ft from continuous light traffic	2

Table 6. Estimate of Outdoor Background Sounds Based on General Type of Community Area and Nearby Automotive Traffic Activity

The measured or estimated average minimum background sound levels should now be compared, band-by-band, with the "tentative outdoor noise criterion" determined previously. The larger of these values, in each frequency band, now becomes the octave band sound pressure levels that comprise the "final outdoor noise criterion" for the equipment installation.

Any new intruding sound is generally judged in comparison with the existing background sound. If the new sound stands out above the existing sound, the neighbors may notice it, be disturbed by it, and object to it. On the other hand, if the new sound can hardly be heard in the presence of the old sound, it will pass relatively unnoticed. Therefore, if the sound coming from the equipment is below or just equal to the final noise criterion, it will not be noticed and our objectives will have been satisfied.

If there are two or more different criterion for a particular installation, the analysis should be carried out for each situation and the lowest final criterion should be used.

Determining Sound Attenuation Requirements Example Continued

Step 6: Determine Final Noise Criterion. In the Item 6 spaces insert the higher value, in each frequency band, of either the Item 4 or Item 5 values. This is the "final noise criterion." At this point the values across Item 6 should read "67-58-52-47-42-39-38-37," as noted in the completed sample in **Appendix F1**.

Octave Band Center Frequency in Hz	Curve Number In Figure 3						
	1	2	3	4	5	6	7
63	40	45	50	55	60	65	70
125	37	42	47	52	57	62	67
250	32	37	42	47	52	57	57
500	27	32	37	42	47	52	52
1000	22	27	32	37	42	47	48
2000	18	23	28	33	38	43	39
4000	14	19	24	29	34	39	44
8000	12	17	22	27	32	37	42

Table 7. Octave Band Sound Pressure Levels (dB) of Outdoor Background Noise Curves in **Figure 3**

Fundamentals of Sound

Steps 7: Determine Sound Pressure Levels at the Proper Distance

The BAC Selection Program can measure the sound levels radiated by its units at various distances for the five principle directions, (four horizontal and one vertical). The sample sound rating data sheet shown in **Appendix D** indicates the five principle directions and the type of sound data available for a Series 3000 Cooling Tower at 300 ft. Sound data can be generated for different distances, as required for the application, for all BAC units in the BAC Selection Program.

Current sound data for all BAC equipment is available from your local BAC Representative and from the BAC Selection Program, available at www.BaltimoreAircoil.com.

Steps 8 through 11: Adjust for the Effects of Reflecting Walls

Frequently, the geometry of an installation involves some nearby reflecting walls or buildings, which adds to the acoustic complexity of the site. Let us consider this for three typical situations:

- Cases in which reflecting walls modify the radiation pattern of the sound from the unit to the neighbor
- Cases in which close-in walls confine the unit and cause a build-up of close-in sound levels
- Cases in which the unit is located in a well and all the sound radiates from the top

Determining Sound Attenuation Requirements Example Continued

Step 7: Use BAC Selection Program to Determine the Sound Pressure Levels at 300 ft. Decide on the preferred orientation of the cooling tower at the site. Using the sample data from **Appendix D**, the BAC Sound Rating Data Sheet, determine the sound pressure levels at 300 ft (91.4 m) from the side of the cooling tower facing the college classroom. Insert these sound pressure level values in the Item 7 spaces of the Sound Evaluation Work Sheet found in **Appendix F1**.

Step 8: Apply Reflection Adjustment. Had there been a sound increase due to the presence of a reflecting wall that met one of the conditions illustrated in **Appendix E**, corrections would be inserted now in the Item 8 spaces. Had this been a close-in problem involving a build-up of sound levels due to some nearby enclosing walls around the tower, “+5 dB” would have been inserted in the Item 8 spaces. Since neither of these conditions applied in this example, we insert “0” in each of the Item 8 spaces.

Effect of Reflecting Walls

There are several factors that influence the power of the reflected sound:

1. The sound radiation pattern (directivity) of the equipment
2. The radiating area of the equipment
3. The orientation of the equipment
4. The distance between the unit to the neighbors
5. The distance of the equipment to the reflecting wall
6. The area of the reflecting wall
7. Various angles of incidence and reflection between the equipment, the wall, and the neighbors

Because so many variables are involved, a simplified procedure for estimating the influence of a reflecting wall is provided. We caution that if a large surface is located near the equipment, it should be considered as a potential reflector of sound. **If the equipment is oriented such that its loudest side is already facing toward the neighbor, the influence of the reflecting wall can be ignored.** However, if this is not the case, these conditions must be met for the reflected sound to be of concern:

1. The area of the reflecting wall is at least three times the area of the side of the equipment that faces that wall.
2. The distance from the unit to the reflecting wall is less than half the distance from the equipment to the neighbor.
3. If a simple optical ray diagram is drawn from the center of each unit to all parts of the reflecting wall, and the reflecting rays are then drawn away from the wall, the neighbor is located within the reflected angular range as shown in **Figure E1** in **Appendix E.**
4. If each of these three conditions is met, then the sound pressure levels at the neighbor may be higher than if the wall were not there.

Determining Sound Attenuation Requirements Example Continued

Step 9: Tabulate Resultant Unit L_p at Critical Neighbor Location. Item 9 is the sum of Items 7 and 8 (see **Appendix F**, **page J86**). This is the sound pressure level of the cooling tower at the 300 ft (91.4 m) distance.

Step 10: Determine Outdoor Noise Criterion for the Critical Neighbor. To simplify the next step, copy into Item 10 the values taken from Item 6, the "Final Noise Criterion" (**Appendix F**).

Step 11: Ascertain Tentative Sound Reduction Required for Unit. Subtract the Final Noise Criterion (Item 10) from the Resultant Cooling Tower Sound Pressure Levels (Item 9). Enter this calculation into Item 11. Any positive-valued remainder represents sound excess above the criterion. Any negative-valued remainder means that the cooling tower level is below the criterion and no sound reduction is required in the frequency bank; hence, "0" is inserted in that space.

If the cooling tower levels in all eight octave bands are below the criterion values, there should be no sound problem. If two or three of the cooling tower levels exceed the criterion values by only 1, 2, or 3 dB, there will probably be no sound problem. If several octave band sound levels exceed the criterion by 5 to 10 dB, or more, a sound problem should be anticipated – the higher the sound excess, the greater likelihood there will be a problem if suitable measures are not taken.

Fundamentals of Sound

Step 12: Adjust for the Judgment Factor of the Engineer

At this point, some remarks should be made on the overall reliability of this approach, and an opportunity should be provided for inserting a judgment factor. Since the original criterion selection was based mostly on lower range NC values for the various environments considered, the derivation presented here may be somewhat conservative. Because of this, decisions based on this approach will usually lead to acceptance of the sound from the equipment. As explained throughout the procedure, several approximations are made, such as for the sound reduction of various general types of walls, and the sound estimates of community or traffic background sounds, and others. These approximations may lead to some variability from one installation to the next, although it is believed that a small amount of variability can be accommodated by the procedure without changing the results unreasonably.

Experience shows that where the criterion is based on sleeping at night, the criterion should not be exceeded, and therefore, the conclusions reached by this procedure should be followed. However, where the criterion is based on somewhat less critical daytime activities, and the background sound frequently ranges considerably above the average minimum conditions used here, then the risk is not too great if the criterion is exceeded by about 5 dB. In such cases the criterion should not be exceeded by more than 5 dB for fear of serious objections. If it is decided to permit the sound to exceed the criterion by as much as 10 dB or more, sound reduction steps should be considered for future addition to the installation, even though they may not be included in the initial installation.

Determining Sound Attenuation Requirements Example Continued

Step 12: Apply Judgement Factor. Insert the cooling tower owner's Judgment Factor. For a "conservative approach" insert 0 dB in the Item 12 spaces of the Work Sheet. To purposely allow the cooling tower sound to exceed the acceptable levels slightly, insert 5 dB in the Item 12 spaces.

Step 13: Tabulate Final Sound Reduction Requirement for Job. The Final Sound Reduction Requirement for the cooling tower is the difference, in each band, obtained by subtracting Item 12 from Item 10 as shown in **Appendix F1** on **page J86**. These are the attenuation values in each octave band necessary to reduce the cooling tower sound to an acceptable level.

In view of the above, if the equipment's owner, architect, or engineer chooses to follow a conservative approach or even to allow for some excess sound on a particular project (that is, permit the equipment's sound to exceed the background sounds slightly and thus be identifiable and possibly disturbing to the neighbors), this opportunity is afforded in Items 12 of the Sound Evaluation Work Sheet (**Appendix F** on **page J86**).

Step 13: Determine the Final Sound Reduction Requirement

The sound reduction required for evaporative cooling equipment is the excess of the equipment's sound pressure levels over the applicable noise criterion levels. This is shown numerically by the dB values found in Item 13 of the Sound Evaluation Work Sheet (**Appendix F**) when the particular calculation is carried out. Whether it will be a simple or complex sound reduction problem lies largely in the amount and frequency distribution of the required sound reduction. A brief discussion of sound control for evaporative cooling equipment is given in the next section.

Acknowledgement:

BAC extends its sincere appreciation to Mark E. Schaffer, P.E. (President of Schaffer Acoustics Inc of Pacific Palisades, CA) for his contributions to this article.

Evaporative Cooling Equipment Sound Control

Job conditions may allow some quieting to be obtained by strategically positioning the equipment, controlling the fan motor, installing a low sound fan option, or constructing barrier walls located between the equipment and neighbor. Additional sound reduction needs may be met with packaged attenuators or other acoustic treatments, which, in general, can achieve high frequency noise reduction rather easily but usually involve larger weight and space requirements to accomplish low frequency quieting.

XE Models

XE models are tailored for projects that require an extremely efficient unit. In addition to lower sound, this solution reduces energy consumption, system wiring, switch gear cost, and starter costs. With the reduction in sound levels and energy consumption. XE models are an environmentally conscious approach to reducing sound.

High Solidity Axial Fans

Adding a high solidity fan decreases sound levels by decreasing fan speed, which proportionally decreases sound levels. BAC offers three fan options for reduced sound pressure levels.

Standard Fan - All BAC standard fans are selected to optimize low sound levels and maximize thermal performance.

Low Sound Fan - The Low Sound Fan option reduces sound levels up to 9 dBA and has been certified in accordance with CTI Standard STD-201.

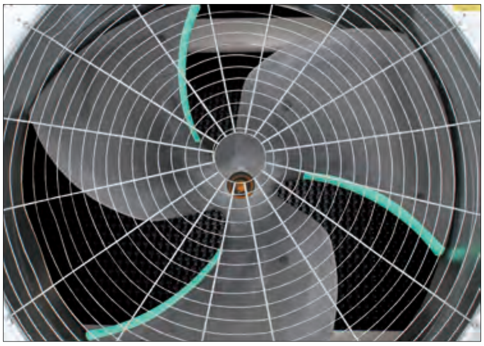
Whisper Quiet Fan - For the most extreme sound limitations, BAC's Whisper Quiet Fan can reduce sound 10-20 dBA.

Intake and Discharge Sound Attenuation

Factory designed, tested, and rated sound attenuation is available for both the air intake and discharge. Adding sound attenuation dampens the sound propagating from the unit.

Water Silencers

The water splashing noise produced in induced draft counterflow cooling towers can be the dominant source of sound at short distances. Water silencers reduce this noise to nearly negligible levels.



Whisper Quiet Fan

An Evaporative Condenser with Full Sound Attenuation

Fundamentals of Sound

Single-Side Air Intake Units

Particularly sound-sensitive areas can be accommodated by facing the back panel to the sound-sensitive direction, reducing the propagation of sound.

Centrifugal Fan Units

Centrifugal fans have inherent low sound characteristics. The ability of centrifugal fan units to overcome higher static pressures allows for the units to be ducted. Ducting shields blade noise to further reduce sound.

BALTIGUARD™ Fan Drive System

The BALTIGUARD™ Fan System consists of two standard motors and drive assemblies. A full size motor (sized for the design conditions) and a lower horsepower motor (sized at approximately one third the horsepower of the standard motor) are connected to the same fan shaft. When operating the BALTIGUARD™ Fan System with the low horsepower motor, fan speed is reduced, leading to sound level reductions of approximately 6-8 dBA. Since periods of reduced load often coincide with requirements for lower sound levels, such as at night, the BALTIGUARD™ Fan System can often provide the desired sound reduction and is a convenient solution for meeting the needs of sound sensitive installations.

Variable Frequency Drive (VFD) Controls

The human ear picks up sharp variances in sound levels more effectively than a gradual change, so the sound generated from a unit cycled on and off is much more noticeable compared to the sound of a unit continuously operated. The “soft-start” feature provided by a VFD minimizes the start-up sound. Additionally, VFDs provide smooth acceleration to maximum speed. These features blend the evaporative cooling equipment sound levels into the background and make the units less noticeable to neighbors and building occupants.

Barrier Walls (Provided by Outside Sources)

Barrier walls dampen the noise from evaporative cooling equipment to minimize sound transmission. Barrier walls can also provide value by concealing the unit from view. Layout requirements should be taken into consideration during design to ensure that the unit has an adequate supply of fresh ambient air. BAC recommends working with an acoustical consultant in conjunction with your local BAC Representative to achieve specified sound requirements, while maintaining unit efficiency.

Series V Centrifugal Fan Single-side Air Intake Unit with Full Sound Attenuation

BALTIGUARD™ Fan Drive System

VFD Controls

Barrier Walls Being Erected Around FXV Dual Air Intake Units

Effects of Sound Reduction Options on Equipment Performance

The cost of sound attenuation, including the effect on performance, must be evaluated versus simpler methods such as over sizing the unit(s) to meet the sound criteria for a project.

To determine the most fitting sound solution, consult your local BAC Representative who can provide the most cost effective option to meet your specific needs. Note that with either low sound fans or "add-on" attenuation, lower sound levels often come at the expense of lower airflow. The system designer must ensure that the manufacturer's ratings are adjusted to account for any decrease in thermal performance from this reduction in airflow. Thus, engineering requirements can often dictate the solution. When attempting to reduce sound, some other considerations which may affect the type of sound mitigation chosen are the site configuration (i.e. reflecting walls, receiver elevation relative to the source) and signature of the noise source (pure tone, pulsation, etc.). Evaluating a sound problem involves accounting for many variables yet there are a variety of solutions that can silence HVAC equipment to provide your sound attenuation needs.

Summary

This section provides a simple and direct evaluation method for determining whether or not a given evaporative cooling equipment installation is producing, or will produce, excess sound. It also offers some general information on methods that can be used to reduce the sound.

Current sound data for all BAC equipment is available from your local BAC Representative and from the BAC Selection Program, available at www.BaltimoreAircoil.com. Consult your local BAC Representative for specific project applications.

Fundamentals of Sound

Appendix A

The Calculation of Sound Power Level (L_w) From Measured Sound Pressure Levels (L_p)

Sound power is a measure of the total acoustic power radiated by a sound source. "Sound power level" is the sound power, expressed in decibels, relative to a reference power typically 10^{-12} watt.

Sound power is not directly measured as such. Instead, it is a calculated quantity and is obtained from the measurement of sound pressure levels at a suitable number of measurement positions. Even in indoor testing with reverberant or semi-reverberant rooms and a standard reference sound source, sound power level is calculated from sound pressure level measurements. In this discussion, no technical detail is given for the derivation of sound power level; instead, a very simple procedure is provided for establishing the approximate sound power level of evaporative cooling equipment for the case in which the sound pressure level is measured at four horizontal positions (each position at a specific distance from each of the four sides) plus one vertical position above the unit. The measurement positions may be at any distance between 2 and 4 times the unit's largest dimension, which is usually its length.

The measured sound pressure levels must be obtained with accurate, calibrated equipment, and the sound data must be in the conventional eight octave bands of frequency. The measurements should be made under essentially free-field conditions: i.e., outside in an area free of any nearby reflecting surfaces. The unit is assumed to be located on the ground or on a platform reasonably close to ground level.

The approximate sound power level in each of the eight octave bands is the sum, by decibel addition, of the individual five sound pressure level readings in each octave band plus a correction term (K) which is a function of the number of measurements positions, the measurement distance and the reference power. In equation form, this can be expressed as:

$$L_w = \sum L_p + K$$

The decibel summation of a number of sound pressure levels is determined from the material given in **Appendix C** and the correction terms are given in **Table A** for the appropriate conditions. The use of the five measurement positions and the decibel addition of the five readings automatically introduce the directivity characteristics of the unit into the calculated sound power level. No further provision for directivity is required in this simplified method.

To illustrate this procedure, suppose we wish to estimate the sound power level (L_W) in one octave band for the case of the five-position measurements 50 ft (15.2 m) from a cooling tower. Assume the five sound pressure levels measured in the particular frequency band are 56, 53, 59, 53, and 47 dB (reference 0.0002 microbar).

By the decibel addition method shown in **Appendix C** we find that the decibel sum of these five sound pressure levels is 62 dB. From **Table A** we then find that at 50 ft (15.2 m) measurement distance, the correction term is 25 dB reference 10^{-12} watt. For this example:

$$\begin{aligned} L_w &= \sum L_p + K \\ &= 62 + 25 \\ &= 87 \text{ dB} \end{aligned}$$

The same procedure could be followed for all octave bands to get the complete L_w of the cooling tower. The procedure given here is for the specific five measurement positions noted and may not be applicable generally to other situations. The procedure is not accurate to less than 1 dB, so fractional values of decibels should not be used or relied upon.

Measurement Distance to Acoustic Center (ft)	Correction Term K
25	19
30	20
35	21
40	23
45	24
50	25
60	26
70	27
80	29
90	30
100	31

Table A. Correction Term K for L_w Reference 10^{-12} Watt (dB)

Fundamentals of Sound

Appendix B

The Calculation of Average Sound Pressure Level (L_p) For A Given Sound Power Level (L_w)

For comparative purposes it may occasionally be necessary to estimate the approximate average sound pressure level radiated by a unit for which only the sound power level is given. There are also some applications that are best appraised by converting sound power back to average sound pressure levels. The procedure outlined in this appendix will provide this estimate.

It is important to realize that the resulting value is an average sound pressure level that theoretically would be radiated the same in all directions from the unit. In practice, the unit probably would not radiate the same levels in all directions; but, when only the sound power level is given it is not possible to know the directivity characteristics of the unit.

The average sound pressure level at a desired distance is obtained by subtracting from the sound power level in any given octave frequency band the appropriate correction term (C) from **Table B1**. In equation form, this relationship is expressed as:

$$L_p \text{ Avg.} = L_w - C$$

As an illustration, suppose we wish to know the average sound pressure at a distance of 50 ft (15.2 m) for a cooling tower that is stated to have a sound power level 87 dB reference 10^{-12} watt. (Note that this is the counterpart of the example given in **Appendix A**). From **Table B1**, for a distance of 50 ft, we see that the correction term is 32 dB.

$$\begin{aligned} L_p \text{ Avg.} &= L_w - C \\ &= 87 - 32 \\ &= 55 \text{ dB} \end{aligned}$$

By comparing this value with the five levels used in the calculation in **Appendix A**, we see that although this is an average value, it actually does not equal any of the levels from the five measured directions. Note again that the average value is not intended to show the directivity characteristics of the sound source.

If two competitive cooling towers are being compared for a particular site condition, a comparison of the sound power level or the average sound pressure level may be a general clue to the relative sound from the two units, but a more careful comparison should take into account the actual sound levels to be radiated in the particular critical direction(s).

Measurement Distance to Acoustic Center (ft)	Correction Term C
25	26
30	27
35	28
40	30
45	31
50	32
60	33
70	34
80	36
90	37
100	38

Table B1. Correction Term C for L_p
Reference 10^{-12} Watt (dB)

NOTE: The correction term C is based on the sound radiating uniformly over a hemisphere. This would apply for a typical ground level installation or for a unit located on a large roof. If there are conditions such that the sound will radiate over a large angle, say a 3/4 sphere, add 3 dB to the above C. Subtract 3 dB from the above C for a 1/4 sphere radiation.

For distance beyond 100 ft (30.4 m) calculate the average L_p for 50 ft (15.2 m) using the method here; then extrapolate by subtracting the desired distance using the L_p reduction values of **Table B2** below.

Distance (ft)	Octave Band Center Frequency in Hz							
	63	125	250	500	1000	2000	4000	8000
100	6	6	6	6	6	6	7	7
125	8	8	8	8	8	8	9	10
160	10	10	10	10	10	10	11	12
200	12	12	12	12	12	13	14	15
250	14	14	14	14	14	15	16	18
320	16	16	16	16	16	17	18	21
400	18	18	18	18	19	19	21	24
500	20	20	20	20	21	22	24	27
630	22	22	22	22	23	24	27	31
800	24	24	24	25	25	26	30	35
1000	26	26	26	27	27	29	34	40
1250	28	28	28	29	30	32	38	46
1600	30	30	30	31	32	35	43	53
2000	32	32	32	33	35	38	47	61
2500	34	34	34	35	38	42	53	70

Table B2. Reduction of Sound Pressure Level (dB) for Distances Beyond 50 ft

Fundamentals of Sound

Appendix C

Addition of Decibels

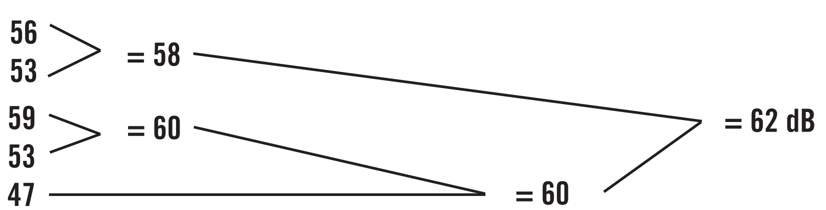
Since decibels are logarithmic values it is not proper to add them by normal algebraic addition. For example, 63 dB plus 63 dB does not equal 126 dB but only 66 dB.

A very simple, but adequate schedule for adding decibels is as follows:

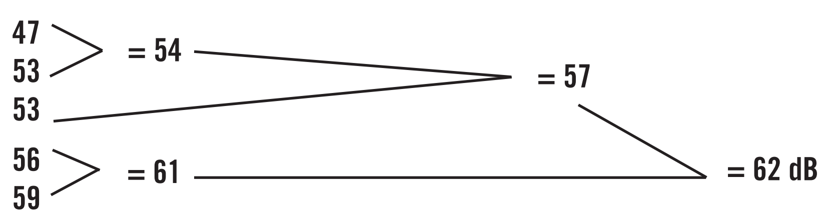
When Two Decibel Values Differ By	Add the Following Amount to the Higher Value
0 or 1 dB	3 dB
2 or 3 dB	2 dB
4 to 8 dB	1 dB
9 dB or more	0 dB

When several decibel values are to be added, perform the above operation on any two numbers at a time, the order does not matter. Continue the process until only a single value remains.

As an illustration let us add the five sound levels used in the example of **Appendix A**.



Or, suppose we arrange the same numbers in a different order, as in:



Sometimes, using different orders of adding may yield sums that might differ by 1 dB, but this is not a significant difference in acoustics. In general, the above simplified summation procedure will yield accurate sums to the nearest 1 dB. This degree of accuracy is considered acceptable in the material given in this article.

Appendix D

Baltimore Aircoil Company, Inc.

Cooling Tower Selection Program

Version: 8.5.2 NA
Product data correct as of: March 26, 2015

Project Name:
Selection Name:
Project State/Province: Maryland
Project Country: United States
Date: June 24, 2015

Model Information

Product Line: New Series 3000
Model: S3E-1222-07N
Number of Units: 1
Fan Type: Standard Fan
Fan Motor: (1) 25.00 = 25.00 HP/Unit
Total Standard Fan Power: Full Speed, 25.00 BHP/Unit

Intake Option: None
Internal Option: None
Discharge Option: None

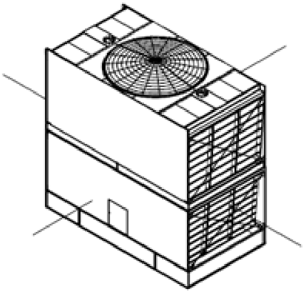
Octave band and A-weighted sound pressure levels (Lp) are expressed in decibels (dB) reference 0.0002 microbar. Sound power levels (Lw) are expressed in decibels (dB) reference one picowatt. Octave band 1 has a center frequency of 63 Hertz.

Top
Sound Pressure (dB)

Octave Band	Distance 5 ft.	50 ft.
1	85	74
2	86	74
3	84	74
4	81	68
5	78	63
6	72	59
7	68	54
8	67	51
A-wgtd	**83**	**70**

Air Inlet
Sound Pressure (dB)

Octave Band	Distance 5 ft.	50 ft.
1	82	68
2	83	67
3	82	69
4	75	65
5	69	60
6	63	52
7	58	46
8	55	43
A-wgtd	**77**	**66**



End
Sound Pressure (dB)

Octave Band	Distance 5 ft.	50 ft.
1	78	72
2	79	66
3	76	68
4	69	62
5	65	57
6	57	49
7	50	43
8	48	39
A-wgtd	**72**	**64**

End
Sound Pressure (dB)

Octave Band	Distance 5 ft.	50 ft.
1	78	72
2	79	66
3	76	68
4	69	62
5	65	57
6	57	49
7	50	43
8	48	39
A-wgtd	**72**	**64**

Air Inlet
Sound Pressure (dB)

Octave Band	Distance 5 ft.	50 ft.
1	82	68
2	83	67
3	82	69
4	75	65
5	69	60
6	63	52
7	58	46
8	55	43
A-wgtd	**77**	**66**

Sound Power (dB)

Octave Band	Center Frequency (Hertz)	Lw
1	63	103
2	125	101
3	250	102
4	500	97
5	1000	92
6	2000	86
7	4000	81
8	8000	78

Note: The use of frequency inverters (variable frequency drives) can increase sound levels.

Fundamentals of Sound

Appendix E: Figures For Single Air Intake Units

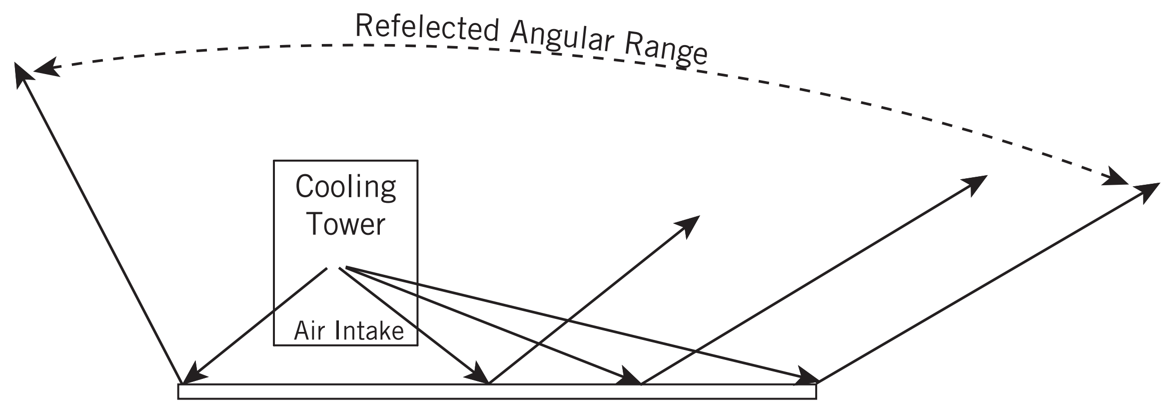
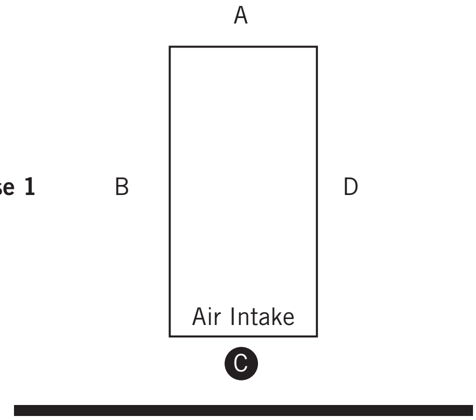


Figure B1. Neighbor area influenced by the reflecting wall

In **Cases 1-10**, a few representative reflecting walls are shown for various orientations, and approximate sound pressure level adjustments are suggested for **A, B, C,** and **D** directions away from the equipment. These adjustments should be made using the 50 ft (15.2 m). **Cases 1-6 apply to units having one air intake, while Cases 7-10 apply to units having two air intakes. Cases 11-13 apply to PT2, PFi and PCC units which have air intakes on all four sides.**

As an example, for Case 1, if the neighbor is located off the A side of the unit, apply the “A” adjustment to the A side 50 ft (15.2 m) sound pressure level rating of the unit and then correct as necessary to the neighbor’s distance. If the situation is that of Case 9 and the neighbor is located in the direction D, then the “D” adjustment would be utilized to arrive at a 50 ft sound pressure level for the unit.

Case 1



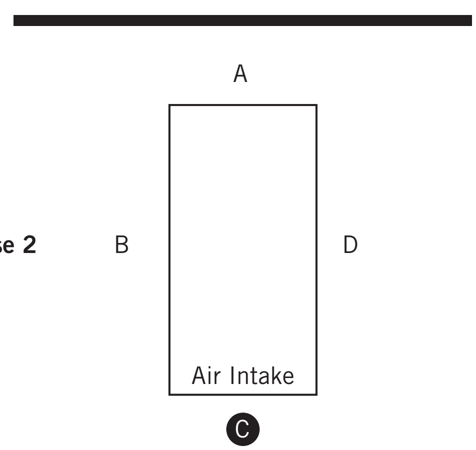
A. Use average of A and C levels

B. Use average of B and C levels

C. Not applicable

D. Use average of D and C levels

Case 2



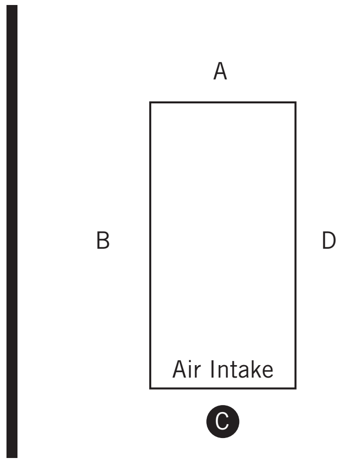
A. Not applicable

B. Use greater of B level or average of B and A levels

C. No change to C levels

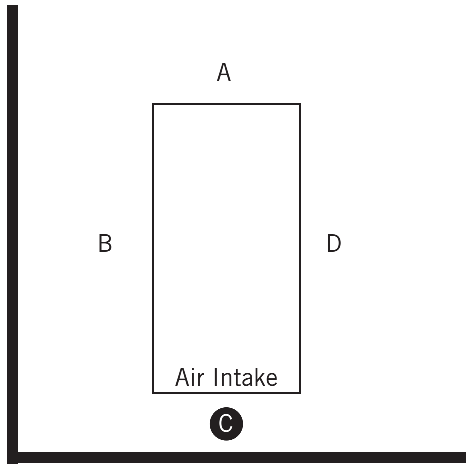
D. Use greater of D level or average of D and A levels

Case 3



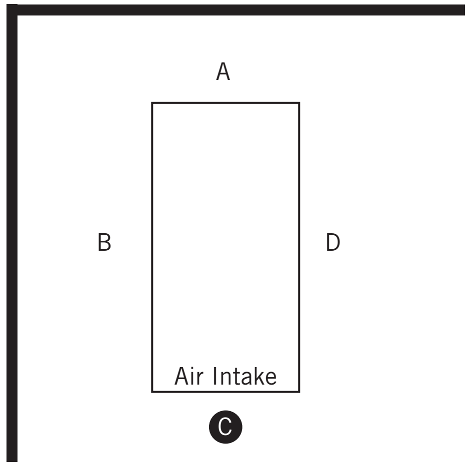
A. Use greater of A level or average of A and B levels
B. Not applicable
C. No change to C levels
D. Add 2 dB to D levels

Case 4



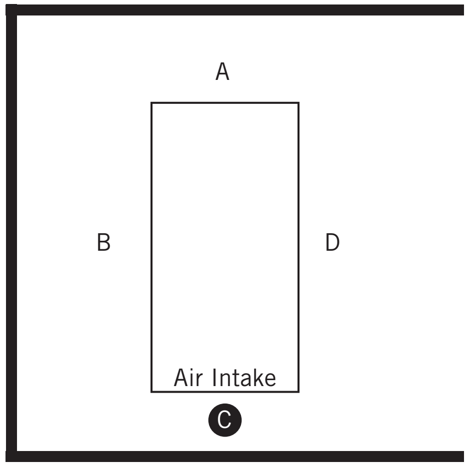
A. Use average of A and C levels
B. Not applicable
C. Not applicable
D. Use average of D and C levels

Case 5



A. Not applicable
B. Not applicable
C. No change to C levels
D. Use average of A, C, D levels

Case 6

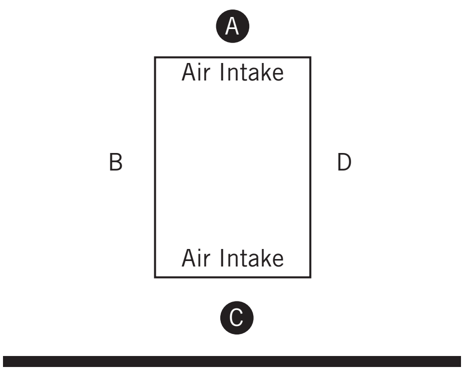


For sound levels out the open end of a 3-sided enclosure, add 3 dB to the sound pressure levels of the air intake side of the unit.

Fundamentals of Sound

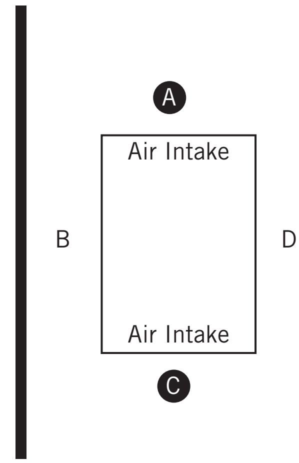
Appendix E: Figures For Dual Air Intake Units

Case 7



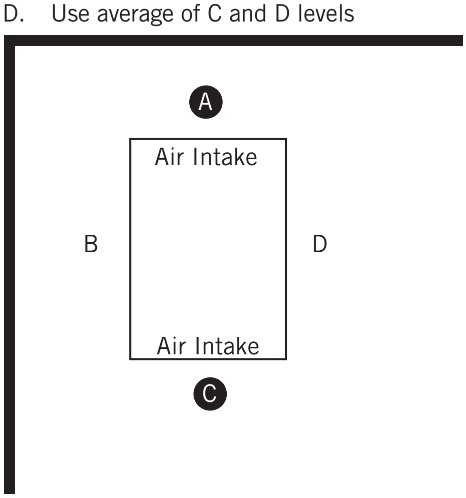
A. Add 2 dB to A levels
B. Use average of B and C levels
C. Not applicable
D. Use average of C and D levels

Case 8



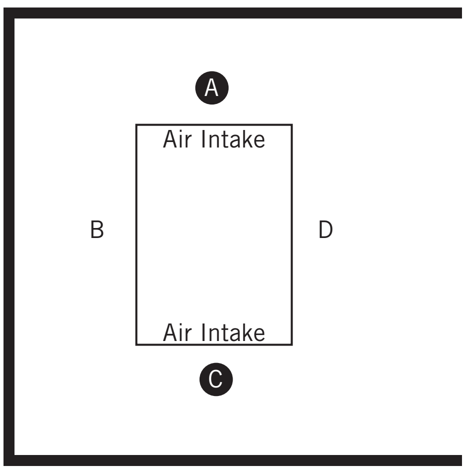
A. No change to A levels
B. Not applicable
C. No change to C levels
D. Add 3 dB to D levels

Case 9



A. Not applicable
B. Not applicable
C. Add 2 dB to C levels
D. Add 3 dB to D levels

Case 10

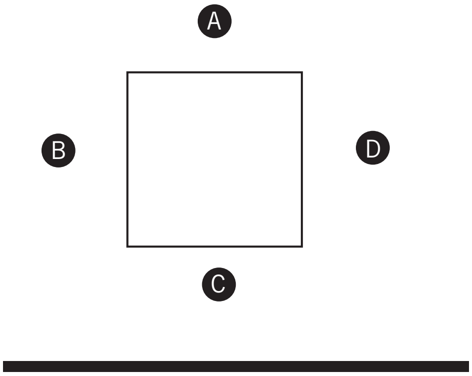


For sound levels out the open end of a 3-sided enclosure, add 3 dB to the sound pressure levels of the air intake side(s) of the unit.

These figures and their associated adjustment values are to be used to correct base 50 ft sound pressure level ratings in the neighbor direction for the effect of the reflecting surface conditions shown. Instructions on when and how to do so are presented on **page J68**.

Appendix E: Figures For PT2, PFi, and PCC Quad Intake Units

Case 11



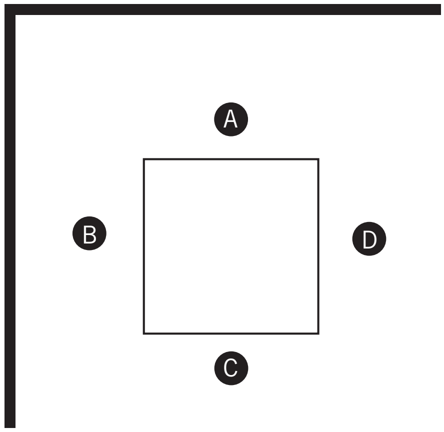
A. Add 3 dB to A levels

B. Add 2 dB to B levels

C. Not applicable

D. Add 2 dB to D levels

Case 12



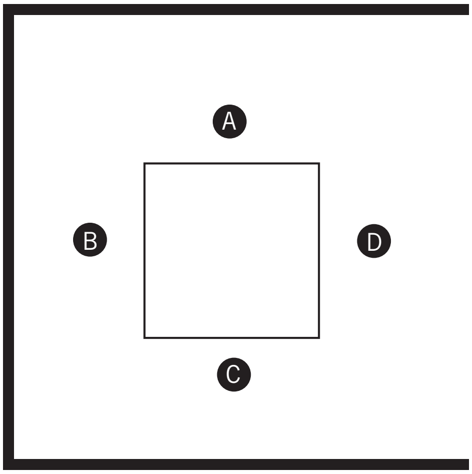
A. Not applicable

B. Not applicable

C. Add 3 dB to C levels

D. Add 3 dB to D levels

Case 13



For sound levels out the open end of a 3-sided enclosure, add 5 dB to the sound pressure levels of D, the exposed air intake side of the unit.

NOTE: PT2, PFi, and PCC units have air intakes on all four sides.

Fundamentals of Sound

Appendix F1

BAC Sound Evaluation Worksheet: Sample Using the Running Example from Page J65 to J72

Job Name Example

Address

Architect

Date

Engineer

BAC Unit

Steps	Items	Octave Band Center Frequency in Hz							
		63	125	250	500	1000	2000	4000	8000
Noise Criterion	1. Determine appropriate "NC" Criterion for neighbor activity from ASHRAE Handbook or **Table 3** of this section.	NC =30							
	2. Insert sound pressure levels (Lp) for selected "NC" Criterion (Obtain values from **Table 4**).	57	48	41	35	31	29	28	27
	3. Tabulate sound reduction provided by wall construction (Obtain values from **Table 5**).	10	10	10	10	10	10	10	10
	4. Establish tentative outdoor Noise Criterion for the unit (Item 2 plus Item 3).	67	58	51	45	41	39	38	37
	5. List average minimum outdoor background sound levels (Measured, or estimated from **Figure 3** and **Tables 6** and **7**).	60	57	52	47	42	38	34	32
	6. Set final outdoor background Noise Criterion (high value, by octave band, of Items 4 and 5).	67	58	52	47	42	39	38	37
Sound Levels	7. Enter unit sound pressure level rating at 300 ft from the BAC selection program. This sample uses the End L_p ratings from the data sheet provided in **Appendix D.**	55	49	51	45	41	32	27	23
	8. Apply reflection adjustment to meet condition existing at unit site. Refer to **Appendix E** for the effects of reflecting of walls; or add 5dB for close-in build up of noise; 0 dB if no reflection effects.	0	0	0	0	0	0	0	0
	9. Tabulate resultant unit Lp at critical neighbor location (Item 7 plus Item 8).	55	49	51	45	41	32	27	23
Comparison, Criteria vs Levels	10. Copy item 6 levels from above. This is the outdoor noise criterion for the critical neighbor.	67	58	52	47	42	39	38	37
	11. Ascertain tentative sound reduction required for unit (Item 9 minus Item 10). Insert "0" for negative values.	12	9	1	2	1	7	11	14
	12. Apply judgement factor (For conservative approach, use "0" in all bands. To permit unit noise to exceed background levels slightly, insert "5").	0	0	0	0	0	0	0	0
	13. Tabulate final sound reduction requirement for the job (Item 11 minus Item 12).	12	9	1	2	1	7	11	14

Appendix F2

BAC Sound Evaluation Worksheet

Job Name ______________________ **Date** ______________________

Address ______________________ **Engineer** ______________________

Architect ______________________ **BAC Unit** ______________________

Steps	Items	Octave Band Center Frequency in Hz							
		63	125	250	500	1000	2000	4000	8000
Noise Criterion	1. Determine appropriate "NC" Criterion for neighbor activity from ASHRAE Handbook or **Table 3** of this section.	**NC =**							
	2. Insert sound pressure levels (Lp) for selected "NC" Criterion (Obtain values from **Table 4**).								
	3. Tabulate sound reduction provided by wall construction (Obtain values from **Table 5**).								
	4. Establish tentative outdoor Noise Criterion for the unit (Item 2 plus Item 3).								
	5. List average minimum outdoor background sound levels (Measured, or estimated from **Figure 3** and **Tables 6** and **7).**								
	6. Set final outdoor background Noise Criterion (high value, by octave band, of Items 4 and 5).								
Sound Levels	7. Enter unit sound pressure level rating at 300 ft from the BAC selection program. Enter the unit sound pressure level at the desired distance from the BAC Selection Software.								
	8. Apply reflection adjustment to meet condition existing at unit site. Refer to **Appendix E** for the effects of reflecting of walls; or add 5dB for close-in build up of noise; 0 dB if no reflection effects.								
	9. Tabulate resultant unit Lp at critical neighbor location (Item 7 plus Item 8).								
Comparison, Criteria vs Levels	10. Copy item 6 levels from above. This is the outdoor noise criterion for the critical neighbor.								
	11. Ascertain tentative sound reduction required for unit (Item 9 minus Item 10). Insert "0" for negative values.								
	12. Apply judgement factor (For conservative approach, use "0" in all bands. To permit unit noise to exceed background levels slightly, insert "5").								
	13. Tabulate final sound reduction requirement for the job (Item 11 minus Item 12).								

Layout Guidelines

Included are the design layout guidelines for evaporative cooling products in several situations typically encountered by designers. These guidelines represent minimum spacing requirements. If available, greater spacing should be utilized whenever possible.

Overview

Operational efficiency of evaporative cooling equipment depends upon an adequate supply of fresh, ambient air to provide design capacity. Other important considerations, such as the proximity to building air intakes or discharges, also must be taken into account when selecting and designing the equipment site.

As the size of an installation increases, the total amount of heat being rejected into the atmosphere and the volume of discharge air increases — to the point where the units can virtually create their own environment. As a result, it becomes increasingly difficult to apply a set of general guidelines to each case. In such installations, particularly those in wells or enclosures, some air will recirculate. The recirculation should be minimized or design wet-bulb temperature must be adjusted to allow for the recirculation. Consequently, any job that involves four or more cells should be referred to your local BAC Representative for review.

Axial fan units are not generally suited for indoor or ducted applications. In such situations, a Series V centrifugal fan unit is recommended.

This section covers the general layout guidelines for the following BAC products:

1. Series 3000 Cooling Towers
2. Series 1500 Cooling Towers
3. FXT Cooling Towers
4. Series V Cooling Towers, Closed Circuit Cooling Towers, and Evaporative Condensers
5. FXV Closed Circuit Cooling Towers
6. HXV Hybrid Closed Circuit Cooling Towers
7. CXVB and CXVT Evaporative Condensers

For PT2, PFi and PCC layout guidelines, see **page J108**.

?

DID YOU KNOW?

As the size of an installation increases, the total amount of heat being rejected into the atmosphere and the volume of discharge air increases — to the point where the units can virtually create their own environment.

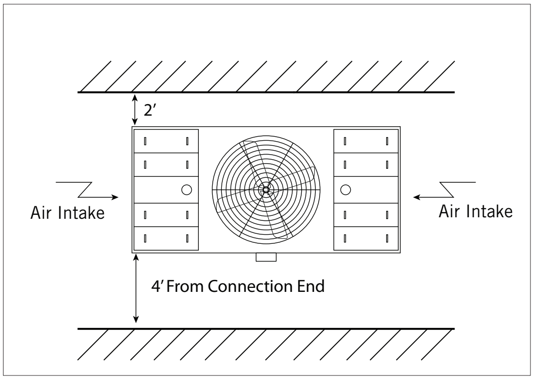


Figure 1a. Plan View of the Recommended Unit Servicing and Maintenance Spacing for a Dual Air Intake Unit: Series 3000 Cooling Towers, Dual Air Intake FXV Closed Circuit Cooling Towers, and CXVT Evaporative Condensers (Series 3000 Cooling Tower Shown)

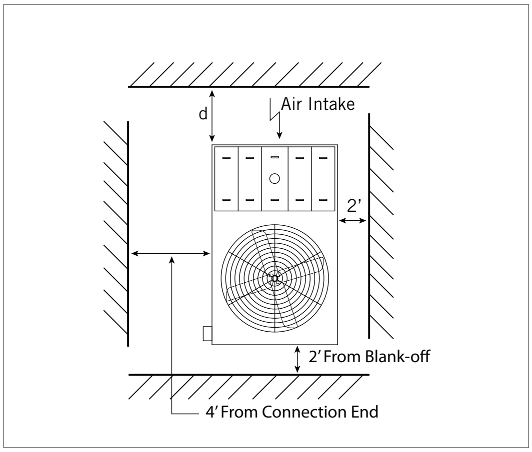


Figure 1b. Plan View of Recommended Unit Servicing and Maintenance Spacing for Single Air Intake Units: Series 1500 Cooling Towers, FXV Closed Circuit Cooling Towers, CXV Evaporative Condensers, and Series V Cooling Towers[1], Closed Circuit Cooling Towers, and Evaporative Condensers (Series 1500 Cooling Tower Shown)

NOTE: 1. On Models VT0-12 through 176, VC1-10 through 205, VF1-009, 018, 027, 036, and VF1-048 clearance equal to the length of the unit should be provided on one end to facilitate fan shaft removal.

General Considerations

When selecting the site, consider the following factors:

1. Locate the unit to prevent the warm discharge air from being introduced into the fresh air intakes of the unit's building(s), intakes of neighboring buildings, or from being carried over any populated area such as a building entrance.
2. Consider the potential for plume formation and its effect on the surroundings, such as large windowed areas, and pedestrian or vehicular traffic arteries, particularly if the unit(s) will be operated during low ambient temperatures.
3. Provide sufficient unobstructed space around the unit(s) to ensure an adequate supply of fresh, ambient air to the air intake. Avoid situations that promote recirculation of unit discharge air, such as units located:
   a. Adjacent to walls or structures that might deflect some of the discharge airstream back into the air intake.
   b. Where building air intakes or exhausts, such as boiler stacks in the vicinity of the unit, might raise the intake wet-bulb temperature or starve the unit of air.
4. Provide adequate space around the unit for piping and proper servicing and maintenance, as shown in **Figures 1a, 1b, and 1c**.
5. If applicable the top of the fan discharge cylinder, velocity recovery stack, or discharge sound attenuation must be at least level with, and preferably higher than, any adjacent walls or buildings.
6. Orient the unit so the prevailing summer wind blows the discharge air away from the air intakes of the unit(s).
7. When the unit is installed with intake sound attenuation, the distances given in the **Tables 1-12** on pages **J92-J95** below should be measured from the face of the intake sound attenuation.
8. On larger unit installations, the problem of ensuring an adequate supply of fresh, ambient air to the tower intakes becomes increasingly difficult. See the "Multi-Cell Installation" section on **page J104.**
9. If the installation does not meet the recommended guidelines, the units will have a greater tendency to recirculate, and the design conditions should be altered to include an allowance for the recirculation. For instance, if the design conditions are 95°F/85°F/78°F (36.7°C/29.4°C/25.6°C) and it was estimated that the allowance for recirculation rate was 1 degree Fahrenheit (.56 degrees Celsius), then the new design conditions would be 95°F/85°F/79°F (36.7°C/29.4°C/26.1°C), and the units should be re-selected based on the new design conditions.

Layout Guidelines

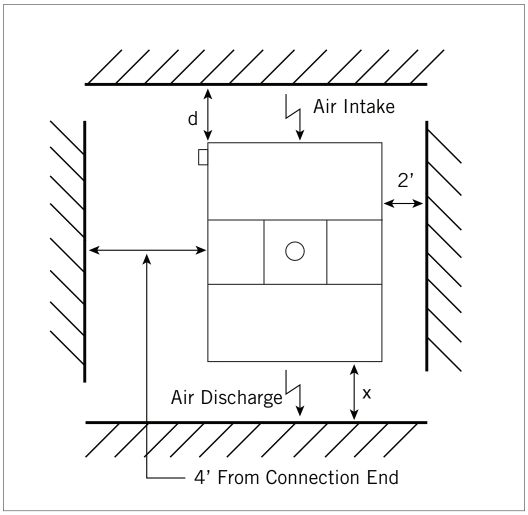


Figure 1c. Plan View of Recommended Unit Servicing and Maintenance Spacing for FXT Cooling Towers

The "Layout Guidelines" describe several typical site layouts for BAC's cooling towers, closed circuit cooling towers, and evaporative condensers. If these guidelines do not cover a particular situation or if the layout criteria cannot be met, please refer the application to your BAC Representative for review. Please indicate prevailing wind direction, geographic orientation of the unit(s), and other factors such as large buildings and other obstructions that may influence layout decisions.

Installations Adjacent to a Building or Wall(s)

1. **Unit Orientation:** When a unit is located near a building wall, the preferred arrangement is to have the unit situated with the cased end or blank-off side (unlouvered side) facing the adjacent wall or building.
2. **Air Intake Requirements**: Should it be necessary to install a unit with the air intake facing a wall, provide at least distance "d" between the air intake and the wall, as illustrated in **Figures 2a** and **2b**.

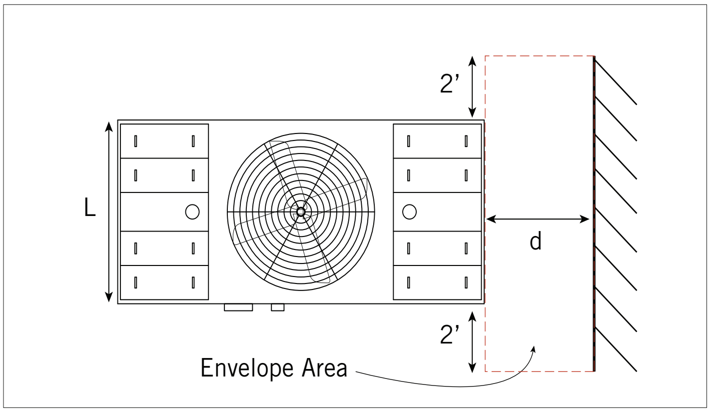


Figure 2a. Plan View of a Dual Air Intake Unit Adjacent to Wall

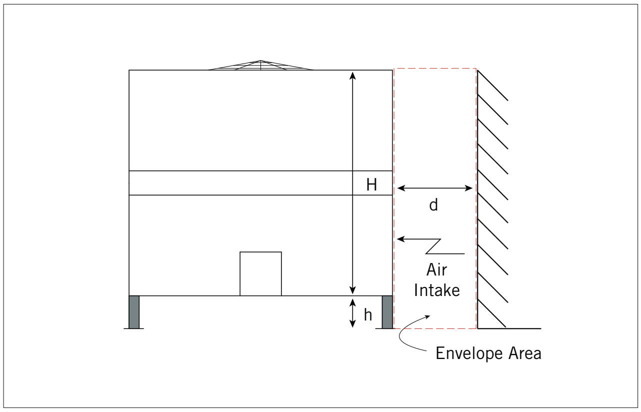


Figure 2b. Elevation View of a Dual Air Intake Unit Adjacent to Wall

Below is the method for determining the minimum acceptable dimension “d” for a unit located with the air intake facing a solid wall:

The maximum acceptable envelope air velocity is 300 FPM[3], as illustrated in the following equation:

Envelope Velocity = Airflow / Envelope Area $\leq$ 300 FPM

The envelope area as illustrated on **Figures 2a** and **2b** on **page J90** is [(L +2 +2) * d] + [2(H+h) * d], where:

“H” – Height of the air intake face in feet

“h” – Elevation of the unit from the roof/ground/pad in feet. The maximum "h" value is 4'. For units installed at height greater than 4' use h = 4.

“L” – Length of the air intake in feet

“d” – Minimum acceptable distance between the wall and the air intake face in feet

“x” – Minimum acceptable distance between wall and discharge face in feet (FXT only)[2]

$$\text{Therefore, } d = \frac{\text{Airflow}^1}{300\,[L + 4 + 2\,(H+h)\,]}$$

The minimum acceptable dimension “d” for the products is tabulated in **Tables 1 through 12** on **pages J92-J95**. The distance “d” was calculated using the largest horsepower model in the box size.

NOTE:

1. The louver face airflow for the FXV Closed Circuit Cooling Towers and CXVB Evaporative Condensers is 70% of the total unit airflow. The remaining 30% of the airflow enter the unit through the top of the coil section.
2. Calculate "x" with same equation for "d" using discharge face dimensions.
3. If a Series V unit cannot be designed to meet these criteria, a tapered discharge hood can be used to increase the maximum allowable downward air velocity to 400 FPM.

Example: Model S3E-1424-12S Adjacent to a Solid Wall

What is the minimum distance required between the air intake of the **S3E-1424-12S** when installed facing a wall?

Unit Airflow = 262,850 CFM * 3 cells = 788,550 CFM

Note: Series 3000 units are dual air intake units, therefore the air intake airflow is half of the total unit airflow.

$$\text{Airflow} = \frac{\text{Unit Airflow}}{2} = \frac{788{,}550}{2}$$

Airflow = 394,275 CFM

H = 19’ 9”= 19.75’, h = 0’

L = 42’ 3”= 42.25’

Solving for “d”,

$$d = \frac{\text{Airflow}}{300\,[L+4+2(H+h)]}$$

$$d = \frac{394{,}275}{300\,[42.25 + 4 + 2\,(19.75 + 0)]}$$

$$d = 15.33'$$

This is rounded to the next 0.5’ increment. Therefore, the air intake should be located no less than 15.5’ from the solid wall.

Layout Guidelines

Example: Model VT1-415-R Adjacent to a Solid Wall

VT1-415-R with tapered discharge hood is installed adjacent to a solid wall. What is the minimum distance required between the air intake of the **VT1-415-R** when installed facing a wall?

Unit Airflow = 90,250 CFM

H = 8' 4"= 8.33'

h = 0'

L = 11' 8" = 11.67'

Note: With a tapered discharge hood, envelope velocity is increased to 400 FPM.

Solving for "d",

$$d = \frac{\text{Airflow}}{400\ [L+4+2(H+h)]}$$

$$d = \frac{90{,}250\ \text{CFM}}{400\ \text{FPM}\ [11.67 + 4 + 2(8.33 + 0)]}$$

$$d = 6.98'$$

This is rounded to the next 0.5' increment. Therefore, the air intake should be located no less than 7.0' from the solid wall.

Minimum Acceptable Air Intake Distance "d" (ft) to Solid Wall

Model Number	One Cell			Two Cell			Three Cell			Four Cell		
	h=0'	h=2'	h=4'	h=0'	h=2'	h=4'	h=0'	h=2'	h=4'	h=0'	h=2'	h=4'
S3E/XES3E-8518-05x	5.0	4.5	4.0	7.5	7.0	6.5	9.5	8.5	8.0	10.5	10.0	9.0
S3E/XES3E-8518-06x	5.5	5.0	4.5	8.5	8.0	7.5	11.0	10.0	9.5	12.0	11.5	11.0
S3E/XES3E-8518-07x	6.0	5.5	5.0	9.5	9.0	8.0	12.0	11.0	10.5	13.5	13.0	12.0
S3E/XES3E-1020-06x	5.5	5.0	4.5	8.5	8.0	7.5	10.5	10.0	9.5	12.0	11.5	10.5
S3E/XES3E-1020-07x	6.0	5.5	5.0	9.5	9.0	8.5	12.0	11.0	10.5	13.5	12.5	12.0
S3E/XES3E-1222-06x	6.0	5.5	5.0	9.0	8.5	8.0	11.0	10.5	9.5	12.0	11.5	11.0
S3E/XES3E-1222-07x	7.5	7.0	6.5	11.5	10.5	10.0	14.0	13.0	12.5	15.5	14.5	14.0
S3E/XES3E-1222-10x	8.0	7.5	7.0	12.5	12.0	11.0	15.5	15.0	14.0	18.0	17.0	16.5
S3E/XES3E-1222-12x	7.5	7.0	6.5	12.0	11.5	11.0	15.5	14.5	14.0	17.5	17.0	16.5
S3E/XES3E-1222-13x	7.5	7.0	6.5	12.0	11.5	11.0	15.5	14.5	14.0	17.5	17.0	16.5
S3E/XES3E-1222-14x	8.0	7.5	7.0	13.0	12.5	11.5	16.5	16.0	15.0	19.5	18.5	18.0
S3E/XES3E-1424-07x	8.0	7.5	7.0	12.0	11.0	10.5	14.0	13.5	12.5	15.5	15.0	14.5
S3E/XES3E-1424-12x	9.0	8.0	7.5	14.0	13.0	12.5	17.5	16.5	16.0	19.5	19.0	18.0
S3E/XES3E-1424-13x	8.5	8.0	7.5	14.0	13.0	12.5	17.0	16.5	16.0	19.5	19.0	18.0
S3E/XES3E-1424-14x	8.5	8.0	7.5	14.0	13.0	12.5	17.5	16.5	16.0	20.0	19.0	18.5

Table 1. Series 3000 Cooling Towers

NOTE: Refer to notes on Page J91 for calculation information.

Model Number	One Cell			Two Cell			Three Cell			Four Cell		
	h=0’	h=2’	h=4’	h=0’	h=2’	h=4’	h=0’	h=2’	h=4’	h=0’	h=2’	h=4’
S15E/XE15E-1285-06x	5.5	5	4.5	8.5	8	7	10.5	9.5	9	11.5	11	10.5
S15E/XE15E-1285-07x	6	5.5	5	9	8.5	8	11.5	10.5	10	13	12	11.5
S15E/XE15E-1285-09x	6	5	5	9.5	8.5	8	11.5	11	10	13.5	12.5	12
S15E/XE15E-1285-10x	6	5.5	5	9.5	9	8.5	12.5	11.5	11	14.5	13.5	13
S15E/XE15E-1212-07x	7.5	7	6	11	10	9.5	13	12.5	11.5	14.5	14	13
S15E/XE15E-1212-09x	7.5	7	6.5	11.5	11	10	14.5	13.5	13	16	15.5	14.5
S15E/XE15E-1212-10x	8	7.5	7	12.5	12	11	15.5	14.5	14	17.5	17	16
S15E/XE15E-1212-11x	8	7.5	7	12.5	11.5	11	15.5	14.5	14	17.5	17	16
S15E/XE15E-1212-12x	8	7	6.5	12.5	11.5	11	15.5	14.5	14	17.5	17	16
S15E/XE15E-1218-07x	9.5	8.5	8	13	12	11.5	15	14.5	13.5	16.5	15.5	15
S15E/XE15E-1218-09x	9.5	9	8.5	14	13.5	12.5	16.5	16	15	18	17.5	17
S15E/XE15E-1218-10x	10.5	9.5	9	15.5	14.5	14	18	17.5	16.5	20	19.5	18.5
S15E/XE15E-1218-11x	10.5	9.5	9	15.5	14.5	14	18.5	17.5	17	20.5	19.5	19
S15E/XE15E-1218-12x	10	9.5	9	15	14.5	13.5	18.5	17.5	17	20.5	19.5	19

Table 2. Series 1500 Cooling Towers

Model Number	No Discharge Hood			4’ Discharge Hood		
	h=0’	h=2’	h= 4’	h=0’	h=2’	h= 4’
VT0-12-E to VT0-176-O	5	6	3	3.5	3	3
VT1-N209-P to VT1-N255-P	6.5	6	5	5	4.5	4
VT1-N301-Q to VT1-N395-R	8	7.5	6.5	6	5.5	5
VT1-N418-P to VT1-N510-P	9	8.5	7.5	7	6.5	6
VT1-M316-O to VT1-M420-R	8.5	7.5	6.5	6.5	5.5	5
VT1-M431-O to VT1-M610-R	10.5	9.5	8.5	8	7	6.5
VT1-M632-O to VT1-M840-R	12	11	10	9	8.5	7.5
VT1-M948-O to VT1-M1260-R	14	13.5	12.5	11	10	9.5
VT1-275-P to VT1-415-R	9	8.5	7.5	7	6.5	6
VT1-416-O to VT1-600-P	11.5	10.5	9	8.5	8	7
VT1-550-P to VT1-830-R	13.5	12.5	11.5	10	9.5	8.5
VT1-825-P to VT1-1335-S	17	16	15	13	12	11.5

Table 4. VT0 and VT1 Cooling Towers

Model Number	No Discharge Hood			4’ Discharge Hood		
	h=0’	h=2’	h=4’	h=0’	h=2’	h=4’
VTL-016-E to VTL-039-H	3	3	3	3	3	3
VTL-045-H to VTL-079-K	3	3	3	3	3	3
VTL-082-K to VTL-095-K	3	3	3	3	3	3
VTL-103-K to VTL-137-M	4.5	3.5	3	3	3	3
VTL-152-M to VTL-227-O	6	5	4.5	4.5	4	3
VTL-245-P to VTL-272-P	7	6	5.5	5	4.5	4

Table 5. VTL Cooling Towers

Layout Guidelines

Minimum Acceptable Air Intake Distance “d” (ft) to Solid Wall

NOTE:

1. "d" value was calculated using the largest horsepower motor available.
2. Max "h" value is 4'. For units installed at height greater than 4' use "d" value for h = 4.

Model Number	One Cell						
	h=0'	h=2'	h=4'	Model Number	h=0'	h=2'	h=4'
FXV-0806A, 0806B	4	3.5	3	FXV-0818B	8	7.5	7
FXV-0809A	5	4	3.5	FXV-1212B	7.5	6.5	6
FXV-0809B	5	4.5	4	FXV-1212C	8	7	6.5
FXV-0812A	6	5	4.5	FXV-1218B	9.5	8.5	8
FXV-0812B	6.5	5.5	5	FXV-1218C	10	9	8.5
FXV-0818A	7	6.5	6				

Table 6. FXV Closed Circuit Cooling Towers

Model Number	One Cell			Two Cell		
	h=0'	h=2'	h=4'	h=0'	h=2'	h=4'
CXVB-X-0806-X	4	3.5	3	—	—	—
CXVB-X-0809-X	5	4.5	4	—	—	—
CXVB-X-0812-X	6	5.5	5	—	—	—
CXVB-X-0818-X	8	7	6.5	—	—	—
CXVB-X-1212-X	7.5	7	6.5	11.5	10.5	10
CXVB-X-1218-X	9.5	9	8.5	13.5	13	12

Table 7. CXVB Evaporative Condensers

Model Number	h=0'		h=2'		h=4'	
	x	d	x	d	x	d
FXT-58, 68	3	3	3	3	3	3
FXT-74, 87, 95	4	4	3.5	3.5	3	3
FXT-115, 130, 136	5	5	4.5	4.5	4	4
FXT-160, 175, 192	6.5	6.5	5.5	5.5	5	5
FXT-216, 240, 257	6.5	6.5	6	6	5.5	5.5

Table 3. FXT Cooling Towers

FXV Dual Air Intake Model Number	CXVT Dual Air Intake Model Number	One Cell			Two Cell		
		h=0'	h=2'	h=4'	h=0'	h=2'	h=4'
FXV-288-XXX	CXVT-x-1224-x and XECXVTx-1224-x	7.5	6.5	6	13.5	10	9.5
FXV-364-XXX	CXVT-x-1426-x and XECXVTx-1426-x	10.5	10	9.5	13.5	13	12.5
—	CXVT-x-2424-x and XECXVTx-2424-x	—	—	—	11	10	9.5
—	CXVT-x-2826-x and XECXVTx-2826-x	—	—	—	13.5	13	12.5

Table 8. FXV and CXVT Dual Air Intake Units

Model Number		No Discharge Hood			4' Discharge Hood		
		h=0'	h=2'	h=4'	h=0'	h=2'	h=4'
VF1-009-XXX	VC1-10 to 25	3	3	3	3	3	3
VF1-018-XXX	VC1-30 to 65	3	3	3	3	3	3
VF1-027-XXX	VC1-72 to 90	3	3	3	3	3	3
VF1-036-XXX	VC1-100 to 135	4	3.5	3	3	3	3
VF1-048-XXX	VC1-150 to 205	5	4.5	4	3.5	3	3
VF1-072-XXX	VC1-N208 to N230	6.5	5.5	5	5	4	3.5
VF1-096-XXX	VC1-N243 to N315	7	6	5.5	5	4.5	4
VF1-144N-XXX	VC1-N338 to N470	7	6.5	6	5	4.5	4
VF1-192-XXX	—	10	9	8	7	6.5	6
VF1-288N-XXX	—	9.5	8.5	8	7	6.5	6
VF1-144-XXX	VC1-386 to 516	10	9	8	7.5	6.5	6
VF1-216-XXX	VC1-540 to 804	13	11.5	10.5	9.5	8.5	8
VF1-288-XXX	VC1-772 to 1032	13.5	12.5	11.5	10	9.5	8.5
VF1-432-XXX	VC1-1158 to 1608	17.5	16	15	13	12	11.5
—	VC1-C216 to C320	6	5.5	5	4.5	4	3.5
—	VC1-C339 to C469	7	6.5	6	5.5	5	4.5

Table 9. VF1 and VC1 Units

Model Number	No Discharge Hood		
	h=0'	h=2'	h=4'
VCA-122A to 191A	3.5	3	3
VCA-174A to 259A	5.5	5	4.5
VCA-261A to 322A	5	4.5	4
VCA-323A to 446A	6	5.5	5
VCA-300A to 512A	7	6.5	6
VCA-460A to 779A	9	8.5	7.5
VCA-662A to 1024A	10.5	10	9
VCA-S700A to S884A	10	9.5	8.5
VCA-920A to 1558A	12.5	12	11
VCA-302A to 661A	9	8	7.5
VCA-526A to 1010A	11.5	10.5	9.5
VCA-S870A to S1204A	13	12	11
VCA-605A to 1321A	13.5	12.5	11.5
VCA-930A to 2019A	15.5	14.5	14

Table 10. VCA Evaporative Condensers

Model Number		No Discharge Hood			4' Discharge Hood		
		h=0'	h=2'	h=4'	h=0'	h=2'	h=4'
VFL-012-XXX	VCL-016 to 035	3	3	3	3	3	3
VFL-024-XXX	VCL-038 to 079	3	3	3	3	3	3
VFL-036-XXX	VCL-087 to 120	4.5	3.5	3	3	3	3
VFL-048-XXX	VCL-134 to 155	4.5	4	3.5	3.5	3	3
VFL-072-XXX	VCL-167 to 234	6	5.5	5	4.5	4	3.5
VFL-096-XXX	VCL-257 to 299	7	6.5	5.5	5.5	5	4.5

Table 11. VFL and VCL Units

Model Number	One Cell		
	h=0'	h=2'	h=4'
HXV-64X	6	5.5	5
HXV-66X	7.5	7	6

Table 12. HXV Hybrid Closed Circuit Cooling Towers

Layout Guidelines

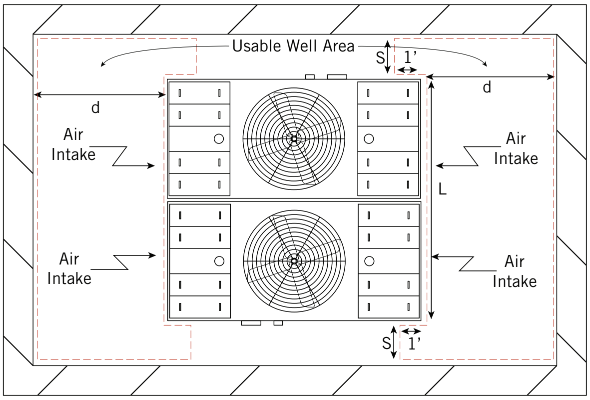


Figure 5. Plan View of Dual Air Intake Unit in a Well Enclosure

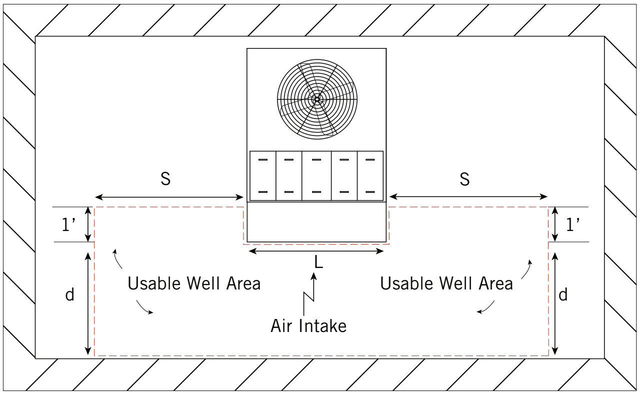


Figure 6. Plan View of Single Air Intake Unit in a Well Enclosure

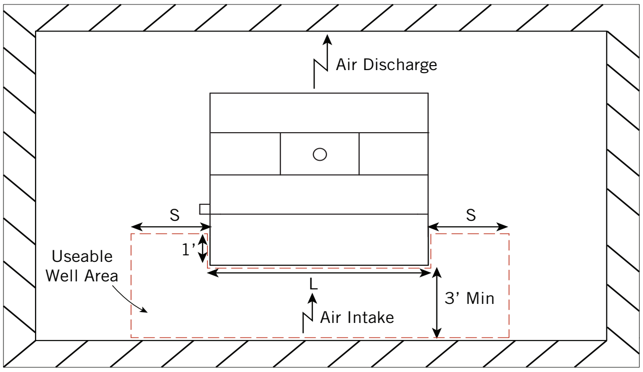


Figure 7. Plan View of Single Air Intake And Horizontal Discharge Units in a Well Enclosure

Well Layout

The following method is used to determine the minimum acceptable dimension "d" for units installed in a well layout.

The maximum allowable downward air velocity for a well installation is 400 FPM. The downward velocity is determined using the following equation:

Downward Air Velocity = Airflow / Useable Well Area ≤ 400 FPM

The useable well area at each air intake face is defined as illustrated in **Figures 5, 6, and 7**.

Usable Well Area = d (L+2s)+2(s * 1'), where:

"d" – minimum acceptable distance between the air intake of the unit and the wall of the well in feet

"L" – length of the air intake of the unit in feet

"s" – Distance usable well area extends beyond unit length (L). Maximum value for "s" is 4'. If greater than 4' clearance beyond the sides of the unit, use s = 4

$$\text{Therefore, } d = \frac{\left(\dfrac{\text{Airflow}^{1}}{400}\right) - 2s}{L + 2s}$$

The minimum acceptable distance "d" for well installations is tabulated in **Tables 12-23** on **pages J98-J100.**

NOTE:

1. The louver face airflow for the FXV Closed Circuit Cooling Towers and CXVB Evaporative Condensers is 70% of the total unit airflow. The remaining 30% of the airflow enters the unit through the top of the coil section.

Example: Model FXV-0809B-28D-M in a Well

What is the minimum distance between the air intake of the FXV-0809-28D-M and the enclosure wall of the well?

Unit Airflow = 56,670 CFM

Note: Air intake airflow is 70% of total unit airflow for FXV Closed Circuit Cooling Towers

Airflow = Unit Airflow * 0.70 = 56,670 * 0.70

Airflow = 39,669 CFM

L = 9'

s = 4'

Solving for "d",

$$d = \frac{\left(\frac{\text{Airflow}}{400}\right) - 2s}{L + 2s}$$

$$d = \frac{\left(\frac{39,669}{400}\right) - (2*4)}{9 + (2*4)}$$

$$d = 5.36'$$

This is rounded up to the next 0.5’ increment. Therefore the air intake should be no less than 5.5’ from the enclosure walls.

Example: Model VF1-144-31Q in a Well

If the VF1-144-31Q has a 4’ tapered discharge hood, what is the minimum distance between the air intake of the VF1-144-31Q and the enclosure wall in a well?

Unit Airflow = 86,500 CFM

L = 11’ 8”= 11.67’

s = 4'

400 FPM = maximum allowable air downward velocity for a VF1 with a tapered discharge hood

Solving for "d",

$$d = \frac{\left(\frac{\text{Airflow}}{400}\right) - 2s}{L + 2s}$$

$$d = \frac{\left(\frac{86,500}{400}\right) - (2*4)}{11.67' + (2*4)}$$

$$d = 10.59'$$

This is rounded up to the next 0.5’ increment. Therefore the air intake should be no less than 11’ from the enclosure walls.

Layout Guidelines

Minimum Acceptable Air Intake Distance “d” (ft) in a Well

NOTE:
1. "d" value was calculated using the largest horsepower motor available and 4' clearance on both sides of the units intake face.

Model Number	One Cell	Two Cell	Three Cell	Four Cell
S3E/XES3E-8518-05x	6.0	8.5	9.5	10.0
S3E/XES3E-8518-06x	7.5	10.5	11.5	12.5
S3E/XES3E-8518-07x	9.0	12.0	13.5	14.5
S3E/XES3E-1020-06x	7.5	10.0	11.0	12.0
S3E/XES3E-1020-07x	9.0	12.0	13.0	14.0
S3E/XES3E-1222-06x	8.0	10.0	11.0	11.5
S3E/XES3E-1222-07x	10.5	13.5	14.5	15.5
S3E/XES3E-1222-10x	13.5	17.0	19.0	19.5
S3E/XES3E-1222-12x	14.5	18.0	20.0	21.0
S3E/XES3E-1222-13x	14.5	18.5	20.5	21.5
S3E/XES3E-1222-14x	16.5	21.0	23.0	24.0
S3E/XES3E-1424-07x	10.5	13.5	14.5	15.0
S3E/XES3E-1424-12x	16.0	19.5	21.0	22.0
S3E/XES3E-1424-13x	16.5	20.0	22.0	22.5
S3E/XES3E-1424-14x	17.0	21.0	22.5	23.5

Table 12. Series 3000 Cooling Towers

Model Number	One Cell	Two Cell	Three Cell	Model Number	One Cell	Two Cell	Three Cell
S15E/XE15E-1285-06x	7.0	9.5	10.5	S15E/XE15E-1212-11x	13.5	17.0	18.5
S15E/XE15E-1285-07x	8.0	11.0	12.0	S15E/XE15E-1212-12x	13.5	17.5	19.0
S15E/XE15E-1285-09x	9.0	12.5	14.0	S15E/XE15E-1218-07x	11.0	13.5	14.0
S15E/XE15E-1285-10x	10.5	14.0	15.5	S15E/XE15E-1218-09x	13.0	15.5	17.0
S15E/XE15E-1212-07x	9.5	12.0	13.0	S15E/XE15E-1218-10x	15.0	18.0	19.0
S15E/XE15E-1212-09x	11.5	14.5	15.5	S15E/XE15E-1218-11x	15.5	18.5	19.5
S15E/XE15E-1212-10x	13.0	16.0	18.0	S15E/XE15E-1218-12x	16.0	19.0	20.5

Table 13. Series 1500 Cooling Towers

Minimum Acceptable Air Intake Distance “d” (ft) in a Well

Model Number	One Cell
FXT-58, 68	3.5
FXT-74, 87, 95	5
FXT-115, 130, 136	6
FXT-160, 175, 192	7
FXT-216, 240, 257	8.5

Table 14. FXT Cooling Towers

Model Number	One Cell
VTL-016-E to VTL-039-H	3
VTL-045-H to VTL-079-K	3
VTL-082-K to VTL-095-K	4
VTL-103-K to VTL-137-M	5.5
VTL-152-M to VTL-227-O	7
VTL-245-P to VTL-272-P	8.5

Table 15. VTL Cooling Towers with or without a Tapered Discharge Hood

Model Number	One Cell
VT0-12-E to VT0-176-O	4.5
VT1-N209-P to VT1-N255-P	6.5
VT1-N301-Q to VT1-N395-R	8
VT1-N418-P to VT1-N510-P	8.5
VT1-M316-O to VT1-M420-R	10
VT1-M431-O to VT1-M610-R	11.5
VT1-M632-O to VT1-M840-R	12.5
VT1-M948-O to VT1-M1260-R	14
VT1-275-P to VT1-415-R	11
VT1-416-O to VT1-600-P	12.5
VT1-550-P to VT1-830-R	14
VT1-825-P to VT1-1335-S	16.5

Table 16. VT0 and VT1 Cooling Towers with or without a Tapered Discharge Hood

Model Number	One Cell
FXV-0806A	3.5
FXV-0806B, FXV-0809A	5
FXV-0809B	5.5
FXV-0812A	6
FXV-0812B, FXV-0818A	7.5
FXV-0818B, FXV-1212B	9
FXV-1212C	10
FXV-1218B	10
FXV-1218C	11.5

Table 17. FXV Closed Circuit Cooling Tower

FXV Dual Air Intake Model Number	CXVT Model Number	One Cell	Two Cell
FXV-288-x	CXVT-x-1224-x and XECXVTx-1224-x	9.5	12.5
FXV-364-Xx	CXVT-x-1426-x and XECXVTx-1426-x	12	15
—	CXVT-x-2424-x and XECXVTx-2424-x	—	12.5
—	CXVT-x-2826-x and XECXVTx-2826-x	—	15

Table 18. FXV and CXVT Dual Air Intake Units

Model Number	One Cell	Two Cell
CXVB-X-0806-X	4.5	—
CXVB-X-0809-X	5.5	—
CXVB-X-0812-X	7	—
CXVB-X-0818-X	8	—
CXVB-X-1212-X	9.5	14
CXVB-X-1218-X	11	15

Table 19. CXVB Evaporative Condensers

Layout Guidelines

Model Number	One Cell
HXV-64X	7
HXV-66X	8.5

Table 20. HXV Hybrid Closed Circuit Cooling Tower

Model Number		One Cell
VCL-016 to 035	VFL-012-XXX	3
VCL-038 to 079	VFL-024-XXX	3
VCL-087 to 120	VFL-036-XXX	5.5
VCL-134 to 155	VFL-048-XXX	6
VCL-167 to 234	VFL-072-XXX	8
VCL-257 to 299	VFL-096-XXX	9

Table 21. VCL and VFL Units with or without a Tapered Discharge Hood

Model Number	One Cell
VCA-122A to 191A	3.5
VCA-174A to 259A	5.5
VCA-261A to 322A	6.5
VCA-323A to 446A	6.5
VCA-300A to 512A	9
VCA-460A to 779A	10.5
VCA-662A to 1024A	11
VCA-S700A to S884A	11
VCA-920A to 1558A	12.5
VCA-302A to 661A	11
VCA-526A to 1010A	13
VCA-S870A to S1204A	14
VCA-605A to 1321A	14
VCA-930A to 2019A	15.5

Table 22. VCA Evaporative Condensers

Model Number		One Cell
VC1-10 to 25	VF1-009-XXX	3
VC1-30 to 65	VF1-018-XXX	3
VC1-72 to 90	VF1-027-XXX	3
VC1-100 to 135	VF1-036-XXX	3
VC1-150 to 205	VF1-048-XXX	4.5
VC1-N208 to N230	VF1-072-XXX	6.5
VC1-N243 to N315	VF1-096-XXX	8
VC1-N338 to N470	VF1-144N-XXX	7.5
—	VF1-192-XXX	10
—	VF1-288N-XXX	9
VC1-386 to 516	VF1-144-XXX	11.5
VC1-540 to 804	VF1-216-XXX	14
VC1-772 to 1032	VF1-288-XXX	14.5
VC1-1158 to 1608	VF1-432-XXX	16.5
VC1-C216 to C320	—	6.5
VC1-C339 to C469	—	7

Table 23. VC1 and VF1 Units with or without a Tapered Discharge Hood

› Louvered or Slotted Wall Installations

Check to see if the layout meets the requirements for a well installation. If the criteria for the well installation are met, the layout is satisfactory. If the layout does not satisfy the criteria for the well installation, analyze the layout as follows:

1. **Air intake requirements:**
   a. Units should be arranged within the enclosure such that the air intake directly faces the louver or slot locations as shown in **Figures 8 and 9**, with a minimum distance of three feet.
   b. If the available space does not permit the unit to be arranged with the air intakes facing the louvered or slotted walls and the enclosure cannot be modified to permit such an arrangement, consider the alternative illustrated in **Figures 10 and 11** on the following page. This arrangement should be restricted to one-cell or two-cell installations. The usable area of the louvers is only the length extending beyond the width of the unit.
2. **Louver requirements:**
   c. Louvers must provide at least 50% net free area to ensure that the unit airflow is not reduced due to friction or dynamic losses and that sufficient air is drawn through the openings and not downward from above.
   d. The required total louver or slot area is based on drawing the airflow through the net free area of the louvers at a velocity of 600 FPM or less.
   e. Locate the louver area in the walls of the enclosure such that air flows uniformly to the air intakes.
   f. If the unit is elevated to ensure the discharge is at the same level or above the top of the enclosure, it is acceptable to extend the louvered or slot area below the base of the units up to 2' if needed to achieve the minimum gross louver area. To calculate air velocity through the louver, the usable louvered or slot area may extend beyond the ends of the unit by a value 1/2 the unit length (L), with 6' maximum on either side.

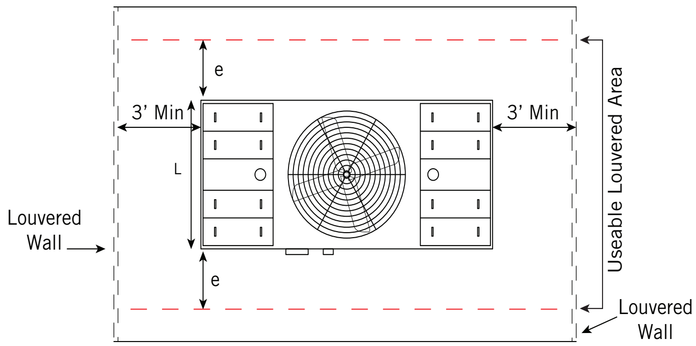


Figure 8. Plan View of Dual Air Intake Unit in Enclosure with Louvered Walls

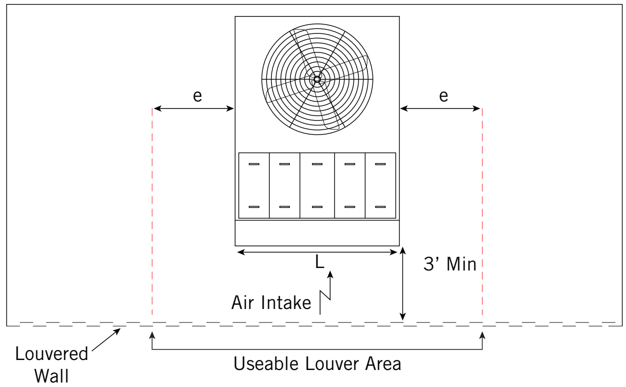


Figure 9. Plan View of Single Air Intake Unit in Enclosure with Louvered Walls

Layout Guidelines

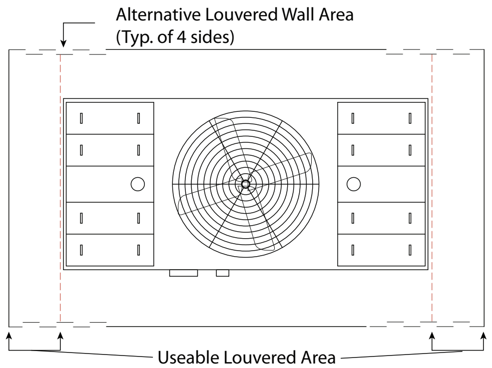


Figure 10. Plan View of Dual Air Intake Unit with Alternate Louver Arrangement

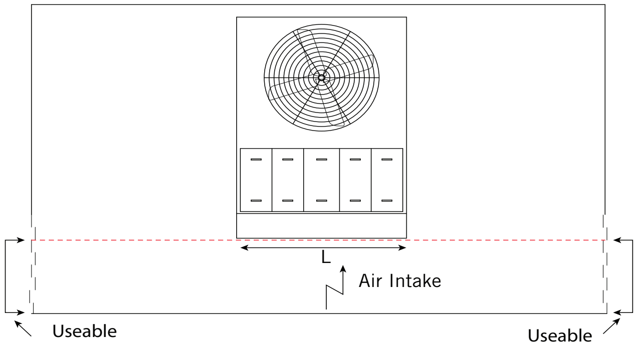


Figure 11. Plan View of Single Air Intake Unit with Alternate Louver Arrangement

Calculate the louver velocity as follows:

$$\text{Louver Velocity} = \frac{\text{Airflow}}{\text{\% Louver Free Area * Usable Louver Area}} \leq 600 \text{ FPM}$$

"e" - Distance usable louvered area may extend beyond unit length (L) as illustrated in **Figures 8 and 9.** The value for "e" is 1/2 the unit length (L), not to exceed 6'.

Example: S3E-1222-06M-2 in a Louvered Enclosure

The enclosure is 27.5' long by 38' wide by 10' tall. The enclosure walls are equal in elevation to the unit discharge height. The louvers are 70% free area and 3' 0" from the air intake of the tower. The louvers extend the full width of the enclosure (38') on both air intake ends and they extend 9' vertically of the 10' enclosure height.

Unit Airflow = 120,200 CFM x 2 cells = 240,400 CFM

Note: Series 3000 units are dual air intake units, therefore the air intake airflow is half of the total unit airflow.

Airflow = Total Unit Airflow/2 = 240,400/2 = 120,200 CFM

L = 23' 10" = 23.83', L/2 = 23.83'/2 = 11.9'

L/2 > 6', therefore e = 6'

Maximum Usable Louver Length = L + 2e = 23.83' + (2*6) = 35.83' (of total 38' louver length)

Area = 35.83*9 = 322.47 ft^2

$$\text{Louver Velocity} = \frac{\text{Airflow}}{\text{(\% Louver Free Area) * (Usable Louver Area)}}$$

$$= \frac{120{,}200}{0.70 * 322.47}$$

$$= 527 \text{ FPM}$$

Therefore, louver sizing is sufficient because 532 FPM < 600 FPM maximum allowable louver velocity.

› Indoor Installation Layout Guidelines: Applicable for Series V Centrifugal Fan Products Only (VTO, VT1, VTL, VF1, VC1, VCL, and VFL)

1. **Air intake requirements:**
    a. Louvers must have at least 50% net free area.
    b. Install the cooling tower with the limitations shown in **Figure 12** for uniform air distribution.
    c. Determine the total louver or slot area required based on drawing the total unit airflow through the net free area of the lovers at a velocity of 800 FPM or less.
    d. The louver or slot area should be located in the walls of the enclosure so that air flows uniformly to all air intakes.
    e. It is acceptable to extend the louvered or slot area below the base of the unit if needed to achieve the minimum gross free area. The usable louvered or slot area may also be extended beyond the ends of the tower by a maximum 4'.
    f. As a general rule, axial fan units cannot be located indoors.

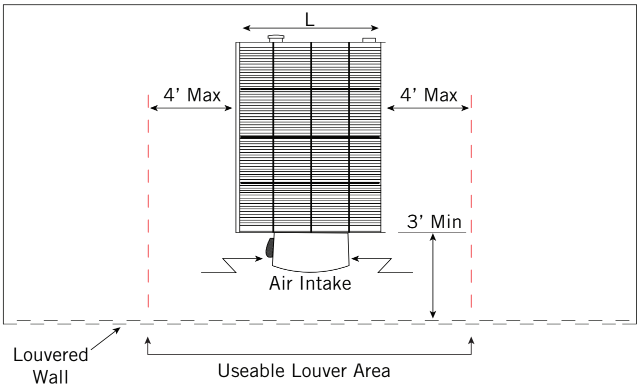


Figure 12. Plan View of Single Air Intake Unit in Enclosure with Louvered Walls and Closed Top Installation

2. **Ductwork requirements:**
    a. Air velocities in the intake duct should be kept below 800 FPM to hold static pressure losses to a minimum and ensure a uniform supply of air to all fans. In general the maximum allowable External Static Pressure (ESP) on Series V centrifugal fan units is 1/2". Consult the factory for any ESP greater than 1/2".
    b. Air velocities in the discharge duct(s) should not exceed 1,000 FPM to reduce friction losses in the duct, and more importantly, to ensure uniform air distribution through the unit.
    c. Turns in intake or discharge ducts should be avoided. Where turns must be used, velocities should be minimized in the vicinity of the turn. Turns in discharge ducting should be designed in accordance with the "2/3's rule" shown in **Figure 13a** and **13b**.
    d. Where individual fan sections are to be cycled for capacity control, each fan section must be ducted as a separate system on both intake and discharge to avoid recirculation within the ductwork. All ductwork systems should be symmetrical to ensure that each fan section operates against the same ESP.
    e. Access doors must be provided in both the intake and discharge ducts.
    f. When multi-cell units are located indoors with the room as the plenum, the installation must be operated as a single unit to avoid pulling air through an idle cell.

Layout Guidelines

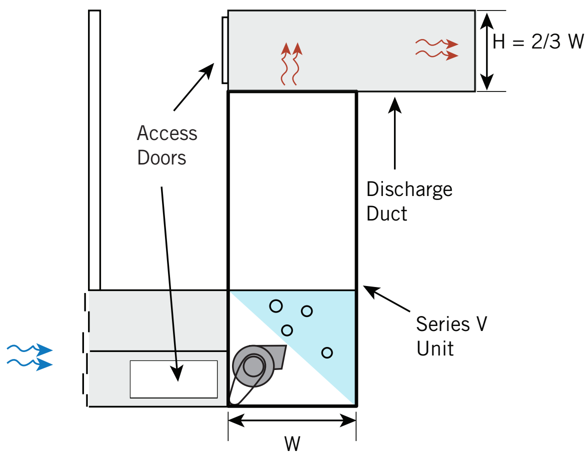


Figure 13a. Elevation Side View of Ducted Unit Enclosure

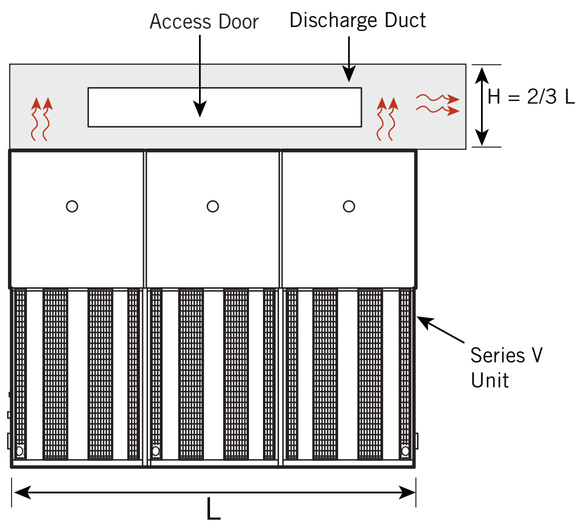


Figure 13b. Elevation Front View of Ducted Unit

Multi-Cell Installation

Multiple cells create a "wall" of moist discharge air which could easily be swept into the air intakes due to prevailing wind. To minimize the potential of recirculation of the discharge air, the units should be situated with adequate spacing between air intakes.

When multiple cells are arranged with the air intakes facing each other, the distance between air intakes should follow the equation below:

M = (2 * d) + (number of cells per module), where "d" is obtained from the appropriate model for "Installations Adjacent to a Building or Wall(s)" on **page J90-J92**.

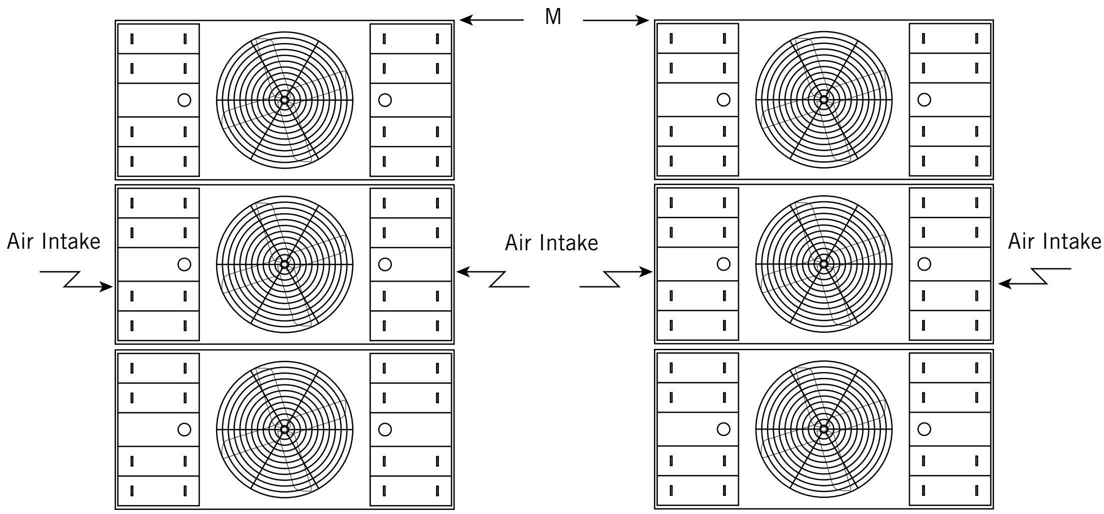


Figure 14. Plan View of Multi-Cell Units with Air Intakes Facing Each Other

Example: Model S3E-1222-14R (see Figure 14)

There are two banks of three cell unit modules on a roof. There are no enclosures surrounding the unit installation. The two banks of units have air intakes facing each other. What is the minimum distance "M" between banks of units?

From **Table 1** on **page J92**, d = 15'

M	=	(2 * d) + (number of units per module)
	=	(2 * 15) + 3
	=	33 feet

The calculated "M" dimension of 33 feet will minimize the potential for recirculation of the discharge air.

Group units in two cell or three cell modules, spaced at least one unit length between adjacent end walls to allow fresh air to circulate around each group, as shown in **Figure 15**.

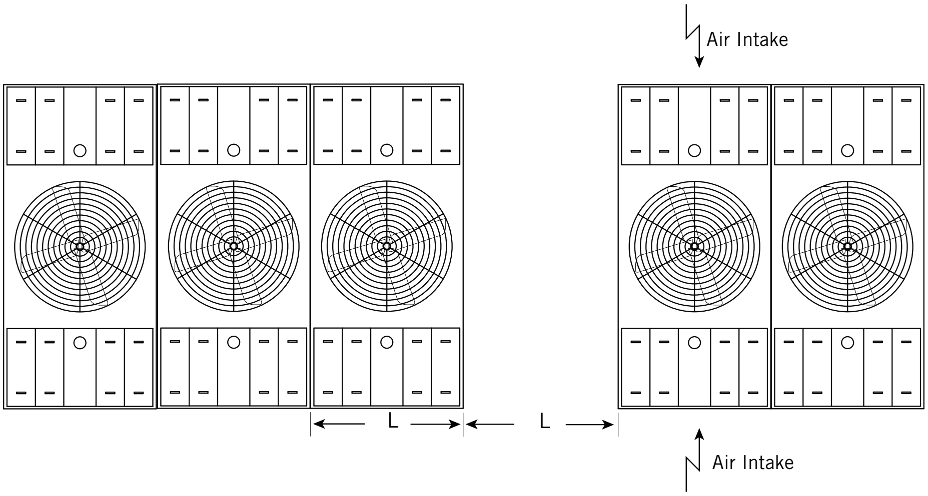


Figure 15. Plan View of Recommended Multi-cell Installation

In the extreme case, when multiple cells are arranged with the air intakes facing each other in a well, the dimensions between the cells should follow the following requirements.

1. **Enclosure:** The bottom 3 feet of the well should be louvered a minimum of 50% net free area to allow air flow under the units as shown in **Figure 17**.
2. **Support:** The units should be raised off the roof deck to allow fresh air to flow under to the air intakes between the bank of cells.
3. **The distance between the cells should be determined using the following method:**
   a. Determine the maximum airflow drawn from the louvered area using the following equation:
      CFM drawn through the louvers = Louver Velocity * % Louver Free Area * Usable Louver Area
      CFM drawn through the louvers = 600 FPM * % Louver Free Area * Usable Louver Area
   b. Determine the CFM drawn from the top of the enclosure using the following equation:
      CFM drawn from the top of the enclosure = 400 FPM * Usable Well Area

Layout Guidelines

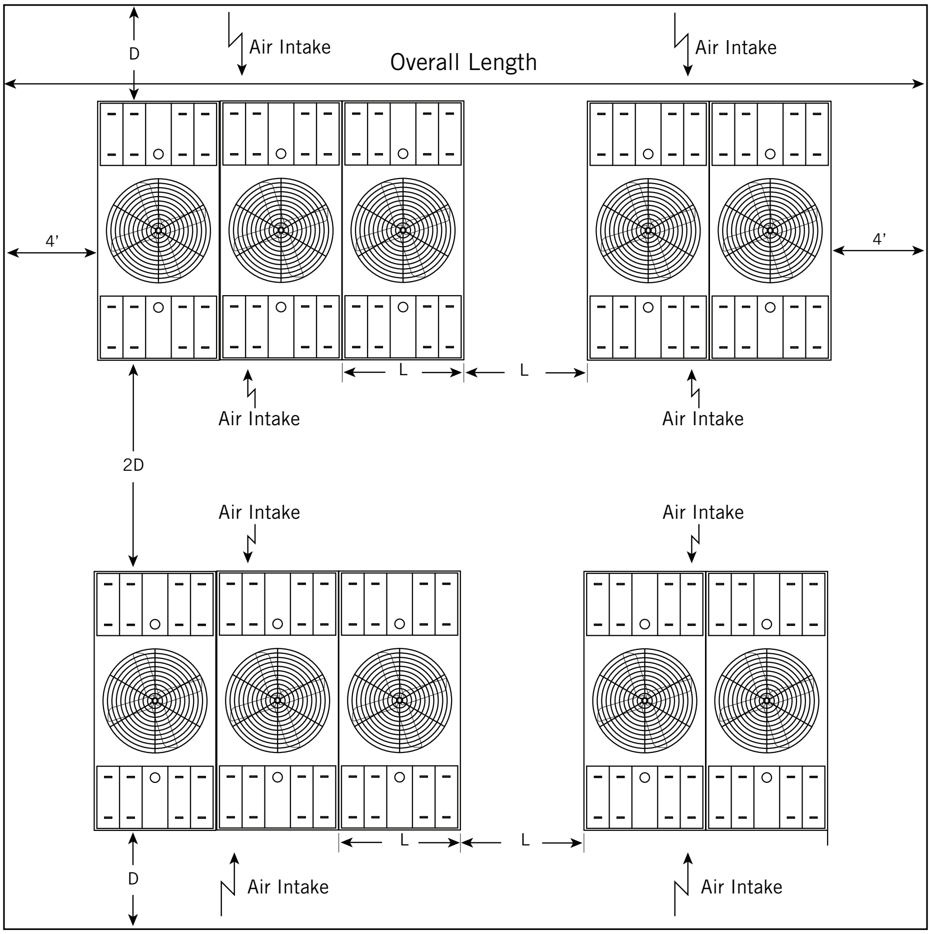


Figure 16. Plan View of Multi-cell Installation

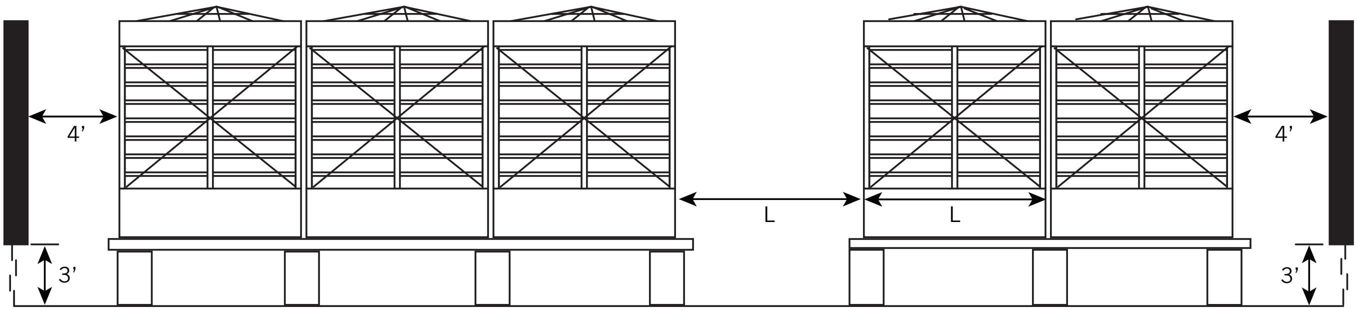


Figure 17. Elevation View of Recommended Enclosure

Example: (10) S3E-1222-14S (See Figure 16)

Bottom 3' of enclosure is louvered with 50% net free area. What is the minimum distance "D" between the banks of cells.

Unit Airflow = 244,030 CFM * 10 cells = 2,440,300 CFM

L = 11' 10" = 11.83'

Usable Length = (Number of cells * L) + (Number of Openings * L) + 4' + 4'

= (5 * 11.83) + (1 * 11.83) + 4 + 4
= 78.98' feet

Usable Width = 4D

CFM Drawn Through Louvers = Louver Velocity * % Louver Free Area * Usable Louver Area

= Louver Velocity * % Louver Free Area * Perimeter of the Enclosure * Height of Louvered Wall
= Louver Velocity * % Louver Free Area * [2(Usable Length + Usable Width) * Louver Height]
= 600 * 0.5 * [2(78.98 + 4D) * 3]
= 142,164 + 7,200D

CFM Drawn from Top of the Enclosure = Downward Velocity * Usable Area

= Downward Velocity * (Usable Length * Usable Width)
= 400 * 78.98 * 4D
= 400 * 4D * 80
= 126,368D

Total CFM = CFM Drawn through louvers + CFM Drawn from Top of the Enclosure

2,449,300 = 142,164 + 7,200D + 126,368D
133,568D = 2,298,136

D = 17.21'

The “Layout Guidelines” describe several typical site situations involving evaporative cooling products. If these guidelines do not cover a particular situation or if the layout criteria cannot be met, please refer the application to the your local BAC Representative for review. Please indicate prevailing wind direction, geographic orientation of the unit(s), and other factors such as large buildings and other obstructions that may influence layout decisions.

PT2, PFi, & PCC Layout Guidelines

Included are the layout guidelines for PT2 Cooling Towers, PFi Closed Circuit Cooling Towers, and PCC Evaporative Condensers in several situations typically encountered by designers. These guidelines represent minimum spacing requirements. If available, greater spacing should be utilized whenever possible.

Overview

Operational efficiency of evaporative cooling equipment depends upon an adequate supply of fresh, ambient air to provide design capacity. Other important considerations, such as the proximity to building air intakes or discharges, must also be taken into account when selecting and designing the equipment site.

As the size of an installation increases, the total amount of heat being rejected into the atmosphere and the volume of discharge air increase — to the point where the units can virtually create their own environment. As a result, it becomes increasingly difficult to apply a set of general guidelines to each case. In such installations, particularly those in wells or enclosures, some air will recirculate. The recirculation should be minimized or the design wet bulb temperature must be adjusted to allow for the recirculation. Consequently, any job that involves four or more cells should be referred to your local BAC Representative for review.

Axial fan units are not generally suited for indoor or ducted applications. In such situations, a Series V centrifugal fan unit is recommended.

?

DID YOU KNOW?

As the size of an installation increases, the total amount of heat being rejected into the atmosphere and the volume of discharge air increase — to the point where the units can virtually create their own environment. Following these layout guidelines can minimize air recirculation and ensure optimal performance.

General Considerations

When selecting the site consider the following factors:

1. Locate the unit to prevent the warm discharge air from being introduced into the fresh air intakes of the building(s) served by the unit, intakes of neighboring buildings, or from being carried over any populated area such as a building entrance.
2. Consider the potential for plume formation and its effect on the surroundings, such as large windowed areas, and pedestrian or vehicular traffic arteries, particularly if the unit(s) will be operated during low ambient temperatures.
3. Provide sufficient unobstructed space around the unit(s) to ensure an adequate supply of fresh, ambient air to the air intakes. Avoid situations which promote recirculation of unit discharge air, such as units located:
   a. Adjacent to walls or structures that might deflect some of the discharge airstream back into the air intakes.
   b. Where building air intakes or exhausts, such as boiler stacks in the vicinity of the unit, might raise the entering wet bulb temperature or starve the unit of air.
4. Provide adequate space around the unit for piping and proper servicing and maintenance, as shown in **Figure 1**. Maintain 3' minimum around unit for maintenance access and 4' minimum from connection end.
5. The fan discharge cylinder must be at least level with or higher than any adjacent walls or buildings.
6. On larger unit installations, involving multiple cells on one site, the total heat rejection and volume of discharge air may be so great that the units virtually create their own environment. In such situations, the problem of ensuring an adequate supply of fresh, ambient air to the tower intakes becomes increasingly difficult. Therefore, please contact the local BAC Representative for further direction.
7. If the installation does not meet the recommended guidelines, the units will have a greater tendency to recirculate and the design conditions should be altered to include an allowance for the recirculation. For instance, if the design conditions are 95°F/85°F/78°F and it was estimated that the allowance for recirculation rate was 1°F, then the new design conditions would be 95°F/85°F/79°F and the units should be reselected based on the new design conditions.

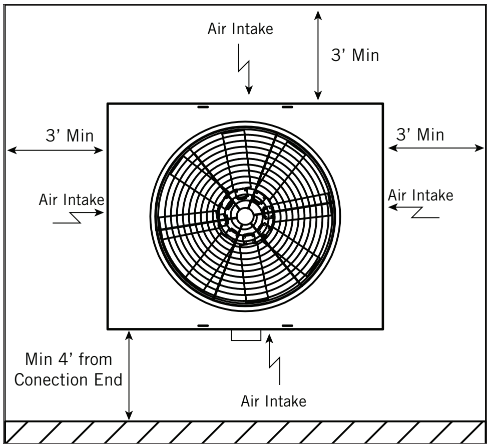


Figure 1. Plan View of Recommended Unit Servicing and Maintenance Spacing

PT2, PFi, & PCC Layout Guidelines

If these guidelines do not cover a particular situation or if the layout criteria cannot be met, please contact your local BAC Representative for review. Please indicate prevailing wind direction, geographic orientation of the unit(s), and other factors such as large buildings and other obstructions that may influence layout decisions.

Installations Adjacent to a Building or Wall(s)

Should it be necessary to install a unit adjacent to a building or wall(s), provide at least distance "X" or "Y" between the air intake and the wall, as illustrated in **Figures 2** and **Figure 3**.

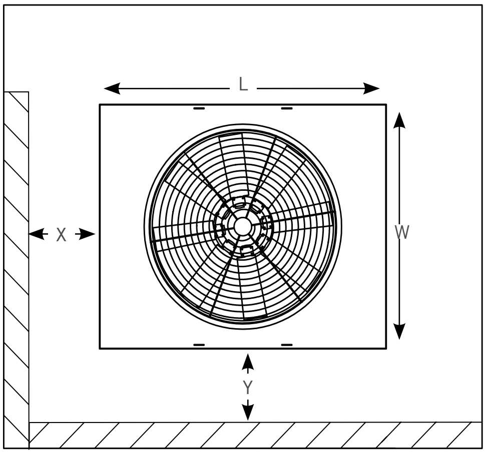


Figure 2. Plan View of PT2, PFi, or PCC Unit Adjacent to One or More Walls

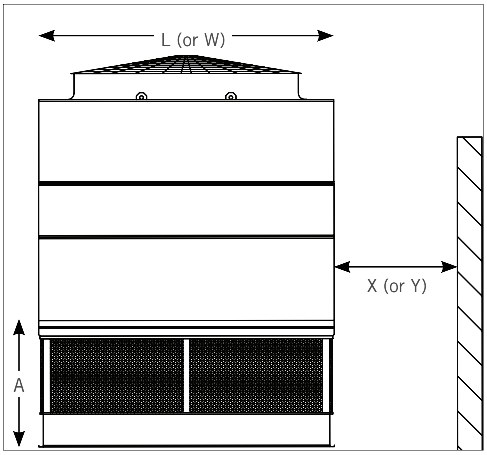


Figure 3. Section View of a PT2, PFi, or PCC Unit Adjacent to Wall

Below is the method for determining the minimum acceptable dimensions "X" and "Y" for a PT2, PFi, or PCC located adjacent to one or more solid wall(s). The recommended envelope air velocity for a PT2 Cooling Tower, PFi Closed Circuit Cooling Tower, and PCC Evaporative Condenser is 300 FPM. We must solve the following equations for the desired distance, "X" or "Y":

Envelope Air Velocity = (% Airflow per Intake) / (Envelope Area)

% Airflow per Inlet = [L (or W) / Total Air Intake Perimeter]

Total Air Intake Perimeter = 2L + 2W

Envelope Area = [(L * Y) + 2(A * Y)] or [(W * X) + 2(A * X)] , where:

"A" = height of the air intake section in feet

"L" = length of the unit in feet

"W" = width of the unit in feet

"X" = minimum acceptable distance between the wall and the air intake face "W", in feet

"Y" = minimum acceptable distance between the wall and the air intake face "L", in feet

The minimum acceptable dimensions "X" and "Y" in this orientation have already been tabulated for 1 thru 4 cell units in **Table 1** for the PT2 Cooling Tower**,** tabulated for 1, 2, and 4 cell units in **Table 2** for the PFi Closed Circuit Cooling Tower, and tabulated in **Table 3** for the PCC Evaporative Condenser.

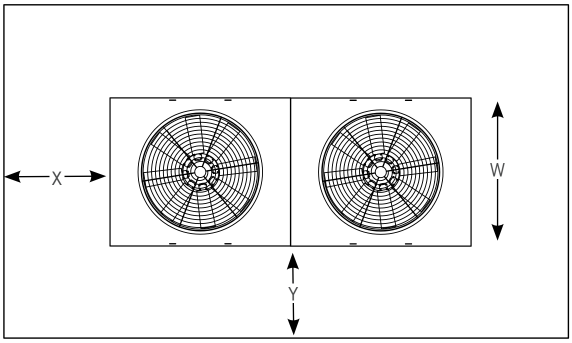


Figure 4. Plan View of a Two Cell PT2-XXXXA-**2 Arrangement
Plan View of PCC-x-0718x, PCC-x-1024x, PCC-x-1224x, PCC-x-1236x, and PCC-x-1240x
Plan View of PFi-0718x, PFi-1024x, PFi-1224x, and PFi-1236x

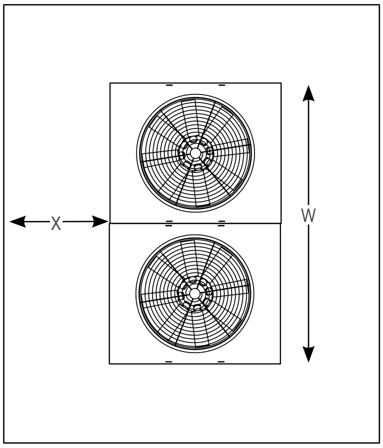


Figure 5. Plan View of a Two Cell PT2-1218A-**T Arrangement
Plan View of a Two Cell PCC-x-2012x, PCC-x-2412x, PCC-x-2418x, and PCC-x-2420x
Plan View of a Two Cell PFi-2012Ax, PFi-2412Ax, and PFi-2418x

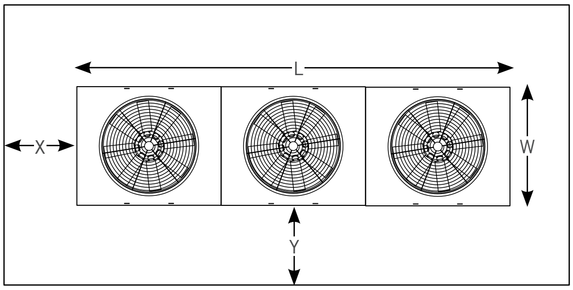


Figure 6. Plan View of a Three Cell PT2 Arrangement

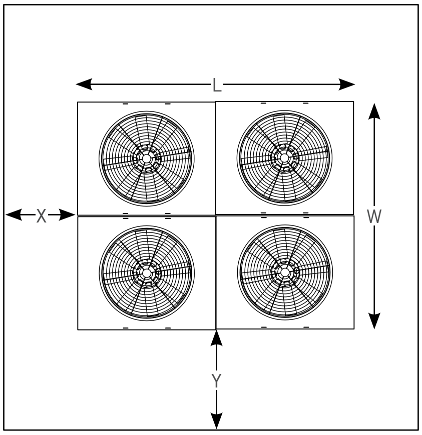


Figure 7. Plan View of a Four Cell PT2 Quad Arrangement
Plan View of a Four Cell PCC-x-2424x, PCC-x-2436x, and PCC-x-2440x

NOTE: PT2-1218A, have two fan mechanicals as standard with an option for one fan mechanical. PFi-1236-x, PFi-1236-x, PFi-2418-x, PCC-x-1218x, PCC-x-1220x, PCC-x-1236x, PCC-x-1240x, PCC-x-2418x, PCC-x-2420x, PCC-x-2420x, PCC-x-2436x, and PCC-x-2440x models have one fan mechanical as standard with an option for two fan mechanicals.

PT2, PFi, & PCC Layout Guidelines

Model Number	Distance from Wall to Air Intake							
	One Cell Width (X)	One Cell Length (Y)	Two Cell Width (X)	Two Cell Length (Y)	Three Cell Width (X)	Three Cell Length (Y)	Four Cell Width (X)	Four Cell Length (Y)
PT2-0412A	3[1]	3[1]	—	—	—	—	—	—
PT2-0709A	3[1]	3[1]	3[1]	4	3[1]	5	—	—
PT2-0809A	3[1]	3[1]	3[1]	4.5	3.5	5.5	—	—
PT2-0812A	3.5	4	3.5	5.5	3.5	6.5	—	—
PT2-1009A	4	4	4.5	6	5	7.5	8	8
PT2-1012A	4	4	5	6	4.5	7	8	8.5
PT2-1212A	4	4.5	5	6.5	5	8	9	9
PT2-1218A	4.5	5.5	PT2-1218A-**2 – 5.5 PT2-1218A-**T – 8	PT2-1218A-**2 – 8.5 PT2-1218A-**T – 7	5.5	10	11	12.5

Table 1. Minimum Acceptable Air Intake Distance “X” and “Y” (feet) to Solid Wall for PT2 Cooling Towers

Model Number	Distance from Wall to Air Intake		Model Number	Distance from Wall to Air Intake		Model Number	Distance from Wall to Air Intake	
	Width (X)	Length (Y)		Width (X)	Length (Y)		Width (X)	Length (Y)
PFi-0406N	3[1]	3[1]	PFi-1212N	4.5	4.5	PFi-1236N	5.5	8.5
PFi-0412N	3[1]	3[1]	PFi-1218N	5	5.5	PFi-2412N	7	5.5
PFi-0709N	3[1]	3[1]	PFi-1024N	4.5	6.5	PFi-2418N	8	7.5
PFi-0718N	3[1]	4.5	PFi-2012N	6.5	5			
PFi-1012N	4	4	PFi-1224N	5.5	7			

Table 2. Minimum Acceptable Air Intake Distance “X” and “Y” (feet) to Solid Wall for PFi Closed Circuit Cooling Towers

NOTES:

1. Minimum distance for maintenance access is 3’.
2. For a plan view of a one cell PT2 arrangement and a plan view of a PFi-0406A, PFi-0412A, PFi-0709A, PFi-1212A, and PFi-1218A refer to **Figure 2** on **Page J110**. For plan views of all other configurations, see **Page J111**.

Model Number	Distance from Wall to Air Intake		Model Number	Distance from Wall to Air Intake		Model Number	Distance from Wall to Air Intake	
	Width (X)	Length (Y)		Width (X)	Length (Y)		Width (X)	Length (Y)
PCC-x-0406x	3[1]	3[1]	**PCC-x-1220x**	4	6	**PCC-x-2412x**	6	4.5
PCC-x-0412x	3[1]	3[1]	**PCC-x-1024x**	4.5	6.5	**PCC-x-2418x**	7	6.5
PCC-x-0709x	3[1]	3[1]	**PCC-x-2012x**	6.5	5.5	**PCC-x-2420x**	8	5
PCC-x-0718x	3[1]	4.5	**PCC-x-1224x**	4.5	6	**PCC-x-2424x**	7.5	7.5
PCC-x-1012x	4	4.5	**PCC-x-1236x**	4.5	7	**PCC-x-2436x**	9.5	10.5
PCC-x-1212x	3.5	3.5	**PCC-x-1240x**	5	8	**PCC-x-2440x**	10	11
PCC-x-1218x	4	5						

Table 3. Minimum Acceptable Air Intake Distance "X" and "Y" (feet) to Solid Wall for PCC Evaporative Condensers

NOTES:

1. Minimum distance for maintenance access is 3'.
2. For a plan view of a PCC-x-0406x, PCC-x-0412x, PCC-x-0709-x, PCC-x-1212x, PCC-x-1218x, and PCC-x-1220x refer to **Figure 2** on **Page J110**. For plan views of all other configurations, see **Page J111**.

PT2, PFi, & PCC Layout Guidelines

Example 1: Model PT2-1212A-3P1 with Air Intake Face "L" Adjacent to a Solid Wall

Find minimum acceptable distance "Y".

Referencing the PT2 Engineering Data:

Unit CFM = 104,080 CFM

A = 4'-10 3/8" (4.9')   L = 11'-11 3/4" (12')   W = 11'-10" (11.9')

Total Air Intake Perimeter = 2L + 2W = 47.8'

300 FPM = suggested envelope air velocity for a unit

Envelope Velocity = (Airflow per Intake) / (Envelope Area)

$$\% \text{ Airflow to Inlet} = \frac{L}{\text{Total Air Intake Perimeter}} = \frac{12'}{47.8'} = 25\%$$

$$300 \text{ FPM} = \frac{104{,}080 \text{ CFM} * 25\%}{(12' * Y) + 2(4.9' * Y)}$$

Solve for "Y" to find the distance from the "W" Side of the unit to the wall:

$$Y * (21.8) = \frac{26{,}020 \text{ CFM}}{(300 \text{ FPM})} \qquad Y = \frac{[(26{,}020 \text{ CFM}) / (300 \text{ FPM})]}{21.8'} \qquad Y = 3.98'$$

This is rounded up to the next 0.5' increment. Therefore, the air intake should be located no less than 4 feet from the solid wall.

Example 2: Model PT2-0412A-2J1 with Air Intake Face "W" Adjacent to a Solid Wall

Find minimum acceptable distance "X".

Referencing the PT2 Engineering Data:

Unit CFM = 33,520 CFM

A = 3.2'

L = 11'-11 3/4" (12')

W = 4'

Total Air Intake Perimeter = 2L + 2W = 32'

300 FPM = suggested envelope air velocity for a unit

Envelope Velocity = (Airflow per Intake) / (Envelope Area)

$$\% \text{ Airflow to Intake} = \frac{W}{\text{Total Air Intake Perimeter}} = \frac{4'}{32'} = 12.5\%$$

$$300 \text{ FPM} = \frac{34{,}790 \text{ CFM} * 12.5\%}{(4' * X) + 2\,(3.2' * X)}$$

Solving for "X,"

$$X * (10.4) = \frac{4{,}350 \text{ CFM}}{300 \text{ FPM}}$$

$$X = \frac{[(4{,}350 \text{ CFM}) / (300 \text{ FPM})]}{10.4'}$$

X = 1.39'

This is rounded up to the next 0.5' increment, so the intake would be located 1.5' from the solid wall. However, since the minimum distance from a wall is 3' for maintenance access, the air intake should be located no less than 3' from the solid wall.

PT2, PFi, & PCC Layout Guidelines

Well Installation

Use the method outlined in Installations Adjacent to a Building or Wall(s) on **page J110** to determine the minimum acceptable dimensions “X” and “Y” for PT2 Cooling Towers, PFi Closed Circuit Cooling Towers, or PCC Evaporative Condensers installed in a well layout.

Next, determine the downward air velocity for the well installation. The maximum allowable downward air velocity for a well installation is 400 FPM for PT2 Cooling Towers, PFi Closed Circuit Cooling Towers, or PCC Evaporative Condensers. The downward air velocity is determined using the following equation:

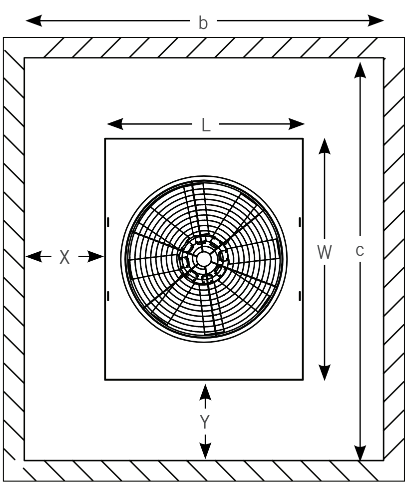


Figure 8. Plan View of a PT2, PFi, or PCC Unit in a Well Enclosure

Downward Air Velocity = (Unit CFM) / (Usable Well Area)

The usable well area is defined as illustrated in **Figure 8**.

Usable Well Area = Well Area – Unit Area

Where:

Well Area = b * c

Unit Area = L * W

“L” = length of the unit in feet.

“W” = width of the unit in feet.

“b” = length of the well in feet.

“c” = width of the well in feet.

Example: Model PT2-1212A-3M1 in a 20’ x 20’ Well

Referencing the PT2 Engineering Data:

Unit CFM = 84,520 CFM

L = 11’-11 3/4” (12’)

W = 11’-10” (11.9’)

b = 20’

c = 20’

400 FPM = maximum acceptable envelope air velocity for a PT2 Cooling Tower in a well installation.

Usable Well Area = Well Area – Unit Area

Usable Well Area = (b * c) – (L * W)

Usable Well Area = (20’ * 20’) – (12’ * 11.9’) = 257.2’

Downward Air Velocity = (Unit CFM) / (Usable Well Area)

Downward Air Velocity = 84,520 CFM / 257.2’ = 328.6 FPM

328.6 FPM < 400 FPM. Therefore, the installation results in an acceptable downward air velocity.

Louvered or Slotted Wall Installations

Check to see if the layout meets the requirements for a well installation. If the criteria for the well installation are met, the layout is satisfactory. If the layout does not satisfy the criteria for the well installation, analyze the layout as follows:

1. Air intake requirements:
   a. Units should be arranged within the enclosure such that they maintain a minimum distance of three feet (3’) between the unit air intakes and the louvered or slotted wall for uniform air distribution and 4’ from the connection end.
2. Louver Requirements:
   a. Louvers must provide at least 50% net free area to ensure that the unit airflow is not reduced due to friction or dynamic losses and that sufficient air is drawn through the openings and not downward from above.
   b. The required total louver or slot area is based on drawing the total unit airflow through the net free area of the louvers at a velocity of 600 FPM or less.
   c. Locate the louver area in the walls of the enclosure such that air flows uniformly to the air intakes.

Louver area and unit airflow are related to louver velocity as follows:

$$\text{Louver Velocity} = \frac{(\text{Unit Airflow} * \%\ \text{Airflow})}{[(\%\ \text{Louver Free Area}) * (\text{Louver Area})]}$$

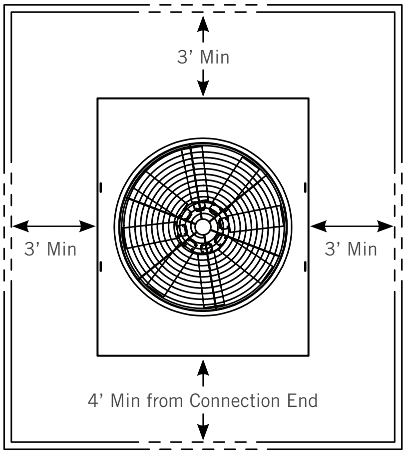


Figure 9. Plan View of a PCC, PFi, or PT2 Unit in an Enclosure with Louvered Walls

PT2, PFi, & PCC Layout Guidelines

Example: **PT2-0709A-2L in a Louvered Enclosure**

The enclosure walls are equal in elevation to the unit discharge height. The louvers are 70% free area and 3' from the air intake of the tower. Find the required louver area to produce a minimum Louver Velocity of 600 FPM.

Referencing the PT2 Engineering Data:

Unit CFM = 46,500 CFM

A = 3.9' L = 9' W = 7.4'

Total Air Intake Perimeter = 2L + 2W = 32.8'

Maximum Allowable Louver Velocity = 600 FPM

For "W" Side (7.4'):

% Airflow = W / Total Air Intake Perimeter

7.4' / 32.8' = 23%

$$\text{Louver Velocity} = \frac{(\text{Unit Airflow} * \%\ \text{Airflow})}{[(\%\ \text{Louver Free Area}) * (\text{Louver Area})]}$$

$$600 = \frac{(46{,}000\ \text{CFM} * 23\%)}{(70\%) * \text{Louver Area}} \qquad \text{Louver Area} = \frac{(10{,}580\ \text{CFM} / 0.7)}{600}$$

Louver Area = 25.19 square feet

For "L" Side (9'):

% Airflow = L / Total Air Intake Perimeter

9' / 32.8' = 27%

$$\text{Louver Velocity} = \frac{(\text{Unit Airflow} * \%\ \text{Airflow})}{[(\%\ \text{Louver Free Area}) * (\text{Louver Area})]}$$

$$600 = \frac{(46{,}000\ \text{CFM} * 27\%)}{(70\%) * \text{Louver Area}} \qquad \text{Louver Area} = \frac{(12{,}555\ \text{CFM} / 0.7)}{600}$$

Louver Area = 30 square feet

The louver areas on the "W" sides of the unit must equal or exceed 25.5 square feet, and the louver areas on the "L" sides of the unit must equal or exceed 30 square feet.

Multi-Row Installations

Multiple cells arranged end-to-end create a "wall" of moist discharge air which could easily be swept into the air intakes due to prevailing wind. To minimize the potential of recirculation of the discharge air, the units should be situated with adequate spacing between air intakes.

When multiple cells are arranged with the air intakes facing each other, the distance between air intakes should follow the equation below:

M = (2 * X) + (number of cells per module) or M = (2 * Y) + (number of cells per module), where "X" and "Y" are obtained from the appropriate model in **Table 1, Table 2** or **Table 3**.

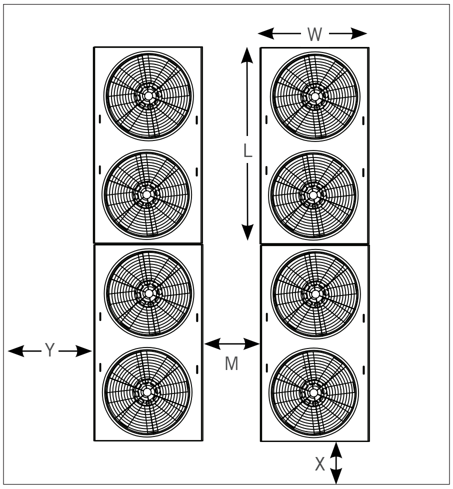


Figure 10. Plan View of Multi-Cell PCC, PFi, or PT2 Units with Air Intakes Facing

Example: **Qty (2) of Model PT2-1218A-1M2**

There are two modules of two cells of each on a roof. There are no enclosures surrounding the unit installation. The two banks of units have air intakes "L" facing each other. The minimum distance "M" between rows of units is determined as follows:

From **Table 1**, face "L" corresponds to distance "Y" and Y = 8.5',

M = (2 * Y) + (number of units per module)

= (2 * 8.5') + (2)

= 19 feet

The calculated "M" dimension of 19 feet will minimize the potential for recirculation of the discharge air.

Multi-cell banks (i.e. more than one row or quad) should be elevated a minimum of 2 feet to allow air equalization under the cells, and minimize recirculation.

If these guidelines do not cover a particular situation or if the layout criteria cannot be met, please contact your local BAC Representative for review. Please indicate prevailing wind direction, geographic orientation of the unit(s), and other factors such as large buildings and other obstructions that may influence layout decisions.

Cooling Tower Pumping and Piping

Tower Pumping

Tower pumping does not present great difficulty in terms of good pump application. This is because of a normally high order of application safety factor. Troubles do occur occasionally, however, and these troubles can be classified as caused by:

1. Incorrect pump head estimation.
2. Pump cavitation and loss of pumping ability, as caused by inadequate pump suction pressure.
3. Air in pump suction; as caused by tower pan vortex, pan drain down or faulty bypass.
4. Unstable pump operational points as caused by:
   a. Improper application of tower bypass controls.
   b. High pressure drop tower spray nozzles in combination with tower bypass.
5. Inadequate maintenance procedures causing:
   a. Plugged suction strainer.
   b. Lack of tower treatment with consequent fouling of the condenser.

It is intended that each potential trouble source be evaluated so that the necessary design safeguards can be erected against operational problems.

Open "Tower" System Pump Head Requirements

The pumping head determination procedure for the "open" tower piping loop differs from the conventional "closed" loop piping circuit used for most Hydronic (Heat-Cool) applications. The difference concerns consideration of "open" loop static heads.

The closed loop circuit has no need for consideration of static heads for pump selection because of a balance or cancellation of static heads between the supply and return risers. Static head lost by water flow to any height in the supply piping is cancelled by a static head "regain" as water flows down the return piping. The only pump head requirement for the "closed" loop is that due to flow-friction pressure drop; static heights are not considered.

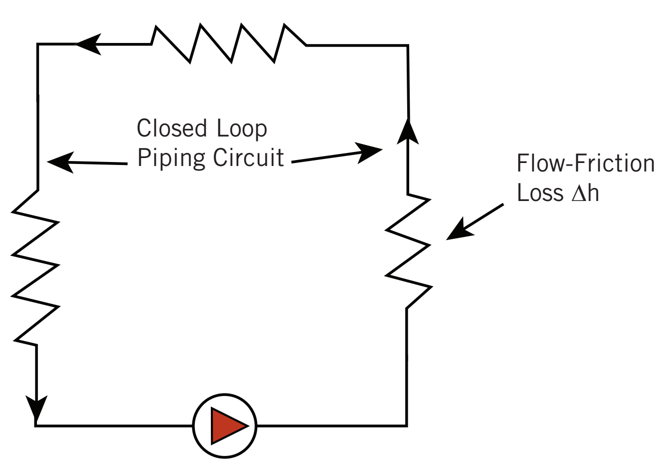


Figure 1. Static Height Not Considered for Pump Selection in Closed Loop

For the legend, see **page J165**.

The “open” or tower circuit is different from the “closed” loop circuit. The difference is that all static heads are not cancelable. In the open piping circuit, the pump must raise fluid from a low reference level to a higher level; this requires pump work, and open statics becomes an important consideration for pump selection.

In **Figure 2**, the required pump head will be the pipe flow-friction loss from A to D plus the energy head (H_s) required to raise water from the lower to higher level.

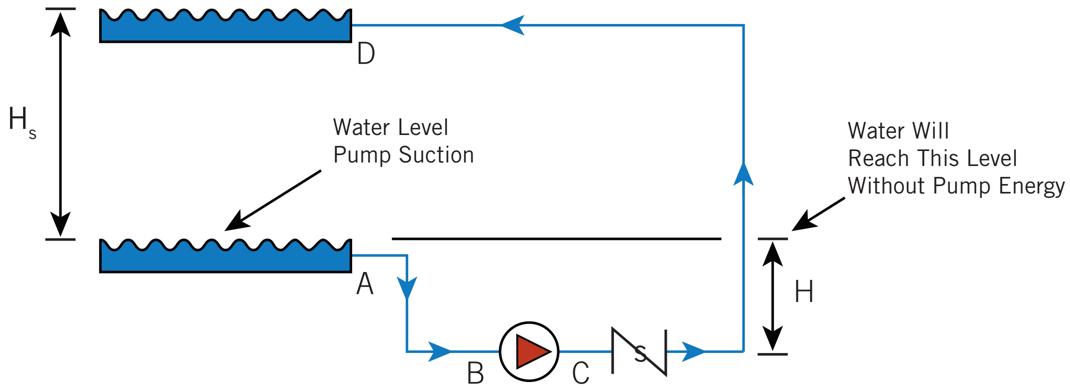


Figure 2. Open Piping Circuit

The cooling tower circuit differs slightly from the basic “open” circuit in that the discharge piping is connected directly to a distribution basin. Some towers are furnished with a distribution manifold with nozzles which require additional pressure.

For the tower piping circuit, the pump must overcome the piping flow friction loss; piping, condenser, cooling tower losses, and valves. It must also provide the energy head necessary to raise water from a low to a higher static head level.

Cooling Tower Pumping and Piping

Most discussions concerning tower and/or open piping circuits would simply define the required pump static energy head as H_o (in **Figure 3**); the "open" height of the piping circuit. This is, however, an ever-simplified assumption which may or may not be true depending on whether or not a "siphon draw" is established in the downcomer return piping DE.

The nature of the downcomer siphon draw and its limitations should be evaluated.

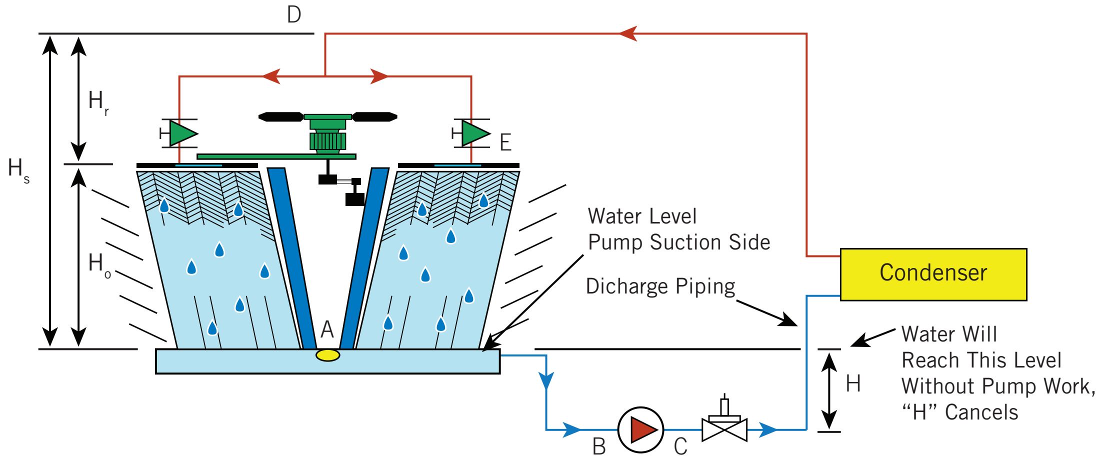


Figure 3. Typical "Open" Tower Piping Circuit

Downcomer Siphon Draw

In **Figure 3**, water is being discharged at E. Pressure at D must be equal to exit loss plus flow-friction loss DE and minus the static pressure reduction caused by downcomer return static height H_r.

Pressure reduction to D as caused by static height H_r will generally, but not always, permit cancellation of height H_r as a part of the required pump head. This is because of a resultant siphon draw action in the downcomer.

Given that the "siphon draw" does indeed occur, the required pump head will become:

PUMP HEAD in Figure 3 = $H_0 + \Delta h$ (AE)

The pump head selection statement shown above is commonly accepted as a truism. It has limitations, however, and will not apply under certain circumstances. These circumstances should be understood if unnecessary cost and embarrassment are to be avoided by the consultant.

Exit loss and flow-friction loss in the downcomer will generally be less than the downcomer height H_r. For this circumstance the downcomer must operate at subatmospheric pressure when the siphon draw is established. If the downcomer vacuum is broken, the expected siphon draw will not occur and the estimated pump head may be inadequate.

The expected downcomer return siphon draw vacuum can be broken by any of three basic application circumstances:

- Top vented downcomer.
- Inadequate downcomer flow rates; bottom vented downcomer.
- Fluid vapor pressure or flash considerations.

Top Vented Downcomer

A downcomer vent will break the siphon draw vacuum. The vent may be a simple loose pipe connection - or it may be a mechanical vent purposefully applied at the downcomer return high point.

Vents are sometimes applied to establish known reference pumping conditions when downcomer return siphon draw conditions propose stability problems; as with a very high downcomer, when fluid boiling is a probability or when start-up downcomer flow rates are anticipated as inadequate for the siphon draw.

Given a top vented downcomer, it will be seen that the pump must raise water from the pump suction pan water level to the highest vented point in the downcomer.

Considering this point to occur at D in **Figure 3**, the required pump static head will become:

$$\mathbf{H_o + H_r \text{ or } H_s}$$

The total pumping head to point D will become H_s plus the flow-friction loss Δh (AD). Separate consideration must now be given to the downcomer return.

Since the pump has raised water to level "D," it will have provided a fluid head equal to H_r to overcome flow-friction loss in the downcomer. There are two different pumping possibilities; fluid head H_r greater than downcomer flow-friction loss Δh (DE) and the reverse: H_r less than Δh (DE).

The usual pumping circumstance will be the condition of H_r greater than Δh (DE). This is because the available fluid head H_r is the equivalent of 100 ft / 100 ft pipe friction loss rate. Downcomer piping flow-friction loss will generally be to the order of 4 ft /100 ft. Since the pump has already provided the necessary fluid head to flow the downcomer, $H_r > \Delta h$ (DE); friction flow loss in the downcomer is not a part of the required pump head and total pump head becomes:

$$\textbf{If: } H_r > \Delta h \text{ (DE)}$$

$$\textbf{Then: PUMP HEAD } = H_s + \Delta h \text{ (AD)}$$

High downcomer pressure drops can be caused by control valves or tower spray nozzles. When this pressure drop plus the downcomer pipe flow-friction loss exceeds fluid head H_r, the pump head must be increased by the difference Δh (DE) minus H_r. Total pump head then becomes:

$$\textbf{If: } \Delta h \text{ (DE)} > H_r$$

$$\textbf{Then: PUMP HEAD } = H_s + \Delta h \text{ (AD)} + [\Delta h \text{ (DE)} - H_r]$$

Cooling Tower Pumping and Piping

Bottom Vented Downcomer; Inadequate Flow Rates

Downcomer flow rates can be so low, relative to pipe size, as to allow air to enter at the pipe discharge. This circumstance will cause the downcomer to become vented and will prevent formation of the necessary siphon draw vacuum.

Tests conducted at Bell & Gossett indicate that the siphon draw will not be established when the actual flow-friction loss rate is less than the order of 1 ft /100 ft based on clean pipe pressure drop evaluation.

Pump head requirements for the bottom vented downcomer will be as previously noted for the top vented circumstance.

An unfortunate operational sequence can occur during pump start-up when the pump energy head is devoted towards simply raising water from the low level pan to the highest part of the system.

During this start-up period, flow rates can be so low as to cause "bottom venting" and prevent (sometimes forever) formation of siphon draw circumstances and full design flow rates. A water legged discharge or discharge reducer will provide automatic siphon draw establishment so long as minimum "start-up" flow velocity in the downcomer is to the order of 1 ft/s.

In **Figure 4**, air entry into the pipe discharge is prevented. The minimum flow velocity pulls air bubbles down the piping, finally evacuating the downcomer of air and establishing the siphon draw condition; downcomer pipe full of water and operating at subatmospheric pressure.

Unusual application circumstances will sometimes establish such a low start-up flow rate (less than 1 ft/s velocity) that air bubbles are not carried down the piping. The downcomer cannot then be emptied of air and expected siphon draw will never occur.

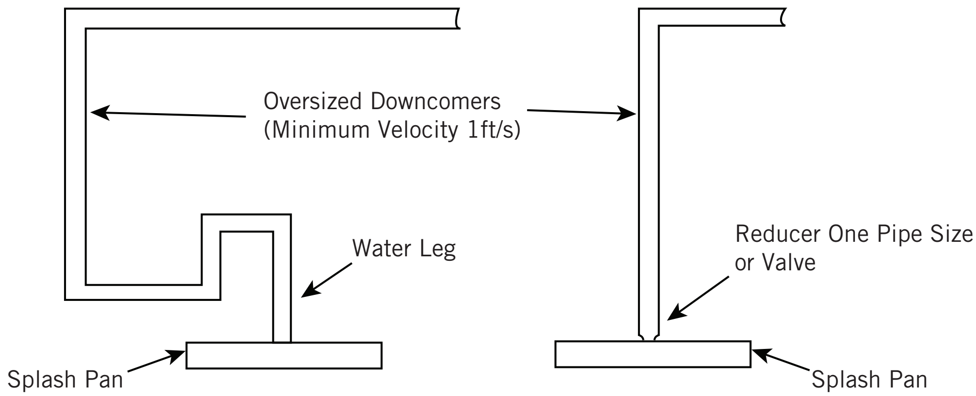


Figure 4. Water Leg or Reducer Help Establish Siphon Draw in Downcomer on Start-Up

For this circumstance it is necessary to separately fill the downcomer with water. This can be accomplished by valve closure at the piping exit in combination with a top vent. During start-up, the exit valve is closed and the vent opened. After the piping is filled, the vent is closed and the exit valve opened.

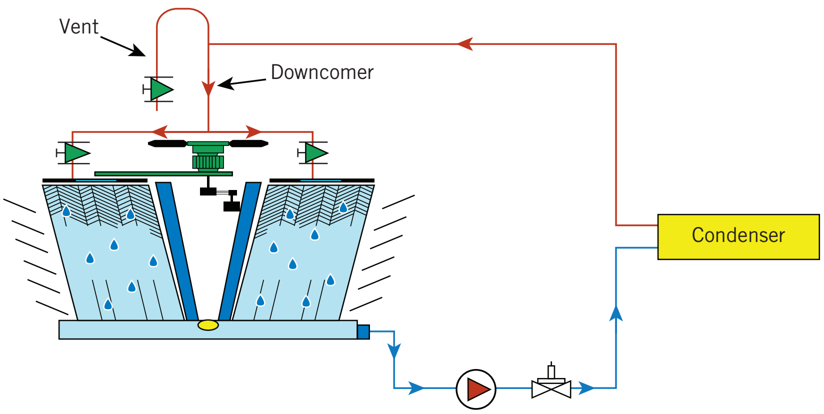


Figure 5. Exit Valve and Vent Permit "Start-Up" Fill of Downcomer Piping

Siphon Draw Limitation Due to Vapor Pressure; Fluid Boiling

Given sufficiently low subatmospheric pressure, any fluid will flash or boil. Fluid pressure in the downcomer piping cannot be less than the pressure at which the fluid boils. Fluid vapor pressure thus provides a siphon draw limitation.

Theoretical cancelable downcomer return static height (due to subatmospheric siphon draw) will vary dependent on fluid vapor or boiling pressure and on atmospheric pressure as this changes from sea level. The variation for water as affected by water temperature and height above sea level is shown in **Table 1**.

Height Above Sea Level (ft)	Water Temperature (°F)						
	Cold	105	120	140	160	180	200
0	34.0	31.8	30.0	27.6	23.4	17.0	7.7
1,000	32.8	30.1	29.0	26.4	22.2	15.8	6.4
2,000	31.6	29.1	28.0	25.3	21.0	14.6	5.2
3,000	30.2	28.2	26.8	24.1	19.9	13.5	4.03
4,000	29.2	27.0	25.6	23.0	18.7	12.2	2.82
5,000	28.0	25.6	24.4	21.8	17.5	11.1	1.61
6,000	26.9	24.6	23.2	20.6	16.4	10.0	0.48
7,000	25.8	23.4	22.2	19.4	15.2	8.8	—
8,000	24.6	22.2	21.0	18.2	14.0	7.6	—
9,000	23.4	21.1	19.8	17.1	12.9	6.4	—
10,000	22.2	19.9	18.6	15.9	11.7	5.2	—

Table 1: Maximum Theoretical Downcomer Return Cancelable Static Height (In Ft) Because of Siphon Draw - Water Only

Cooling Tower Pumping and Piping

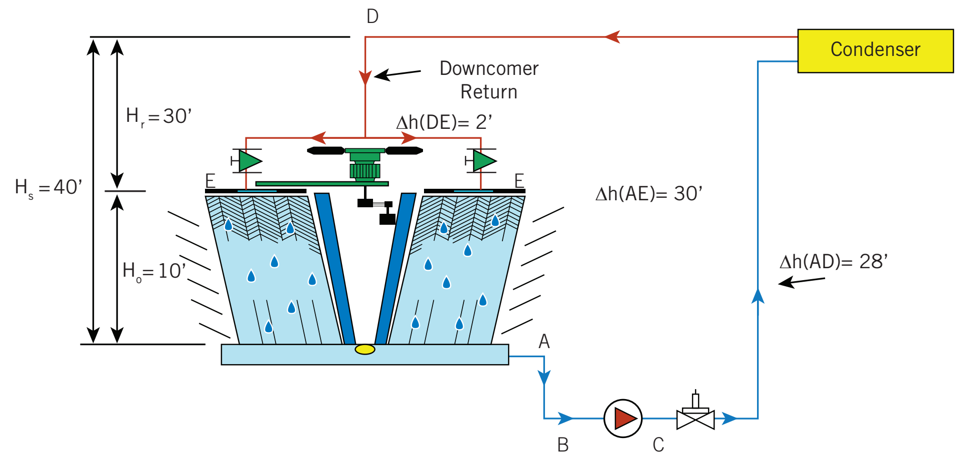


Figure 6. Example Problem

Example Problem

Figure 6 illustrates an example tower schematic for an installation located at 6,000 ft elevation. The tower is to be used to dissipate heat from 180°F water; what is required pump head?

- Figures shown correspond to available fluid head over and above vapor pressure for the water temperature shown.

Reference to **Table 1** shows that the cancelable siphon draw height for 6,000 ft elevation and 180°F water is only 10 ft, while downcomer return static height is 30 ft.

If conventional pump selection practice were to be followed, the pump selection would be:

$$\textbf{WRONG PUMP HEAD} = \Delta h\ (AE) + H_0 = 30\text{ ft} + 10\text{ ft} = 40\text{ ft}$$

It will be noted that this pump selection provides a perfect example of low start-up flow rates; the pump head will just be enough to raise water to the system top. Start-up flow rate will be insignificant.

Even given the special application precautions previously stated, however, the pump selection would not work. This is because water flash in the downcomer will prevent establishment of the presumed 30 ft siphon draw head. In this instance, water would flash because the downcomer return static height exceeds the cancelable siphon draw head (see **Table 1**; 6,000 ft at 180°F = 10 ft).

When downcomer return height exceeds cancelable siphon draw head, it is necessary to separately evaluate downcomer needs. For these circumstances:

The summation of cancelable siphon draw static height plus downcomer return flow-friction loss must exceed downcomer return height; the excess providing anti-flash pressurization.

The necessary downcomer flow-friction loss would generally be established by a balance valve positioned close to the outlet (E). This valve will now provide the necessary “back pressure” to maintain downcomer fluid pressure at above its boiling or vaporization point.

For the particular example, a valve pressure drop equal to the order of 23 ft would establish an overall downcomer return flow-friction loss of 25 ft (23 + 2 = 25ft).

A 25 ft downcomer flow-friction loss added to the theoretical cancelable height of 10 ft (**Table 1**) will establish a pressure over and above boiling of 5 ft at "D."

$$25 \text{ ft} + 10 \text{ ft} = 35 \text{ ft; } 5 \text{ ft over static height } H_r = 30 \text{ ft}$$

The correct pump head selection now becomes:

$$\text{PUMP HEAD} = \Delta h\,(AD) + \Delta h\,(DE) + \Delta h\,(\text{Valve}) + H_0$$
$$= 28 \text{ ft} + 2 \text{ ft} + 23 \text{ ft} + 10 \text{ ft}$$
$$= 63 \text{ ft}$$

For this particular example, a simpler solution could apply an open vent at "D", eliminating need for the downcomer balance valve and its setting.* Required pump head would then become:

$$\text{PUMP HEAD} = \Delta h\,(AD) + H_0 + H_r$$
$$= 28 \text{ ft} + 10 \text{ ft} + 30 \text{ ft}$$
$$= 68 \text{ ft}$$

Either correct solution will provide required design flow rates. Design flow rates would not and could not be established by the "conventional" head selection of 40 ft.

NOTE: In this case, the pump provides an "available" head at D of 30 ft. This fluid head is available for downcomer flow and is greater than flow-friction loss in the downcomer (Δh DE) of 2 ft. Downcomer return flow-friction loss can then be neglected since downcomer fluid will be in "free fall."

Pump Curve Maintenance

In order for a pump to fulfill its fluid flow function, it must be provided with a solid stream of fluid. The centrifugal pump cannot pump fluid and vapor or fluid and air and still provide flow in accordance with its published curve.

a. The pump suction must be under enough pressure so that vapor flash pressure within the pump (cavitation) is prevented.
b. The pump cannot be expected to provide design flow when large quantities of air are drawn into the pump suction; as by tower pan vortex, pan draw-down, or bypass vacuum.

Cooling Tower Pumping and Piping

In addition to flow capacity reduction, the pump will often be mechanically damaged by "shock" loads applied to the impeller or its shaft because of cavitation or air in the suction line.

Large quantities of air in the suction line will break pump shafts in remarkably short order. This is because the pump impeller alternates between virtually no load when an air "gob" enters the impeller casing and an instantaneous shock load of very high order when it slugs against suddenly introduced water.

There are three basic ways for air to be drawn into the suction piping:

- Tower bypass into pump suction line.
- Pan drain-down on start-up.
- Tower vortex.

Tower Bypass Into Suction Line

Improperly applied tower bypass lines connected directly to the pump suction line can cause introduction of large amounts of air into the pump. Air can be drawn into the pump suction when subatmospheric pressures exist at the bypass and discharge line connections.

When the tower illustrated in **Figure 7** is in full bypass, pressure at "B" will be above atmospheric pressure by an amount stated by static height H_1. Pressure at "C" can become subatmospheric, causing air suction unless static pressure reduction caused by height H_2 is counter-balanced by an equal to or greater flow-friction loss in the bypass line.

The bypass control valve and bypass piping should be designed for sufficient pressure drop to prevent subatmospheric pressure at "C" and to cause water to rise into the water leg when the tower is in bypass.

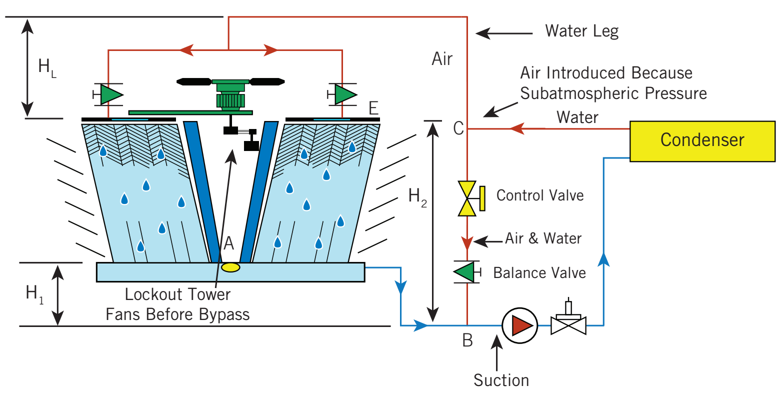


Figure 7. Tower Bypass Can Introduce Air into Pump Suction on Full Bypass - **NOT RECOMMENDED**

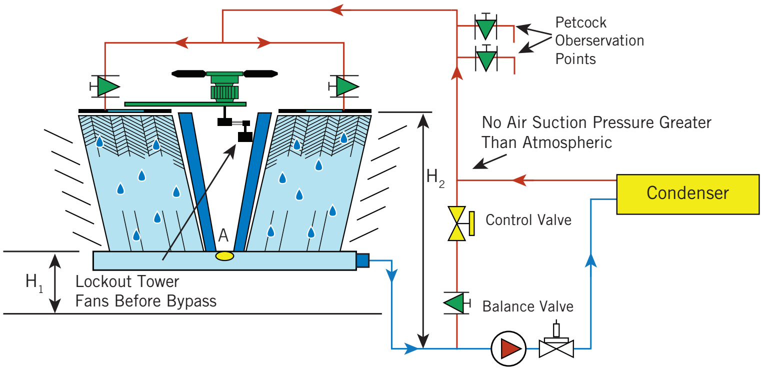


Figure 8. Properly Set Balance Valve Prevents Air Suction into Pump - **NOT RECOMMENDED**

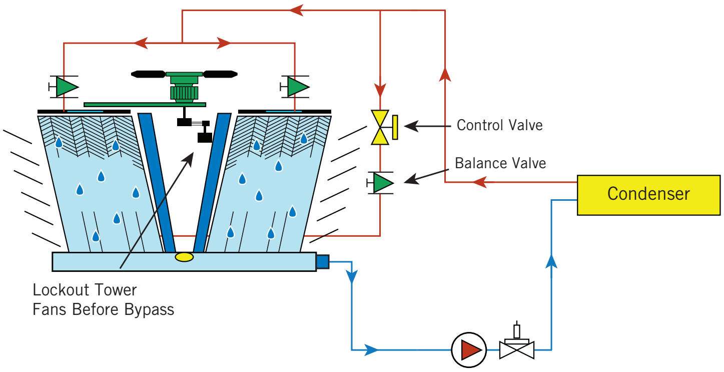


Figure 9. Bypass to Tower - Preferred Bypass System

The desired result will generally be obtained by use of a bypass balance valve with the valve so set that at full tower bypass (**Figure 8**), bypass "back pressure" causes water to rise into the water leg to some set point as established by a petcock design observation point.

It should be noted that tower bypass directly into the tower pan eliminates any possibility of air suction into the pump because of bypass operation and is generally preferred.

Figure 9 illustrates a way of by-passing into the tower pan.

Pan Drain-Down On Start-Up

Many tower pans do not contain sufficient water volume to fill the condenser piping. On pump start-up, the pump can drain the pan dry or lower pan water level to the point of starting a vortex. In either event, air will be drawn into the pump suction; usually with disastrous results.

Right and wrong applications are (**Figures 10** and **11**) shown concerning the pan drain-down problem.

In **Figure 10**, the pump must fill the condenser, and all return piping each time it starts. In addition to a non-flooded condenser on start-up, the pipe and condenser water fill requirement will almost assure pan drain-down and consequent suction line air problems.

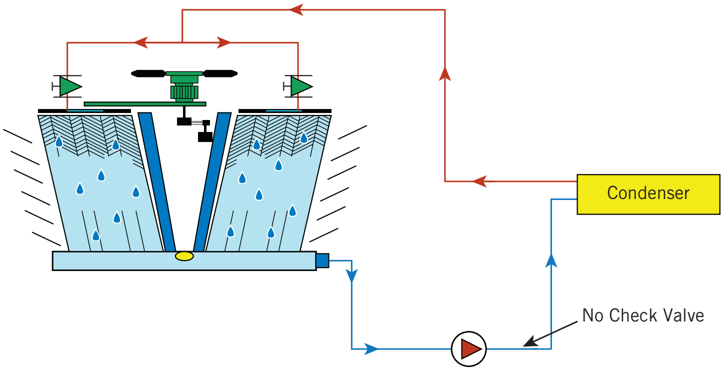


Figure 10. Tower Piping and Condenser Drains into and Overflows Pan on Pump Shut-Down - **WRONG**

Cooling Tower Pumping and Piping

In **Figure 11**, the check valve prevents back drainage of the vertical tower piping, while the water leg prevents drainage of the inside horizontal return piping.

As a general rule, tower piping systems should be fitted with a piping fill line located at the check valve discharge. The fill line will provide two functions:

1. It permits filling of the condenser piping independent of the tower pan and pump. The hazards of pan drain-down on initial pump start-up can be avoided.
2. It is important on chiller start-up that the condenser be flooded on the tower side. Many condensers are located above the tower pan water level and additional insurance as to a flooded condenser under these conditions can be provided by use of an automatic fill or Pressure Reducing Valve. This valve would be set to maintain fill to just below the topmost piping point.

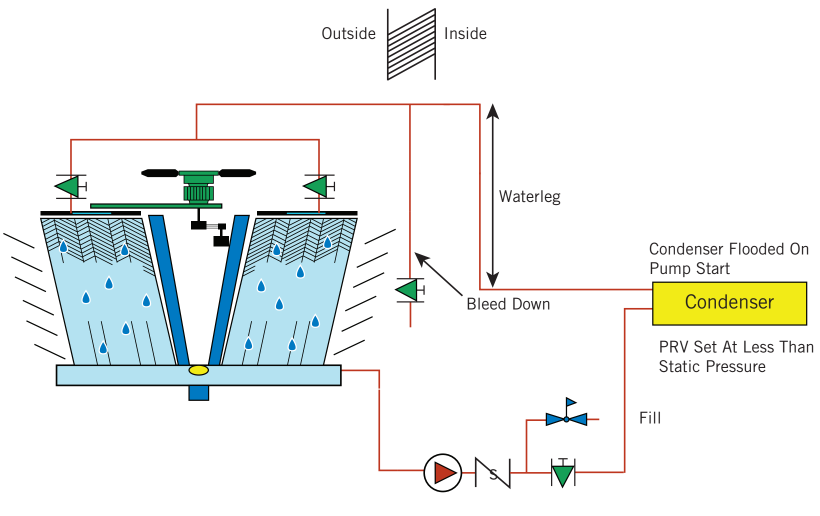


Figure 11. Check, Water Leg and Fill Prevent Piping to Tower Drainage - **RIGHT**

Use of the Pressure Reducing Valve also guards against back drainage problems as caused by a leaking check valve.

In **Figure 11**, it will be noted that the bleed blow-down is located in the top horizontal return piping run. Bleed will only occur during pump operation. The top or "outside" horizontal return piping will always drain to the tower and location of bleed blow-down in this line is to be recommended.

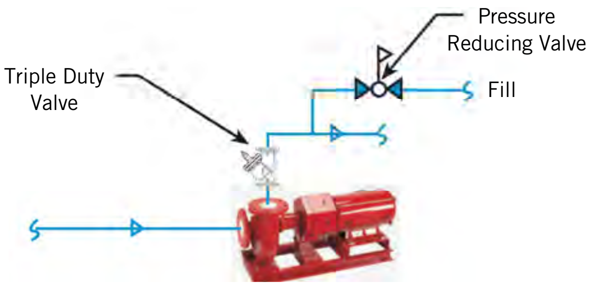


Figure 11A. Location of Fill Valve with a Multi-Purpose Valve-Reference (**Figure 11**)

Tower Vortexing; Excessive Exit Velocities

Solution of the back drainage problem does not necessarily solve all pump suction line air problems. Tower vortexing may still occur when tower pan water level over the pan outlet is insufficient for the flow rate (outlet or exit velocity) actually taking place.

Tower manufacturers often provide vortex breakers in the tower pans and would generally be able to guarantee non-vortex operation up to some stated flow rate for a particular tower, its pan and pan exit pipe size.

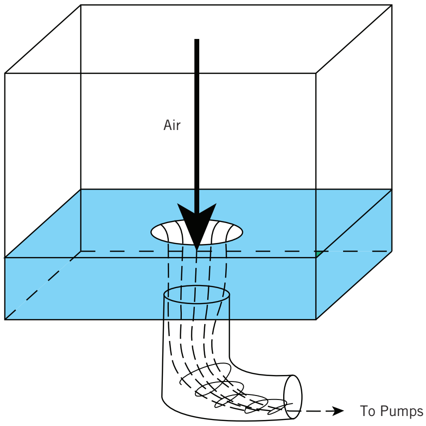


Figure 12. Tower Vortexing

In some cases, pump suction line pipe size may be less than pan exit size. Given a bushed down pan exit, exit velocities may become so high as to cause vortex. Tower exit pipe size should conform to pan exit size for the order of 10 pipe diameters before reducing to the smaller pump suction line size in order to insure that intended tower exit velocities are not exceeded.

It would seem important that the engineer state, as a part of his tower specification, that the tower be able to operate without vortex to the design flow rate plus some reasonable increment. It would then be the engineer's responsibility to provide a pump and piping system combination that establishes some reasonable facsimile of design flow; at least not to exceed the tower manufacturer's requirements.

There are several problems:

1. The initial pump selection head may be overestimated; the less than estimated head causing a flow increase. In this case, use of the throttle or balance valve illustrated in **Figure 11** is to be highly recommended.
2. Improper application of tower bypass controls can cause highly variable pumping points and flow increase possibilities.

Uncontrollable flow increases cannot only cause tower vortex problems, but are also a trouble source concerning pump cavitation.

Design application points concerning stable pump operation will be evaluated after consideration of the suction line pressure drop or cavitation problem.

Cooling Tower Pumping and Piping

NPSH; Cavitation

It is well known that fluids boil at defined temperature-pressure relationships. For any given fluid at a given temperature, pressure reduction to some stated value will cause boiling or vaporization.

A pumped fluid can vaporize or flash within the pump itself because of inadequate pressurization. Fluid vaporization within the pump is generally defined as cavitation and can cause trouble as follows:

1. Pump impeller damage will occur. This is because low pressures in the impeller "eye" will cause vapor bubble formation. The vapor bubbles then collapse or "implode" because of the pressure increase as the bubbles move into higher pressure areas inside the impeller. These hammer-like blows against the impeller can cause physical destruction within a short time.
2. The pump curve will change drastically and in an unpredictable manner. Flow can virtually cease or "slug" because the pump cannot readily deliver both fluid and vapor.
3. Pump shafts can be broken because of slugging of the impeller against alternate bodies of fluid, vapor, and air.
4. Mechanical pump seal failure can occur because the mechanical seal is asked to work under intolerable conditions; vapor flash around the seal causes "dry" operation and rapid wear.

It is most important to successful pump application that adequate (above vaporization) pressures be maintained within the pump.

The engineering tool used to insure adequate anti-flash pressurization is a term defined as "Net Positive Suction Head" (NPSH). NPSH is a rather abstract term which has been subject to much misunderstanding. Before defining NPSH, it will be worthwhile to establish why the term is necessary.

All pumps operate at a lower pressure in the impeller eye and inlet to the impeller vanes than the pressure existing at the pump suction flange. Even though pressure at the pump suction flange is measured and known to be above the flash or vaporization point, the pump can still cavitate because of the pressure reduction that exists from the suction flange to the pump interior.

Internal pump pressure drop occurs because of greatly increased fluid velocities from the pump suction flange to and through the impeller eye and because of turbulence, vane entrance friction losses, etc. In order to prevent cavitation, then, the application engineer must know how much internal pump pressure drop will occur for his design circumstances and for any of a number of specific pump selection possibilities.

The pump manufacturer's measure of this pressure reduction is called **"Required NPSH"**.

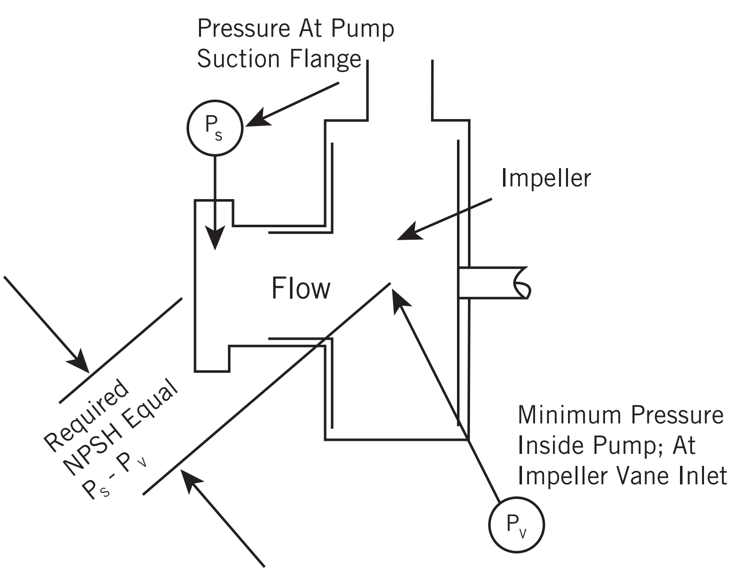


Figure 13. Required NPSH is Measure of Pump Pressure Drop

Test procedures for establishing Required NPSH have been standardized and are carefully followed by pump manufacturers so as to obtain as true an estimation of internal pump pressure drop as possible.

Required NPSH is illustrated on pump curves by several different methods. **Figure 14** shows a separate curve plot of Required NPSH. This type of illustration is used when only a single pump capacity curve is shown.

Regardless of the illustration method, Required NPSH is not a constant value for any pump. Similar to valve pressure drop, Required NPSH will increase with flow increase.

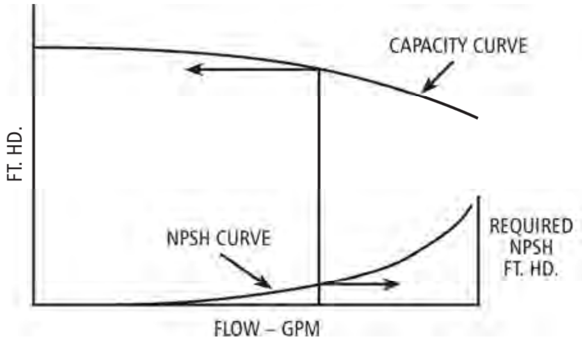


Figure 14. Required NPSH Increases as Flow Increases Through Pump

Again, referencing to valves, it is well known that for a given flow rate, a large valve will cause less pressure drop than a smaller valve. In a similar manner, pumps can be considered as small or large by reference to impeller eye diameter for intended pumped flow rate. For the same pumped flow rate, a small pump (small impeller eye diameter) will have a much higher Required NPSH than a larger pump.

Figure 15 provides some important basic pump application points.

1. Pumps selected to the end of the capacity curve (Ft Hd vs. GPM) are being driven to maximum capability and are the smallest pump that can provide design flow rate. The pump is "small" however, and establishes a maximum Required NPSH (pump pressure drop).

   While generally lowest cost, because of minimum size, the selection establishes maximum trouble potential.

2. Pumps selected to the midpoint area of the capacity curve are larger; impeller eye velocity is reduced and the pump internal pressure drop must be lower.

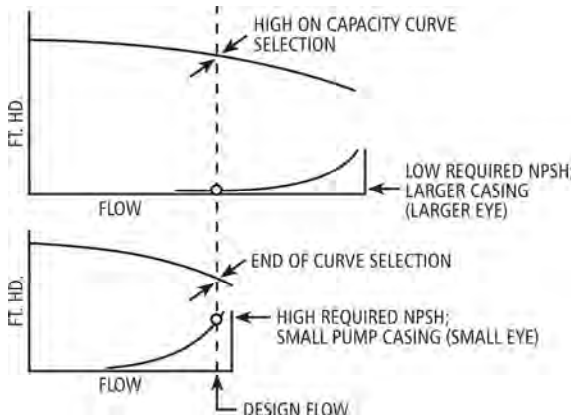


Figure 15. Difference in Required NPSH for Same Flow Most Often Determined b y Pump Size

The pump so selected will cost more than the minimal "end of curve" selection but will reduce trouble potential when NPSH or cavitational problems are a consideration.

It should be noted, in passing, that many potential pump application problems other than cavitation are reduced by midpoint selection: flow balance, noise, etc.

Cooling Tower Pumping and Piping

We have thus far established a basic point; that Required NPSH is a description of a specific pump's internal pressure drop as flow rate through the pump changes. How is knowledge of Required NPSH used for specific pump application problems?

The fundamental manner in which NPSH is used is simple and direct. An assessment is made by the application engineer as to the pressure that will be available at the pump suction flange for the given fluid at design flow rate.

The fluid temperature is also known, and vapor pressure tables define the pressure at which the fluid will boil.

The difference between the available suction flange pressure and the fluid boiling point is then determined and defined as "Available NPSH". Available NPSH is then the available suction flange pressure over and above the fluid boiling point pressure.

What this means is that fluid will not flash or cavitate inside the pump so long as the internal pump pressure drop (Required NPSH) is less than Available NPSH.

As an example, a system under design is intended to pump 212°F water. The application engineer states his conclusion, after calculation that the pump suction flange will be at 12 psig pressure during operation. What is the Available NPSH?

Since 212°F water boils at 0 psig, the Available NPSH must be 12 psi; the pump suction flange pressure will be 12 psi above the fluid boiling point.

Given that the pump internal pressure drop (Required NPSH) is only 8 psi, it will be known that the lowest possible internal pump pressure will still be 4 psi over the boiling point; the pump will not cavitate because Available NPSH is greater than Required NPSH.

Supposing for this example that a pump is inadvertently selected which has a Required NPSH of 14 psi at design flow rate. This condition immediately establishes that the internal pump pressure will be below the boiling point; 12 - 14 = - 2 psi. The internal pump pressure drop (Required NPSH) is greater than Available NPSH; pump cavitation will and must occur.

The example illustrates the fundamental reasoning behind NPSH evaluation procedure. It will be noted, however, that the example has stated NPSH as psi. This has been done only to clarify fundamental usage of the terms. NPSH, whether available or required, is never expressed in psi terms. It is always stated in terms of ft fluid head.

The reason NPSH is stated in terms of ft fluid head is because of the need for generalization. It would not be feasible to publish a different pump capacity curve and NPSH curve for an infinite variety of fluids and, in addition, to provide separate NPSH and capacity curves for all temperature variations with each separate fluid. This would be needed if pump curves and NPSH data were expressed in terms of psi.

Pump curves and NPSH data are illustrated as ft head versus GPM because ft fluid head means differential energy per unit weight of fluid. A pound of water at 85°F weighs as much as a pound of water at 200°F or a pound of gasoline at 60°F. Pump curves and NPSH data expressed as ft head versus GPM is then generalized and the pump data established by water test at 85°F applies without change* to water at 200°F or 45°F, and to gasoline or to a huge variety of fluids within broad temperature and viscosity ranges.

A typical pump curve illustrating capacity and Required NPSH is shown as **Figure 16**.

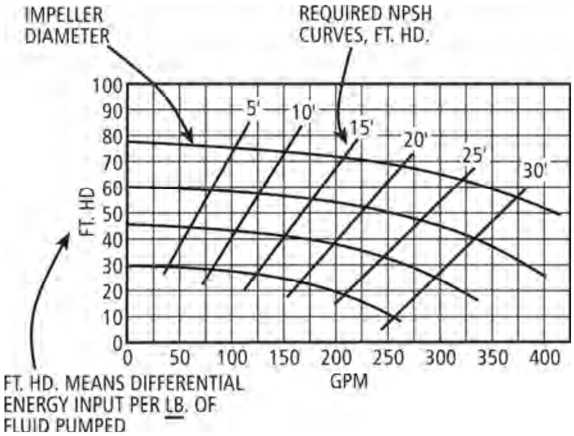


Figure 16. Capacity and NPSH Pump Curve Plot Applies to All Fluids Within Broad Viscosity Range

The need for an ability to apply the developed pump curves to a wide variety of fluids is neatly solved by use of the term ft head. The solution to the one problem causes other difficulties; especially in NPSH application. The difficulty has to do with abstract considerations of the term ft head as classically applied to NPSH evaluations.

NPSH must finally be defined in terms of ft fluid head. Since this is true, the classical methods for application of NPSH data for pump selection is to convert all pressures to ft fluid head, including vapor pressure and atmospheric pressure. It is difficult to picture sea level atmospheric pressure as equivalent to 34 ft of 60°F water head or to 68 ft of fluid at a fluid specific gravity of 0.5. The statements of atmospheric pressure related to ft fluid head are abstract engineering truths, and not concrete, easily visualized truths that can be mentally referenced to gauge pressure readings.

NOTE: Pumping horsepower will change with fluid density.

Cooling Tower Pumping and Piping

Conventional NPSH design evaluations will be avoided in this discussion. This is because of its very abstract nature. Conventional NPSH evaluation can be a very confusing, time consuming procedure for the majority of engineers whose NPSH evaluation needs are generally sporadic.

The B&G NPSH evaluation procedure is as theoretically correct as the conventional. It differs in that the calculation reference is to pump suction flange pressure expressed in terms of psig; gauge pressure - not absolute.

The reference or start point for the evaluation is atmospheric pressure at the pump suction supply level. Simple calculations are then made to determine pump suction flange gauge pressures during operation. An example problem is illustrated in **Figure 17**, for 85°F tower water.

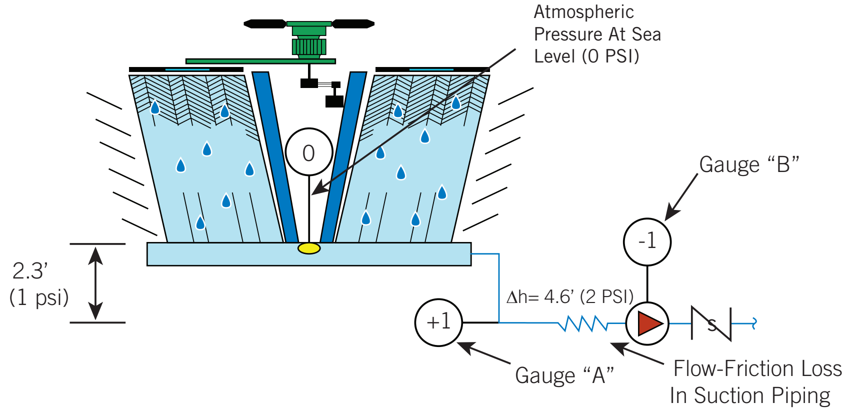


Figure 17. Example Problem

Example Problem

At sea level, the atmospheric pressure pressing on water at the suction pan will be 0 psig.

With tower water at a specific gravity of 1, each 2.3 ft of fluid head = 1 psi.

For these circumstances, and starting with atmospheric pressure at 0 psig, a static fluid head of 2.3 ft would cause +1 psig to be registered at gauge "A." A suction pipe flow-friction loss of 4.6 ft is equivalent to 2 psi pressure drop.

The calculated pump suction gauge pressure reading would then be:

Pump Suction = 0 + 1 - 2 = -1 psig (Gauge "B")

The B&G NPSH Chart (**Figure 18**) is entered at a calculated pump suction gauge pressure of -1 psig. A line is then run vertically to interception with the fluid vapor pressure; for 85°F water, this is the order of 0.6 psia.

It will be noted that velocity head static pressure reduction (h = V2/2g) has not been taken into account.

Velocity head is a point of concern for the pump manufacturer in his development of Required NPSH. The pump test engineer reads pump suction gauge pressure, converts this to ft fluid head and adds velocity head to obtain pump suction pressure as an absolute fluid energy head statement.

The pump application engineer is not concerned with velocity head in his Available NPSH calculation, however. This is because he is not working with an actual gauge reading. His calculation establishes absolute fluid energy head available at the pump suction only when velocity head is not considered.

Velocity head is only considered for NPSH when an actual gauge reading is used. Velocity head will also be considered when a suction static pressure calculation is made for fluid flash possibility in the suction line; but without NPSH reference.

From this interception point (1) a line is run horizontally to interception with the fluid specific gravity line as at point (2). (In this case specific gravity = 1). Available NPSH is read at point (2); in this case @ 31 ft.

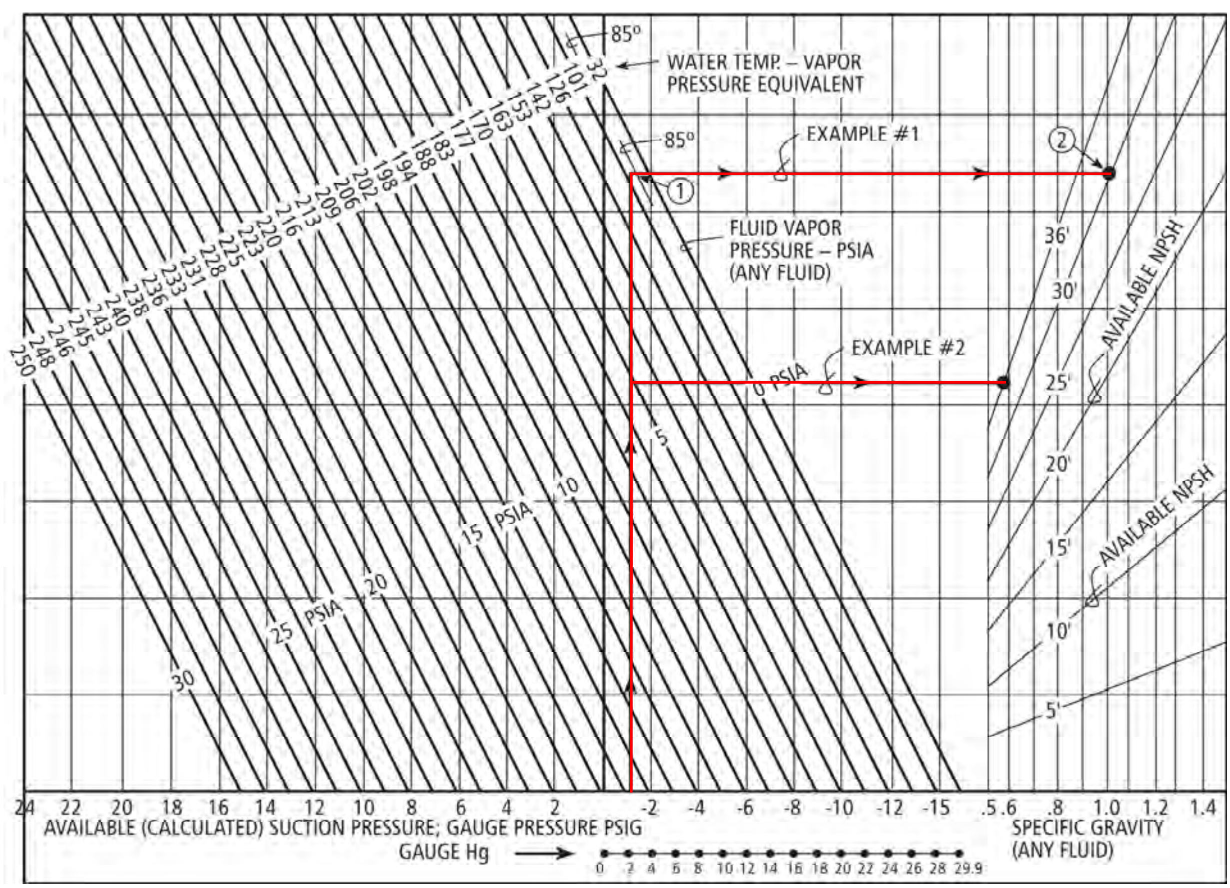


Figure 18

Cooling Tower Pumping and Piping

What has the NPSH Chart accomplished?

The NPSH Chart has simply taken available suction pressure and deducted fluid vapor pressure to establish available pressure over and above the fluid boiling point. This available pressure has then been converted to ft fluid head at the fluid specific gravity. This is fluid pressure-head over and above the fluid boiling point and is defined in conventional pumping terms as Available NPSH.

Our example problem now states that we have 31 ft available NPSH. In order for fluid to flash or cavitate inside the pump, the pump internal pressure drop (Required NPSH) must exceed 31 ft.

To provide a satisfactory pumping system, we need only provide a pump which has a Required NPSH of less than 31 ft.

This will be a simple proposition since only a remarkably bad “end of the curve” pump selection would reach this order of Required NPSH.

The preceding example has important application points as it applies to tower pumping. Before discussing tower pump suction application requirements, however, use of the B&G NPSH Chart for fluids other than water and at elevations above sea level should be pointed out.

When any fluid is to be pumped, the engineer will know its specific gravity and its vapor pressure at the pumping temperature. This data is tabulated in handbooks or is available from the fluid manufacturer.

As an example, an exotic fluid is to be pumped from an open tank in Denver. The fluid manufacturer states that at its pumping temperature, the fluid has a vapor pressure (boiling pressure) of 5 psia and that its specific gravity will be 0.6. Determine Available NPSH for the pumping situation illustrated in **Figure 19**.

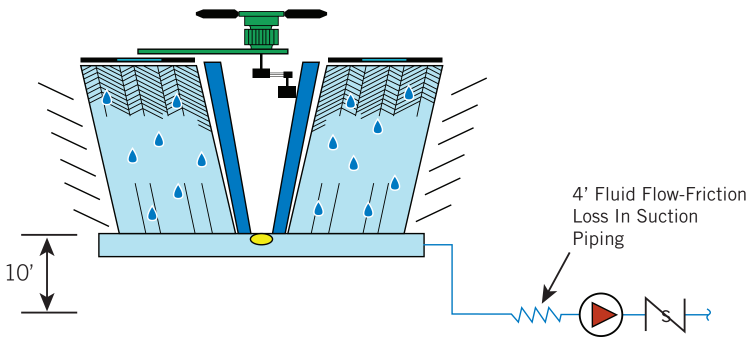


Figure 19. Pumping Diagram; Example Problem

Elevation (ft)	Atmospheric Pressure (psig)
0	0
1,000	-0.5
2,000	-1
3,000	-1.5
4,000	-2
5,000	-2.5
6,000	-3
7,000	-3.5
8,000	-4
9,000	-4.5
10,000	-5

Table 2

It will be useful to tabulate changes in atmospheric pressure with elevation above sea level. It will be noted that atmospheric pressure decreases about 1/2 PSI for every 1,000 ft elevation above sea level.

It will also be useful to tabulate head to psi relationships for various specific gravities.

Fluid Specific Gravity	Ft Fluid Head Equal to 1 PSI
1.5	1.5
1.4	1.64
1.3	1.75
1.2	1.9
1.1	2.1
1.0	2.3 (Usual Water Reference)
0.9	2.6
0.8	2.85
0.7	3.3
0.6	3.85
0.5	4.5

Table 3

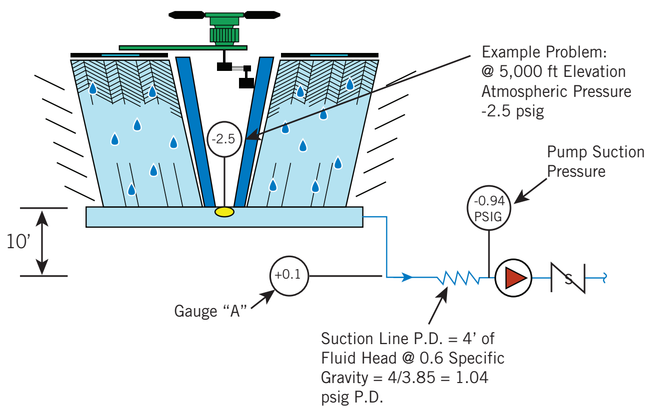


Figure 20. Pump Suction Pressure Example

Suction Pressure Example Problem

The example diagram pump suction pressure would then be established as in **Figure 20**.

In **Figure 20**, atmospheric pressure at -2.5 psig is unaffected by fluid weight. 10 ft of fluid head at 0.6 specific gravity will cause 10/3.85 or about 2.6 psi pressure. Gauge "A" must then read 2.6 psi over atmospheric pressure or +0.1 psig. The fluid flow-friction loss of 4 ft; (4/3.85) 1.04 psi pressure drop so the pump suction pressure will then read -0.94 psig or the order of -1 psig:

(Atmospheric) Static		Friction Loss		
-2.5	**+ 2.6**	**- 1.04**	**=**	**-0.94 or about -1 psig**

The B&G NPSH Chart is then entered at -1 psig. The next step is to proceed upward to an intersection with 5 psia vapor pressure. A horizontal line drawn from this intersection to a 0.6 specific gravity establishes that the pump will have an available NPSH of 35 ft.

A pump is then selected which has a Required NPSH of less than 35 ft at the design flow rate.

The B&G NPSH Chart is generalized and can be used for analysis of pump suction requirements for any fluid and for any piping system; open or closed. It is not limited to cooling tower application.

It would seem that the previous tower NPSH evaluation points out that very simple application rules will eliminate the need for actual evaluation of NPSH requirements for tower systems.

Cooling Tower Pumping and Piping

The Tower Pump and Its Suction Line

It is the unusual tower system that has pump suction troubles. This is because of inherent safety factors. Trouble can be experienced, however, when relatively simple application rules are not followed.

The first pump suction application rule is:

Leave the Suction Line Alone!

So long as the suction line is only pipe and the pump is below the tower pan water level, the available NPSH will be at least to the order of 30 ft. Any pump selected to a reasonable point on its curve will work.

High pressure drop units in the pump suction line are generally installed by the amateur in the "wreck it yourself" approach.

Tower bypass valve, checks, balance valves, and fine mesh strainers can almost always be installed in the pump discharge - and should be.

If it becomes absolutely necessary to install a strainer or check in the suction line, a strong specification should be stated with respect to minimizing allowable pressure drops.

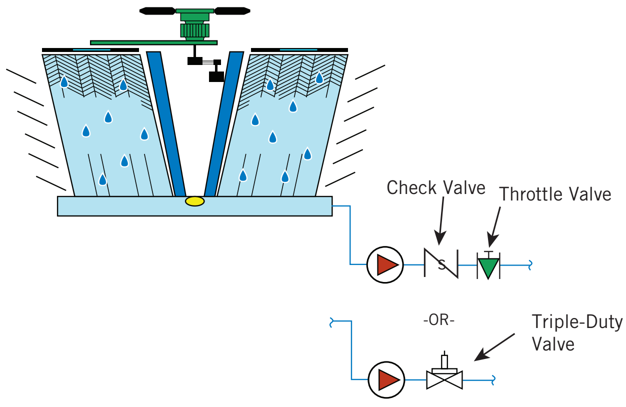


Figure 21. Leave Suction Line Alone - **RIGHT**

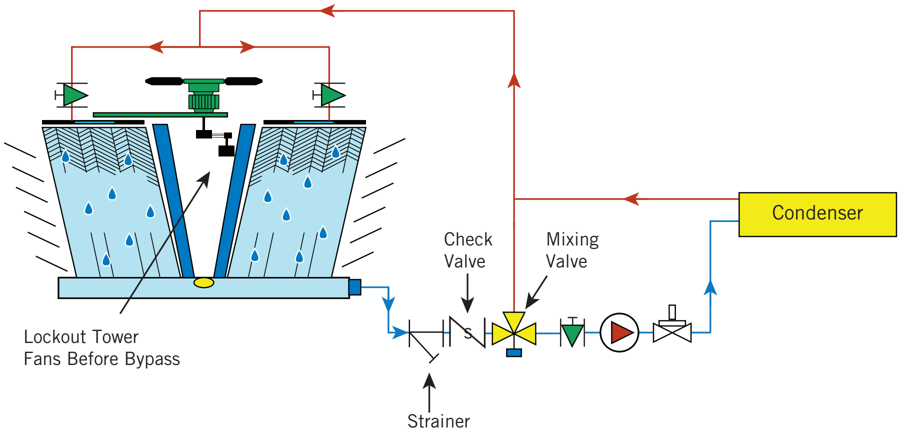


Figure 22. High Pressure Drop Strainer, Check, Control, and Balance Valve in Suction Line - **WRONG**

The second application rule is:

Place the Pump Below Tower Pan Water Level!

In **Figure 23**, the pan water level is shown above the pump for the illustration. This insures a flooded pump on start-up. It is best to maximize "H", if possible, even a minimum "H" of the order of several feet static height will still provide a very high Available NPSH (generally above 30 ft) provided the suction line is left alone, and does not exceed the order of 5 ft friction-flow loss.

In **Figure 24**, the pump will not be flooded on start-up and will, therefore, require the fill as illustrated. A check valve must be provided in the suction line to prevent suction line drainage.

Available NPSH has now been reduced because the pump is above pan water level and because a suction line check or foot valve has become necessary.

The diagramed situation can usually be avoided. If unavoidable, however, a careful NPSH evaluation should be made and strong specifications made concerning allowable check valve pressure drop.

A third suction line application point is:

Avoid "Above the Pump" Air Traps in the Suction Line!

Installations as in **Figure 25** should, and usually can be avoided. When absolutely unavoidable, the modifications shown in **Figure 26** will prove of help.

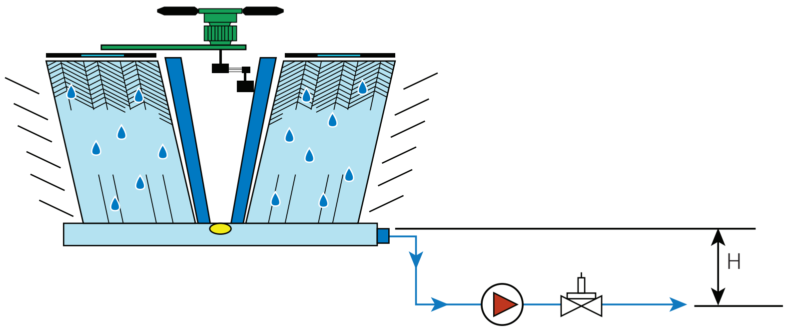


Figure 23. Pump Below Pan Water Level - **RIGHT**

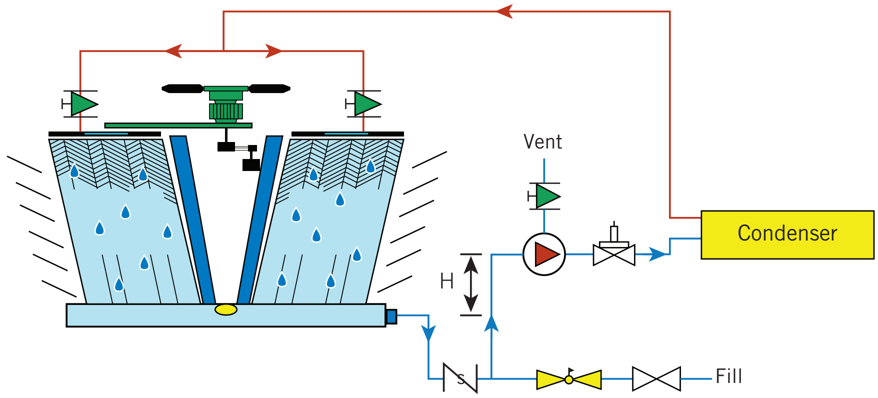


Figure 24. Pump Above Pan Water Level - **Avoid if Possible**

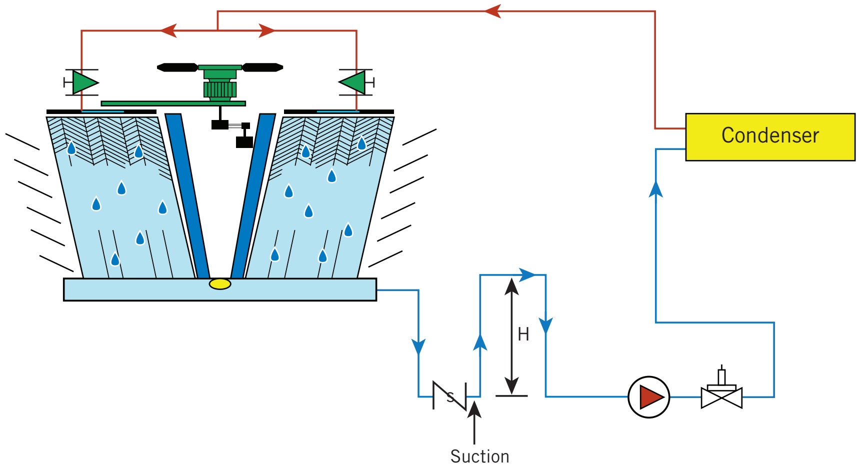


Figure 25. Suction Line Air Trapped - **WRONG**

Cooling Tower Pumping and Piping

While the air trapped suction is still not recommended, the modifications illustrated in **Figure 26** will help alleviate the otherwise intolerable operating conditions established in **Figure 25**.

Careful evaluations as to available pump suction pressures will have to be made and strong specifications stated to allowable check valve pressure drop.

A fourth suction line application point concerns:

Avoid Fine Mesh High Pressure Drop Strainers in the Suction Line!

Pump suction line strainers are apparently one of those peculiar "be darned if you do and darned if you don't" propositions. There are two conflicting needs.

1. Protection of the system; pumps, valves, condenser, spray nozzles, etc. against dirt and debris.
2. The fact of placing a fine mesh strainer in the suction piping will make a mockery of the most careful pump suction pressure evaluation. This is because an uncontrollable variable has been introduced; once the strainer gets clogged cavitation will occur.

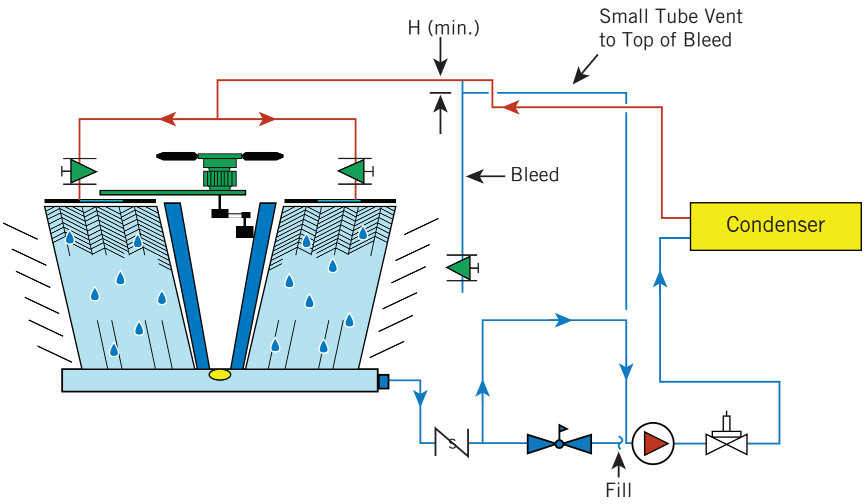


Figure 26. Improved Suction Line Air Trap Installation

The problem is not unsolvable, however, once it is understood that the centrifugal pump will pass fairly large objects. This means that strainer mesh openings from 3/16" to 1/4" can be used if the only function of the strainer is to protect the pump.

Tower pans are usually provided with an exit strainer (at tower outlet to suction piping) of this mesh order. Such tower strainers should be specified since they can be watched and are easily cleaned without piping drainage.

When tower pan strainers cannot be provided, a large mesh low pressure drop strainer can be placed in the suction line. Such strainers should be strongly specified both as to mesh size (3/16" min.) and pressure drop.

Fine mesh strainers are often needed for protection of the condenser, its valves, and/or spray nozzles. The fine mesh strainer should be placed at the pump discharge; usually between pump discharge and the pump check valve. This location will often simplify the work of the operator in removal and cleaning of the easily clogged basket.

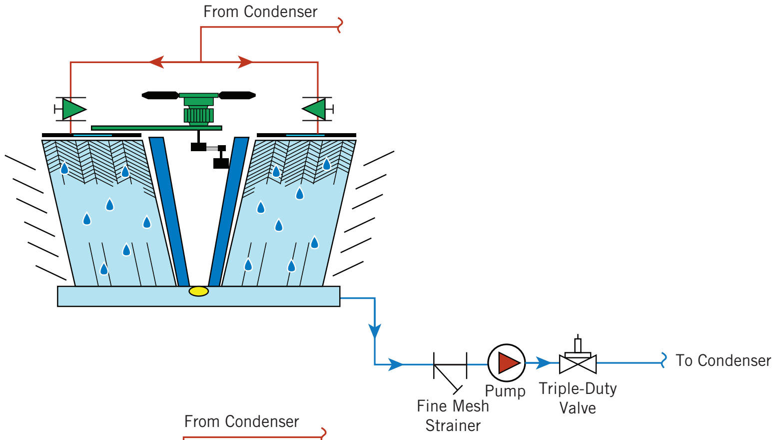


Figure 27. Fine Mesh Strainer in Pump Suction Line - **WRONG**

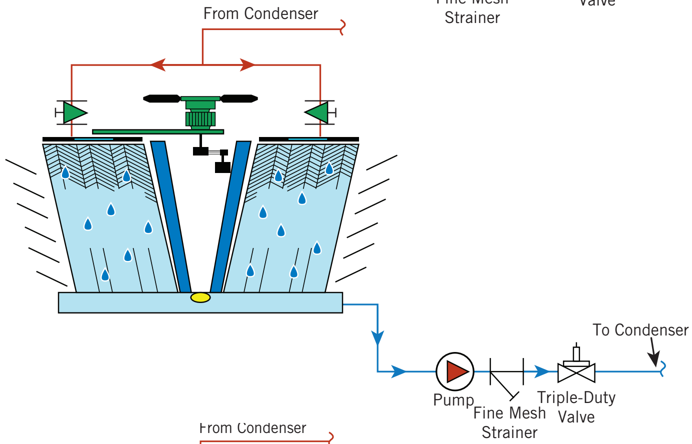


Figure 28. Tower Strainer Protects Pump; Fine Mesh Protects Condenser, Etc. - **RIGHT**

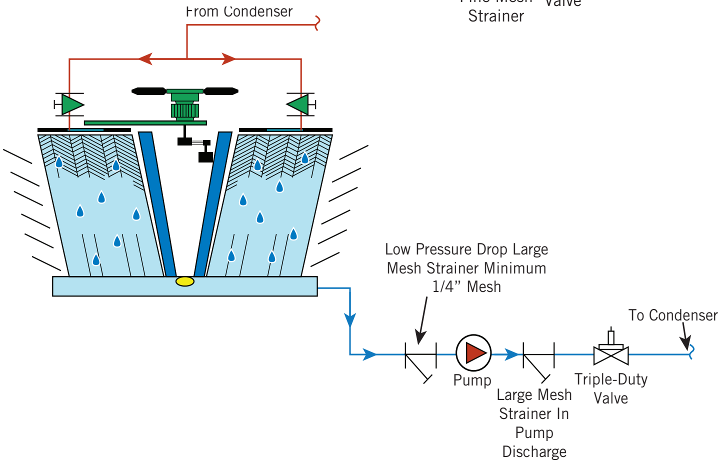


Figure 29. Large Mesh Strainer Protects Pump; Fine Mesh Protects Condenser, Etc. - **RIGHT**

Cooling Tower Pumping and Piping

Strainer clog always has and will continue to present operating problems; old newspapers, cottonwood seeds, tree leaves, etc. seem to find their way with an unerring directional sense to the tower - and ultimately to the tower strainers.

Several protective measures are available; the tower itself can be screened and a tower overflow can be used (in place of bleed blow-down) to “float off” leaves and other debris to drain before they get into the piping strainers.

The importance of a well designed tower pan strainer and proper maintenance should again be emphasized.

Given even the best preventative measures, strainers will still become clogged, however, and the operator should be given simple working tools to determine when strainers need cleaning.

A differential gauge can be placed across the strainer. This can often be set to trigger an alarm under high pressure differential (clogged strainer) conditions. This is illustrated in **Figure 30**, together with a manual differential read-out method.

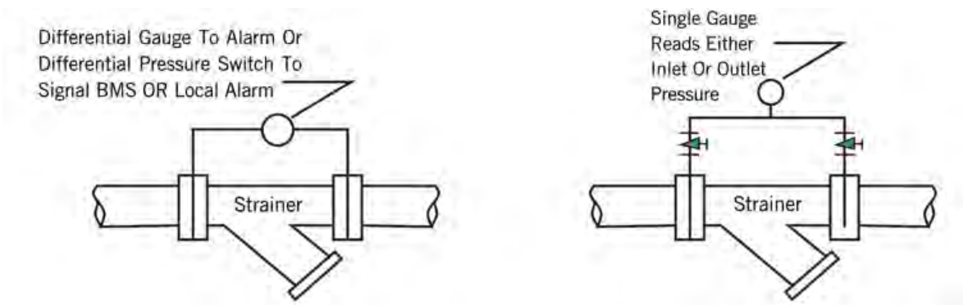


Figure 30. Reading Strainer Pressure Differential

Predicting Pump Operating Points

The System Curve

Actual pump operating points considerably beyond that stated in the pump specification should be guarded against. The more than predicted flow rates can cause tower air vortexing and will increase pump cavitation probability. Increases in system flow rate will decrease available pump suction pressure and, at the same time, state a need for increased suction pressures.

System curve analysis will be used to point out the importance of the initial specification points; the importance of balance or throttle valves and the importance of stable operating points. This is because system operating characteristics may be affected by tower bypass control and other factors.

The closed loop system curve analysis considers only flow-friction loss. Static head losses do not occur in the closed loop piping circuit.

A closed loop piping circuit is illustrated in **Figure 31**. The flow-friction or energy head loss is calculated at 40 ft at a flow rate of 300 GPM.

It should be apparent, for **Figure 31**, that if only 150 GPM flow rate occurred, the flow-friction loss will be less. This is so, and the change in energy head required to drive 150 GPM, rather than 300 GPM, through the piping circuit is defined by the basic flow-friction loss relationship which states:

"Friction loss changes as the square of the flow change."

In other words, a reduction of flow to one half that initially stated means a friction or head loss reduction to $(1/2)^2$ or 1/4 that required for the conditions. If we reduce flow to 150 GPM, from 300 GPM, the friction loss for **Figure 31** will only be 10 ft:

$(40 \times (1/2)^2 = 40 \times 1/4 = 10$ ft).

This relationship can be set up on a programmable calculator, computer, or the B&G System Syzer, available at www.bellgossett.com.

Considered in isolation, the changes in system friction loss can be stated as Ft Head versus GPM in the tables as below.

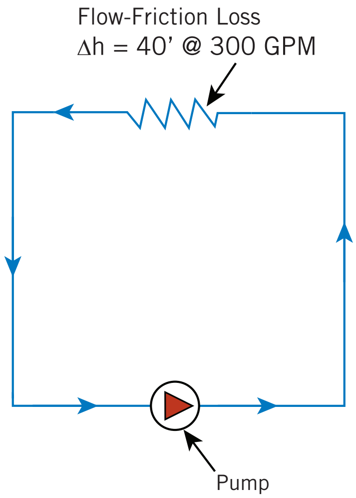


Figure 31. Flow Friction Loss in Closed Piping Circuit Determines Required Pump Head; Height Not Considered

Flow (GPM)	0	50	100	150	200	250	300	350	400
Ft Head	0	1.1	4.4	10	17.8	27.8	40	54.4	71.1

Table 4

The above numbers can also be calculated with the following equation: $\mathbf{H_2 = H_1 * (Q_2/Q_1)^2}$

Where:

H_2 = Future Head Pressure
H_1 = Known Head Pressure
Q_2 = Future Flow (gpm)
Q_1 = Known Flow (gpm)

Flow	Head $(H_2)O$		Equation
0	0	=	$40*(0/300)^2$
50	1.1	=	$40*(50/300)^2$
100	4.4	=	$40*(100/300)^2$
150	10	=	$40*(150/300)^2$
200	17.8	=	$40*(200/300)^2$
250	27.8	=	$40*(250/300)^2$
300	40	=	$40*(300/300)^2$
350	54.4	=	$40*(350/300)^2$
400	71.1	=	$40*(400/300)^2$

Cooling Tower Pumping and Piping

The previous numbers in **Table 4** can be plotted on a Ft Head versus GPM chart as in **Figure 32** and will illustrate the piping circuit flow-friction loss or head relationship for the closed loop piping circuit shown in **Figure 31**.

The First Law of Thermodynamics expressly establishes that:

"ENERGY IN = ENERGY OUT."

It must then follow the plotting of a pump curve across the system curve establishes the point of operation for that particular pump when applied to the particular piping system stated for **Figure 31**. The pumping point must be at the intersection of the pump curve with the system curve; as illustrated in **Figures 32** and **33**. It is recommended to plot this data on the actual pump curve as indicated.

A great many application observations could be made concerning closed loop pumping as shown in **Figure 31**. Our present concern, however, is not with the closed loop but is with the open loop, in particular the tower piping circuit. The difference is that we must take into account the "open" or "static" pumping head.

Supposing now, that we establish the same flow-friction loss; 40 ft at 300 GPM, as for our previous example - but state this to a tower pumping example with a "static" or "open circuit" pumping head requirement of 13 ft.

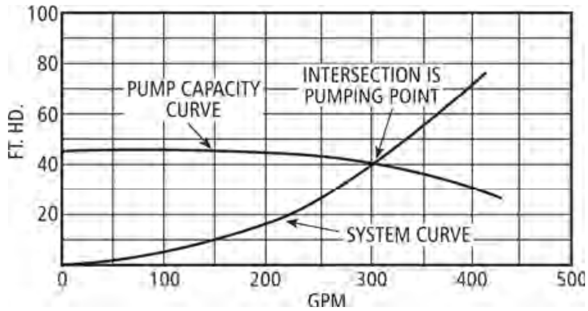


Figure 32. Plot of Flow-Friction Loss or System Curve for **Figure 31**

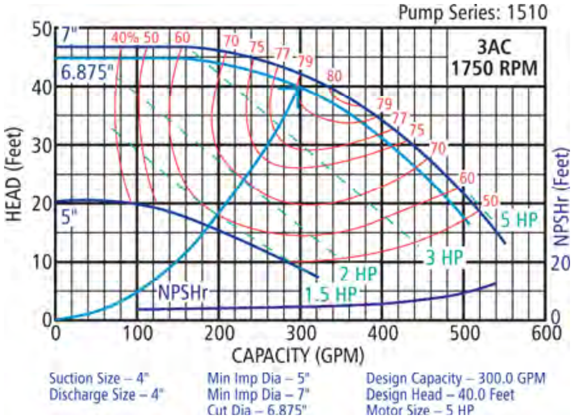


Figure 33. Intersection of System Curve with Pump Curve as Pumping Point

Reference should be made to previous discussion concerning determination of "open" piping circuit pump head requirements (**Pages J120 - J127**).

Given, however, that the flow-friction loss is 40 ft at 300 GPM, we would set up a table exactly as **Table 5** for the closed piping circuit analysis. This would describe the flow-friction loss relationship in the piping circuit shown in **Figure 34**.

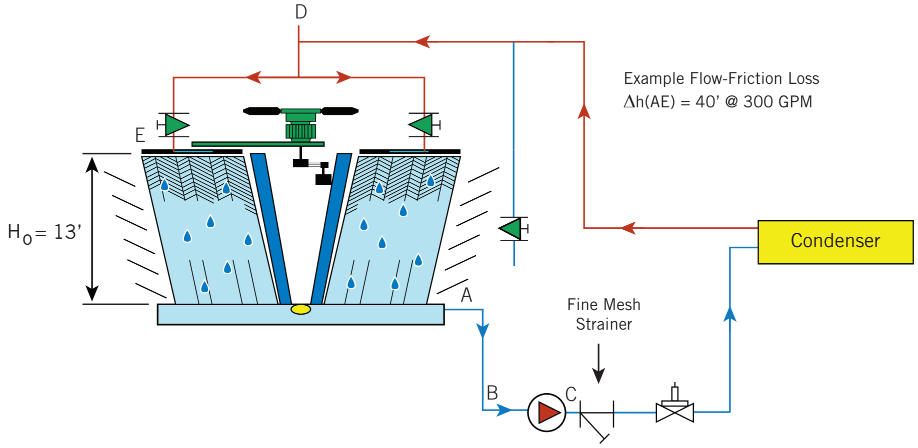


Figure 34. Tower Example; Δh (AE) = 40' H_0 = 13'

Flow (GPM)	0	50	100	150	200	250	300	350	400
Ft Head	0	1.1	4.4	10	17.8	27.8	40	54.4	71.1

Table 5

It will be apparent, from **Figure 34**, that water flow cannot occur, until the pump has raised water from level "A" to level "E"; a height of 13 ft.

The open pipe circuit system curve differs from "closed loop" in that static head loss must be introduced into the problem.

Static head losses are added to the flow-friction losses to establish total head requirement at various flow rates. This is illustrated in **Table 6** for **Figure 34**.

Flow (GPM)	0	50	100	150	200	250	300	350	400
Friction Loss (Ft Head)	0	1.1	4.4	10	17.8	27.8	40	54.4	71.1
Static Head (Ft Head)	13	13	13	13	13	13	13	13	13
Total Head Loss (Ft Head)	13	14.1	17.4	23	30.8	40.8	53	67.4	84.1

Table 6

Plotting of total head loss versus GPM establishes then, the "open system curve" for the piping circuit defined in **Figure 34**. The pump curve intersection with the system curve so described illustrates the actual pumping point. This is again defined by the First Law.

Cooling Tower Pumping and Piping

System curve analysis will be of value in evaluating:

1. Pump operating point shift due to less than anticipated flow-friction loss in the piping circuit.
2. Unstable pump operation as caused by:
   a. Incorrect tower bypass arrangements.
   b. Tower bypass with high pressure drop spray nozzles.

Pump operating points should be stable and as close to that specified as possible in order to set up design safeguards against tower vortexing and pump suction problems.

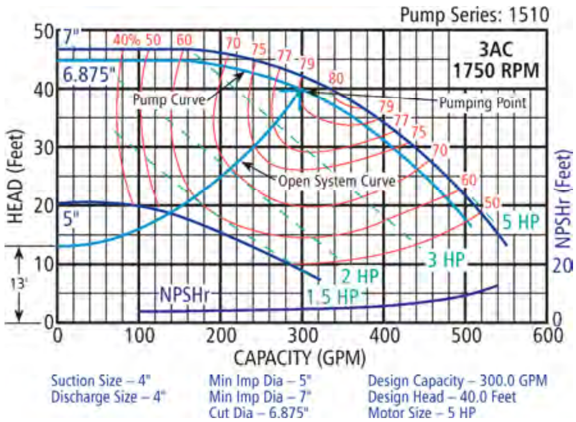


Figure 35. Open System Pumping Point

Non Bypassed Tower Pump Operating Shift

While tower pump static heads can be easily defined, the flow-friction heads will often be less determinate.

Installed condenser pressure drop may be less than specified and the pipe friction loss less than anticipated.

The piping friction loss is often based on a pipe "age" factor, based on possible interior pipe fouling due to aerated tower water. The rate of fouling is a relative unknown, leading to divergent engineering practice.

1. Some engineers design to clean pipe; Hydraulic Institute or B&G System Syzer. The opinion being that the tower must be treated in order to insure condenser performance and that chemical treatment will provide against the pipe fouling problem.
2. Others engineers provide an "age" factor for pipe pressure drop ranging from 50% over "clean" data to 100% or twice that used for the closed loop system. Pipe pressure drop data for "15 year old" pipe is stated to the order of twice that used for clean pipe.*

NOTE: The B&G System Syzer can be used for either clean or "aged" conditions. When used for "15 year old" pipe, the illustrated friction loss is simply multiplied by 2.

Unlike the closed loop heat-cool Hydronic System, it does not generally make a great deal of difference as to whether “clean” or “15 year old” pipe friction loss data is used for the tower system. This is because pipe friction loss is usually only a small part of the total pump head; system statics and the condenser providing the major part.

As an illustrative example, a proposed tower system is composed of the following elements concerning pump head.

Static or Open “Head”	12’
Condenser	25’
Valves, Strainer, etc.	7’
100’ Piping @ 15 Year Old	6’
TOTAL HEAD	50’

The actual clean pipe pressure drop is only 3 ft, so that the true initial head is 47 ft rather than 50 ft. The difference (system curve not shown) would cause an increase in flow rate of some 4%; an insignificant change.

Much more significant and bothersome change can be caused by substitution of a low pressure drop condenser when the pump head estimate is based on the highest pressure drop condenser unit expected to be bid.

The same tower system will be evaluated; estimated head will be compared with actual head loss.

	Estimated Head Loss	Actual Head Loss
Condenser	25’	8’
Valves, Strainer, etc.	7’	7’
150’ Piping @ 15 Year Old	6’	3’
Total Flow-Friction	38’	18’
Static or Open	+ 12’	+ 12’
TOTAL PUMP HEAD	50’	30’

Table 7

Cooling Tower Pumping and Piping

The pump is specified at design flow for 50 ft while the true head loss is only 30 ft. Assuming a design flow rate of 300 GPM, what will the actual flow be?

A system curve table plot is made following procedures previously provided.

Flow (GPM)	0	250	300	350	400	450
Actual Flow-Friction (Ft Head)	0	12.5	18	24.5	32	41
Static Head (Ft Head)	12	12	12	12	12	12
Total Head Loss (Ft Head)	12	24.5	30	36.5	44	53

Table 8

The system curve plot is then as illustrated as **Figure 36**.

The pump point shift has increased flow over design to the order of 45%. Cavitational and/or tower vortex can occur unless corrective measures are applied.

The pump impeller diameter could and should be cut down to match the pump to the system.

It is more usual, however, to simply throttle the pump discharge. This leads to a very important tower application point:

THROTTLE OR BALANCE VALVES SHOULD NOT ONLY BE INSTALLED AT THE PUMP DISCHARGE; THEY SHOULD BE USED! When the balance valve is significantly closed, trim the impeller and open up the balance valve.

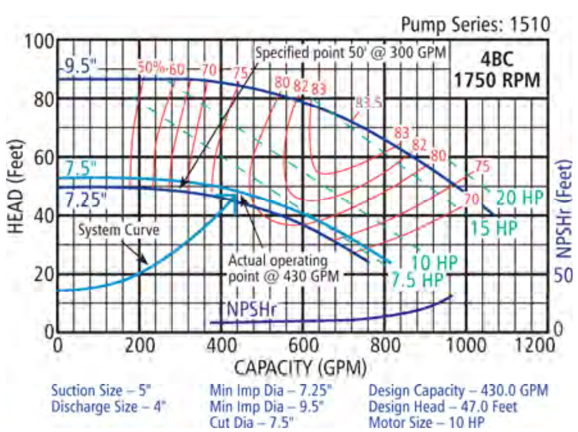


Figure 36. Example System Curve; Less Than Anticipated Pump Head

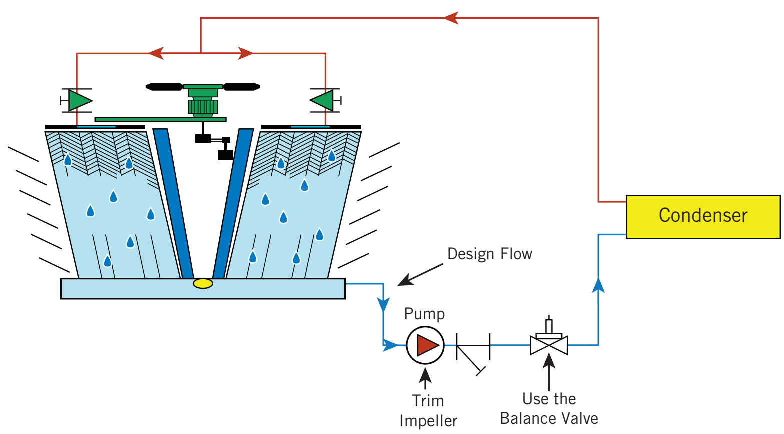


Figure 37. Use of the Balance Valve Will Often Prevent Air Vortex and Suction Pressure Problems

Flow through the tower system can be measured by any of several methods:

1. Pump differential pressure (based on pump curve).
2. Condenser differential pressure (based on manufacturer's data).
3. Triple-Duty Valve (combination check and throttle) differential pressure (based on calibrated C_v data for various valve openings).

Given a stable pumping arrangement, a properly set balance valve will help protect the pump against many operating problems.

The unstable tower pumping system will be aided by use of the balance valve - but problems may still occur because of improper tower bypass applications.

Tower Bypass

Tower Bypass - General Methods

Improperly applied tower bypass control arrangements can cause unstable pump operation and large volume flow changes through the condenser. Condenser flow change can cause chilled water temperature control instability, especially for absorption machines, and will greatly increase pump trouble probability.

There are two basic methods for tower bypass:

1. Bypass to tower pan.
2. Bypass to suction piping.

Bypass to the tower pan will generally be preferred because of greater flow stability and because the possibility of air suction into the pump is greatly reduced.

Bypass control valves that are used are:

1. Three-way "diverting or bypass."
2. Two "linked" two-way valves (usually butterfly valves) acting as a three-way diverting valve.
3. A single two-way butterfly valve placed in the bypass line.

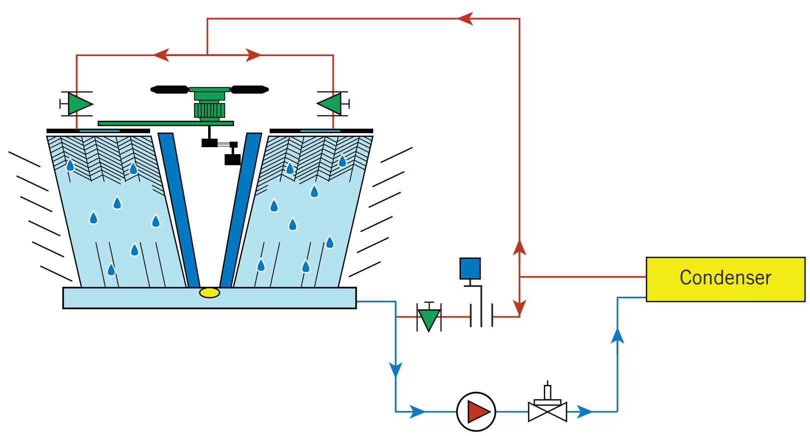


Figure 38A. Basic Tower Bypass Methods - to Suction - **Not Recommended**

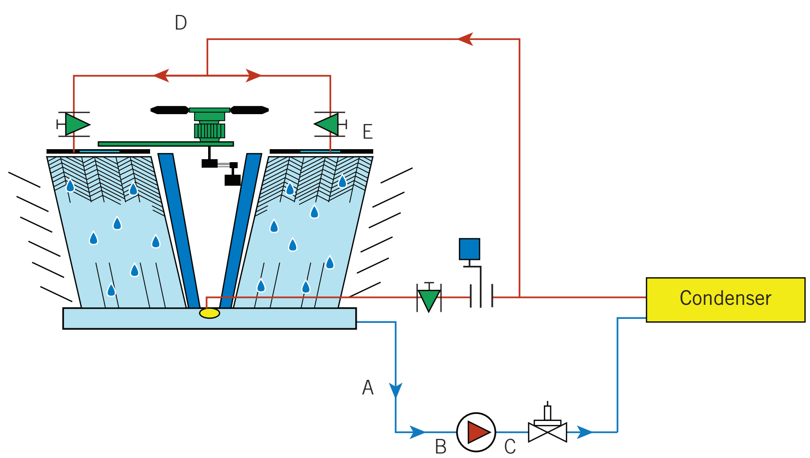


Figure 38B. Basic Tower Bypass Methods - to Basin - **Recommended**

It should be particularly noted that three-way mix valves should not be applied to tower bypass control.

Cooling Tower Pumping and Piping

The three-way mix valve (two inlets; one outlet) should not be used for tower bypass application because it must be placed in the pump suction line and can cause pump suction pressure problems. The three-way mix valve application is "inviting" in the sense that the mix valve costs less and is more readily available than the diverting three-way valve. Its actual application is only an invitation to trouble, however.

Three-way diverting (one inlet; two outlets) application is much preferred since this valve will be placed in the condenser return line (pump discharge) where its operation will not effect pump suction pressures.

Relatively high cost and limited availability generally confines use of the actual three-way diverting valve to sizes in the general order of 4" or less.

For pipe sizes beyond the order of 4" or larger, linked butterfly valves are usually provided to serve the same function.

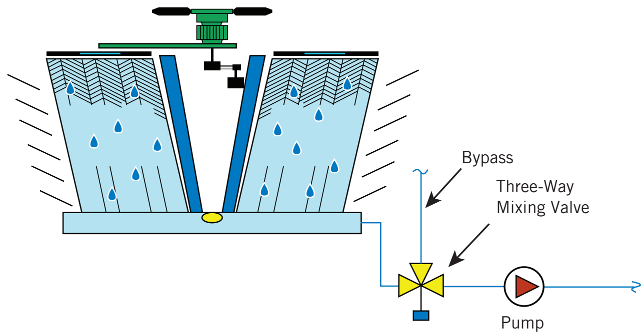


Figure 39. Three-Way "Mix" - **Do Not Use**

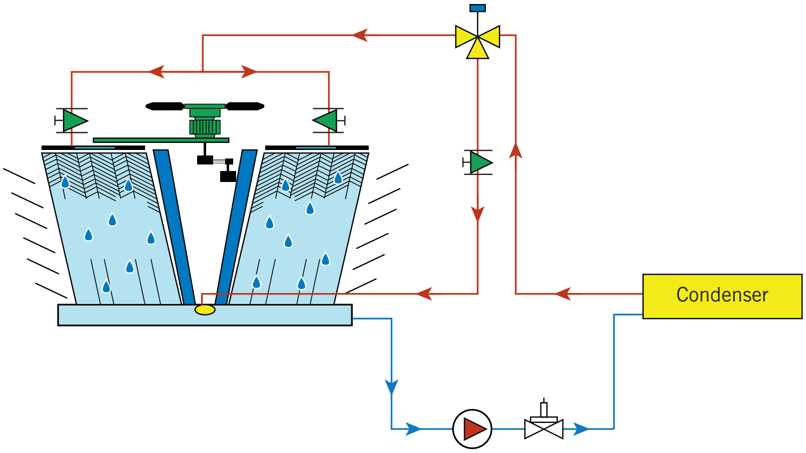


Figure 40A. Use Diverting Valves Not Three-Way Mix

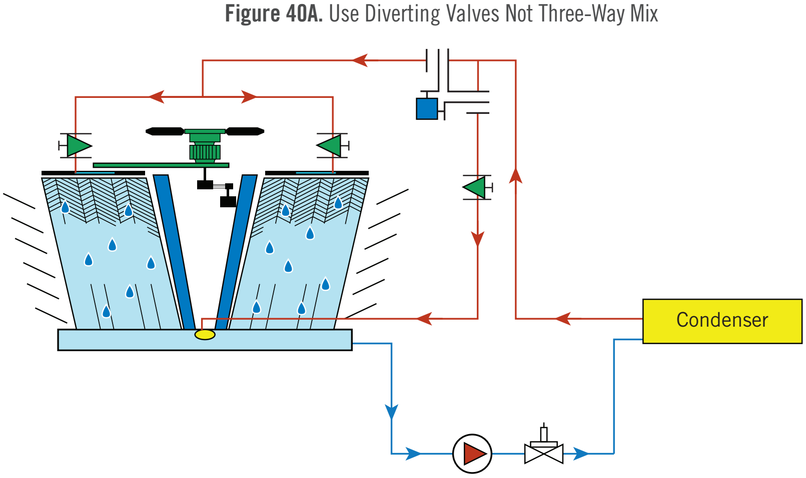


Figure 40B. Use Diverting Valves Not Three-Way Mix

The single two-way butterfly valve is also used for tower bypass; two generalized application possibilities are shown with the valve installed in the bypass line.

Basic conceptual patterns and valve bypass arrangement possibilities have been presented. The problem now is to establish application considerations that will eliminate pump instability when bypass actually occurs. Three working tools are needed:

1. Tower circuit pump head requirements; static and flow-friction. These considerations have already been presented (covered in **pages J120 - J122**).
2. Tower system curve analysis methods. This has been illustrated (covered in **pages J146 - J148**).
3. Knowledge of valve operational patterns; flow-friction loss as related to size and valve opening. This has not been shown (covered in **pages J140 - J144**).

Bypass Valve Operational Characteristics; Valve Coefficient (C_v)

Valve "C_v" is a statement of the flow rate necessary to cause a pressure drop of 1 PSI across the valve.

While the pressure drop at C_v flow rate is conventionally defined as 1 PSI, it is better for general system application to consider this in terms of ft fluid head equivalent. For Hydronic System work then:

C_v = GPM Flow Rate at 2.3 ft Head Friction Loss Across the Valve

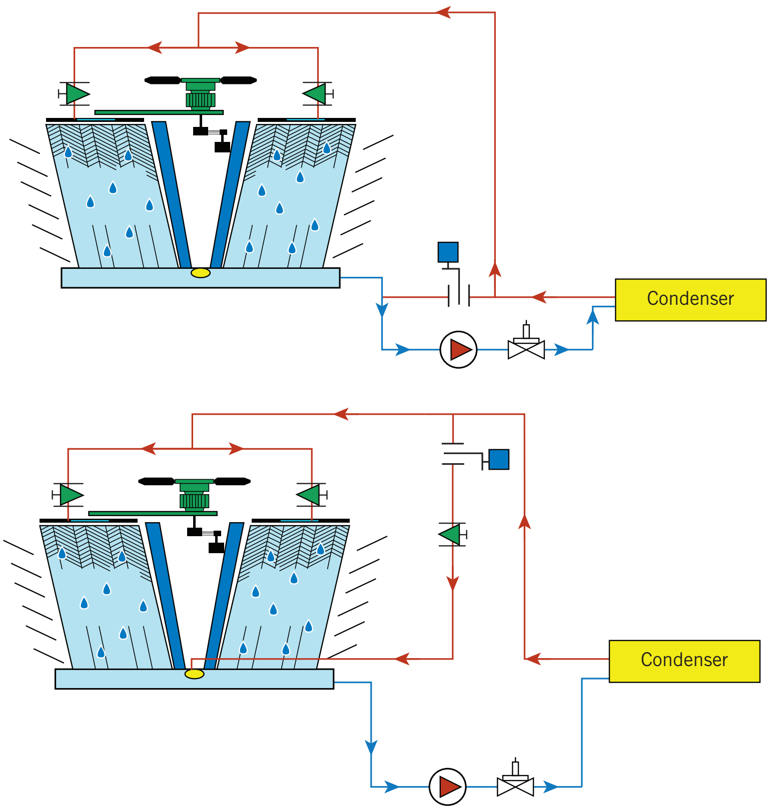


Figure 41. Single Butterfly Also Used for Bypass

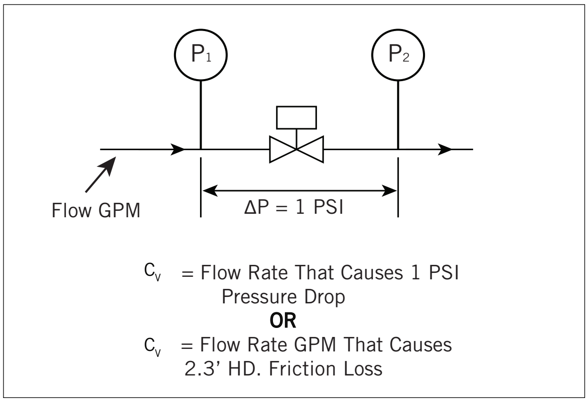


Figure 42. C_v Relationship

Cooling Tower Pumping and Piping

As with the system curve previously described, a change in flow rate will cause a change in head loss. Head loss will change as a squared function of flow rate. The tabulated change can be plotted as in **Table 9** for a valve; C_v =10.

Flow (GPM)	0	5	10	15	20	25	30	35	40
Ft Head	0	0.6	2.3	5.2	9.2	14.4	20.8	28.3	37.0

Table 9

The points shown in **Table 9** can be plotted on a Ft Head versus GPM chart to illustrate the complete flow-friction loss relationship defined by the specific C_v = 10.

The curve illustrates that at a flow rate of 20 GPM a pressure drop of 9.2 ft will occur through a valve rated at 10 C_v. Curve plots are generally not necessary, since the B&G System Syzer will provide this same information in a single simple setting.

As an example in use of C_v, a valve is to be installed for bypass, and application considerations require that a 20 ft head be developed across the valve at 300 GPM design flow rate.

From the B&G System Syzer: 20 ft at 300 GPM = C_v of 102.

A valve selection for C_v = 102 will meet requirements.

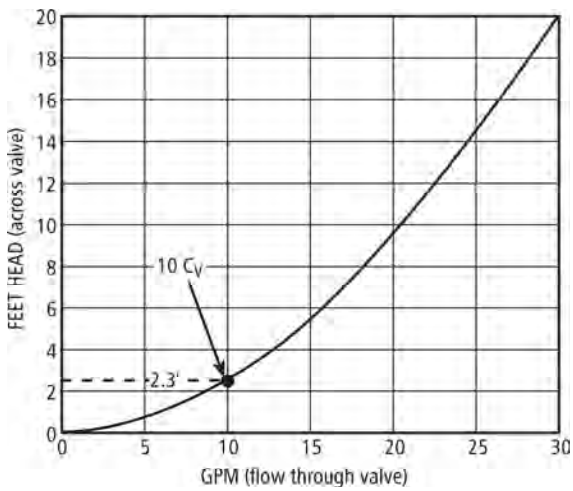


Figure 43. Valve Flow-Friction Loss Relationship Described By C_v = 10

Valve C_v information is provided by control valve manufacturers in either tabulated or chart form.

Figure 43 shows a possible plot of C_v for a line of butterfly valves, 2“ to 12“ in size. This plot illustrates changes in valve C_v from wide open (90°) through various degrees of closure. It should be understood that this plot simply illustrates the general order of C_v relationship for butterflies and should not be used for actual design.

For a C_v selection of 102, the following valve sizes can be used:

Valve Size	C_v = 102 @ Approximate Degree Open
5”	34º
4”	42º
3”	53º
2.5”	68º

Table 10

Actual valve selection would be left to control people. It is of interest to note, however, that 300 GPM dictates a pipe size of 5“ while valve selection possibilities range down to the order of 2-1/2“ with an increased control “range” (degree movement) for the smaller valve. This will usually mean more control precision.

It should be noted that for two-way modulating valves, C_v changes as the valve moves from open to closed. This is not true for a conventional three-way valve applied to modulating service.

Three-way valves are designed to a comparatively constant C_v factor. That is to say; at a constant differential head, a constant total flow will occur through the valve; whether through a single port or through any combination of port openings.

Directly linked butterfly valves acting as a three-way will not necessarily establish this same correlation, however. This will be seen from examination of **Figure 44**.

A 3 inch valve at C_v = 120 will be set for the order of 60° open. This would be the setting for both the tower valve and its linked bypass valve when either is open with the other closed.

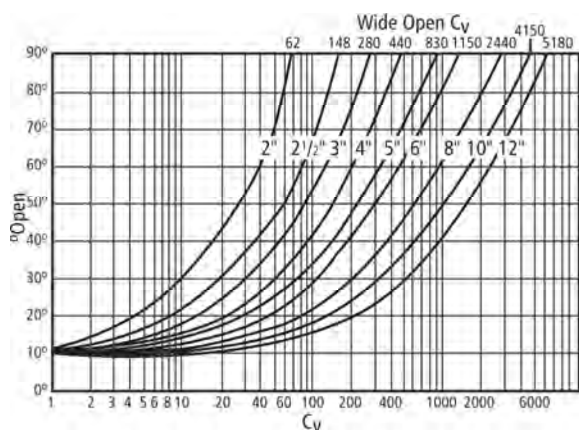


Figure 44. Approximate Butterfly C_v As Related to - Open

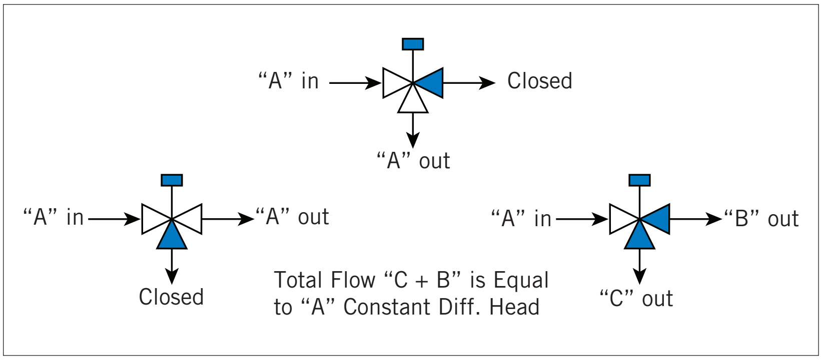


Figure 45. Three-Way Valves are Designed to Constant C_v

Cooling Tower Pumping and Piping

At 50% position, each valve is positioned at 30° and the direct link would state that each valve would have a C_v to the order of 30; with a total "linked" C_v of 60.

This means, unless precautions are taken, that the linked valves will provide a rising pressure drop characteristic on bypass. For the example; pressure drop at a 50% open condition for both valves would be the order of four times that when one valve is open and the other closed.

In terms of tower bypass control, the above means that condenser flow can be reduced when bypass occurs. The precautions taken are:

1. Use of three-way diverting valves when size availability and cost permits.
2. When "linked" butterfly valves are applied, generally in sizes 4" and above, the valves should be selected for low pressure drop characteristics at design flow. This will minimize condenser flow reduction on bypass.
3. Knowledgeable control people will often avoid a single operator with directly linked butterfly valves. They often prefer individual valve operators with "lead-lag" operation to reduce C_v change on bypass.

It should be noted that the peculiar characteristic of butterfly valves is sometimes of benefit.

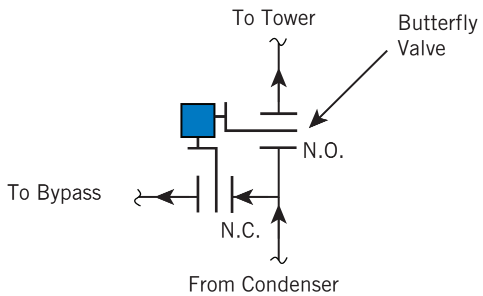


Figure 46. Directly Linked Butterflies can Reduce Condenser Flow when in Partial Bypass and when Valves are Selected to High P.D.

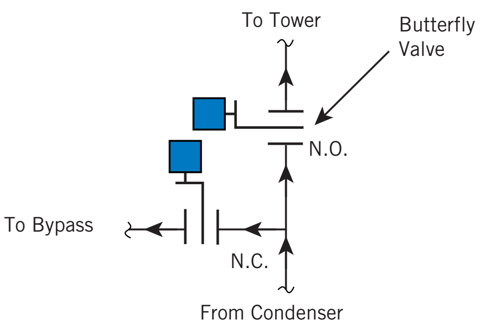


Figure 47. Individual Operators in Lead-Lag Sequence Helps Solve Problem as Does P.D. Selection

Tower Bypass; Design for Flow Stability

Working tools have now been provided for analysis of various tower bypass arrangements as they affect pumping stability. It will again be noted that pumping instability can affect chilled water temperature control and greatly increases pump trouble potential.

Bypass to Pump Suction; Bypass and Condenser Below Tower; Tower with Splash Basin

A proposed floor below condenser installation is shown in **Figure 48**. Bypass is to the pump suction and it will be noted that the usual check valve in the tower suction line (AB_1) has been omitted for discussion reasons.

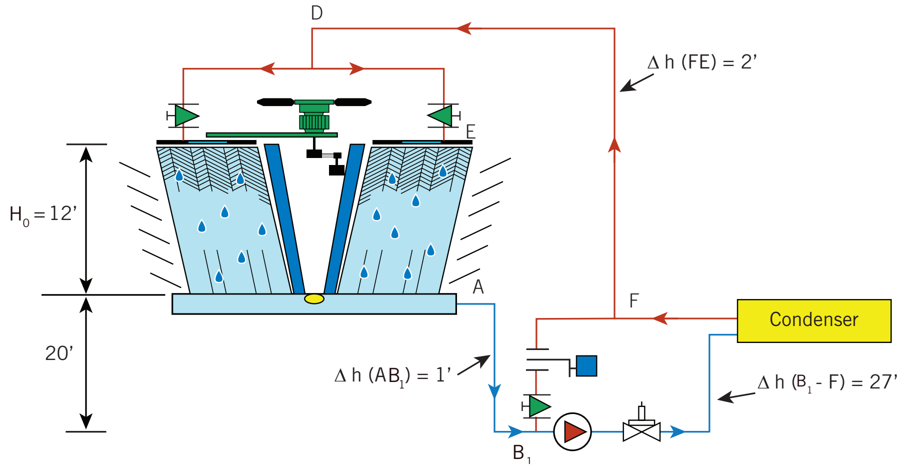


Figure 48. Tower Bypass Example

$$\text{PUMP HEAD SELECTION} = H_0 + \Delta h\,(AB_1) + \Delta h\,(B_1F) + \Delta h\,(FE)$$

$$= 12 + 1 + 27 + 2$$

$$= 42 \text{ ft}$$

Assume now that the bypass valve is 5" butterfly (selected at line size for 300 GPM) and has not yet been "set" by the control contractor; the valve swings to wide open at C_v = 830 (See **Figure 44** on **page J155**).

At 830 C_v and at 300 GPM, the bypass valve would develop only 0.3 ft head resistance and because of this, trouble could develop.

It will be noted for this example, and for all tower bypass to the pump suction, that complete bypass will cause the following changes to occur:

1. Tower suction line friction loss will be eliminated because of no flow.
2. Tower discharge line friction loss will be eliminated.
3. Static head will be lost.

Cooling Tower Pumping and Piping

Pump static head will be lost if bypass valve back-pressure to point "F" is insufficient to maintain a full column of water in the tower line. For our example the levels would change as illustrated in the following diagrams in which gauge readings are stated in Ft Head.

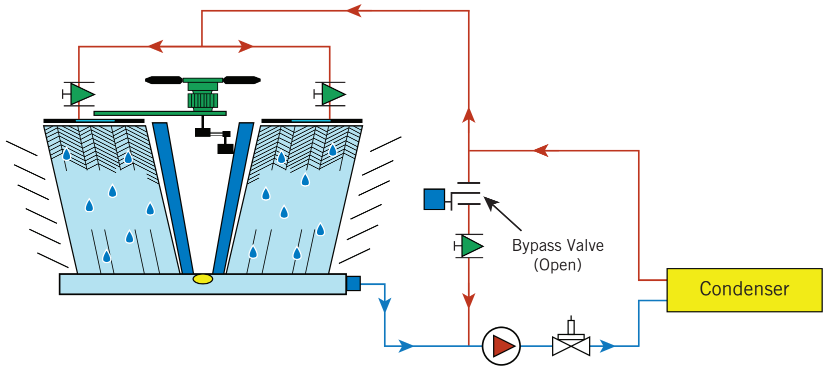


Figure 48A. Pump Off (For **Figure 48** on **Page J157**)

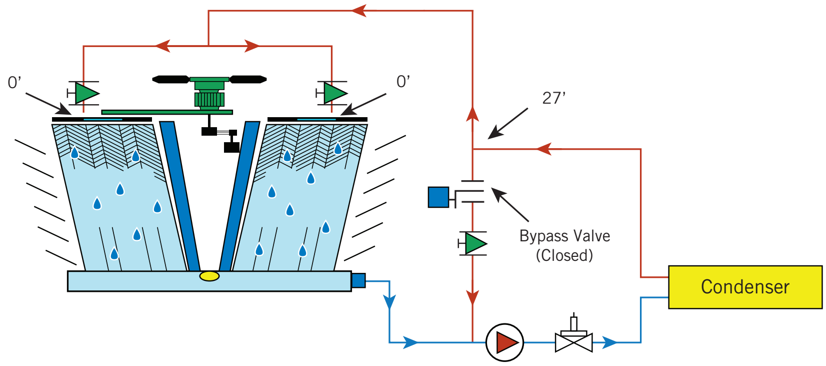


Figure 48B. Pump On; Bypass Closed (For **Figure 48** on **Page J157**)

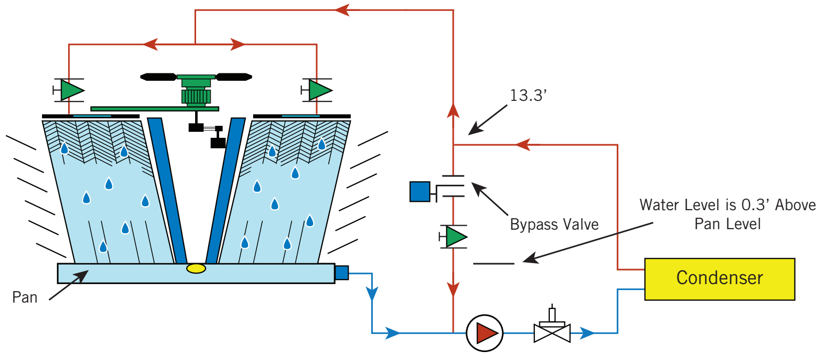


Figure 48C. Pump On; Bypass Open In Valve $C_v = 830$ (For **Figure 48** on **Page J157**)

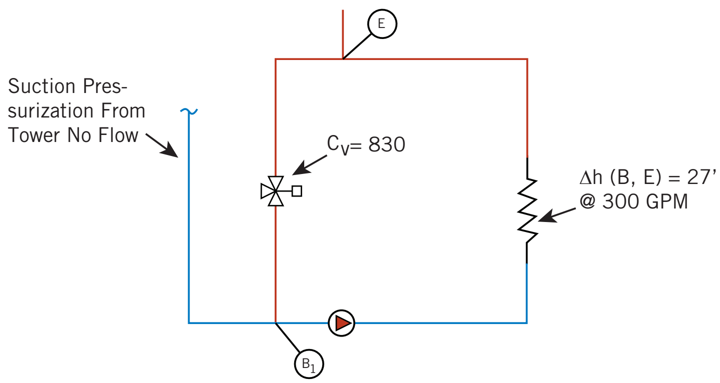


Figure 49. Tower in Total Bypass Establishes Closed Loop Operation; No Statics

The pumped piping circuit on bypass has now become a closed loop since all statics have been lost. The comparative system curves, full tower versus full bypass, can now be illustrated.

System Curve Tables:

Full Tower Flow						
Flow (GPM)	**0**	**100**	**200**	**300**	**350**	**400**
Actual Flow-Friction (Ft Head)	0	3.4	13.1	30	41	53
Static Head (Ft Head)	12	12	12	12	12	12
Total Head Loss (Ft Head)	12	15.4	25.1	42	53	65
Full Bypass Flow						
Flow (GPM)	**0**	**100**	**200**	**300**	**350**	**400**
Actual Flow-Friction (Ft Head)	0	3	12	27.3	36	47
Static Head (Ft Head)	0	0	0	0	0	0
Total Head Loss (Ft Head)	0	3	12	27.3	36	47

Table 11

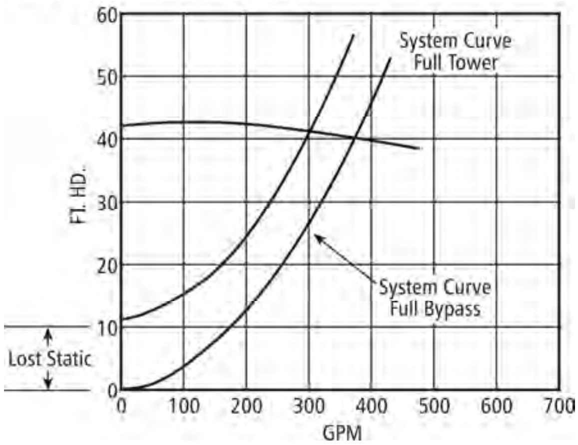


Figure 50. Pump Operating Shift Caused by Loss of Static Head

*Complete loss of all static head as caused by full bypass operation will cause a shift in pump operational point as described in **Figure 50**.

The pumping point shift can be virtually eliminated with reduced system cost and improved controllability by proper sizing and setting of the bypass valve.

Cooling Tower Pumping and Piping

When the bypass is to pump suction and is below tower pan level, the following application point should be observed: The valve should be selected for design flow at a head approximately equal to system static pump-height H_0.

This is the height from tower pan water level to the topmost tower discharge piping. For the example, described in **Figure 49**, H_0 is 12 ft. At a design flow rate of 300 GPM, the valve selection point would be at $C_v = 130$.

Reference to the B&G System Syzer illustrates that a 3" valve at 60° open will satisfy the requirement. Final selection should be left to the control engineer, since it is finally and ultimately his responsibility to both select and set the valve.

It should be pointed out that the valve will often be much smaller than conventional line size. The valve must remain as the control element in the bypass line, however, and the bypass would be pipe sized to usual criteria (in this case 5 in) except for the order of 5 valve size pipe diameters up and downstream of the valve, which would be valve size.

Given proper bypass valve sizing and setting, the operating pump shift will disappear because the "lost" static head is replaced by an introduced flow-friction head.

Other Bypass Application Problems

1. **High System Static Head Requirement**

   It will be noted that as system static pump head (H_0) increases, an intolerable valve pressure drop situation can be created. This would be especially true for a winterized penthouse tower draining into a basement receiving tank.

   The application solution to **Figure 51** is a bypass to the tower sump pan or to the gravity drain line at a point directly below the tower.

   It will be noted that bypass could be installed as shown in **Figure 51** given a reasonable H_0; a reasonable valve selection head. This will be defined by the control valve manufacturer and would generally not exceed the order of 25 ft.

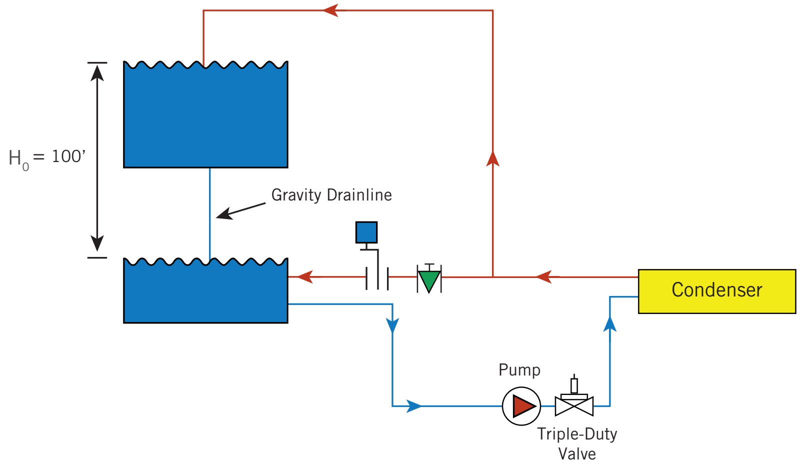


Figure 51. Intolerable Valve Sizing Situation Because of High Static H_0 - **WRONG**

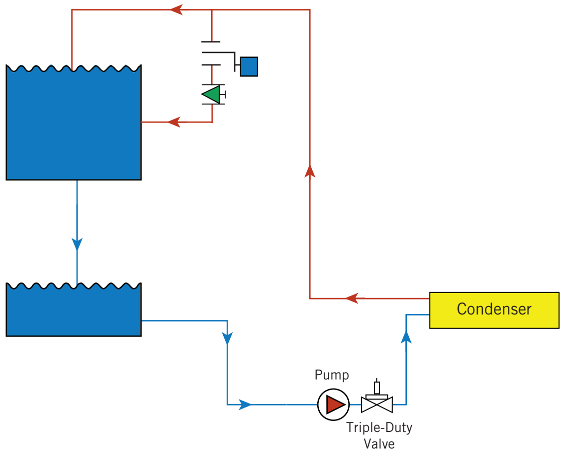


Figure 52. Bypass to Tower Solves High Static Head Bypass Problem

2. High Pressure Drop Spray Nozzle Tower with Bypass

The bypass arrangement in **Figure 53** can propose almost insurmountable pumping problems because of changes in pumping head as bypass occurs.

Pump head requirements for full tower flow will be:

$$\textbf{PUMP HEAD} = H_0 + \text{Nozzle } \Delta h + \text{Friction } \Delta h$$

$$= 10 + 25 + 30$$

$$= 65 \text{ ft}$$

During bypass, static head will be lost, as will flow-friction head through the spray nozzles, discharge piping Δh (ED) and suction piping Δh (AB). The only pumping head that will remain will be flow-friction in the condenser and bypass loop.

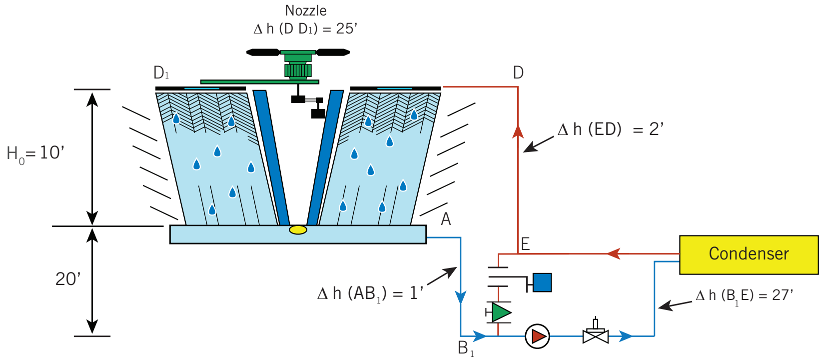


Figure 53. Bypass to Suction with HIGH Pressure Drop Spray Nozzle; Can Establish Intolerable Flow Instability

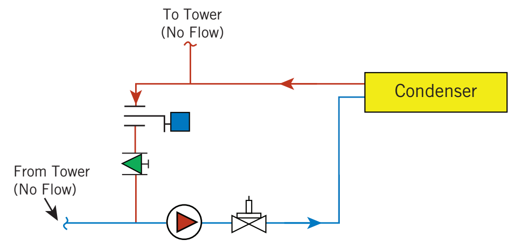


Figure 54. Open Bypass Valve Establishes Closed Loop Pumping Circuit with Lost Static and Lost Flow-Friction Head through Tower Nozzles, Suction, and Discharge Piping

Cooling Tower Pumping and Piping

Given a line sized bypass valve at wide open setting, the new pump head will only be:

PUMP HEAD = 27 + 0.3 = 27.3 ft @ 300 GPM

Pump head has now dropped from 65 ft to the order of 27 ft at design flow. This will result in a remarkable flow change as the bypass valve opens and closes; from a design 300 GPM with bypass closed to the order of 500 GPM with an open bypass.

Location of the bypass valve at a high point in the tower discharge line establishes that the pump static head H_0 will be a constant factor and is not "lost" as in **Figure 55**.

Linked butterfly valves are illustrated in **Figure 55** rather than the conventional diverting valve. This is because of a previously mentioned characteristic of linked butterflies that will, in this case, aid in providing flow stability.

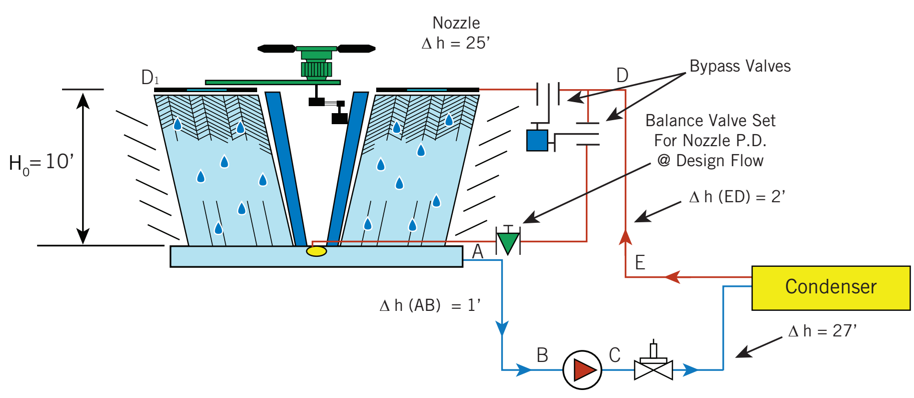


Figure 55. Bypass to Tower with Linked Butterflies and Balance Valve Provides Solution to Flow Instability Problem

The characteristic is that linked butterflies will increase flow-friction head resistance as the valves move from "one side open" to a modulating or "each valve 50% open" position. The characteristic combination valve head increase at 50%, will be to the order of 4 times that for only one side open.

When the valves move to a 50% bypass flow, flow-friction head through the spray nozzles will reduce from 25 ft to the order of 6 ft (50% flow = 25% head). The butterfly valves can now provide the "lost head" difference of 19 ft (25 – 6).

Since the lost spray nozzle head of 19 ft is to be provided at a 50% valve open condition; and since combined valve resistance head is 4 times that at a "one side open" condition. Valve selection will be to design flow and to "lost spray nozzle head" divided by 4. In this case:

Valve Selection Head = 19/4 = 4.7 ft; say 5 ft

Assuming a design flow of 300 GPM, the example valve selection will be 300 GPM @ 5 ft or C_v = 200. This would be line sized butterflies (5") at 50° open.

The balance valve illustrated in **Figure 54** serves the same function as bypass balance on a conventional hydronic three-way controlled coil; in this case it is set to spray nozzle pressure drop at design flow.

The tower piping arrangement is now basically stabilized in terms of pumping flow rates.

(a) Full Tower Flow Pump Head:

Pump Head $= H_0 + \Delta h\ (AD) + \text{Valve}\ \Delta h + \text{Spray}\ \Delta h$

$= 10 + 30 + 5 + 25$

$= 70$ ft

(b) Tower @ 50% Bypass

Pump Head $= H_0 + \Delta h\ (AD) + \text{Valve}\ \Delta h + \text{Spray}\ \Delta h$

$= 10 + 30 + 20 + 6$

$= 66$ ft

It will be noted that pump head has only decreased from 70 ft to 66 ft. This is tolerable since flow changes will be insignificant; 300 to 310 GPM.

(c) Tower @ 100% Bypass

Pump Head $= H_0 + \Delta h\ (AD) + \text{Valve}\ \Delta h + \text{Balance}\ \Delta h$

$= 10 + 30 + 5 + 25$

$= 70$ ft

3. Bypass to Suction; Condenser Above Tower Pan

Severe operating problems can be caused with pump suction bypass as illustrated in **Figure 56**. Improper valve setting will cause air to be introduced into the pump suction, causing pump "air binding" and mechanical pump troubles. These problems have been described on pages **J140 to J144** Lost statics will cause further troubles.

The balance valve, when set, minimizes static head loss problem possibilities. The tower bypass eliminates any possibility of air draw into the pump suction as caused by bypass.

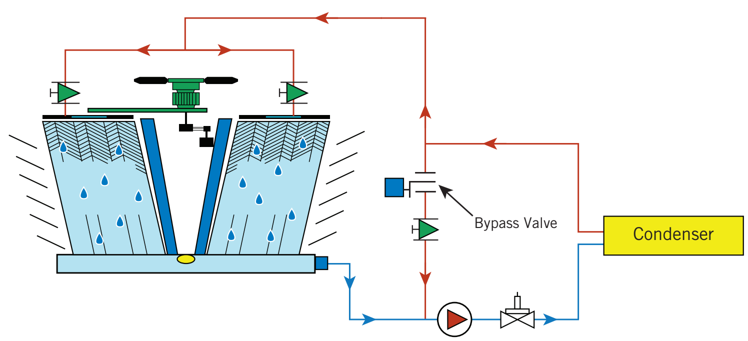


Figure 56. Possible Problem Installation; Bypass to Suction

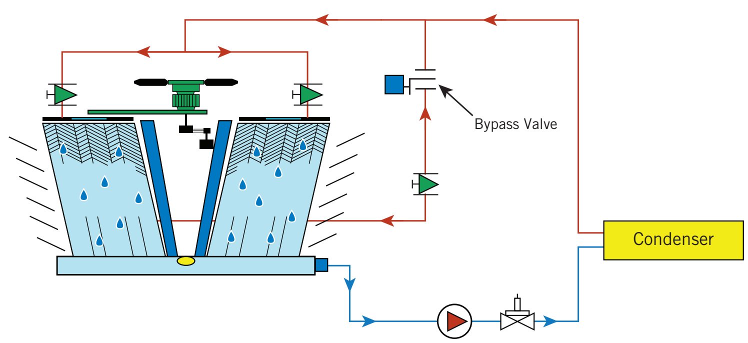


Figure 57. Bypass to Tower Eliminates Suction Air Draw Possibility and Reduces Pump Head Change

Cooling Tower Pumping and Piping

4. Condenser Above Tower

Bypass to the tower should always be employed when the condenser is located above the tower.

Given the downcomer return height H_r is greater than cancellable siphon return statics, balance valve #1 would be set in terms of previous design procedure (**page J122**).

Balance valve #2 is set for open system height H_0; valve pressure drop $= H_0$ ft for full bypass flow rate.

The linked butterfly valves would be selected for a low order of pressure drop at full design flow rate in order to minimize valve pressure drop change effect on total pumping head during partial bypass.

It will be noted that high pressure drop diverting three-way valve application may be preferable. The valves can be much smaller since there is no real concern regarding changed pressure drop on bypass. Use of a high pressure drop diverting valve would often eliminate the need for balance valve #1 as shown on **Figure 58**.

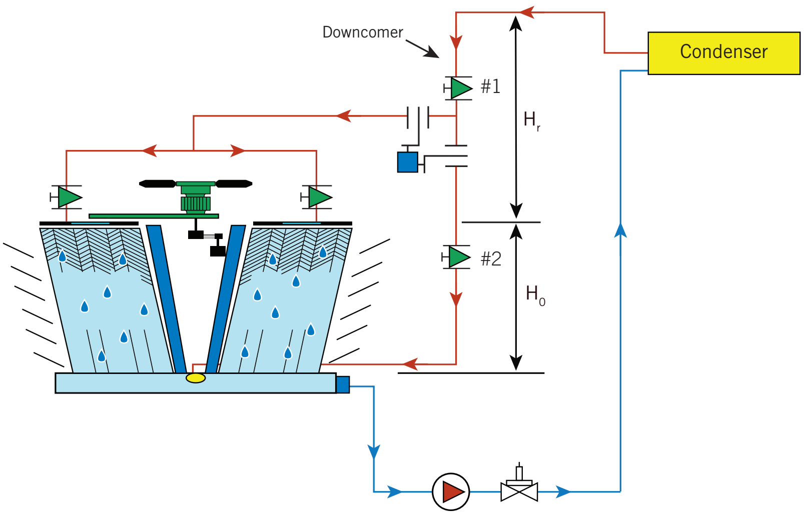


Figure 58. Overhead Condenser; Bypass to Tower with Linked Butterfly

This concludes the pumping and piping considerations covered in this handbook. For more information or considerations for special projects please contact your local BAC Representative or visit www.BaltimoreAircoil.com.

A special thanks to Bell and Gossett, a xylem brand for their contribution to this section. All content was Reprinted with permission from Xylem, Inc.

Cooling Tower Pumping and Piping

Legend

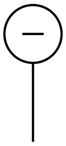

Flow-Friction Loss


Balance Valve (Plug)

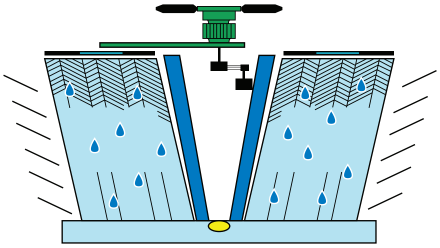
Heat Rejection Equipment

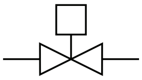

Pump


Valve

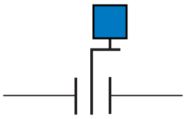

Node

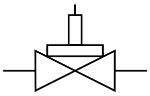
Non-Slam Check Valve

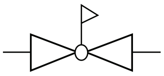

Cooling Tower

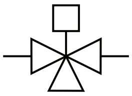

Automatic Valve

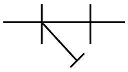

Butterfly Valve


Automatic Butterfly Valve


Triple-Duty Valve


Pressure Reducing Valve


Mixing/Diverting Valve


Strainer

Color Notes:

Friction Loss of Water In Feet Per 100 Ft Length For Schedule 40 Pipe

FRICTION LOSS OF WATER IN FEET PER 100 FEET LENGTH OF SCHEDULE 40 PIPE, BASED ON WILLIAMS & HAZEN FORMULA USING CONSTANT 100. SIZES OF STANDARD PIPE IN INCHES

U.S. Gals. per min.	1/2" Pipe		3/4" Pipe		1" Pipe		1 1/4" Pipe		1 1/2" Pipe		2" Pipe		2 1/2" Pipe		3" Pipe		4" Pipe		5" Pipe		6" Pipe		U. S. Gals. per min.
	Vel. Ft. per Sec.	Loss in Feet	Vel. Ft. per Sec.	Loss in Feet	Vel. Ft. per Sec.	Loss in Feet	Vel. Ft. per Sec.	Loss in Feet	Vel. Ft. per Sec.	Loss in Feet	Vel. Ft. per Sec.	Loss in Feet	Vel. Ft. per Sec.	Loss in Feet	Vel. Ft. per Sec.	Loss in Feet	Vel. Ft. per Sec.	Loss in Feet	Vel. Ft. per Sec.	Loss in Feet	Vel. Ft. per Sec.	Loss in Feet	
2	2.10	7.4	1.20	1.9	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2
4	4.21	27.0	2.41	7.0	1.49	2.14	.86	.57	.63	.26	....	....	....	....	....	....	....	....	....	....	....	....	4
6	6.31	57.0	3.61	14.7	2.23	4.55	1.29	1.20	.94	.56	.61	.20	....	....	....	....	....	....	....	....	....	....	6
8	8.42	98.0	4.81	25.0	2.98	7.8	1.72	2.03	1.26	.95	.82	.33	.52	.11	....	....	....	....	....	....	....	....	8
10	10.52	147.0	6.02	38.0	3.72	11.7	2.14	3.05	1.57	1.43	1.02	.50	.65	.71	.45	.07	....	....	....	....	....	....	10
12	....	....	7.22	53.0	4.46	16.4	2.57	4.3	1.89	2.01	1.23	.79	.78	.23	.54	.10	....	....	....	....	....	....	12
15	....	....	9.02	80.0	5.60	25.0	3.21	6.5	2.36	3.00	1.53	1.08	.98	.36	.68	.15	....	....	....	....	....	....	15
18	....	....	10.84	108.2	6.69	35.0	3.86	9.1	2.83	4.24	1.84	1.49	1.18	.50	.82	.21	....	....	....	....	....	....	18
20	....	....	12.03	136.0	7.44	42.0	4.29	11.1	3.15	5.20	2.04	1.82	1.31	.61	.91	.25	.51	.06	....	....	....	....	20
25	....	....	....	....	9.30	64.0	5.36	16.6	3.80	7.30	2.55	2.73	1.63	.92	1.13	.38	.64	.09	....	....	....	....	25
30	....	....	....	....	11.15	89.0	6.43	23.0	4.72	11.0	3.06	3.84	1.96	1.29	1.36	.54	.77	.13	.49	.04	....	....	30
35	....	....	....	....	13.02	119.0	7.51	31.2	5.51	14.7	3.57	5.10	2.29	1.72	1.59	.71	.89	.17	.57	.06	....	....	35
40	....	....	....	....	14.88	152.0	8.58	40.0	6.30	18.8	4.08	6.6	2.61	2.20	1.82	.91	1.02	.22	.65	.08	....	....	40
45	....	....	....	....	....	....	9.65	50.0	7.08	23.2	4.60	8.2	2.94	2.80	2.04	1.15	1.15	.28	.73	.09	....	....	45
50	....	....	....	....	....	....	10.72	60.0	7.87	28.4	5.11	9.9	3.27	3.32	2.27	1.38	1.28	.34	.82	.11	.57	.04	50
55	....	....	....	....	....	....	11.78	72.0	8.66	34.0	5.62	11.8	3.59	4.01	2.45	1.58	1.41	.41	.90	.14	.62	.05	55
60	....	....	....	....	....	....	12.87	85.0	9.44	39.6	6.13	13.9	3.92	4.65	2.72	1.92	1.53	.47	.98	.16	.68	.06	60
65	....	....	....	....	....	....	13.92	99.7	10.23	45.9	6.64	16.1	4.24	5.4	2.89	2.16	1.66	.53	1.06	.19	.74	.076	65
70	....	....	....	....	....	....	15.01	113.0	11.02	53.0	7.15	18.4	4.58	6.2	3.18	2.57	1.79	.63	1.14	.21	.79	.08	70
75	....	....	....	....	....	....	16.06	129.0	11.80	60.0	7.66	20.9	4.91	7.1	3.33	3.00	1.91	.73	1.22	.24	.85	.10	75
80	....	....	....	....	....	....	17.16	145.0	12.59	68.0	8.17	23.7	5.23	7.9	3.63	3.28	2.04	.81	1.31	.27	.91	.11	80
85	....	....	....	....	....	....	18.21	163.8	13.38	75.0	8.68	26.6	5.56	8.1	3.78	3.54	2.17	.91	1.39	.31	.96	.12	85
90	....	....	....	....	....	....	19.30	180.0	14.71	84.0	9.19	29.4	5.88	9.8	4.09	4.08	2.30	1.00	1.47	.34	1.02	.14	90
95	....	....	....	....	....	....	....	....	14.95	93.0	9.70	32.6	6.21	10.8	4.22	4.33	2.42	1.12	1.55	.38	1.08	.15	95
100			....	....	....	....	....	....	15.74	102.0	10.21	35.8	6.54	12.0	4.54	4.96	2.55	1.22	1.63	.41	1.13	.17	100
110	8"	PIPE	....	....	....	....	....	....	17.31	122.0	11.23	42.9	7.18	14.5	5.00	6.0	2.81	1.46	1.79	.49	1.25	.21	110
120	....	....	....	....	....	....	....	....	18.89	143.0	12.25	50.0	7.84	16.8	5.45	7.0	3.06	1.17	1.96	.58	1.36	.24	120
130	....	....	....	....	....	....	....	....	20.46	166.0	13.28	58.0	8.48	18.7	5.91	8.1	3.31	1.97	2.12	.67	1.47	.27	130
140	.90	.08	....	....	....	....	....	....	22.04	190.0	14.30	67.0	9.15	22.3	6.35	9.2	3.57	2.28	2.29	.76	1.59	.32	140
150	.96	.09	....	....	....	....	....	....	....	....	15.32	76.0	9.81	25.5	6.82	10.5	3.82	2.62	2.45	.88	1.70	.36	150
160	1.02	.10	....	....	....	....	....	....	....	....	16.34	86.0	10.46	29.0	7.26	11.8	4.08	2.91	2.61	.98	1.82	.40	160
170	1.08	.11			....	....	....	....	....	....	17.36	96.0	11.11	34.1	7.71	13.3	4.33	3.26	2.77	1.08	1.92	.45	170
180	1.15	.13	10"	PIPE	....	....	....	....	....	....	18.38	107.0	11.76	35.7	8.17	14.0	4.60	3.61	2.94	1.22	2.04	.50	180
190	1.21	.14	....	....	....	....	....	....	....	....	19.40	118.0	12.42	39.6	8.63	15.5	4.84	4.01	3.10	1.35	2.16	.55	190
200	1.28	.15	....	....	....	....	....	....	....	....	20.42	129.0	13.07	43.1	9.08	17.8	5.11	4.4	3.27	1.48	2.27	.62	200
220	1.40	.18	.90	.06	....	....	....	....	....	....	22.47	154.0	14.38	52.0	9.99	21.3	5.62	5.2	3.59	1.77	2.50	.73	220
240	1.53	.22	.98	.07	....	....	....	....	....	....	24.51	182.0	15.69	61.0	10.89	25.1	6.13	6.2	3.92	2.08	2.72	.87	240
260	1.66	.25	1.06	.08	....	....	....	....	....	....	26.55	211.0	16.99	70.0	11.80	29.1	6.64	7.2	4.25	2.41	2.95	1.00	260
280	1.79	.28	1.15	.09	....	....	....	....	....	....	....	....	18.30	81.0	12.71	33.4	7.15	8.2	4.58	2.77	3.18	1.14	280
300	1.91	.32	1.22	.11	....	....	....	....	....	....	....	....	19.61	92.0	13.62	38.0	7.66	9.3	4.90	3.14	3.40	1.32	300
320	2.05	.37	1.31	.12			....	....	....	....	....	....	20.92	103.0	14.52	42.8	8.17	10.5	5.23	3.54	3.64	1.47	320
340	2.18	.41	1.39	.14	12"	PIPE			....	....	....	....	22.22	116.0	15.43	47.9	8.68	11.7	5.54	3.97	3.84	1.62	340
360	2.30	.45	1.47	.15	....	....			....	....	....	....	23.53	128.0	16.34	53.0	9.19	13.1	5.87	4.41	4.08	1.83	360
380	2.43	.50	1.55	.17	1.08	.069	14"	PIPE	....	....	....	....	24.84	142.0	17.25	59.0	9.69	14.0	6.19	4.86	4.31	2.00	380
400	2.60	.54	1.63	.19	1.14	.075	....	....	....	....	....	....	26.14	156.0	18.16	65.0	10.21	16.0	6.54	5.4	4.55	2.20	400
450	2.92	.68	1.84	.23	1.28	.95	....	....	....	....	....	....	....	....	20.40	78.0	11.49	19.8	7.35	6.7	5.11	2.74	450
500	3.19	.82	2.04	.28	1.42	.113	1.04	.06	....	....	....	....	....	....	22.70	98.0	12.77	24.0	8.17	8.1	5.68	2.90	500
550	3.52	.97	2.24	.33	1.56	.135	1.15	.07	....	....	....	....	....	....	24.96	117.0	14.04	28.7	8.99	9.6	6.25	3.96	550
600	3.84	1.14	2.45	.39	1.70	.159	1.25	.08	....	....	....	....	....	....	27.23	137.0	15.32	33.7	9.80	11.3	6.81	4.65	600
650	4.16	1.34	2.65	.45	1.84	.19	1.37	.09	....	....	....	....	....	....	....	....	16.59	39.0	10.62	13.2	7.38	5.40	650
700	4.46	1.54	2.86	.52	1.99	.22	1.46	.10	....	....	....	....	....	....	....	....	17.87	44.9	11.44	15.1	7.95	6.21	700
750	4.80	1.74	3.06	.59	2.13	.24	1.58	.11			....	....	....	....	....	....	19.15	51.0	12.26	17.2	8.50	7.12	750
800	5.10	1.90	3.26	.66	2.27	.27	1.67	.13	16"	PIPE	....	....	....	....	....	....	20.42	57.0	13.07	19.4	9.08	7.96	800
850	5.48	2.20	3.47	.75	2.41	.31	1.79	.14	1.36	.08	....	....	....	....	....	....	21.70	64.0	13.89	21.7	9.65	8.95	850
900	5.75	2.46	3.67	.83	2.56	.34	1.88	.16	1.44	.084			....	....	....	....	22.98	71.0	14.71	24.0	10.20	10.11	900
950	6.06	2.87	3.88	.91	2.70	.38	2.00	.18	1.52	.095	20"	PIPE	....	....	....	....	....	....	15.52	26.7	10.77	11.20	950
1000	6.38	2.97	4.08	1.03	2.84	.41	2.10	.19	1.60	.10	1.02	.04	....	....	....	....	....	....	16.34	29.2	11.34	12.04	1000
1100	7.03	3.52	4.49	1.19	3.13	.49	2.31	.23	1.76	.12	1.12	.04	....	....	....	....	....	....	17.97	34.9	12.48	14.55	1100
1200	7.66	4.17	4.90	1.40	3.41	.58	2.52	.27	1.92	.14	1.23	.05	....	....	....	....	....	....	19.61	40.9	13.61	17.10	1200
1300	8.30	4.85	5.31	1.62	3.69	.67	2.71	.32	2.08	.17	1.33	.06	....	....	....	....	....	....	....	....	14.72	18.4	1300
1400	8.95	5.50	5.71	1.87	3.98	.78	2.92	.36	2.24	.19	1.43	.06	24"	PIPE	....	....	....	....	....	....	15.90	22.60	1400
1500	9.58	6.24	6.12	2.13	4.26	.89	3.15	.41	2.39	.21	1.53	.07	....	....	....	....	....	....	....	....	17.02	25.60	1500
1600	10.21	7.00	6.53	2.39	4.55	.98	3.34	.47	2.56	.24	1.63	.08			....	....	....	....	....	....	18.10	26.90	1600
1800	11.50	8.78	7.35	2.95	5.11	1.21	3.75	.58	2.87	.30	1.84	.10	1.28	.04	30"	PIPE	....	....	....	....	....	....	1800
2000	12.78	10.71	8.16	3.59	5.68	1.49	4.17	.71	3.19	.37	2.04	.12	1.42	.05	....	....	....	....	....	....	....	....	2000
2200	14.05	12.78	8.98	4.24	6.25	1.81	4.59	.84	3.51	.44	2.25	.15	1.56	.06	....	....	....	....	....	....	....	....	2200
2400	15.32	14.2	9.80	5.04	6.81	2.08	5.00	0.99	3.83	.52	2.45	.17	1.70	.07	1.09	.020	....	....	....	....	....	....	2400
2600	....	....	10.61	5.81	7.38	2.43	5.47	1.17	4.15	.60	2.66	.20	1.84	.08	1.16	.027	....	....	....	....	....	....	2600
2800	....	....	11.41	6.70	7.95	2.75	5.84	1.32	4.47	.68	2.86	.23	1.98	.09	1.27	.030	....	....	....	....	....	....	2800
3000	....	....	12.24	7.62	8.52	3.15	6.01	1.49	4.79	.78	3.08	.27	2.13	.10	1.37	.037	....	....	....	....	....	....	3000
3200	....	....	13.05	7.80	9.10	3.51	6.68	1.67	5.12	.88	3.27	.30	2.26	.12	1.46	.041	....	....	....	....	....	....	3200
3500	....	....	14.30	10.08	9.95	4.16	7.30	1.97	5.59	1.04	3.59	.35	2.49	.14	1.56	.047	....	....	....	....	....	....	3500
3800	....	....	15.51	13.4	10.80	4.90	7.98	2.36	6.07	1.20	3.88	.41	2.69	.17	1.73	.05	....	....	....	....	....	....	3800
4200	....	....	....	....	11.92	5.88	8.76	2.77	6.70	1.44	4.29	.49	2.99	.20	1.91	.07	....	....	....	....	....	....	4200
4500	....	....	....	....	12.78	6.90	9.45	3.22	7.18	1.64	4.60	.56	3.20	.22	2.04	.08	....	....	....	....	....	....	4500
5000	....	....	....	....	14.20	8.40	10.50	3.92	8.01	2.03	5.13	.68	3.54	.27	2.26	.09	....	....	....	....	....	....	5000
5500	....	....	....	....	....	....	11.55	4.65	8.78	2.39	5.64	.82	3.90	.33	2.50	.11	....	....	....	....	....	....	5500
6000	....	....	....	....	....	....	12.60	5.50	9.58	2.79	6.13	.94	4.25	.38	2.73	.13	....	....	....	....	....	....	6000
6500	....	....	....	....	....	....	13.65	6.45	10.39	3.32	6.64	1.10	4.61	.45	2.96	.15	....	....	....	....	....	....	6500
7000	....	....	....	....	....	....	14.60	7.08	11.18	3.70	7.15	1.25	4.97	.52	3.18	.17	....	....	....	....	....	....	7000
8000	....	....	....	....	....	....	....	....	12.78	4.74	8.17	1.61	5.68	.66	3.64	.23	....	....	....	....	....	....	8000
9000	....	....	....	....	....	....	....	....	14.37	5.90	9.20	2.01	6.35	.81	4.08	.28	....	....	....	....	....	....	9000
10000	....	....	....	....	....	....	....	....	15.96	7.19	10.20	2.44	7.07	.98	4.54	.33	....	....	....	....	....	....	10000
12000	....	....	....	....	....	....	....	....	....	....	12.25	3.41	8.50	1.40	5.46	.48	....	....	....	....	....	....	12000
14000	....	....	....	....	....	....	....	....	....	....	14.30	4.54	9.95	1.87	6.37	.63	....	....	....	....	....	....	14000
16000	....	....	....	....	....	....	....	....	....	....	....	....	11.38	2.40	7.28	.81	....	....	....	....	....	....	16000
18000	....	....	....	....	....	....	....	....	....	....	....	....	12.76	2.97	8.18	1.02	....	....	....	....	....	....	18000
20000	....	....	....	....	....	....	....	....	....	....	....	....	14.20	3.60	9.10	1.23	....	....	....	....	....	....	20000

Cooling Towers in Parallel

Whenever cooling towers are to be installed in parallel with common supply and return piping, special consideration should be given to the piping design to ensure balanced water flow through each tower. Otherwise, unequal water levels could develop in the tower basins, which, in the extreme, could cause one tower to overflow while air is being drawn through the other into the circulating pump.

Design Considerations

To avoid unequal water levels, BAC recommends the following on multiple tower installations:

1. The towers should be installed with the overflow levels at the same elevation. Set the system operating level so the minimum operating level is maintained in each unit. Refer to **Tables 1-6** on **pages J168 to J171** for the operating and overflow levels for all current BAC factory-assembled cooling towers. For previous generation cooling tower operating and overflow levels, contact your local BAC Representative. Note that the location of the overflow connection on the unit and the elevation of the actual overflow level are often different. If a situation exists where the towers cannot be adjusted so the overflow levels are at the same elevation, contact your local BAC Representative for assistance.
2. Keep the supply and return piping as symmetrical as possible to obtain balanced flows through each tower.
3. Install manual valves at the inlets and outlets of each tower for final adjustment of water flow and to serve as shut-off valves when isolating one tower for service. Whenever the inlet valves are closed, close the outlet valves. If automatic valves are used on the inlets, use automatic valves on the outlets and operate both inlet and outlet valves simultaneously. Please contact your local BAC Representative if water flow will vary through the cooling towers as a result of multiple pump operation.
4. Install equalizing lines, with shut-off valves, between tower basins to correct any differences in basin water levels that may develop during operation due to dirty strainers, valve position changes, etc.

Equalizers

The purpose of an equalizer is not to correct unbalanced flows due to piping design. This should be accomplished with balancing valves. Equalizers serve to correct any difference in water levels that may develop during operation.

While exact rules for sizing equalizer lines do not exist, BAC's experience indicates they should be selected to pass 15% of the flow rate of the largest tower when a water level differential of 1" (0.083 ft head) exists between the two cold water basins. In other words, at a flow rate equal to 15% of the design flow rate of the larger tower, the total friction loss in the equalizer lines, including entrance and exit losses should be equal to or less than 0.083 ft H_2O = 0.036 psi.

Listed in **Table 7** on **page J171** are the typical equalizer sizes for two towers placed 10 to 20 ft apart. In developing this table, allowance has been made for a gate or butterfly valve in the line plus a typical number of fittings. The flow rate to be used with the table is the design flow rate of the larger tower.

Table 8 on **page J172** lists, by product, the maximum connection sizes that can be installed at the specified location. These maximums must be adhered to since they represent the largest fitting that can be physically accommodated in this unit.

Cooling Towers in Parallel

Model Number	Operating Height			Overflow Height		
	Above Basin Bottom (in)	Above Unit Base (in)	Operating Volume (gal)	Above Basin Bottom (in)	Above Unit Base (in)	Overflow Volume (gal)
VTL-016-E to VTL-039-H	5 1/2	7 1/8	38	10	11 5/8	72
VTL-045-H to VTL-079-K	5 1/2	7 1/8	76	10	11 5/8	146
VTL-082-K to VTL-095-K	5 1/2	7 1/8	114	10	11 5/8	215
VTL-103-K to VTL-137-M	5 1/2	7 1/8	153	10	11 5/8	287
VTL-152-M to VTL-227-O	5 1/2	7 1/8	230	10	11 5/8	432
VTL-245-P to VTL-272-P	5 1/2	7 1/8	308	10	11 5/8	574

Table 1. VTL Basin Water Levels and Volumes

Model Number	Operating Height			Overflow Height		
	Above Basin Bottom (in)	Above Unit Base (in)	Operating Volume (gal)	Above Basin Bottom (in)	Above Unit Base (in)	Overflow Volume (gal)
VTO 12-E to VTO-28-H	12 7/8	20 3/8	11	19 1/8	26 1/8	26
VTO 32-H to VTO-57-K	12 7/8	20 3/8	24	19 1/8	26 1/8	55
VTO 65-J to VTO-88-L	12 7/8	20 3/8	37	19 1/8	26 1/8	85
VTO 102-L to VTO-116-M	12 7/8	20 3/8	50	19 1/8	26 1/8	114
VTO 132-L to VTO-176-O	15 1/2	30 7/8	72	22 1/2	36 3/4	153
VT1-N209-P to VT1-N255-P	17	22 5/8	212	31	36 5/8	488
VT1-N301-Q to VT1-N395-R	17	22 5/8	322	31	36 5/8	742
VT1-N418-P to VT1-N510-P	17	22 5/8	431	31	36 5/8	994
VT1-M316-O to VT1-M420-R	18	23 3/4	367	26 1/4	32	595
VT1-M431-N to VT1-M610-P	18	23 3/4	559	26 1/4	32	905
VT1-M632-O to VT1-M840-R	18	23 3/4	734	26 1/4	32	1,190
VT1-M948-O to VT1-M1260-R	18	23 3/4	1101	26 1/4	32	1,785
VT1-275-P to VT1-415-R	14	19 5/8	474	24 1/2	30 1/8	900
VT1-416-O to VT1-600-P	14	19 5/8	720	24 1/2	30 1/8	1,367
VT1-550-P to VT1-830-R	14	19 5/8	965	24 1/2	30 1/8	1,832
VT1-825-P to VT1-1335-S	14	19 5/8	1,455	24 1/2	30 1/8	2,764

Table 2. VTO and VT1 Basin Water Levels and Volumes

Model Number	Operating Height			Overflow Height		
	Above Basin Bottom (in)	Above Unit Base (in)	Operating Volume (gal)	Above Basin Bottom (in)	Above Unit Base (in)	Overflow Volume (gal)
S3E/XES3E-8518-05x	8 3/4	10 3/4	404	14 1/8	16 1/8	857
S3E/XES3E-8518-06x	8 3/4	10 3/4	404	14 7/8	16 7/8	921
S3E/XES3E-8518-07x	8 3/4	10 3/4	404	17 1/2	19 1/2	1,149
S3E/XES3E-1020-06x	8 3/4	10 3/4	500	14 3/4	16 3/4	1,152
S3E/XES3E-1020-07x	8 3/4	10 3/4	500	15 1/2	17 1/2	1,236
S3E/XES3E-1222-06x	8 3/4	10 3/4	639	14 5/8	16 5/8	1,474
S3E/XES3E-1222-07x	8 3/4	10 3/4	639	15 1/4	17 1/4	1,564
S3E/XES3E-1222-10x	9 3/4	11 3/4	745	20 1/8	22 1/8	2,182
S3E/XES3E-1222-12x	9 3/4	11 3/4	745	21 5/8	23 5/8	2,400
S3E/XES3E-1222-13x	9 3/4	11 3/4	745	22	24	2,455
S3E/XES3E-1222-14x	9 3/4	11 3/4	745	22	24	2,455
S3E/XES3E-1424-07x	9 3/4	11 3/4	989	16	18	2,165
S3E/XES3E-1424-12x	9 3/4	11 3/4	946	19 5/8	21 5/8	2,742
S3E/XES3E-1424-13x	9 3/4	11 3/4	946	20 1/4	22 1/4	2,860
S3E/XES3E-1424-14x	9 3/4	11 3/4	946	21	23	3,004

Table 3. Series 3000 Basin Water Levels and Volumes

Model Number	Operating Height			Overflow Height		
	Above Basin Bottom (in)	Above Unit Base (in)	Operating Volume (gal)	Above Basin Bottom (in)	Above Unit Base (in)	Overflow Volume (gal)
FXT-58, 68	6	9 5/8	55	14	17 5/8	197
FXT-74, 87, 95	6	9 5/8	82	14	17 5/8	273
FXT-115, 130, 136	6	9 5/8	126	14	17 5/8	420
FXT-160, 175, 192	6	9 5/8	168	14	17 5/8	558
FXT-216, 240, 257	6	9 5/8	168	16	19 5/8	666

Table 4. FXT Basin Water Levels and Volumes

Cooling Towers in Parallel

Model Number	Operating Height			Overflow Height		
	Above Basin Bottom (in)	Above Unit Base (in)	Operating Volume (gal)	Above Basin Bottom (in)	Above Unit Base (in)	Overflow Volume (gal)
S15E/XE15E-1285-06x	7	9	214	13 1/2	15 1/2	575
S15E/XE15E-1285-07x	7	9	214	14	16	604
S15E/XE15E-1285-09x	7	9	214	16	18	719
S15E/XE15E-1285-10x	7	9	214	17	19	777
S15E/XE15E-1212-07x	7	9	303	15	17	943
S15E/XE15E-1212-09x	7	9	303	16 1/4	18 1/4	1,046
S15E/XE15E-1212-10x	7	9	303	16 3/4	18 3/4	1,087
S15E/XE15E-1212-11x	7	9	303	17 1/2	19 1/2	1,149
S15E/XE15E-1212-12x	7	9	303	17 1/2	19 1/2	1,149
S15E/XE15E-1218-07x	9	17	685	16 3/4	24 3/4	1,655
S15E/XE15E-1218-09x	9	17	685	18	26	1,812
S15E/XE15E-1218-10x	9	17	685	18 3/4	26 3/4	1,906
S15E/XE15E-1218-11x	9	17	685	19	27	1,937
S15E/XE15E-1218-12x	9	17	685	19 1/2	27 1/2	2,000

Table 5. Series 1500 Basin Water Levels and Volumes

Model Number	Operating Height			Overflow Height		
	Interior Basin Bottom (in)	Exterior Unit Base (in)	Operating Volume (gal)	Interior Basin Bottom (in)	Exterior Unit Base (in)	Overflow Volume (gal)
PT2-0412A	6 5/8	8 5/8	160	10 1/2	12 1/2	265
PT2-0709A	6 5/8	8 5/8	150	10 1/2	12 1/2	300
PT2-0809A	6 5/8	8 5/8	160	10 1/2	12 1/2	335
PT2-1009A	6 5/8	8 5/8	175	10 1/2	12 1/2	375
PT2-0812A	6 5/8	8 5/8	215	10 1/2	12 1/2	450
PT2-1012A	6 5/8	8 5/8	225	10 1/2	12 1/2	500
PT2-1212A	6 5/8	8 5/8	245	10 1/2	12 1/2	570
PT2-1218A	8 1/2	15	615	11 3/4	18	1,022

Table 6. PT2 Basin Water Levels and Volumes

Flow to Tower (USGPM)	Equalizer Size (IPS)[1]
Up to 120	3
121 - 240	4
241 - 630	6
631 - 1,170	8
1,171 - 1,925	10
1,926 - 2,820	12
2,821 - 3,465	14
2,336 - 3,850	(2) 10 or (1) 16
3,851 - 5,640	(2) 12 or (1) 18
5,641 - 6,930	(2) 14 or (1) 20
6,931 - 7,560	(3) 12 or (2) 16 or (1) 20

Table 7. Equalizer Connection Sizes

NOTES:
1. Schedule 40 for 3” - 10”, Standard Weight for 12” and above.

Cooling Towers in Parallel

CAUTION: Where bottom connections are employed, care must be taken to ensure that the supporting steel does not interfere with the proposed connection.

Type of Unit	End Connection[1] (in)	Back Connection[2] (in)	Bottom Connection[3] (in)
Low Profile and Series V			
VTL-016-E to VTL-272-P	6	—	10
VT0-12-E to VT0-116-M	4	6	—
VT0-132-L to VT0-176-O	6	8	—
VT1-N209-P to VT1-N510-P	12	12	—
VT1-M316-O to VT1-M1260-R	14	14	20
VT1-275-P to VT1-1335-S	14	14	20
Series 3000			
S3E/XES3E-8518 to S3E/XES3E-1424	14	14	14
Series 1500			
S15E/XES15E-1285	10	10	10
S15E/XES15E-1212	12	12	12
S15E/XES15E-1218	14	14	14
FXT			
FXT-58 to FXT-95	6	—	6
FXT-115 to FXT-257	8	—	8
PT2			
PT2-0412	—	—	—
PT2-0709, PT2-0809, PT2-0812	12	12	14
PT2-1009, PT2-1012, PT2-1212, PT2-1218	12	12	14

Table 8. Maximum Allowable Equalizer Connection Sizes and Locations

NOTES:

1. End equalizer connections on the Series V (VTL, VT0, VT1) and Series 3000 Cooling Towers must be located on end of tower opposite the suction connection. The low operating level of VTL and Series 1500 Cooling Towers may restrict the use of the end equalizer connection. Consult your local BAC Representative for applications requiring end equalizers on these products. PT2 end equalizer connections are defined as Face A/B.
2. PT2 Cooling Towers have a "side" connection which is defined as Face C.
3. Bottom connections for 8" through 20" will be a bolt circle for 150# standard flange and 6" and smaller will be MPT. On model VTL Cooling Towers, all bottom connections will be a bolt circle for 150# flanges.

Sample Problem

Given: A S3E-8518-06M tower cooling 975 USGPM from 95°F (35°C) to 85°F (29.4°C) at 78°F (25.6°C) entering wet bulb is to be installed in parallel with an existing FXT-240 tower cooling 750 USGPM from 95°F (35°C) to 85°F (29.4°C) at 78°F (25.6°C) entering wet bulb. The cooling towers will be arranged side-by-side as shown below:

NOTE: Figures 1-4 are NOT to scale.

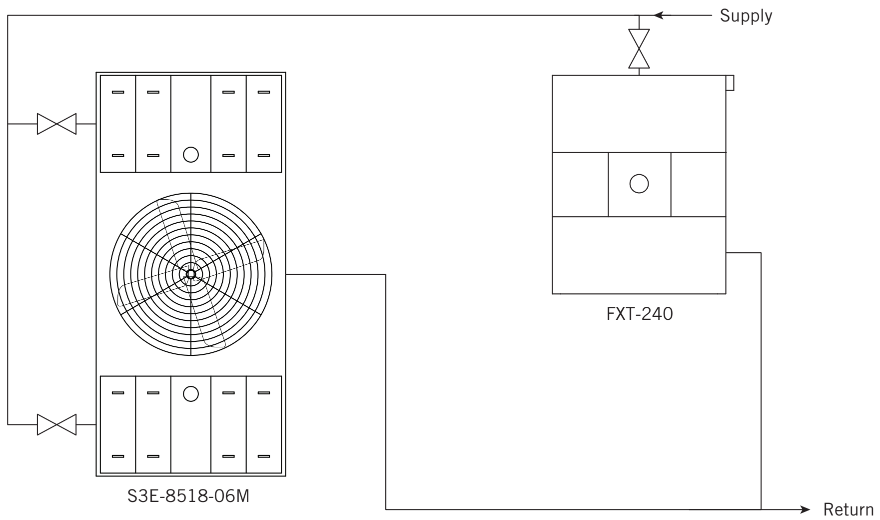


Figure 1. Sample Problem; Plan View

Find: What size equalizer line should be used and where should it be connected to the towers? Also, what is the proper elevation for the towers?

Solution

a. The larger flow rate is 975 USGPM. From **Table 7**, find an 8" equalizer is satisfactory for tower flow rates of 631 USGPM to 1,170 USGPM.

b. From **Table 8**, an 8" equalizer connection can be located either on the ends or on the bottom of both units. With towers situated side-by-side, it is more convenient to locate the equalizer connections on the ends of both towers, as shown in **Figure 2**.

c. From **Table 3** the overflow level for the S3E-8518-06M is 16 3/4" above the exterior base of the unit. The operating level is 14 3/4" above the exterior base of the unit. **Table 4** shows the overflow level of the FXT-240 is 19 5/8" above the exterior base of the unit. Its operating level is 9 5/8" above the exterior base of the unit. In order to have the overflow level at the same elevation, the S3E-8518-06M must be installed 2 7/8" above the base of the FXT-240.

d. To set the operating levels, raise the float ball on the make-up valve arrangement in the FXT-240 by 8" to obtain a 17 5/8" operating level. This setting will maintain the 14 3/4" minimum operating level required for the model S3E-8518-06M. This is illustrated in **Figures 3** and **4**. Adjust the float balls to ensure the make-up valves operate evenly. Note, adjusting the valves may cause one valve to operate excessively while the other remains closed.

Cooling Towers in Parallel

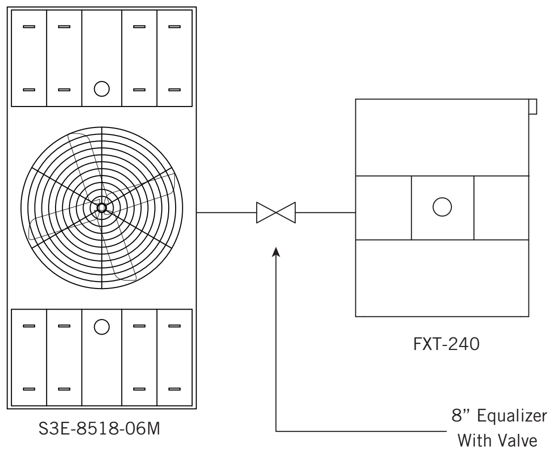


Figure 2. Sample Problem; Equalizer Connection Plan View

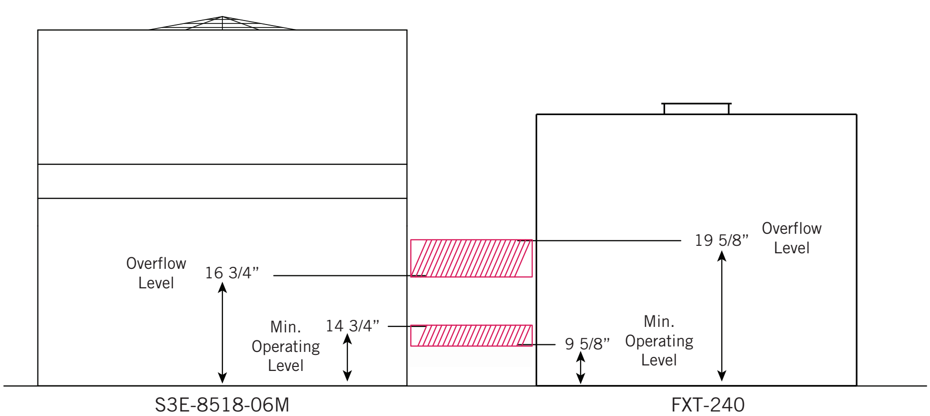


Figure 3. Sample Problem; Side View

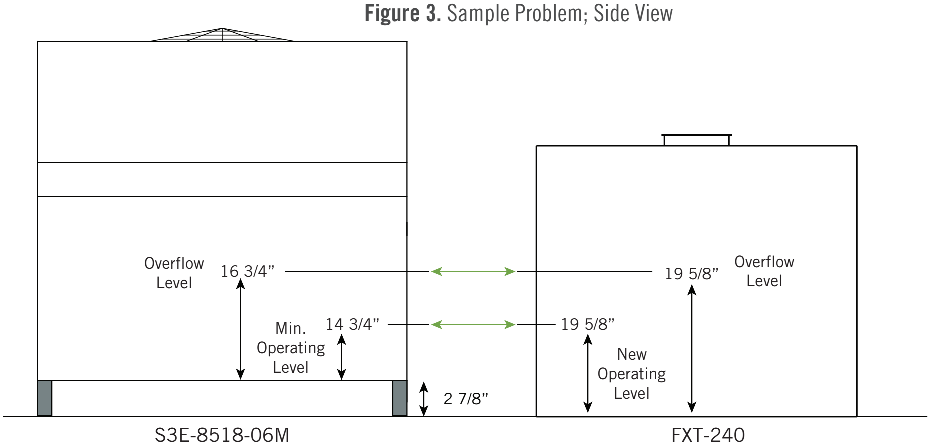


Figure 4. Sample Problem; Side View (Elevated)

Piping Considerations - Maximum Fluid Velocity

BAC designs its standard evaporative cooling products to limit fluid velocities to approximately 10 ft/s through all piping connections. This generally accepted piping practice is recommended for a variety of reasons:

Friction Loss

Higher fluid velocities increase friction losses (commonly referred to as "pressure drop"), resulting in increased pump energy costs.

Noise and Vibration

Systems designed to current codes minimize excessive noise or vibration when the fluid velocity is held to 10 ft/s or less.

Erosion / Corrosion

Fluids at high velocities have a greater propensity to damage the inside walls of pipe. The effect of velocity is increased with chemically aggressive fluids or fluids with a high amount of solids entrained in the fluid stream.

Hydraulic Shock

Also known as "water hammer," hydraulic shock can cause excessive damage upon start-up and shut down. Maintaining a low fluid velocity will substantially reduce the impact of hydraulic shock.

BAC STANDARD CONNECTION SIZES (OUTLET/INLET)

Connection Diameter (in)	Maximum Flow (gpm)	Maximum Fluid Velocity (ft/s)	Connection Diameter (in)	Maximum Flow (gpm)	Maximum Fluid Velocity (ft/s)
3	225	10.2	10	2,300	9.4
4	400	10.2	12	3,200	9.1
6	900	10.2	14	3,700	7.8
8	1,600	10.2	16	4,650	6.7

BAC's Closed Circuit Cooling Tower Selection Software is programmed to automatically select the appropriate quantity and size of entering and leaving process fluid connections, to maintain the limits listed above. Only by specific customer request and acceptance BAC will provide evaporative cooling products designed for higher velocities. Fewer connection points and smaller pipe sizes associated with high fluid velocities may reduce installation costs, but the customer must also consider the increased operating costs and equipment maintenance concerns. Successful operation of BAC's equipment in the system is based on established industry principles.

Connection Guide

A summary of connection types used by BAC follows. The specific connection type for a particular BAC model can be found on the unit print drawing, available on www.BaltimoreAircoil.com, or contact your local BAC Representative.

Beveled for Welding (BFW)

This connection type is a pipe stub with a beveled edge. The bevel allows for easier welding in the field and a full penetration weld. Weld materials fill the trimmed area between two beveled edges as shown here (**Figure 1**).

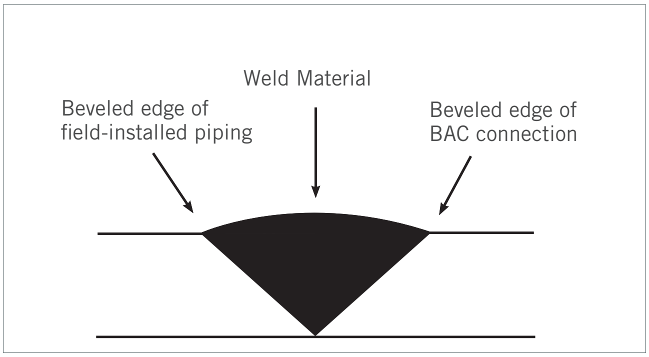


Figure 1. Weld Details

Grooved to Suit a Mechanical Coupling

This connection type is a pipe stub with a groove to accept a mechanical pipe coupling (**Figure 2**).

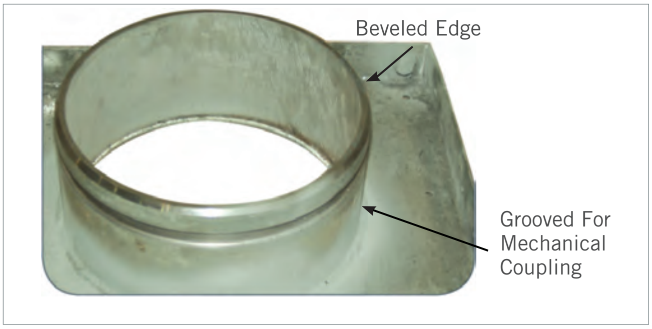


Figure 2. Beveled for Welding/Grooved Connection

Beveled for Welding and Grooved Connection

Many of BAC's connections are both beveled for weld and grooved to suit a mechanical coupling. Either method of fastening to field-fabricated piping can be used when this connection type is provided (**Figure 2**).

Side Outlet Depressed Sump Box

This option is offered to facilitate horizontal piping below the cold water basin of a unit, and is a compact alternative to using an elbow in the piping arrangement, saving installation time and cost (**Figure 3**).

Figure 3. Side Outlet Depressed Sump Box

ASME Class 150 Flat Face Flange

This connection type is a standard bolt and hole pattern at the point of connection to mate to an ASME Class 150 Flat Face Flange. When BAC provides this connection type to a hot water basin mounting bolts are permanently fastened to the connection plate. When BAC provides this connection type on a cold water basin, a back-up ring and neoprene washers are provided. All other components (piping, nuts, bolts, flatwashers, etc.) are provided by others unless otherwise specified (**Figures 4 and 5**).

Figure 4. An ASME Class 150 Flat Face Flange Pattern With Mounting Bolts is shown on this Hot Water Basin Panel

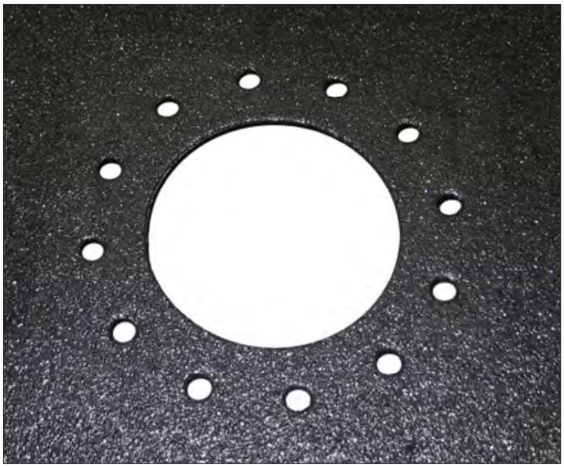


Figure 5. An ASME Class 150 Flat Face Flange Pattern is Shown on this Cold Water Basin Panel

Male Pipe Thread (MPT)

This connection type is a threaded pipe stub connection designed to mate with a Female Pipe Thread (FPT) fitting (**Figure 6**).

Figure 6. MPT Connection

Remote Sump Tank Selection for a Cooling Tower

NOTE: This section provides a simplified method for the selection of a remote sump tank for an open circuit cooling tower only. For information on sizing a remote sump tank for a closed circuit cooling tower or evaporative condenser, see **page J226**.

Remote sump tanks are used on evaporative cooling systems to provide a means of cold water basin freeze protection during cold weather operation. The remote sump tank is usually located in a heated, indoor space, and may preclude the need to winterize the cooling tower. A remote sump tank must provide sufficient storage to accommodate the surge volume, defined as all of the water that will drain back to the tank during the cooling system shutdown, the surge volume includes:

- Cooling Tower Volume: The total volume of water contained within the cooling tower during operation, including water within the distribution system and falling through the fill section.
- System Piping Volume: The volume of water contained in all system piping located above the operating water level of the remote sump tank.
- System Components Volume: The volume of water contained within any heat exchanger or other equipment located above the operating water level of the remote sump that will drain to the tank when the cooling system is shut down.

This method is a conservative approach as it will not consider any volume reductions based on flow rates. Cold water basin volumes at the overflow level are given in **Tables 2** through **6**. **Table 7** provides pipe capacities (gallons per linear foot) for common Schedule 40 nominal pipe sizes, which can be used to determine system piping volume. For specific information for your application, contact your local BAC Representative.

Please note that on remote sump applications, the standard float valve(s) and strainer(s) are omitted from the cold water basin and a properly sized outlet connection is added.

Safety Factor

When selecting a remote sump tank, select a model with a net available volume that is 5% greater than the surge volume. Engineering data on BAC's RS Remote Sump Tanks is provided in **Table 1**, see page **H5** for dimensional information on Remote Sumps. Note that the minimum operating level must be maintained in the remote sump tank to prevent vortexing of air through the tank's suction connection.

Model Number	Shipping Weights (lbs)	Maximum Weight (lbs)[1]	Maximum Storage Volume (gal)	"X" Minimum Operating Level[2]	Net Available Volume (gal)
RS 94	240	1,070	94	8 1/2"	72
RS 212	`350	2,220	212	8 1/2"	163
RS 335	470	3,410	335	8 1/2"	257
RS 457	610	4,630	457	8 1/2"	351
RS 702	800	6,970	702	8 1/2"	539
RS 946	1,030	9,340	946	8 1/2"	727
RS 1390	1,260	13,470	1,390	8 1/2"	1,068

Table 1: RS Remote Sump Tank Engineering Data

NOTES:
1. Maximum weight is for tank filled with water to spillout.
2. Minimum operating level "X" is measured from inside bottom of tank.

Model Number	Overflow Volume (gal)
S3E/XES3E-8518-05x	857
S3E/XES3E-8518-06x	921
S3E/XES3E-8518-07x	1,149
S3E/XES3E-1020-06x	1,152
S3E/XES3E-1020-07x	1,236
S3E/XES3E-1222-06x	1,474
S3E/XES3E-1222-07x	1,564
S3E/XES3E-1222-10x	2,182
S3E/XES3E-1222-12x	2,400
S3E/XES3E-1222-13x	2,455
S3E/XES3E-1222-14x	2,455
S3E/XES3E-1424-07x	2,165
S3E/XES3E-1424-12x	2,742
S3E/XES3E-1424-13x	2,860
S3E/XES3E-1424-14x	3,004

Table 2. Series 3000 - Cold Water Basin Volume at Overflow

Model Number	Overflow Volume (gal)
FXT-58 to 68	197
FXT-74 to 95	273
FXT-115 to 136	420
FXT-160 to 192	558
FXT-216 to 257	666

Table 5. FXT - Cold Water Basin Volume at Overflow

Model Number	Overflow Volume (gal)
PT2-0412A	265
PT2-0709A	300
PT2-0809A	335
PT2-1009A	375
PT2-0812A	450
PT2-1012A	500
PT2-1212A	570
PT2-1218A	1,022

Table 6. PT2 - Cold Water Basin Volume at Overflow

Model Number	Overflow Volume (gal)
VTL-016-E to VTL-039-H	72
VTL-045-H to VTL-079-K	146
VTL-082-K to VTL-095-K	215
VTL-103-K to VTL-137-M	287
VTL-152-M to VTL-227-O	432
VTL-245-P to VTL-272-P	574
VT0-12-E to VT0-28-H	26
VT0-32-H to VT0-57-K	55
VT0-65-J to VT0-88-L	85
VT0-102-L to VT0-116-M	114
VT0-132-L to VT0-176-O	153
VT1-N209-P to VT1-N255-P	488
VT1-N301-Q to VT1-N395-R	742
VT1-N418-P to VT1-N510-P	994
VT1-M316-O to VT1-M420-R	595
VT1-M431-N to VT1-M610-P	905
VT1-M632-O to VT1-M840-R	1,190
VT1-M948-O to VT1-M1260-R	1,785
VT1-275-P to VT1-415-R	900
VT1-416-O to VT1-600-P	1,367
VT1-550-P to VT1-830-R	1,832
VT1-825-P to VT1-1335-S	2,764

Table 4. Series V - Cold Water Basin Volume at Overflow

Model Number	Overflow Volume (gal)	Model Number	Overflow Volume (gal)
S15E/XE15E-1285-06x	575	S15E/XE15E-1212-11x	1,149
S15E/XE15E-1285-07x	604	S15E/XE15E-1212-12x	1,149
S15E/XE15E-1285-09x	719	S15E/XE15E-1218-07x	1,655
S15E/XE15E-1285-10x	777	S15E/XE15E-1218-09x	1,812
S15E/XE15E-1212-07x	943	S15E/XE15E-1218-10x	1,906
S15E/XE15E-1212-09x	1,046	S15E/XE15E-1218-11x	1,937
S15E/XE15E-1212-10x	1,087	S15E/XE15E-1218-12x	2,000

Table 3. Series 1500 - Cold Water Basin Volume at Overflow

Remote Sump Tank Selection for a Cooling Tower

Nominal Pipe Size (in)	Gallons Per Linear Foot
2	0.174
3	0.384
4	0.662
6	1.503
8	2.603
10	4.101
12	5.822
14	7.04
16	9.193
18	11.636
20	14.461
24	20.916

Table 7. Schedule 40 Pipe Capacities - Not Applicable for Other Types of Piping

Example

A VTL-059-H will be installed on a cooling tower/heat exchanger system that will also utilize an RS Remote Sump Tank. The tower side volume contained in the heat exchanger is 25 gallons. The system has been designed with 35 feet of 4" pipe that will be above the operating level of the remote sump tank. What is the correct RS Remote Sump Tank selection?

Solution: From **Table 4,** the cold water basin volume at overflow for the VTL-059-H is 146 gallons.

From **Table 7**, the 4" pipe will contain 0.662 gallons of water per linear foot. The total volume contained in the 4" pipe is 23 gallons.

The tower side volume of the heat exchanger is 25 gallons.

The total volume required is:

Cooling Tower Volume at Overflow	146 gallons
+ System Piping Volume	23 gallons
+ System Components Volume	25 gallons
= Total Volume	194 gallons

194 gallons x 1.05 (safety factor) = 204 gallons required.

From the remote sump tank engineering data available on page H5, the correct RS Remote Sump Tank selection is an RS-335, which has a net available volume of 257 gallons.

Refrigerant Piping

The following recommendations are given for ammonia piping. Local codes or ordinances governing ammonia mains should also be followed, in addition to the recommendations here.

Recommended Material

Because copper and copper-bearing materials are attacked by ammonia, they are not used in ammonia piping systems. Steel piping, fittings, and valves of the proper pressure rating are suitable for ammonia gas and liquid.

Ammonia piping should conform to ASME Standard B31.5, Refrigerant Piping and IIAR Standard 2, which states the following:

1. Liquid lines 1.5 inches and smaller shall be not less than Schedule 80 carbon steel pipe.
2. Liquid lines 2 through 6 inches shall be not less than Schedule 40 carbon steel pipe.
3. Liquid lines 8 through 12 inches shall be not less than Schedule 20 carbon steel pipe.
4. Vapor lines 6 inches and smaller shall be not less than Schedule 40 carbon steel pipe.
5. Vapor lines 8 through 12 inches shall be not less than Schedule 20 carbon steel pipe.
6. Vapor lines 14 inches and larger shall be not less than Schedule 10 carbon steel pipe.
7. All threaded pipe shall be Schedule 80.
8. Carbon steel pipe shall be ASTM Standard A 53 Grade A or B, Type E (electric resistance welded) or Type S (seamless); or ASTM Standard A 106 (seamless), except where temperature-pressure criteria mandate a higher specification material. Standard A 53 Type F is not permitted for ammonia piping.

Fittings

Couplings, elbows, and tees for threaded pipe are for a minimum of 3000 psi design pressure and constructed of forged steel. Fittings for welded pipe should match the type of pipe used (i.e., standard fittings for standard pipe and extra-heavy fittings for extra-heavy pipe).

Tongue and groove or ANSI flanges should be used in ammonia piping. Welded flanges for low-side piping can have a minimum 150 psi design pressure rating. On systems located in high ambients, low-side piping and vessels should be designed for 200 to 225 psig. The high side should be 250 psig if the system uses water-cooled or evaporative cooled condensing. Use 300 psig minimum for air-cooled designs.

Refrigerant Piping

Steel Line Size		Saturated Suction Temperature, °F					
		-60		-40		-20	
IPS	SCH	Δt = 0.25°F Δp = 0.046	Δt = 0.50°F Δp = 0.092	Δt = 0.25°F Δp = 0.077	Δt = 0.50°F Δp = 0.155	Δt = 0.25°F Δp = 0.123	Δt = 0.50°F Δp = 0.245
3/8	80	0.03	0.05	0.06	0.09	0.11	0.16
1/2	80	0.06	0.10	0.12	0.18	0.22	0.32
3/4	80	0.15	0.22	0.28	0.42	0.50	0.73
1	40	0.30	0.45	0.57	0.84	0.99	1.44
1 /14	40	0.82	1.21	1.53	2.24	2.65	3.84
1 1/2	40	1.25	1.83	2.32	3.38	4.00	5.80
2	40	2.43	3.57	4.54	6.59	7.79	11.26
2 1/2	40	3.94	5.78	7.23	10.56	12.50	18.03
3	40	7.10	10.30	13.00	18.81	22.23	32.09
4	40	14.77	21.21	26.81	38.62	45.66	65.81
5	40	26.66	38.65	48.68	70.07	82.70	119.60
6	40	43.48	62.83	79.18	114.26	134.37	193.44
8	40	90.07	129.79	163.48	235.38	277.80	397.55
10	40	164.26	236.39	297.51	427.71	504.98	721.08
12	ID*	264.07	379.88	477.55	686.10	808.93	1,157.59

Steel Line Size		Saturated Suction Temperature, °F					
		0		20		40	
IPS	SCH	Δt = 0.25°F Δp = 0.184	Δt = 0.50°F Δp = 0.368	Δt = 0.25°F Δp = 0.265	Δt = 0.50°F Δp = 0.530	Δt = 0.25°F Δp = 0.366	Δt = 0.50°F Δp = 0.582
3/8	80	0.18	0.26	0.28	0.40	0.41	0.53
1/2	80	0.36	0.52	0.55	0.80	0.82	1.05
3/4	80	0.82	1.18	1.26	1.83	1.87	2.38
1	40	1.62	2.34	2.50	3.60	3.68	4.69
1 /14	40	4.30	6.21	6.63	9.52	9.76	12.42
1 1/2	40	6.49	9.34	9.98	14.34	14.68	18.64
2	40	12.57	18.12	19.35	27.74	28.45	36.08
2 1/2	40	20.19	28.94	30.98	44.30	45.37	57.51
3	40	35.87	51.35	54.98	78.50	80.40	101.93
4	40	73.56	105.17	112.34	160.57	164.44	208.34
5	40	133.12	190.55	203.53	289.97	296.88	376.18
6	40	216.05	308.62	329.59	469.07	480.96	609.57
8	40	444.56	633.82	676.99	962.47	985.55	1,250.34
10	40	806.47	1,148.72	1,226.96	1,744.84	1,786.55	2,263.99
12	ID*	1,290.92	1,839.28	1,964.56	2,790.37	2,862.23	3,613.23

Table 1 Suction Line Capacities in Tons for Ammonia with Pressure Drops of 0.25 and 0.50°F per 100 ft Equivalent

NOTE: Capacities are in tons of refrigeration resulting in a line friction loss (Δp in psi per 100 ft equivalent pipe length), with corresponding change (Δt in °F per 100 ft) in saturation temperature.*

* The inside diameter of the pipe is the same as the nominal pipe size.

Pipe Joints

Joints between lengths of pipe or between pipe and fittings can be threaded if the pipe size is 1.25 in. or smaller. Pipe 1.5 inches or larger should be welded. An all-welded piping system is superior.

Threaded Joints. Many sealants and compounds are available for sealing threaded joints. The manufacturer's instructions cover compatibility and application method. Do not use excessive amounts or apply on female threads because any excess can contaminate the system.

Welded Joints. Pipe should be cut and beveled before welding. Use pipe alignment guides to align the pipe and provide a proper gap between pipe ends so that a full penetration weld is obtained. The weld should be made by a qualified welder, using proper procedures such as the Welding Procedure Specifications, prepared by the National Certified Pipe Welding Bureau (NCPWB).

Gasketed Joints. A compatible fiber gasket should be used with flanges. Before tightening flange bolts to valves, controls, or flange unions, properly align the pipe and bolt holes. When flanges are are used to straighten pipe, they put stress on adjacent valves, compressors, and controls, causing the operating mechanism to bind. To prevent leaks, flange bolts are drawn up evenly when connecting the flanges. Flanges at compressors and other system components must not move or indicate stress when all bolts are loosened.

Union Joints. Steel (3000 psi) ground joint unions are used for gage and pressure control lines with screwed valves and for joints up to 0.75 in. When tightening this type of joint, the two pipes must be axially aligned. To be effective, the two parts of the union must match perfectly. Ground joint unions should be avoided if at all possible.

Pipe Location

Piping should be at least 7.5 ft above the floor. Locate pipes carefully in relation to other piping and structural members, especially when the lines are to be insulated. The distance between insulated lines should be at least three times the thickness of the insulation for screwed fittings, and four times for flange fittings. The space between the pipe and adjacent surfaces should be three-fourths of these amounts.

Hangers located close to the vertical risers to and from compressors keep the piping weight off the compressor. Pipe hangers should be placed no more than 8 to 10 ft apart and with in 2 ft of a change in direction of the piping. Hangers should be designed to bear on the outside of insulated lines. Sheet metal sleeves on the lower half of the insulation are usually sufficient. Where piping penetrates a wall, a sleeve should be installed and where the pipe penetrating the wall is insulated, it must be adequately sealed.

Piping to and from compressors and to other components must provide for expansion and contraction. Sufficient flange or union joints should be located in the piping that components can be assembled easily during initial installation and also disassembled for servicing.

Refrigerant Piping

System Practices for Ammonia Refrigerant

Steel Line Size		Suction Lines (Δt = 1˚F) Saturated Suction Temperature, ˚F					Discharge Lines	Steel Line Size		Liquid Lines	
IPS	SCH	-40 Δp = 0.31	-20 Δp = 0.49	0 Δp = 0.73	20 Δp = 1.06	40 Δp = 1.46	Δt = 1˚F Δp = 2.95	IPS	SCH	Velocity = 100 fpm	Δp = 2.0 psi Δt = 0.7˚F
3/8	80	-	-	-	-	-	-	3/8	80	8.6	12.1
1/2	80	-	-	-	-	-	3.1	1/2	80	14.2	24.0
3/4	80	-	-	-	2.6	3.8	7.1	3/4	80	26.3	54.2
1	40	-	2.1	3.4	5.2	7.6	13.9	1	80	43.8	106.4
1 /14	40	3.2	5.6	8.9	13.6	19.9	36.5	1 1/4	80	78.1	228.6
1 1/2	40	4.9	8.4	13.4	20.5	29.9	54.8	1 1/2	80	107.5	349.2
2	40	9.5	16.2	26.0	39.6	57.8	105.7	2	40	204.2	811.4
2 1/2	40	15.3	25.9	41.5	63.2	92.1	168.5	2 1/2	40	291.1	1292.6
3	40	27.1	46.1	73.5	111.9	163.0	297.6	3	40	449.6	2287.8
4	40	55.7	94.2	150.1	228.7	333.0	606.2	4	40	774.7	4662.1
5	40	101.1	170.4	271.1	412.4	600.9	1095.2	5	40	-	-
6	40	164.0	276.4	439.2	667.5	971.6	1771.2	6	40	-	-
8	40	337.2	566.8	901.1	1366.6	1989.4	3623.0	8	40	-	-
10	40	611.6	1027.2	1634.3	2474.5	3598.0	-	10	40	-	-
12	ID*	981.6	1644.5	2612.4	3963.5	5464.6	-	12	ID*	-	-

Table 2. Suction, Discharge, and Liquid Line Capacities in Tons for Ammonia (Single- or High-Stage Applications)

Notes:

1. Table capacities are in tons of refrigeration.
   Δp = pressure drop due to line friction, psi per 100 ft of equivalent line length
   Δt = corresponding change in saturation temperature, ˚F per 100 ft
2. Line capacity for other saturation temperatures Δt and equivalent lengths Lc

$$\text{Line capacity} = \text{Table capacity}\ \frac{\text{Table Lc}}{\text{Actual Lc}} \times \frac{\text{Actual } \Delta t}{\text{Table } \Delta t}^{0.55}$$

3. Saturation temperature Δt for other capacities and equivalent lengths Lc

$$\Delta t = \text{Table } \Delta t\ \frac{\text{Actual Lc}}{\text{Table Lc}} \times \frac{\text{Actual Capacity}}{\text{Table Capacity}}^{1.8}$$

4. Values in the table are based on 90˚F condensing temperature. Multiply table capacities by the following factors for other condensing temperatures:

Condensing Temperature, ˚F	Suction Lines	Discharge Lines
70	1.05	0.78
80	1.02	0.89
90	1.00	1.00
100	0.98	1.11

5. Discharge and liquid line capacities are based on 20˚F suction. Evaporator temperature is 0˚F. The capacity is affected less than 3% when applied from -40 to +40˚F extremes.

*The inside diameter of the pipe is the same as the nominal pipe size.

Nominal Size, in.	Pumped Liquid Overfeed Ratio			High-Pressure Liquid at 3 psi [a]	Hot-Gas Defrost [a]	Equalizer High Side [b]	Thermosiphon Lubricant Cooling Lines Gravity Flow, [c] 1000 Btu/h		
	3:1	4:1	5:1				Supply	Return	Vent
1/2	10	7.5	6	30	-	-	-	-	-
3/4	22	16.5	13	69	4	50	-	-	-
1	43	32.5	26	134	8	100	-	-	-
1 1/4	93.5	70	56	286	20	150	-	-	-
1 1/2	146	110	87.5	439	30	225	200	120	203
2	334	250	200	1016	50	300	470	300	362
2 1/2	533	400	320	1616	92	500	850	530	638
3	768	576	461	2886	162	1000	1312	870	1102
4	1365	1024	819	-	328	2000	2261	1410	2000
5	-	-	-	-	594	-	3550	2214	3624
6	-	-	-	-	970	-	5130	3200	6378
8	-	-	-	-	-	-	8874	5533	11596

Table 3. Liquid Ammonia line capacities (capacity in tons of refrigeration, except as noted)

Source: Wile (1977)

a. Hot-gas line sizes are based on 1.5 psi pressure drop per 100 ft of equivalent length at 100 psig discharge pressure and 3 times the evaporator refrigeration capacity.

b. Line sizes are based on experience using total system evaporator tons.

c. From Frick Co. (1995). Values for line sizes above 4 in are extrapolated.

Pipe Sizing

Table 1 presents practical suction line sizing data based on 0.25°F and 0.50°F differential pressure drop equivalent per 100 ft for the total equivalent length of pipe, assuming no liquid in the suction line. **Table 2** lists data for sizing suction and discharge lines at 1°F differential pressure drop equivalent per 100 ft equivalent length of pipe, and for sizing liquid lines at 100 fpm. Charts prepared by Wile (1977) present pressure drops in saturation temperature equivalents. For a complete discussion of the basis of these line sizing charts, see Timm (1991). **Table 3** presents line sizing information for pumped liquid lines, high-pressure liquid lines, hot-gas defrost lines, equalizing lines, and thermosiphon lubricant cooling ammonia lines.

Valves

Stop Valves. These valves, also commonly called shutoff or isolation valves, are generally manually operated, although motor-actuated units are available. ASHRAE *Standard 15* requires these valves in the inlet and outlet lines to all condensers, compressors, and liquid receivers. Additional valves are installed on vessels, evaporators, and long lengths of pipe so they can be isolated in case of leaks and to facilitates pumping out for servicing and evacuation. Sections of liquid piping that can experience hydraulic lockup in normal operation must be protected with a relief device (preferably vented back into the system). Only qualified personnel should be allowed to operate stop valves.

Installing globe-type stop valves with the valve stems horizontal lessens the chance (1) for dirt or scale to lodge on the valve seat or disk and cause it to leak or (2) for liquid or lubricant to pocket in the area below the seat. Wet suction return lines (recirculation system) should use angle valves or globe valves (with their stems horizontal) to reduce the possibility of liquid pockets and to reduce pressure drop.

Refrigerant Piping

Welded flanged or weld-in-line valves are desirable for all line sizes; however, screwed valves may be used for 1 1/4" and smaller lines. Ammonia globe and angle valves should have the following features:

- Soft seating surfaces for positive shutoff (no copper or copper alloy)
- Back seating to permit repacking the valve stem while in service
- Arrangement that allows packing to be tightened easily
- All-steel construction (preferable)
- Bolted bonnets above 1 in., threaded bonnets for 1 in. and smaller

Consider seal cap valves in refrigerated areas and for all ammonia piping. To keep pressure drop to a minimum, consider angle valves (as opposed to globe valves).

Control Valves. Pressure regulators, solenoid valves, check valves, gas-powered suction stop valves, and thermostatic expansion valves can be flanged for easy assembly and removal. Alternative weld-in line valves with nonwearing body parts are available. Valves 1.5 in. and larger should have welded companion flanges. Smaller valves can have threaded companion flanges.

A strainer should be used in front of self-contained control valves to protect them from pipe construction material and dirt.

Solenoid Valves. Solenoid Valve stems should be upright with their coils protected from moisture. They should have flexible conduit connections, where allowed by codes, and an electric pilot light wired in parallel to indicate when the coil is energized.

Solenoid valves for high-pressure liquid feed to evaporators should have soft seats for positive shutoff. Solenoid valves for other applications, such as in suction lines, hot-gas lines, or gravity feed lines, should be selected for the pressure and temperature of the fluid flowing and for the pressure drop available.

Relief Valves. Safety Valves must be provided in conformance with ASHRAE *Standard 15* and Section VIII, Division 1, of the ASME *Boiler and Pressure Vessel Code*. For ammonia systems, IIAR Bulletin 109 also addresses the subject of safety valves.

Dual relief valve arrangements enable testing of the relief valves (**Figure 1**). The three-way stop valve is constructed so that it is always open to one of the relief valves if the other is removed to be checked or repaired.

Isolated Line Sections

Sections of piping that can be isolated between hand valves or check valves can be subjected to extreme hydraulic pressures if cold liquid refrigerant is trapped in them and subsequently warmed. Additional safety valves for such piping must be provided.

Insulation and Vapor Retarders

Insulation and effective vapor retarders on low-temperature systems are very important. At low temperatures, the smallest leak in the vapor retarder can allow ice to from inside the insulation, which can totally destroy the integrity of the entire insulation system. The result can cause a significant increase in load and power usage.

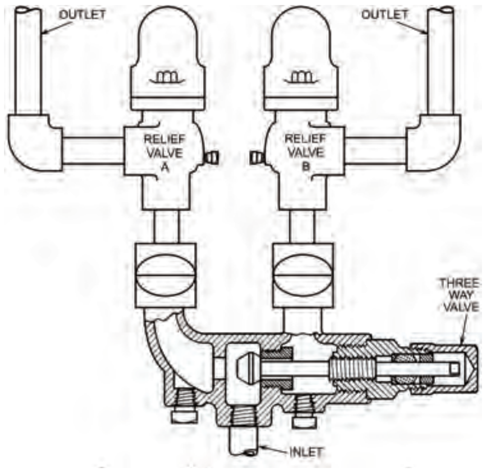


Figure 1. Dual Relief Valve Fitting For Ammonia

Table 3 Unfrozen Composition Data, Initial Freezing Point, and Specific Heats of Foods*

Food Item	Moisture Content, % x_{wo}	Protein, % x_p	Fat, % x_f	Carbohydrate Total, % x_c	Carbohydrate Fiber, % x_{fb}	Ash, % x_a	Initial Freezing Point, °F	Specific Heat Above Freezing, Btu/lb·°F	Specific Heat Below Freezing, Btu/lb·°F	Latent Heat of Fusion, Btu/lb
Vegetables										
Artichokes, globe	84.94	3.27	0.15	10.51	5.40	1.13	29.8	0.93	0.48	122
Jerusalem	78.01	2.00	0.01	17.44	1.60	2.54	27.5	0.87	0.54	112
Asparagus	92.40	2.28	0.20	4.54	2.10	0.57	30.9	0.96	0.43	133
Beans, snap	90.27	1.82	0.12	7.14	3.40	0.66	30.7	0.95	0.44	130
lima	70.24	6.84	0.86	20.16	4.90	1.89	30.9	0.84	0.49	101
Beets	87.58	1.61	0.17	9.56	2.80	1.08	30.0	0.93	0.46	126
Broccoli	90.69	2.98	0.35	5.24	3.00	0.92	30.9	0.96	0.43	130
Brussels sprouts	86.00	3.38	0.30	8.96	3.80	1.37	30.6	0.93	0.46	123
Cabbage	92.15	1.44	0.27	5.43	2.30	0.71	30.4	0.96	0.44	132
Carrots	87.79	1.03	0.19	10.14	3.00	0.87	29.5	0.94	0.48	126
Cauliflower	91.91	1.98	0.21	5.20	2.50	0.71	30.6	0.96	0.44	132
Celeriac	88.00	1.50	0.30	9.20	1.80	1.00	30.4	0.93	0.45	126
Celery	94.64	0.75	0.14	3.65	1.70	0.82	31.1	0.97	0.42	136
Collards	90.55	1.57	0.22	7.11	3.60	0.55	30.6	0.96	0.44	130
Corn, sweet, yellow	75.96	3.22	1.18	19.02	2.70	0.62	30.9	0.86	0.47	109
Cucumbers	96.01	0.69	0.13	2.76	0.80	0.41	31.1	0.98	0.41	138
Eggplant	92.03	1.02	0.18	6.07	2.50	0.71	30.6	0.96	0.44	132
Endive	93.79	1.25	0.20	3.35	3.10	1.41	31.8	0.97	0.40	135
Garlic	58.58	6.36	0.50	33.07	2.10	1.50	30.6	0.76	0.52	84
Ginger, root	81.67	1.74	0.73	15.09	2.00	0.77	—	0.90	0.46	117
Horseradish	78.66	9.40	1.40	8.28	2.00	2.26	28.8	0.88	0.51	113
Kale	84.46	3.30	0.70	10.01	2.00	1.53	31.1	0.91	0.44	121
Kohlrabi	91.00	1.70	0.10	6.20	3.60	1.00	30.2	0.96	0.45	131
Leeks	83.00	1.50	0.30	14.15	1.80	1.05	30.7	0.90	0.46	119
Lettuce, iceberg	95.89	1.01	0.19	2.09	1.40	0.48	31.6	0.98	0.39	138
Mushrooms	91.81	2.09	0.42	4.65	1.20	0.89	30.4	0.95	0.44	132
Okra	89.58	2.00	0.10	7.63	3.20	0.70	28.8	0.95	0.49	129
Onions	89.68	1.16	0.16	8.63	1.80	0.37	30.4	0.94	0.45	129
dehydrated flakes	3.93	8.95	0.46	83.28	9.20	3.38	—	—	—	6
Parsley	87.71	2.97	0.79	6.33	3.30	2.20	30.0	0.94	0.46	126
Parsnips	79.53	1.20	0.30	17.99	4.90	0.98	30.4	0.89	0.48	114
Peas, green	78.86	5.42	0.40	14.46	5.10	0.87	30.9	0.90	0.47	113
Peppers, freeze-dried	2.00	17.90	3.00	68.70	21.30	8.40	—	—	—	3
sweet, green	92.19	0.89	0.19	6.43	1.80	0.30	30.7	0.96	0.43	132
Potatoes, main crop	78.96	2.07	0.10	17.98	1.60	0.89	30.9	0.88	0.46	113
sweet	72.84	1.65	0.30	24.28	3.00	0.95	29.7	0.83	0.50	104
Pumpkins	91.60	1.00	0.10	6.50	0.50	0.80	30.6	0.95	0.43	132
Radishes	94.84	0.60	0.54	3.59	1.60	0.54	30.7	0.97	0.42	136
Rhubarb	93.61	0.90	0.20	4.54	1.80	0.76	30.4	0.97	0.44	135
Rutabaga	89.66	1.20	0.20	8.13	2.50	0.81	30.0	0.94	0.46	129
Salsify (vegetable oyster)	77.00	3.30	0.20	18.60	3.30	0.90	30.0	0.87	0.49	110
Spinach	91.58	2.86	0.35	3.50	2.70	1.72	31.5	0.96	0.42	132
Squash, summer	94.20	0.94	0.24	4.04	1.90	0.58	31.1	0.97	0.42	135
winter	87.78	0.80	0.10	10.42	1.50	0.90	30.6	0.93	0.45	126
Tomatoes, mature green	93.00	1.20	0.20	5.10	1.10	0.50	30.9	0.96	0.42	134
ripe	93.76	0.85	0.33	4.64	1.10	0.42	31.1	0.97	0.43	135
Turnip	91.87	0.90	0.10	6.23	1.80	0.70	30.0	0.96	0.45	132
greens	91.07	1.50	0.30	5.73	3.20	1.40	31.6	0.96	0.42	131
Watercress	95.11	2.30	0.10	1.29	1.50	1.20	31.5	0.97	0.40	137
Yams	69.60	1.53	0.17	27.89	4.10	0.82	—	0.83	0.49	100
Fruits										
Apples, fresh	83.93	0.19	0.36	15.25	2.70	0.26	30.0	0.91	0.47	120
dried	31.76	0.93	0.32	65.89	8.70	1.10	—	0.61	0.68	46
Apricots	86.35	1.40	0.39	11.12	2.40	0.75	30.0	0.92	0.47	124
Avocados	74.27	1.98	15.32	7.39	5.00	1.04	31.5	0.88	0.47	107
Bananas	74.26	1.03	0.48	23.43	2.40	0.80	30.6	0.85	0.48	107
Blackberries	85.64	0.72	0.39	12.76	5.30	0.48	30.6	0.93	0.46	123
Blueberries	84.61	0.67	0.38	14.13	2.70	0.21	29.1	0.91	0.49	122
Cantaloupes	89.78	0.88	0.28	8.36	0.80	0.71	29.8	0.94	0.46	129
Cherries, sour	86.13	1.00	0.30	12.18	1.60	0.40	28.9	0.92	0.49	124
sweet	80.76	1.20	0.96	16.55	2.30	0.53	28.8	0.89	0.51	116
Cranberries	86.54	0.39	0.20	12.68	4.20	0.19	30.4	0.93	0.46	124

Table 3 Unfrozen Composition Data, Initial Freezing Point, and Specific Heats of Foods* (*Continued*)

Food Item	Moisture Content, % x_{wo}	Protein, % x_p	Fat, % x_f	Carbohydrate Total, % x_c	Carbohydrate Fiber, % x_{fb}	Ash, % x_a	Initial Freezing Point, °F	Specific Heat Above Freezing, Btu/lb·°F	Specific Heat Below Freezing, Btu/lb·°F	Latent Heat of Fusion, Btu/lb
Currants, European black	81.96	1.40	0.41	15.38	0.00	0.86	30.2	0.89	0.47	118
red and white	83.95	1.40	0.20	13.80	4.30	0.66	30.2	0.92	0.47	120
Dates, cured	22.50	1.97	0.45	73.51	7.50	1.58	3.7	0.55	0.55	32
Figs, fresh	79.11	0.75	0.30	19.18	3.30	0.66	27.7	0.88	0.54	113
dried	28.43	3.05	1.17	65.35	9.30	2.01	—	0.60	0.98	41
Gooseberries	87.87	0.88	0.58	10.18	4.30	0.49	30.0	0.94	0.47	126
Grapefruit	90.89	0.63	0.10	8.08	1.10	0.31	30.0	0.95	0.45	131
Grapes, American	81.30	0.63	0.35	17.15	1.00	0.57	29.1	0.89	0.49	117
European type	80.56	0.66	0.58	17.77	1.00	0.44	28.2	0.88	0.52	116
Lemons	87.40	1.20	0.30	10.70	4.70	0.40	29.5	0.94	0.48	126
Limes	88.26	0.70	0.20	10.54	2.80	0.30	29.1	0.94	0.48	127
Mangos	81.71	0.51	0.27	17.00	1.80	0.50	30.4	0.89	0.47	117
Melons, casaba	92.00	0.90	0.10	6.20	0.80	0.80	30.0	0.95	0.45	132
honeydew	89.66	0.46	0.10	9.18	0.60	0.60	30.4	0.94	0.44	129
watermelon	91.51	0.62	0.43	7.18	0.50	0.26	31.3	0.95	0.42	132
Nectarines	86.28	0.94	0.46	11.78	1.60	0.54	30.4	0.92	0.45	124
Olives	79.99	0.84	10.68	6.26	3.20	2.23	29.5	0.90	0.49	115
Oranges	82.30	1.30	0.30	15.50	4.50	0.60	30.6	0.91	0.47	118
Peaches, fresh	87.66	0.70	0.90	11.10	2.00	0.46	30.4	0.93	0.45	126
dried	31.80	3.61	0.76	61.33	8.20	2.50	—	0.61	0.83	46
Pears	83.81	0.39	0.40	15.11	2.40	0.28	29.1	0.91	0.49	120
Persimmons	64.40	0.80	0.40	33.50	0.00	0.90	28.0	0.78	0.55	92
Pineapples	86.50	0.39	0.43	12.39	1.20	0.29	30.2	0.92	0.46	124
Plums	85.20	0.79	0.62	13.01	1.50	0.39	30.6	0.91	0.45	123
Pomegranates	80.97	0.95	0.30	17.17	0.60	0.61	26.6	0.88	0.55	116
Prunes, dried	32.39	2.61	0.52	62.73	7.10	1.76	—	0.61	0.84	46
Quinces	83.80	0.40	0.10	15.30	1.90	0.40	28.4	0.91	0.51	120
Raisins, seedless	15.42	3.22	0.46	79.13	4.00	1.77	—	0.49	0.49	22
Raspberries	86.57	0.91	0.55	11.57	6.80	0.40	30.9	0.95	0.46	124
Strawberries	91.57	0.61	0.37	7.02	2.30	0.43	30.6	0.96	0.44	132
Tangerines	87.60	0.63	0.19	11.19	2.30	0.39	30.0	0.93	0.46	126
Whole Fish										
Cod	81.22	17.81	0.67	0.0	0.0	1.16	28.0	0.90	0.51	117
Haddock	79.92	18.91	0.72	0.0	0.0	1.21	28.0	0.90	0.51	115
Halibut	77.92	20.81	2.29	0.0	0.0	1.36	28.0	0.89	0.52	112
Herring, kippered	59.70	24.58	12.37	0.0	0.0	1.94	28.0	0.78	0.54	86
Mackerel, Atlantic	63.55	18.60	13.89	0.0	0.0	1.35	28.0	0.80	0.53	91
Perch	78.70	18.62	1.63	0.0	0.0	1.20	28.0	0.89	0.51	113
Pollock, Atlantic	78.18	19.44	0.98	0.0	0.0	1.41	28.0	0.88	0.51	112
Salmon, pink	76.35	19.94	3.45	0.0	0.0	1.22	28.0	0.88	0.52	110
Tuna, bluefin	68.09	23.33	4.90	0.0	0.0	1.18	28.0	0.82	0.52	98
Whiting	80.27	18.31	1.31	0.0	0.0	1.30	28.0	0.90	0.51	115
Shellfish										
Clams	81.82	12.77	0.97	2.57	0.0	1.87	28.0	0.90	0.51	117
Lobster, American	76.76	18.80	0.90	0.50	0.0	2.20	28.0	0.87	0.51	110
Oysters	85.16	7.05	2.46	3.91	0.0	1.42	28.0	0.91	0.51	122
Scallop, meat	78.57	16.78	0.76	2.36	0.0	1.53	28.0	0.89	0.51	113
Shrimp	75.86	20.31	1.73	0.91	0.0	1.20	28.0	0.87	0.52	109
Beef										
Brisket	55.18	16.94	26.54	0.0	0.0	0.80	—	0.76	0.56	79
Carcass, choice	57.26	17.32	24.05	0.0	0.0	0.81	28.0	0.77	0.55	82
select	58.21	17.48	22.55	0.0	0.0	0.82	28.9	0.78	0.54	83
Liver	68.99	20.00	3.85	5.82	0.0	1.34	28.9	0.83	0.52	99
Ribs, whole (ribs 6-12)	54.54	16.37	26.98	0.0	0.0	0.77	—	0.75	0.55	78
Round, full cut, lean and fat	64.75	20.37	12.81	0.0	0.0	0.97	—	0.81	0.52	93
full cut, lean	70.83	22.03	4.89	0.0	0.0	1.07	—	0.84	0.51	102
Sirloin, lean	71.70	21.24	4.40	0.0	0.0	1.08	28.9	0.84	0.50	103
Short loin, porterhouse steak, lean	69.59	20.27	8.17	0.0	0.0	1.01	—	0.83	0.51	100
T-bone steak, lean	69.71	20.78	7.27	0.0	0.0	1.27	—	0.83	0.51	100
Tenderloin, lean	68.40	20.78	7.90	0.0	0.0	1.04	—	0.82	0.51	98
Veal, lean	75.91	20.20	2.87	0.0	0.0	1.08	—	0.87	0.50	109

Table 3 Unfrozen Composition Data, Initial Freezing Point, and Specific Heats of Foods* (*Continued*)

Food Item	Moisture Content, % x_{wo}	Protein, % x_p	Fat, % x_f	Carbohydrate Total, % x_c	Carbohydrate Fiber, % x_{fb}	Ash, % x_a	Initial Freezing Point, °F	Specific Heat Above Freezing, Btu/lb·°F	Specific Heat Below Freezing, Btu/lb·°F	Latent Heat of Fusion, Btu/lb
Pork										
Backfat	7.69	2.92	88.69	0.0	0.0	0.70	—	0.52	0.71	11
Bacon	31.58	8.66	57.54	0.09	0.0	2.13	—	0.64	0.64	45
Belly	36.74	9.34	53.01	0.0	0.0	0.49	—	0.67	0.80	53
Carcass	49.83	13.91	35.07	0.0	0.0	0.72	—	0.74	0.74	71
Ham, cured, whole, lean	68.26	22.32	5.71	0.05	0.0	3.66	—	0.83	0.53	98
country cured, lean	55.93	27.80	8.32	0.30	0.0	7.65	—	0.75	0.55	80
Shoulder, whole, lean	72.63	19.55	7.14	0.0	0.0	1.02	28.0	0.86	0.53	104
Sausage										
Braunschweiger	48.01	13.50	32.09	3.13	0.0	3.27	—	0.72	0.57	69
Frankfurter	53.87	11.28	29.15	2.55	0.0	3.15	28.9	0.75	0.55	77
Italian	51.08	14.25	31.33	0.65	0.0	2.70	—	0.74	0.57	74
Polish	53.15	14.10	28.72	1.63	0.0	2.40	—	0.75	0.56	77
Pork	44.52	11.69	40.29	1.02	0.0	2.49	—	0.70	0.58	64
Smoked links	39.30	22.20	31.70	2.10	0.0	4.70	—	0.67	0.59	56
Poultry Products										
Chicken	65.99	18.60	15.06	0.0	0.0	0.79	27.0	0.79	0.42	95
Duck	48.50	11.49	39.34	0.0	0.0	0.68	—	0.73	0.59	70
Turkey	70.40	20.42	8.02	0.0	0.0	0.88	—	0.84	0.54	101
Egg										
White	87.81	10.52	0.0	1.03	0.0	0.64	30.9	0.93	0.43	126
dried	14.62	76.92	0.04	4.17	0.0	4.25	—	0.55	0.50	21
Whole	75.33	12.49	10.02	1.22	0.0	0.94	30.9	0.87	0.47	108
dried	3.10	47.35	40.95	4.95	0.0	3.65	—	0.49	0.48	4
Yolk	48.81	16.76	30.87	1.78	0.0	1.77	30.9	0.73	0.54	70
salted	50.80	14.00	23.00	1.60	0.0	10.60	1.0	0.72	0.91	73
sugared	51.25	13.80	22.75	10.80	0.0	1.40	25.0	0.73	0.61	74
Lamb										
Composite of cuts, lean	73.42	20.29	5.25	0.0	0.0	1.06	28.6	0.86	0.51	105
Leg, whole, lean	74.11	20.56	4.51	0.0	0.0	1.07	—	0.86	0.51	107
Dairy Products										
Butter	17.94	0.85	81.11	0.06	0.0	0.04	—	0.57	0.63	26
Cheese										
Camembert	51.80	19.80	24.26	0.46	0.0	3.68	—	0.74	0.80	74
Cheddar	36.75	24.90	33.14	1.28	0.0	3.93	8.8	0.66	0.73	53
Cottage, uncreamed	79.77	17.27	0.42	1.85	0.0	0.69	29.8	0.89	0.48	114
Cream	53.75	7.55	34.87	2.66	0.0	1.17	—	0.75	0.70	77
Gouda	41.46	24.94	27.44	2.22	0.0	3.94	—	0.69	0.66	59
Limburger	48.42	20.05	27.25	0.49	0.0	3.79	18.7	0.72	0.67	70
Mozzarella	54.14	19.42	21.60	2.22	0.0	2.62	—	0.75	0.59	78
Parmesan, hard	29.16	35.75	25.83	3.22	0.0	6.04	—	0.62	0.70	42
Processed American	39.16	22.15	31.25	1.30	0.0	5.84	19.6	0.67	0.66	56
Roquefort	39.38	21.54	30.64	2.00	0.0	6.44	2.7	0.67	0.80	57
Swiss	37.21	28.43	27.45	3.38	0.0	3.53	14.0	0.66	0.69	53
Cream										
Half and half	80.57	2.96	11.50	4.30	0.0	0.67	—	0.89	0.52	116
Table	73.75	2.70	19.31	3.66	0.0	0.58	28.0	0.86	0.53	106
Heavy whipping	57.71	2.05	37.00	2.79	0.0	0.45	—	0.78	0.55	83
Ice Cream										
Chocolate	55.70	3.80	11.0	28.20	1.20	1.00	21.9	0.74	0.66	80
Strawberry	60.00	3.20	8.40	27.60	0.30	0.70	21.9	0.76	0.65	86
Vanilla	61.00	3.50	11.00	23.60	0.0	0.90	21.9	0.77	0.65	88
Milk										
Canned, condensed, sweetened	27.16	7.91	8.70	54.40	0.0	1.83	5.0	0.56	—	39
Evaporated	74.04	6.81	7.56	10.04	0.0	1.55	29.5	0.85	0.50	106
Skim	90.80	3.41	0.18	4.85	0.0	0.76	—	0.94	0.43	130
dried	3.16	36.16	0.77	51.98	0.0	7.93	—	0.43	—	5
Whole	87.69	3.28	3.66	4.65	0.0	0.72	30.9	0.93	0.43	126
dried	2.47	26.32	26.71	38.42	0.0	6.08	—	0.44	—	3
Whey, acid, dried	3.51	11.73	0.54	73.45	0.0	10.77	—	0.40	—	5
sweet, dried	3.19	12.93	1.07	74.46	0.0	8.35	—	0.40	—	5

Table 3 Unfrozen Composition Data, Initial Freezing Point, and Specific Heats of Foods* (*Continued*)

Food Item	Moisture Content, % x_{wo}	Protein, % x_p	Fat, % x_f	Carbohydrate Total, % x_c	Carbohydrate Fiber, % x_{fb}	Ash, % x_a	Initial Freezing Point, °F	Specific Heat Above Freezing, Btu/lb·°F	Specific Heat Below Freezing, Btu/lb·°F	Latent Heat of Fusion, Btu/lb
Nuts, Shelled										
Almonds	4.42	19.95	52.21	20.40	10.90	3.03	—	0.53	—	6
Filberts	5.42	13.04	62.64	15.30	6.10	3.61	—	0.50	—	8
Peanuts, raw	6.50	25.80	49.24	16.14	8.50	2.33	—	0.53	—	9
dry roasted with salt	1.55	23.68	49.66	21.51	8.00	3.60	—	0.50	—	2
Pecans	4.82	7.75	67.64	18.24	7.60	1.56	—	0.52	—	7
Walnuts, English	3.65	14.29	61.87	18.34	4.80	1.86	—	0.50	—	5
Candy										
Fudge, vanilla	10.90	1.10	5.40	82.30	0.0	0.40	—	0.45	—	15
Marshmallows	16.40	1.80	0.20	81.30	0.10	0.30	—	0.48	—	24
Milk chocolate	1.30	6.90	30.70	59.20	3.40	1.50	—	0.44	—	2
Peanut brittle	1.80	7.50	19.10	69.30	2.00	1.50	—	0.42	—	3
Juice and Beverages										
Apple juice, unsweetened	87.93	0.06	0.11	11.68	0.10	0.22	—	0.92	0.43	126
Grapefruit juice, sweetened	87.38	0.58	0.09	11.13	0.10	0.82	—	0.92	0.43	126
Grape juice, unsweetened	84.12	0.56	0.08	14.96	0.10	0.29	—	0.90	0.43	121
Lemon juice	92.46	0.40	0.29	6.48	0.40	0.36	—	0.95	0.41	133
Lime juice, unsweetened	92.52	0.25	0.23	6.69	0.40	0.31	—	0.95	0.41	133
Orange juice	89.01	0.59	0.14	9.85	0.20	0.41	31.3	0.93	0.42	128
Pineapple juice, unsweetened	85.53	0.32	0.08	13.78	0.20	0.30	—	0.91	0.43	123
Prune juice	81.24	0.61	0.03	17.45	1.00	0.68	—	0.89	0.45	117
Tomato juice	93.90	0.76	0.06	4.23	0.40	1.05	—	0.96	0.41	135
Cranberry-apple juice drink	82.80	0.10	0.0	17.10	0.10	0.0	—	0.89	0.44	119
Cranberry-grape juice drink	85.60	0.20	0.10	14.00	0.10	0.10	—	0.91	0.43	123
Fruit punch drink	88.00	0.0	0.0	11.90	0.10	0.10	—	0.92	0.43	126
Club soda	99.90	0.0	0.0	0.0	0.0	0.10	—	1.00	0.39	144
Cola	89.40	0.0	0.0	10.40	0.0	0.10	—	0.93	0.42	129
Cream soda	86.70	0.0	0.0	13.30	0.0	0.10	—	0.91	0.43	125
Ginger ale	91.20	0.0	0.0	8.70	0.0	0.0	—	0.94	0.41	131
Grape soda	88.80	0.0	0.0	11.20	0.0	0.10	—	0.93	0.42	128
Lemon-lime soda	89.50	0.0	0.0	10.40	0.0	0.10	—	0.93	0.42	129
Orange soda	87.60	0.0	0.0	12.30	0.0	0.10	—	0.92	0.43	126
Root beer	89.30	0.0	0.0	10.60	0.0	0.10	—	0.93	0.42	128
Chocolate milk, 2% fat	83.58	3.21	2.00	10.40	0.50	0.81	—	0.90	0.44	120
Miscellaneous										
Honey	17.10	0.30	0.0	82.40	0.20	0.20	—	0.48	—	25
Maple syrup	32.00	0.00	0.20	67.20	0.0	0.60	—	0.58	—	46
Popcorn, air-popped	4.10	12.00	4.20	77.90	15.10	1.80	—	0.49	—	6
oil-popped	2.80	9.00	28.10	57.20	10.00	2.90	—	0.48	—	4
Yeast, baker's, compressed	69.00	8.40	1.90	18.10	8.10	1.80	—	0.85	0.52	100

*Composition data from USDA (1996). Initial freezing point data from Table 1 in Chapter 30 of the 1993 *ASHRAE Handbook—Fundamentals* and USDA (1968). Specific heats calculated from equations in this chapter. Latent heat of fusion obtained by multiplying water content expressed in fractional form by 144 Btu/lb, the heat of fusion of water (Table 1 in Chapter 30 of the 1993 *ASHRAE Handbook—Fundamentals*).

Thermophysical Properties of Refrigerants

This section presents data for the thermodynamic and transport properties of refrigerants, arranged for the occasional users. The refrigerants have a thermodynamic property charge on pressure-enthalpy coordinates with an abbreviated set of tabular data for the saturated liquid and vapor on the facing page.

1. Refrigerant 717 (Ammonia)
2. Refrigerant 22 (Chlorodifluoromethane)
3. Refrigerant 134a (1,1,1,2-Tetrafluoroethane)
4. Refrigerant 404A [R-125/143a/134a (44/52/4)]
5. Refrigerant 507A [R-125/143a (50/50)]
6. Refrigerant 290 (Propane)
7. Refrigerant 744 (Carbon Dioxide)

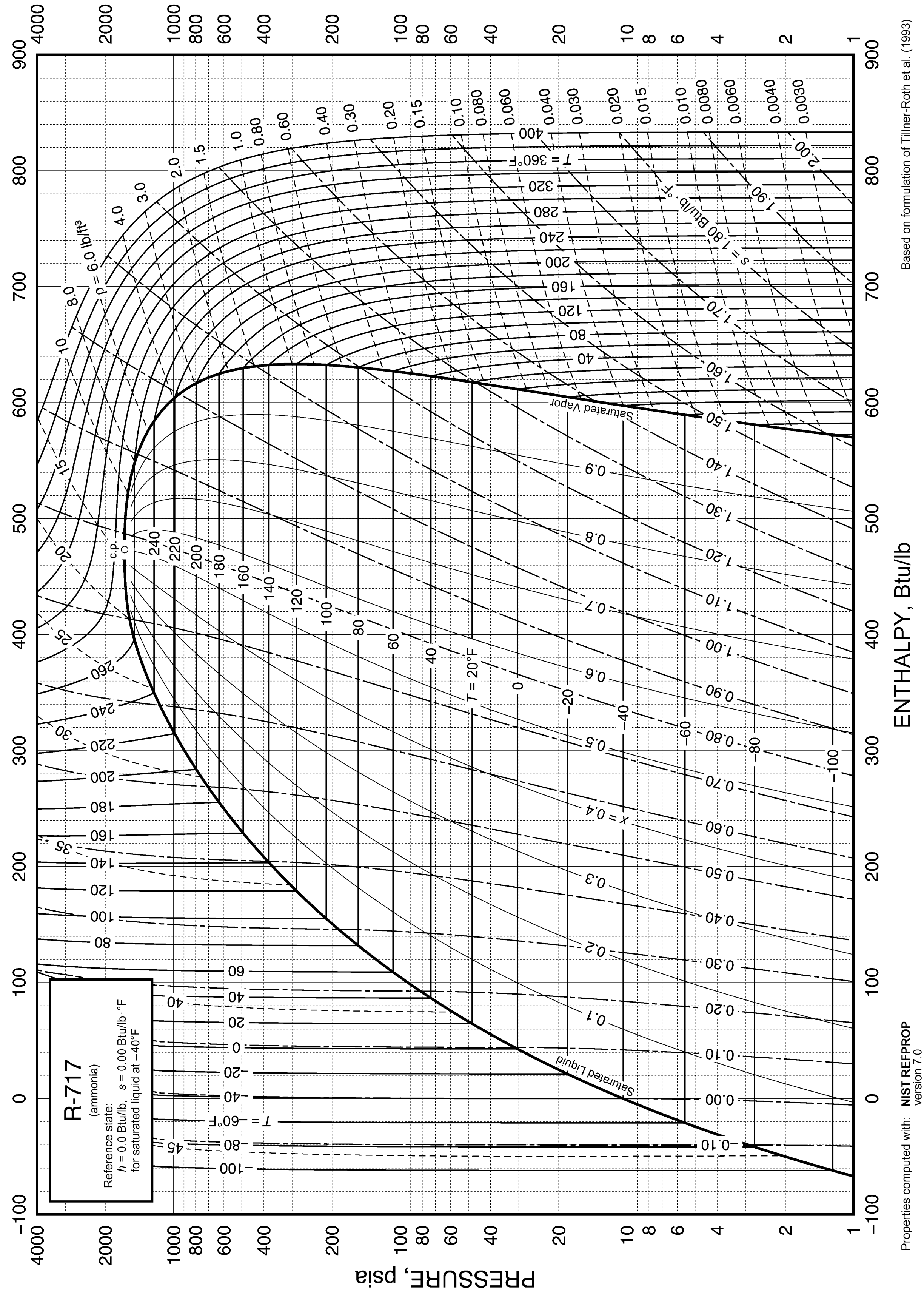


Fig. 18 Pressure-Enthalpy Diagram for Refrigerant 717 (Ammonia)

Refrigerant 717 (Ammonia) Properties of Saturated Liquid and Saturated Vapor

Temp.,* °F	Pressure, psia	Density, lb/ft³ Liquid	Volume, ft³/lb Vapor	Enthalpy, Btu/lb Liquid	Enthalpy, Btu/lb Vapor	Entropy, Btu/lb·°F Liquid	Entropy, Btu/lb·°F Vapor	Specific Heat c_p, Btu/lb·°F Liquid	Specific Heat c_p, Btu/lb·°F Vapor	c_p/c_v Vapor	Vel. of Sound, ft/s Liquid	Vel. of Sound, ft/s Vapor	Viscosity, lb_m/ft·h Liquid	Viscosity, lb_m/ft·h Vapor	Thermal Cond., Btu/h·ft·°F Liquid	Thermal Cond., Btu/h·ft·°F Vapor	Surface Tension, dyne/cm	Temp.,* °F
–107.78[a]	0.883	45.75	249.92	–69.830	568.765	–0.18124	1.63351	1.0044	0.4930	1.3252	6969	1161.8	1.354	0.0165	0.4735	0.01135	62.26	–107.78
–100	1.237	45.47	182.19	–61.994	572.260	–0.15922	1.60421	1.0100	0.4959	1.3262	6830	1173.8	1.232	0.0168	0.4647	0.01138	60.47	–100
–90	1.864	45.09	124.12	–51.854	576.688	–0.13142	1.56886	1.0176	0.5003	1.3278	6666	1188.6	1.099	0.0171	0.4534	0.01143	58.19	–90
–80	2.739	44.71	86.546	–41.637	581.035	–0.10416	1.53587	1.0254	0.5056	1.3296	6513	1202.9	0.986	0.0175	0.4422	0.01149	55.94	–80
–70	3.937	44.31	61.647	–31.341	585.288	–0.07741	1.50503	1.0331	0.5118	1.3319	6367	1216.7	0.891	0.0179	0.4310	0.01158	53.73	–70
–60	5.544	43.91	44.774	–20.969	589.439	–0.05114	1.47614	1.0406	0.5190	1.3346	6228	1229.7	0.810	0.0182	0.4198	0.01168	51.54	–60
–50	7.659	43.50	33.105	–10.521	593.476	–0.02534	1.44900	1.0478	0.5271	1.3379	6092	1242.2	0.741	0.0186	0.4088	0.01180	49.39	–50
–40	10.398	43.08	24.881	0.000	597.387	0.00000	1.42347	1.0549	0.5364	1.3419	5959	1253.9	0.680	0.0190	0.3978	0.01193	47.26	–40
–30	13.890	42.66	18.983	10.592	601.162	0.02491	1.39938	1.0617	0.5467	1.3465	5827	1264.9	0.628	0.0194	0.3870	0.01209	45.17	–30
–27.99[b]	14.696	42.57	18.007	12.732	601.904	0.02987	1.39470	1.0631	0.5490	1.3475	5801	1267.1	0.618	0.0195	0.3849	0.01212	44.75	–27.99
–25	15.962	42.45	16.668	15.914	602.995	0.03720	1.38784	1.0651	0.5524	1.3491	5762	1270.2	0.604	0.0196	0.3817	0.01217	44.14	–25
–20	18.279	42.23	14.684	21.253	604.789	0.04939	1.37660	1.0684	0.5583	1.3520	5697	1275.2	0.582	0.0198	0.3764	0.01226	43.11	–20
–15	20.858	42.01	12.976	26.609	606.544	0.06148	1.36567	1.0716	0.5646	1.3550	5632	1280.0	0.561	0.0200	0.3711	0.01236	42.09	–15
–10	23.723	41.79	11.502	31.982	608.257	0.07347	1.35502	1.0749	0.5711	1.3584	5567	1284.7	0.541	0.0202	0.3658	0.01246	41.08	–10
–5	26.895	41.57	10.226	37.372	609.928	0.08536	1.34463	1.0782	0.5781	1.3619	5503	1289.1	0.522	0.0204	0.3606	0.01256	40.08	–5
0	30.397	41.34	9.1159	42.779	611.554	0.09715	1.33450	1.0814	0.5853	1.3657	5438	1293.3	0.505	0.0206	0.3555	0.01267	39.08	0
5	34.253	41.12	8.1483	48.203	613.135	0.10885	1.32462	1.0847	0.5929	1.3698	5373	1297.3	0.488	0.0208	0.3503	0.01279	38.10	5
10	38.487	40.89	7.3020	53.644	614.669	0.12045	1.31496	1.0880	0.6009	1.3742	5308	1301.1	0.472	0.0210	0.3453	0.01291	37.12	10
15	43.126	40.66	6.5597	59.103	616.154	0.13197	1.30552	1.0914	0.6092	1.3789	5243	1304.7	0.457	0.0212	0.3402	0.01304	36.15	15
20	48.194	40.43	5.9067	64.579	617.590	0.14340	1.29629	1.0948	0.6179	1.3840	5178	1308.0	0.443	0.0214	0.3352	0.01317	35.19	20
25	53.720	40.20	5.3307	70.072	618.974	0.15474	1.28726	1.0983	0.6271	1.3894	5113	1311.1	0.429	0.0216	0.3302	0.01331	34.23	25
30	59.730	39.96	4.8213	75.585	620.305	0.16599	1.27842	1.1019	0.6366	1.3951	5048	1314.0	0.416	0.0218	0.3253	0.01345	33.29	30
35	66.255	39.72	4.3695	81.116	621.582	0.17717	1.26975	1.1056	0.6465	1.4012	4982	1316.6	0.404	0.0220	0.3204	0.01360	32.35	35
40	73.322	39.48	3.9680	86.666	622.803	0.18827	1.26125	1.1094	0.6569	1.4078	4916	1319.0	0.392	0.0222	0.3155	0.01376	31.42	40
45	80.962	39.24	3.6102	92.237	623.967	0.19929	1.25291	1.1134	0.6678	1.4147	4850	1321.1	0.381	0.0224	0.3107	0.01392	30.50	45
50	89.205	38.99	3.2906	97.828	625.072	0.21024	1.24472	1.1175	0.6791	1.4222	4784	1323.0	0.370	0.0227	0.3059	0.01409	29.59	50
55	98.083	38.75	3.0045	103.441	626.115	0.22111	1.23667	1.1218	0.6909	1.4301	4717	1324.6	0.360	0.0229	0.3012	0.01426	28.69	55
60	107.63	38.50	2.7479	109.076	627.097	0.23192	1.22875	1.126	0.703	1.438	4650	1325.9	0.350	0.0231	0.2965	0.01445	27.79	60
65	117.87	38.25	2.5172	114.734	628.013	0.24266	1.22095	1.131	0.716	1.447	4583	1327.0	0.340	0.0233	0.2918	0.01464	26.90	65
70	128.85	37.99	2.3094	120.417	628.864	0.25334	1.21327	1.136	0.730	1.457	4515	1327.8	0.331	0.0235	0.2872	0.01483	26.03	70
75	140.59	37.73	2.1217	126.126	629.647	0.26396	1.20570	1.141	0.744	1.467	4447	1328.3	0.322	0.0237	0.2825	0.01504	25.16	75
80	153.13	37.47	1.9521	131.861	630.359	0.27452	1.19823	1.147	0.758	1.478	4378	1328.6	0.313	0.0239	0.2780	0.01525	24.30	80
85	166.51	37.21	1.7983	137.624	630.999	0.28503	1.19085	1.153	0.774	1.490	4309	1328.5	0.305	0.0241	0.2734	0.01548	23.44	85
90	180.76	36.94	1.6588	143.417	631.564	0.29549	1.18356	1.159	0.790	1.502	4240	1328.2	0.297	0.0244	0.2689	0.01571	22.60	90
95	195.91	36.67	1.5319	149.241	632.052	0.30590	1.17634	1.166	0.807	1.515	4170	1327.5	0.289	0.0246	0.2644	0.01595	21.77	95
100	212.01	36.40	1.4163	155.098	632.460	0.31626	1.16920	1.173	0.824	1.529	4099	1326.6	0.282	0.0248	0.2600	0.01620	20.94	100
105	229.09	36.12	1.3108	160.990	632.785	0.32659	1.16211	1.180	0.843	1.544	4028	1325.3	0.274	0.0250	0.2556	0.01646	20.13	105
110	247.19	35.83	1.2144	166.919	633.025	0.33688	1.15508	1.188	0.862	1.561	3956	1323.7	0.267	0.0253	0.2512	0.01673	19.32	110
115	266.34	35.55	1.1262	172.887	633.175	0.34713	1.14809	1.197	0.883	1.578	3884	1321.8	0.260	0.0255	0.2468	0.01702	18.53	115
120	286.60	35.26	1.0452	178.896	633.232	0.35736	1.14115	1.206	0.905	1.597	3811	1319.5	0.254	0.0257	0.2424	0.01732	17.74	120
125	307.98	34.96	0.9710	184.949	633.193	0.36757	1.13423	1.216	0.928	1.617	3737	1316.9	0.247	0.0260	0.2381	0.01763	16.96	125
130	330.54	34.66	0.9026	191.049	633.053	0.37775	1.12733	1.227	0.952	1.638	3662	1313.9	0.241	0.0262	0.2338	0.01795	16.19	130
135	354.32	34.35	0.8397	197.199	632.807	0.38792	1.12044	1.239	0.978	1.662	3587	1310.6	0.235	0.0265	0.2295	0.01829	15.44	135
140	379.36	34.04	0.7817	203.403	632.451	0.39808	1.11356	1.251	1.006	1.687	3511	1306.9	0.229	0.0267	0.2253	0.01865	14.69	140
145	405.70	33.72	0.7280	209.663	631.978	0.40824	1.10666	1.265	1.035	1.715	3434	1302.8	0.223	0.0270	0.2210	0.01903	13.95	145
150	433.38	33.39	0.6785	215.984	631.383	0.41840	1.09975	1.280	1.067	1.745	3356	1298.3	0.217	0.0273	0.2168	0.01943	13.22	150
155	462.45	33.06	0.6325	222.370	630.659	0.42857	1.09281	1.296	1.101	1.778	3277	1293.4	0.211	0.0276	0.2125	0.01986	12.51	155
160	492.95	32.72	0.5899	228.827	629.798	0.43875	1.08582	1.313	1.138	1.813	3198	1288.1	0.206	0.0279	0.2083	0.02031	11.80	160
165	524.94	32.37	0.5504	235.359	628.791	0.44896	1.07878	1.333	1.178	1.853	3117	1282.4	0.200	0.0282	0.2041	0.02079	11.10	165
170	558.45	32.01	0.5136	241.973	627.630	0.45919	1.07167	1.354	1.222	1.896	3035	1276.2	0.195	0.0285	0.1999	0.02130	10.42	170
175	593.53	31.64	0.4793	248.675	626.302	0.46947	1.06447	1.377	1.270	1.944	2952	1269.6	0.190	0.0288	0.1957	0.02185	9.75	175
180	630.24	31.26	0.4473	255.472	624.797	0.47980	1.05717	1.403	1.322	1.998	2868	1262.4	0.185	0.0292	0.1916	0.02245	9.09	180
185	668.63	30.87	0.4174	262.374	623.100	0.49019	1.04974	1.432	1.381	2.058	2783	1254.8	0.179	0.0296	0.1874	0.02310	8.44	185
190	708.74	30.47	0.3895	269.390	621.195	0.50066	1.04217	1.465	1.446	2.126	2696	1246.7	0.174	0.0300	0.1832	0.02381	7.80	190
195	750.64	30.05	0.3633	276.530	619.064	0.51121	1.03443	1.502	1.519	2.203	2608	1238.0	0.169	0.0304	0.1790	0.02458	7.18	195
200	794.38	29.62	0.3387	283.809	616.686	0.52188	1.02649	1.543	1.602	2.290	2519	1228.7	0.165	0.0309	0.1748	0.02545	6.56	200
205	840.03	29.17	0.3156	291.240	614.035	0.53267	1.01831	1.591	1.697	2.392	2428	1218.9	0.160	0.0314	0.1706	0.02641	5.97	205
210	887.64	28.70	0.2938	298.842	611.081	0.54360	1.00986	1.646	1.806	2.509	2336	1208.4	0.155	0.0320	0.1663	0.02749	5.38	210
215	937.28	28.21	0.2733	306.637	607.788	0.55472	1.00109	1.711	1.935	2.648	2243	1197.2	0.150	0.0326	0.1621	0.02872	4.81	215
220	989.03	27.69	0.2538	314.651	604.112	0.56605	0.99193	1.788	2.088	2.814	2147	1185.4	0.145	0.0333	0.1578	0.03013	4.26	220
225	1042.96	27.15	0.2354	322.918	599.996	0.57763	0.98232	1.882	2.272	3.015	2050	1172.7	0.140	0.0340	0.1536	0.03178	3.72	225
230	1099.14	26.57	0.2178	331.483	595.371	0.58953	0.97216	1.999	2.501	3.265	1950	1159.1	0.136	0.0349	0.1492	0.03372	3.20	230
235	1157.69	25.95	0.2010	340.404	590.142	0.60182	0.96133	2.148	2.790	3.582	1848	1144.5	0.131	0.0359	0.1449	0.03607	2.70	235
240	1218.68	25.28	0.1849	349.766	584.183	0.61462	0.94966	2.346	3.171	4.000	1743	1128.8	0.126	0.0370	0.1406	0.03895	2.22	240
245	1282.24	24.55	0.1693	359.695	577.309	0.62809	0.93690	2.624	3.693	4.575	1634	1111.6	0.120	0.0383	0.1363	0.04261	1.76	245
250	1348.49	23.72	0.1540	370.391	569.240	0.64249	0.92269	3.047	4.460	5.420	1520	1092.6	0.115	0.0399	0.1320	0.04744	1.33	250
260	1489.71	21.60	0.1233	395.943	547.139	0.67662	0.88671	5.273	8.106	9.439	1271	1045.9	0.102	0.0446	0.1250	0.06473	0.55	260
270.05[c]	1643.71	14.05	0.0712	473.253	473.253	0.78093	0.78093	∞	∞	∞	0	0.0	—	—	∞	∞	0.00	270.05

*Temperatures on ITS-90 scale [a]Triple point [b]Normal boiling point [c]Critical point

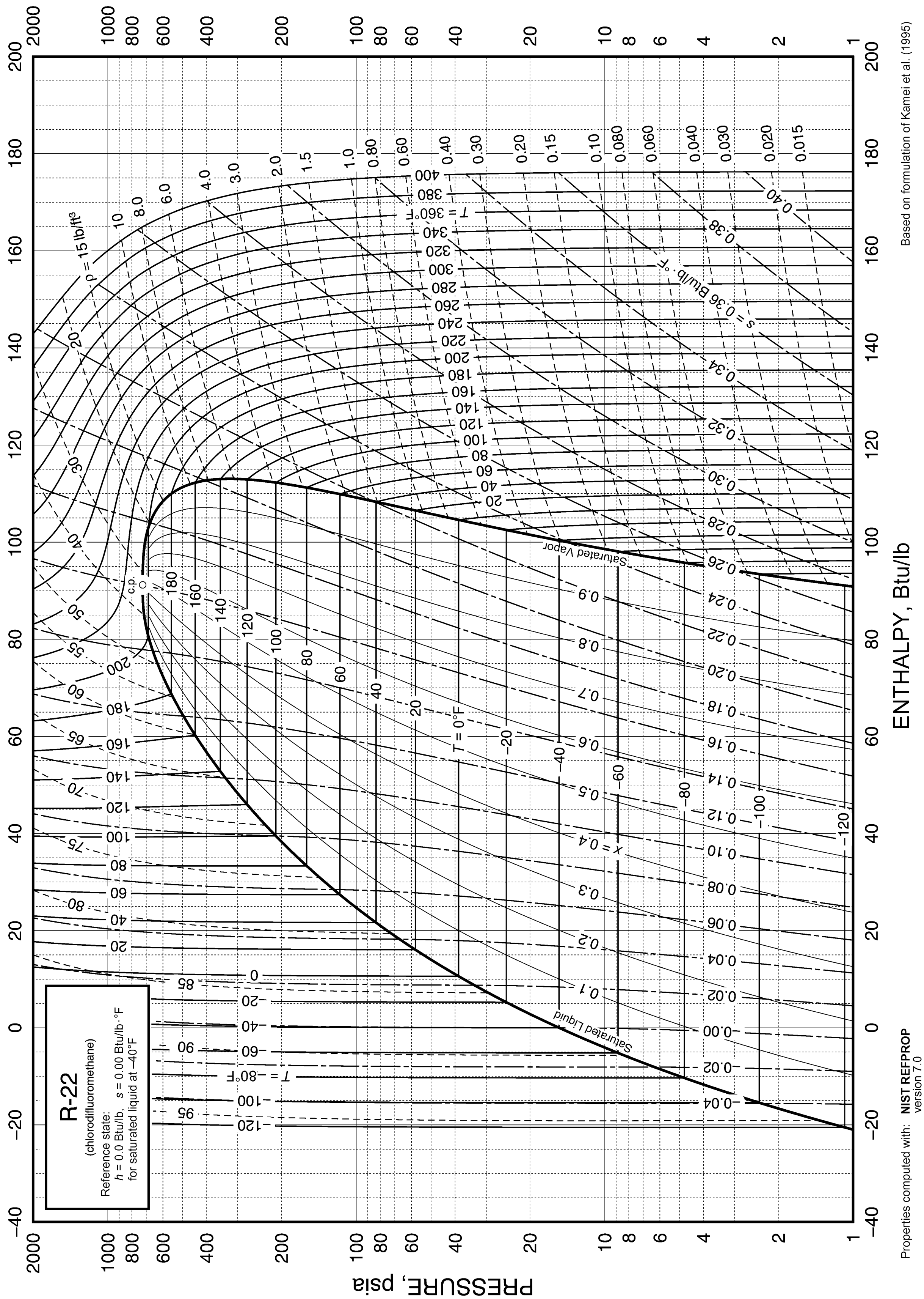


Fig. 2 Pressure-Enthalpy Diagram for Refrigerant 22

Refrigerant 22 (Chlorodifluoromethane) Properties of Saturated Liquid and Saturated Vapor

Temp.,* °F	Pressure, psia	Density, lb/ft³ Liquid	Volume, ft³/lb Vapor	Enthalpy, Btu/lb Liquid	Enthalpy, Btu/lb Vapor	Entropy, Btu/lb·°F Liquid	Entropy, Btu/lb·°F Vapor	Specific Heat c_p, Btu/lb·°F Liquid	Specific Heat c_p, Btu/lb·°F Vapor	c_p/c_v Vapor	Vel. of Sound, ft/s Liquid	Vel. of Sound, ft/s Vapor	Viscosity, lb_m/ft·h Liquid	Viscosity, lb_m/ft·h Vapor	Thermal Cond., Btu/h·ft·°F Liquid	Thermal Cond., Btu/h·ft·°F Vapor	Surface Tension, dyne/cm	Temp.,* °F
–150	0.263	98.28	146.06	–28.119	87.566	–0.07757	0.29600	0.2536	0.1185	1.2437	3716	469.7	2.093	0.0174	0.0831	0.00255	28.31	–150
–140	0.436	97.36	90.759	–25.583	88.729	–0.06951	0.28808	0.2536	0.1204	1.2404	3630	476.2	1.874	0.0180	0.0814	0.00267	27.34	–140
–130	0.698	96.44	58.384	–23.046	89.899	–0.06170	0.28090	0.2536	0.1223	1.2375	3544	482.4	1.692	0.0186	0.0797	0.00280	26.36	–130
–120	1.082	95.52	38.745	–20.509	91.074	–0.05412	0.27439	0.2537	0.1244	1.2350	3458	488.5	1.537	0.0191	0.0780	0.00293	25.40	–120
–110	1.629	94.59	26.444	–17.970	92.252	–0.04675	0.26846	0.2540	0.1265	1.2330	3373	494.2	1.405	0.0197	0.0763	0.00306	24.44	–110
–100	2.388	93.66	18.511	–15.427	93.430	–0.03959	0.26307	0.2543	0.1288	1.2315	3287	499.7	1.290	0.0203	0.0747	0.00320	23.49	–100
–95	2.865	93.19	15.623	–14.154	94.018	–0.03608	0.26055	0.2546	0.1300	1.2310	3245	502.4	1.238	0.0206	0.0739	0.00327	23.02	–95
–90	3.417	92.71	13.258	–12.880	94.605	–0.03261	0.25815	0.2549	0.1312	1.2307	3202	504.9	1.189	0.0208	0.0731	0.00334	22.55	–90
–85	4.053	92.24	11.309	–11.604	95.191	–0.02918	0.25585	0.2552	0.1324	1.2305	3160	507.4	1.144	0.0211	0.0723	0.00341	22.08	–85
–80	4.782	91.76	9.6939	–10.326	95.775	–0.02580	0.25366	0.2556	0.1337	1.2304	3118	509.8	1.101	0.0214	0.0715	0.00348	21.61	–80
–75	5.615	91.28	8.3487	–9.046	96.357	–0.02245	0.25155	0.2561	0.1350	1.2305	3075	512.2	1.060	0.0217	0.0708	0.00355	21.15	–75
–70	6.561	90.79	7.2222	–7.763	96.937	–0.01915	0.24954	0.2566	0.1363	1.2308	3033	514.4	1.021	0.0220	0.0700	0.00363	20.68	–70
–65	7.631	90.31	6.2744	–6.477	97.514	–0.01587	0.24761	0.2571	0.1377	1.2313	2990	516.5	0.985	0.0223	0.0692	0.00370	20.22	–65
–60	8.836	89.82	5.4730	–5.189	98.087	–0.01264	0.24577	0.2577	0.1392	1.2320	2948	518.6	0.951	0.0225	0.0684	0.00378	19.76	–60
–55	10.190	89.33	4.7924	–3.897	98.657	–0.00943	0.24400	0.2583	0.1406	1.2328	2906	520.5	0.918	0.0228	0.0677	0.00386	19.30	–55
–50	11.703	88.83	4.2119	–2.602	99.224	–0.00626	0.24230	0.2591	0.1422	1.2339	2863	522.4	0.887	0.0231	0.0669	0.00394	18.85	–50
–45	13.390	88.33	3.7147	–1.303	99.786	–0.00311	0.24067	0.2598	0.1438	1.2352	2821	524.1	0.857	0.0234	0.0661	0.00402	18.40	–45
–41.46[b]	14.696	87.97	3.4054	–0.381	100.181	–0.00091	0.23955	0.2604	0.1449	1.2362	2791	525.3	0.837	0.0236	0.0656	0.00407	18.08	–41.46
–40	15.262	87.82	3.2872	0.000	100.343	0.00000	0.23910	0.2606	0.1454	1.2367	2778	525.8	0.829	0.0237	0.0654	0.00410	17.94	–40
–35	17.336	87.32	2.9181	1.308	100.896	0.00309	0.23759	0.2615	0.1471	1.2384	2736	527.3	0.802	0.0240	0.0646	0.00418	17.49	–35
–30	19.624	86.80	2.5984	2.620	101.443	0.00615	0.23615	0.2625	0.1488	1.2404	2694	528.7	0.776	0.0242	0.0639	0.00426	17.05	–30
–25	22.142	86.29	2.3204	3.937	101.984	0.00918	0.23475	0.2635	0.1506	1.2426	2651	530.0	0.751	0.0245	0.0631	0.00435	16.60	–25
–20	24.906	85.76	2.0778	5.260	102.519	0.01220	0.23341	0.2645	0.1525	1.2451	2609	531.2	0.728	0.0248	0.0624	0.00444	16.16	–20
–15	27.929	85.24	1.8656	6.588	103.048	0.01519	0.23211	0.2656	0.1544	1.2479	2566	532.3	0.705	0.0251	0.0617	0.00452	15.72	–15
–10	31.230	84.71	1.6792	7.923	103.570	0.01815	0.23086	0.2668	0.1564	1.2510	2524	533.2	0.683	0.0254	0.0609	0.00461	15.28	–10
–5	34.824	84.17	1.5150	9.263	104.085	0.02110	0.22965	0.2681	0.1585	1.2544	2481	534.0	0.662	0.0257	0.0602	0.00471	14.85	–5
0	38.728	83.63	1.3701	10.610	104.591	0.02403	0.22848	0.2694	0.1607	1.2581	2438	534.7	0.642	0.0260	0.0595	0.00480	14.41	0
5	42.960	83.08	1.2417	11.964	105.090	0.02694	0.22735	0.2708	0.1629	1.2622	2396	535.3	0.622	0.0262	0.0587	0.00489	13.98	5
10	47.536	82.52	1.1276	13.325	105.580	0.02983	0.22625	0.2722	0.1652	1.2666	2353	535.7	0.603	0.0265	0.0580	0.00499	13.55	10
15	52.475	81.96	1.0261	14.694	106.061	0.03270	0.22519	0.2737	0.1676	1.2714	2310	536.0	0.585	0.0268	0.0573	0.00509	13.13	15
20	57.795	81.39	0.9354	16.070	106.532	0.03556	0.22415	0.2753	0.1702	1.2767	2268	536.1	0.568	0.0271	0.0566	0.00519	12.70	20
25	63.514	80.82	0.8543	17.455	106.994	0.03841	0.22315	0.2770	0.1728	1.2824	2225	536.1	0.551	0.0274	0.0558	0.00530	12.28	25
30	69.651	80.24	0.7815	18.848	107.445	0.04124	0.22217	0.2787	0.1755	1.2886	2182	535.9	0.534	0.0277	0.0551	0.00540	11.86	30
35	76.225	79.65	0.7161	20.250	107.884	0.04406	0.22121	0.2806	0.1783	1.2953	2139	535.6	0.518	0.0280	0.0544	0.00551	11.45	35
40	83.255	79.05	0.6572	21.662	108.313	0.04686	0.22028	0.2825	0.1813	1.3026	2096	535.1	0.503	0.0283	0.0537	0.00562	11.04	40
45	90.761	78.44	0.6040	23.083	108.729	0.04966	0.21936	0.2845	0.1844	1.3105	2053	534.4	0.488	0.0286	0.0530	0.00574	10.63	45
50	98.763	77.83	0.5558	24.514	109.132	0.05244	0.21847	0.2866	0.1877	1.3191	2010	533.6	0.473	0.0289	0.0522	0.00586	10.22	50
55	107.28	77.20	0.5122	25.956	109.521	0.05522	0.21758	0.2889	0.1911	1.3284	1967	532.6	0.459	0.0292	0.0515	0.00598	9.82	55
60	116.33	76.57	0.4725	27.409	109.897	0.05798	0.21672	0.2913	0.1947	1.3385	1924	531.5	0.445	0.0296	0.0508	0.00611	9.41	60
65	125.94	75.92	0.4364	28.874	110.257	0.06074	0.21586	0.2938	0.1985	1.3495	1880	530.1	0.432	0.0299	0.0501	0.00625	9.02	65
70	136.13	75.27	0.4035	30.350	110.602	0.06350	0.21501	0.2964	0.2025	1.3615	1836	528.6	0.419	0.0302	0.0494	0.00638	8.62	70
75	146.92	74.60	0.3734	31.839	110.929	0.06625	0.21417	0.2992	0.2067	1.3746	1793	526.9	0.406	0.0305	0.0487	0.00653	8.23	75
80	158.33	73.92	0.3459	33.342	111.239	0.06899	0.21333	0.3022	0.2112	1.3889	1749	525.0	0.394	0.0309	0.0479	0.00668	7.84	80
85	170.38	73.23	0.3207	34.859	111.530	0.07173	0.21250	0.3054	0.2160	1.4046	1705	522.9	0.381	0.0312	0.0472	0.00684	7.46	85
90	183.09	72.52	0.2975	36.391	111.801	0.07447	0.21166	0.3089	0.2212	1.4218	1660	520.6	0.369	0.0316	0.0465	0.00701	7.08	90
95	196.50	71.80	0.2762	37.938	112.050	0.07721	0.21083	0.3126	0.2267	1.4407	1615	518.1	0.358	0.0320	0.0458	0.00718	6.70	95
100	210.61	71.06	0.2566	39.502	112.276	0.07996	0.20998	0.3166	0.2327	1.4616	1570	515.4	0.346	0.0324	0.0450	0.00737	6.33	100
105	225.46	70.30	0.2385	41.084	112.478	0.08270	0.20913	0.3209	0.2391	1.4849	1525	512.4	0.335	0.0328	0.0443	0.00757	5.96	105
110	241.06	69.52	0.2217	42.686	112.653	0.08545	0.20827	0.3257	0.2461	1.5107	1479	509.2	0.324	0.0332	0.0436	0.00778	5.60	110
115	257.45	68.72	0.2062	44.308	112.799	0.08821	0.20739	0.3309	0.2538	1.5396	1433	505.8	0.313	0.0336	0.0428	0.00801	5.24	115
120	274.65	67.90	0.1918	45.952	112.914	0.09098	0.20649	0.3367	0.2623	1.5722	1387	502.1	0.302	0.0341	0.0421	0.00825	4.88	120
125	292.69	67.05	0.1785	47.621	112.996	0.09376	0.20557	0.3431	0.2717	1.6090	1340	498.1	0.292	0.0346	0.0413	0.00851	4.53	125
130	311.58	66.18	0.1660	49.316	113.040	0.09656	0.20462	0.3504	0.2822	1.6509	1292	493.9	0.281	0.0351	0.0406	0.00880	4.19	130
135	331.37	65.27	0.1544	51.041	113.043	0.09937	0.20364	0.3585	0.2941	1.6990	1244	489.4	0.271	0.0356	0.0399	0.00911	3.85	135
140	352.08	64.32	0.1435	52.798	113.000	0.10222	0.20261	0.3679	0.3076	1.7548	1195	484.6	0.260	0.0362	0.0391	0.00946	3.51	140
145	373.74	63.34	0.1334	54.591	112.907	0.10509	0.20153	0.3787	0.3233	1.8201	1146	479.5	0.250	0.0369	0.0383	0.00984	3.18	145
150	396.38	62.31	0.1238	56.425	112.756	0.10800	0.20040	0.3913	0.3416	1.8976	1095	474.1	0.240	0.0375	0.0376	0.01027	2.86	150
155	420.04	61.22	0.1149	58.305	112.539	0.11096	0.19919	0.4063	0.3633	1.9907	1044	468.4	0.230	0.0383	0.0368	0.01076	2.54	155
160	444.75	60.07	0.1064	60.240	112.247	0.11397	0.19790	0.4243	0.3897	2.1047	992	462.3	0.219	0.0391	0.0361	0.01131	2.24	160
165	470.56	58.84	0.0984	62.237	111.866	0.11705	0.19650	0.4467	0.4225	2.2474	939	455.8	0.209	0.0400	0.0353	0.01195	1.93	165
170	497.50	57.53	0.0907	64.309	111.378	0.12022	0.19497	0.4750	0.4643	2.4310	884	449.0	0.198	0.0410	0.0346	0.01270	1.64	170
175	525.62	56.10	0.0834	66.474	110.760	0.12350	0.19328	0.5124	0.5198	2.6759	828	441.7	0.188	0.0422	0.0340	0.01360	1.36	175
180	554.98	54.52	0.0764	68.757	109.976	0.12693	0.19136	0.5641	0.5972	3.0184	769	433.9	0.176	0.0436	0.0335	0.01470	1.09	180
185	585.63	52.74	0.0695	71.196	108.972	0.13056	0.18916	0.6410	0.7132	3.5317	706	425.6	0.165	0.0452	0.0332	0.01609	0.83	185
190	617.64	50.67	0.0626	73.859	107.654	0.13450	0.18651	0.7681	0.9067	4.3857	639	416.6	0.152	0.0474	0.0334	0.01793	0.58	190
195	651.12	48.14	0.0556	76.875	105.835	0.13893	0.18316	1.020	1.295	6.090	565	406.9	0.138	0.0502	0.0347	0.02061	0.35	195
200	686.20	44.68	0.0479	80.593	103.010	0.14437	0.17835	1.778	2.472	11.190	480	395.8	0.121	0.0547	0.0395	0.02574	0.15	200
205.06[c]	723.74	32.70	0.0306	91.208	91.208	0.16012	0.16012	∞	∞	∞	0	0.0	—	—	∞	∞	0.00	205.06

*Temperatures on ITS-90 scale [b]Normal boiling point [c]Critical point

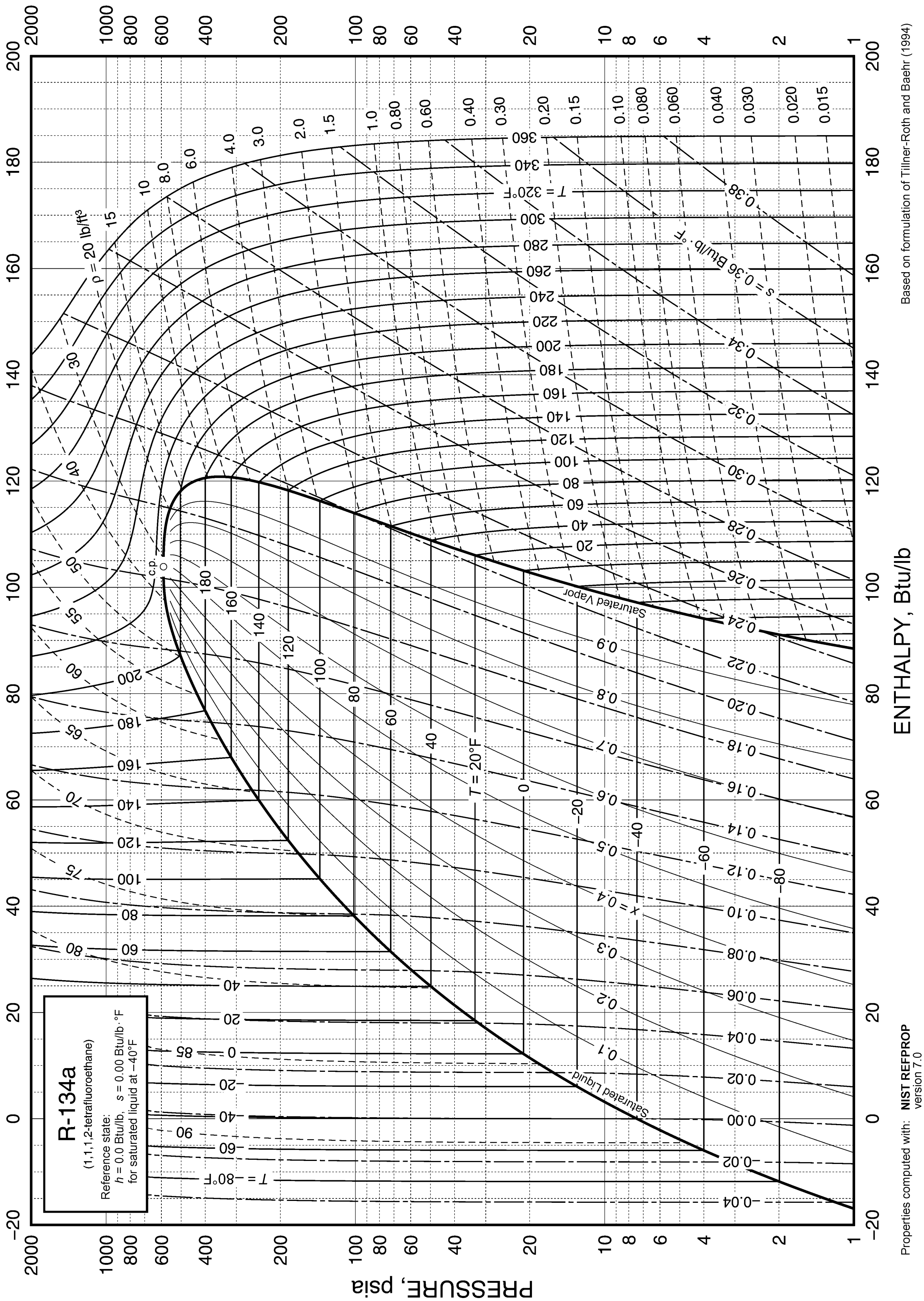


Fig. 8 Pressure-Enthalpy Diagram for Refrigerant 134a

Refrigerant 134a (1,1,1,2-Tetrafluoroethane) Properties of Saturated Liquid and Saturated Vapor

Temp.,* °F	Pressure, psia	Density, lb/ft³ Liquid	Volume, ft³/lb Vapor	Enthalpy, Btu/lb Liquid	Enthalpy, Btu/lb Vapor	Entropy, Btu/lb·°F Liquid	Entropy, Btu/lb·°F Vapor	Specific Heat c_p, Btu/lb·°F Liquid	Specific Heat c_p, Btu/lb·°F Vapor	c_p/c_v Vapor	Vel. of Sound, ft/s Liquid	Vel. of Sound, ft/s Vapor	Viscosity, lb_m/ft·h Liquid	Viscosity, lb_m/ft·h Vapor	Thermal Cond., Btu/h·ft·°F Liquid	Thermal Cond., Btu/h·ft·°F Vapor	Surface Tension, dyne/cm	Temp.,* °F
–153.94[a]	0.057	99.33	568.59	–32.992	80.362	–0.09154	0.27923	0.2829	0.1399	1.1637	3674	416.0	5.262	0.0156	0.0840	0.00178	28.07	–153.94
–150	0.072	98.97	452.12	–31.878	80.907	–0.08791	0.27629	0.2830	0.1411	1.1623	3638	418.3	4.790	0.0159	0.0832	0.00188	27.69	–150
–140	0.129	98.05	260.63	–29.046	82.304	–0.07891	0.26941	0.2834	0.1443	1.1589	3545	424.2	3.880	0.0164	0.0813	0.00214	26.74	–140
–130	0.221	97.13	156.50	–26.208	83.725	–0.07017	0.26329	0.2842	0.1475	1.1559	3452	429.9	3.238	0.0170	0.0794	0.00240	25.79	–130
–120	0.365	96.20	97.481	–23.360	85.168	–0.06166	0.25784	0.2853	0.1508	1.1532	3360	435.5	2.762	0.0176	0.0775	0.00265	24.85	–120
–110	0.583	95.27	62.763	–20.500	86.629	–0.05337	0.25300	0.2866	0.1540	1.1509	3269	440.8	2.396	0.0182	0.0757	0.00291	23.92	–110
–100	0.903	94.33	41.637	–17.626	88.107	–0.04527	0.24871	0.2881	0.1573	1.1490	3178	446.0	2.105	0.0187	0.0739	0.00317	22.99	–100
–90	1.359	93.38	28.381	–14.736	89.599	–0.03734	0.24490	0.2898	0.1607	1.1475	3087	450.9	1.869	0.0193	0.0722	0.00343	22.07	–90
–80	1.993	92.42	19.825	–11.829	91.103	–0.02959	0.24152	0.2916	0.1641	1.1465	2998	455.6	1.673	0.0199	0.0705	0.00369	21.16	–80
–75	2.392	91.94	16.711	–10.368	91.858	–0.02577	0.23998	0.2925	0.1658	1.1462	2954	457.8	1.587	0.0201	0.0696	0.00382	20.71	–75
–70	2.854	91.46	14.161	–8.903	92.614	–0.02198	0.23854	0.2935	0.1676	1.1460	2909	460.0	1.509	0.0204	0.0688	0.00395	20.26	–70
–65	3.389	90.97	12.060	–7.432	93.372	–0.01824	0.23718	0.2945	0.1694	1.1459	2866	462.1	1.436	0.0207	0.0680	0.00408	19.81	–65
–60	4.002	90.49	10.321	–5.957	94.131	–0.01452	0.23590	0.2955	0.1713	1.1460	2822	464.1	1.369	0.0210	0.0671	0.00420	19.36	–60
–55	4.703	90.00	8.8733	–4.476	94.890	–0.01085	0.23470	0.2965	0.1731	1.1462	2778	466.0	1.306	0.0212	0.0663	0.00433	18.92	–55
–50	5.501	89.50	7.6621	–2.989	95.650	–0.00720	0.23358	0.2976	0.1751	1.1466	2735	467.8	1.248	0.0215	0.0655	0.00446	18.47	–50
–45	6.406	89.00	6.6438	–1.498	96.409	–0.00358	0.23252	0.2987	0.1770	1.1471	2691	469.6	1.193	0.0218	0.0647	0.00460	18.03	–45
–40	7.427	88.50	5.7839	0.000	97.167	0.00000	0.23153	0.2999	0.1790	1.1478	2648	471.2	1.142	0.0221	0.0639	0.00473	17.60	–40
–35	8.576	88.00	5.0544	1.503	97.924	0.00356	0.23060	0.3010	0.1811	1.1486	2605	472.8	1.095	0.0223	0.0632	0.00486	17.16	–35
–30	9.862	87.49	4.4330	3.013	98.679	0.00708	0.22973	0.3022	0.1832	1.1496	2563	474.2	1.050	0.0226	0.0624	0.00499	16.73	–30
–25	11.299	86.98	3.9014	4.529	99.433	0.01058	0.22892	0.3035	0.1853	1.1508	2520	475.6	1.007	0.0229	0.0616	0.00512	16.30	–25
–20	12.898	86.47	3.4449	6.051	100.184	0.01406	0.22816	0.3047	0.1875	1.1521	2477	476.8	0.968	0.0231	0.0608	0.00525	15.87	–20
–15	14.671	85.95	3.0514	7.580	100.932	0.01751	0.22744	0.3060	0.1898	1.1537	2435	477.9	0.930	0.0234	0.0601	0.00538	15.44	–15
–14.93[b]	14.696	85.94	3.0465	7.600	100.942	0.01755	0.22743	0.3061	0.1898	1.1537	2434	477.9	0.929	0.0234	0.0601	0.00538	15.44	–14.93
–10	16.632	85.43	2.7109	9.115	101.677	0.02093	0.22678	0.3074	0.1921	1.1554	2393	478.9	0.894	0.0237	0.0593	0.00552	15.02	–10
–5	18.794	84.90	2.4154	10.657	102.419	0.02433	0.22615	0.3088	0.1945	1.1573	2350	479.8	0.860	0.0240	0.0586	0.00565	14.60	–5
0	21.171	84.37	2.1579	12.207	103.156	0.02771	0.22557	0.3102	0.1969	1.1595	2308	480.5	0.828	0.0242	0.0578	0.00578	14.18	0
5	23.777	83.83	1.9330	13.764	103.889	0.03107	0.22502	0.3117	0.1995	1.1619	2266	481.1	0.798	0.0245	0.0571	0.00592	13.76	5
10	26.628	83.29	1.7357	15.328	104.617	0.03440	0.22451	0.3132	0.2021	1.1645	2224	481.6	0.769	0.0248	0.0564	0.00605	13.35	10
15	29.739	82.74	1.5623	16.901	105.339	0.03772	0.22403	0.3147	0.2047	1.1674	2182	482.0	0.741	0.0250	0.0556	0.00619	12.94	15
20	33.124	82.19	1.4094	18.481	106.056	0.04101	0.22359	0.3164	0.2075	1.1705	2140	482.2	0.715	0.0253	0.0549	0.00632	12.53	20
25	36.800	81.63	1.2742	20.070	106.767	0.04429	0.22317	0.3181	0.2103	1.1740	2098	482.2	0.689	0.0256	0.0542	0.00646	12.12	25
30	40.784	81.06	1.1543	21.667	107.471	0.04755	0.22278	0.3198	0.2132	1.1777	2056	482.2	0.665	0.0258	0.0535	0.00660	11.72	30
35	45.092	80.49	1.0478	23.274	108.167	0.05079	0.22241	0.3216	0.2163	1.1818	2014	481.9	0.642	0.0261	0.0528	0.00674	11.32	35
40	49.741	79.90	0.9528	24.890	108.856	0.05402	0.22207	0.3235	0.2194	1.1862	1973	481.5	0.620	0.0264	0.0521	0.00688	10.92	40
45	54.749	79.32	0.8680	26.515	109.537	0.05724	0.22174	0.3255	0.2226	1.1910	1931	481.0	0.598	0.0267	0.0514	0.00703	10.53	45
50	60.134	78.72	0.7920	28.150	110.209	0.06044	0.22144	0.3275	0.2260	1.1961	1889	480.3	0.578	0.0270	0.0507	0.00717	10.14	50
55	65.913	78.11	0.7238	29.796	110.871	0.06362	0.22115	0.3297	0.2294	1.2018	1847	479.4	0.558	0.0273	0.0500	0.00732	9.75	55
60	72.105	77.50	0.6625	31.452	111.524	0.06680	0.22088	0.3319	0.2331	1.2079	1805	478.3	0.539	0.0275	0.0493	0.00747	9.36	60
65	78.729	76.87	0.6072	33.120	112.165	0.06996	0.22062	0.3343	0.2368	1.2145	1763	477.0	0.520	0.0278	0.0486	0.00762	8.98	65
70	85.805	76.24	0.5572	34.799	112.796	0.07311	0.22037	0.3368	0.2408	1.2217	1721	475.6	0.503	0.0281	0.0479	0.00777	8.60	70
75	93.351	75.59	0.5120	36.491	113.414	0.07626	0.22013	0.3394	0.2449	1.2296	1679	474.0	0.485	0.0284	0.0472	0.00793	8.23	75
80	101.39	74.94	0.4710	38.195	114.019	0.07939	0.21989	0.3422	0.2492	1.2382	1636	472.2	0.469	0.0287	0.0465	0.00809	7.86	80
85	109.93	74.27	0.4338	39.913	114.610	0.08252	0.21966	0.3451	0.2537	1.2475	1594	470.1	0.453	0.0291	0.0458	0.00825	7.49	85
90	119.01	73.58	0.3999	41.645	115.186	0.08565	0.21944	0.3482	0.2585	1.2578	1551	467.9	0.437	0.0294	0.0451	0.00842	7.13	90
95	128.65	72.88	0.3690	43.392	115.746	0.08877	0.21921	0.3515	0.2636	1.2690	1509	465.4	0.422	0.0297	0.0444	0.00860	6.77	95
100	138.85	72.17	0.3407	45.155	116.289	0.09188	0.21898	0.3551	0.2690	1.2813	1466	462.7	0.407	0.0301	0.0437	0.00878	6.41	100
105	149.65	71.44	0.3148	46.934	116.813	0.09500	0.21875	0.3589	0.2747	1.2950	1423	459.8	0.393	0.0304	0.0431	0.00897	6.06	105
110	161.07	70.69	0.2911	48.731	117.317	0.09811	0.21851	0.3630	0.2809	1.3101	1380	456.7	0.378	0.0308	0.0424	0.00916	5.71	110
115	173.14	69.93	0.2693	50.546	117.799	0.10123	0.21826	0.3675	0.2875	1.3268	1337	453.2	0.365	0.0312	0.0417	0.00936	5.36	115
120	185.86	69.14	0.2493	52.382	118.258	0.10435	0.21800	0.3723	0.2948	1.3456	1294	449.6	0.351	0.0316	0.0410	0.00958	5.03	120
125	199.28	68.32	0.2308	54.239	118.690	0.10748	0.21772	0.3775	0.3026	1.3666	1250	445.6	0.338	0.0320	0.0403	0.00981	4.69	125
130	213.41	67.49	0.2137	56.119	119.095	0.11062	0.21742	0.3833	0.3112	1.3903	1206	441.4	0.325	0.0324	0.0396	0.01005	4.36	130
135	228.28	66.62	0.1980	58.023	119.468	0.11376	0.21709	0.3897	0.3208	1.4173	1162	436.8	0.313	0.0329	0.0389	0.01031	4.04	135
140	243.92	65.73	0.1833	59.954	119.807	0.11692	0.21673	0.3968	0.3315	1.4481	1117	432.0	0.301	0.0334	0.0382	0.01058	3.72	140
145	260.36	64.80	0.1697	61.915	120.108	0.12010	0.21634	0.4048	0.3435	1.4837	1072	426.8	0.288	0.0339	0.0375	0.01089	3.40	145
150	277.61	63.83	0.1571	63.908	120.366	0.12330	0.21591	0.4138	0.3571	1.5250	1027	421.2	0.276	0.0344	0.0368	0.01122	3.09	150
155	295.73	62.82	0.1453	65.936	120.576	0.12653	0.21542	0.4242	0.3729	1.5738	980	415.3	0.264	0.0350	0.0361	0.01158	2.79	155
160	314.73	61.76	0.1343	68.005	120.731	0.12979	0.21488	0.4362	0.3914	1.6318	934	409.1	0.253	0.0357	0.0354	0.01199	2.50	160
165	334.65	60.65	0.1239	70.118	120.823	0.13309	0.21426	0.4504	0.4133	1.7022	886	402.4	0.241	0.0364	0.0346	0.01245	2.21	165
170	355.53	59.47	0.1142	72.283	120.842	0.13644	0.21356	0.4675	0.4400	1.7889	837	395.3	0.229	0.0372	0.0339	0.01297	1.93	170
175	377.41	58.21	0.1051	74.509	120.773	0.13985	0.21274	0.4887	0.4733	1.8984	786	387.7	0.218	0.0381	0.0332	0.01358	1.66	175
180	400.34	56.86	0.0964	76.807	120.598	0.14334	0.21180	0.5156	0.5159	2.0405	734	379.6	0.206	0.0391	0.0325	0.01430	1.39	180
185	424.36	55.38	0.0881	79.193	120.294	0.14693	0.21069	0.5512	0.5729	2.2321	680	371.0	0.194	0.0403	0.0318	0.01516	1.14	185
190	449.52	53.76	0.0801	81.692	119.822	0.15066	0.20935	0.6012	0.6532	2.5041	624	361.8	0.182	0.0417	0.0311	0.01623	0.90	190
195	475.91	51.91	0.0724	84.343	119.123	0.15459	0.20771	0.6768	0.7751	2.9192	565	352.0	0.169	0.0435	0.0304	0.01760	0.67	195
200	503.59	49.76	0.0647	87.214	118.097	0.15880	0.20562	0.8062	0.9835	3.6309	502	341.3	0.155	0.0457	0.0300	0.01949	0.45	200
205	532.68	47.08	0.0567	90.454	116.526	0.16353	0.20275	1.0830	1.4250	5.1360	436	329.4	0.140	0.0489	0.0300	0.02240	0.26	205
210	563.35	43.20	0.0477	94.530	113.746	0.16945	0.19814	2.1130	3.0080	10.5120	363	315.5	0.120	0.0543	0.0316	0.02848	0.09	210
213.91[c]	588.75	31.96	0.0313	103.894	103.894	0.18320	0.18320	∞	∞	∞	0	0.0	—	—	∞	∞	0.00	213.91

*Temperatures on ITS-90 scale [a]Triple point [b]Normal boiling point [c]Critical point

Refrigerant 134a Properties of Superheated Vapor

Pressure = 14.696 psia
Saturation temperature = –14.92°F

Temp.,* °F	Density, lb/ft³	Enthalpy, Btu/lb	Entropy, Btu/lb·°F	Vel. Sound, ft/s
Saturated				
Liquid	85.7972	7.53	0.01739	2451.2
Vapor	0.3283	100.81	0.22713	478.0
0	0.3158	103.62	0.23335	487.2
20	0.3008	107.45	0.24149	499.0
40	0.2874	111.34	0.24944	510.2
60	0.2753	115.31	0.25723	521.0
80	0.2642	119.35	0.26486	531.5
100	0.2541	123.47	0.27236	541.6
120	0.2448	127.68	0.27974	551.4
140	0.2362	131.96	0.28700	561.0
160	0.2282	136.32	0.29416	570.4
180	0.2208	140.77	0.30122	579.5
200	0.2139	145.30	0.30819	588.5
220	0.2074	149.90	0.31507	597.3
240	0.2013	154.59	0.32187	606.0
260	0.1955	159.36	0.32858	614.5
280	0.1901	164.20	0.33522	622.8
300	0.1850	169.12	0.34178	631.1

Pressure = 25.00 psia
Saturation temperature = 7.22°F

Temp.,* °F	Density, lb/ft³	Enthalpy, Btu/lb	Entropy, Btu/lb·°F	Vel. Sound, ft/s
Saturated				
Liquid	83.4823	14.32	0.03224	2263.9
Vapor	0.5426	104.07	0.22446	481.5
20	0.5245	106.60	0.22982	489.9
40	0.4991	110.61	0.23800	502.4
60	0.4765	114.66	0.24596	514.1
80	0.4563	118.78	0.25373	525.4
100	0.4379	122.96	0.26135	536.2
120	0.4212	127.22	0.26881	546.6
140	0.4058	131.55	0.27615	556.7
160	0.3916	135.95	0.28337	566.5
180	0.3786	140.43	0.29048	576.0
200	0.3663	144.98	0.29750	585.3
220	0.3549	149.61	0.30441	594.4
240	0.3443	154.32	0.31124	603.3
260	0.3343	159.10	0.31798	612.0
280	0.3248	163.96	0.32464	620.6
300	0.3160	168.90	0.33122	629.0

Pressure = 50.00 psia
Saturation temperature = 40.29°F

Temp.,* °F	Density, lb/ft³	Enthalpy, Btu/lb	Entropy, Btu/lb·°F	Vel. Sound, ft/s
Saturated				
Liquid	79.8125	24.79	0.05377	1982.3
Vapor	1.0545	108.74	0.22170	481.7
60	0.9982	113.00	0.23005	496.2
80	0.9489	117.32	0.23822	509.8
100	0.9055	121.68	0.24614	522.5
120	0.8670	126.07	0.25385	534.5
140	0.8322	130.51	0.26139	545.8
160	0.8008	135.01	0.26877	556.7
180	0.7718	139.57	0.27601	567.2
200	0.7454	144.20	0.28313	577.4
220	0.7208	148.89	0.29014	587.2
240	0.6980	153.65	0.29704	596.8
260	0.6768	158.48	0.30385	606.1
280	0.6569	163.38	0.31056	615.2
300	0.6383	168.35	0.31719	624.1

Pressure = 75.00 psia
Saturation temperature = 62.24°F

Temp.,* °F	Density, lb/ft³	Enthalpy, Btu/lb	Entropy, Btu/lb·°F	Vel. Sound, ft/s
Saturated				
Liquid	77.1862	31.98	0.06775	1793.6
Vapor	1.5686	111.67	0.22042	478.1
80	1.4873	115.74	0.22809	492.7
100	1.4092	120.30	0.23639	507.7
120	1.3416	124.85	0.24439	521.6
140	1.2822	129.43	0.25215	534.5
160	1.2294	134.04	0.25971	546.6
180	1.1817	138.69	0.26710	558.2
200	1.1383	143.39	0.27434	569.2
220	1.0984	148.15	0.28145	579.8
240	1.0620	152.97	0.28843	590.1
260	1.0280	157.85	0.29531	600.0
280	0.9966	162.79	0.30208	609.7
300	0.9671	167.80	0.30876	619.0
320	0.9398	172.87	0.31535	628.2
340	0.9138	178.01	0.32186	637.1
360	0.8895	183.21	0.32828	645.9
380	0.8665	188.48	0.33463	654.5
400	0.8448	193.82	0.34091	662.9

Pressure = 100.00 psia
Saturation temperature = 79.17°F

Temp.,* °F	Density, lb/ft³	Enthalpy, Btu/lb	Entropy, Btu/lb·°F	Vel. Sound, ft/s
Saturated				
Liquid	75.0245	37.69	0.07840	1646.8
Vapor	2.0917	113.78	0.21960	472.8
80	2.0858	113.98	0.21998	473.6
100	1.9576	118.80	0.22874	491.6
120	1.8509	123.55	0.23709	507.8
140	1.7597	128.29	0.24512	522.4
160	1.6800	133.02	0.25288	536.0
180	1.6094	137.78	0.26044	548.8
200	1.5463	142.57	0.26781	560.8
220	1.4891	147.40	0.27502	572.3
240	1.4368	152.27	0.28210	583.3
260	1.3886	157.21	0.28905	593.9
280	1.3444	162.19	0.29588	604.1
300	1.3031	167.24	0.30261	614.0
320	1.2647	172.35	0.30925	623.6
340	1.2287	177.52	0.31579	632.9
360	1.1950	182.75	0.32225	642.1
380	1.1633	188.04	0.32863	651.0
400	1.1334	193.39	0.33494	659.8

Pressure = 125.00 psia
Saturation temperature = 93.15°F

Temp.,* °F	Density, lb/ft³	Enthalpy, Btu/lb	Entropy, Btu/lb·°F	Vel. Sound, ft/s
Saturated				
Liquid	73.1279	42.53	0.08715	1524.7
Vapor	2.6279	115.41	0.21898	466.7
100	2.5638	117.16	0.22212	473.9
120	2.4025	122.16	0.23090	492.9
140	2.2694	127.08	0.23924	509.7
160	2.1561	131.96	0.24725	525.0
180	2.0577	136.83	0.25498	539.0
200	1.9710	141.71	0.26250	552.2
220	1.8935	146.62	0.26983	564.6
240	1.8233	151.56	0.27700	576.4
260	1.7592	156.55	0.28402	587.6
280	1.7006	161.59	0.29093	598.4
300	1.6463	166.67	0.29771	608.8
320	1.5959	171.82	0.30440	618.9
340	1.5492	177.02	0.31098	628.7
360	1.5055	182.27	0.31747	638.2
380	1.4644	187.59	0.32388	647.5
400	1.4258	192.97	0.33021	656.6

Pressure = 150.00 psia
Saturation temperature = 105.17°F

Temp.,* °F	Density, lb/ft³	Enthalpy, Btu/lb	Entropy, Btu/lb·°F	Vel. Sound, ft/s
Saturated				
Liquid	71.4013	46.78	0.09464	1419.1
Vapor	3.1801	116.71	0.21844	460.0
120	3.0077	120.64	0.22530	476.6
140	2.8181	125.78	0.23403	496.0
160	2.6620	130.83	0.24231	513.3
180	2.5295	135.83	0.25026	528.9
200	2.4146	140.82	0.25794	543.3
220	2.3132	145.82	0.26539	556.7
240	2.2223	150.83	0.27267	569.3
260	2.1401	155.88	0.27978	581.3
280	2.0658	160.97	0.28675	592.7
300	1.9971	166.10	0.29360	603.7
320	1.9338	171.28	0.30033	614.2
340	1.8751	176.51	0.30696	624.5
360	1.8208	181.80	0.31349	634.4
380	1.7695	187.14	0.31993	644.0
400	1.7216	192.54	0.32628	653.4
420	1.6766	198.00	0.33256	662.6
440	1.6341	203.51	0.33876	671.6
460	1.5940	209.08	0.34488	680.4
480	1.5558	214.71	0.35094	689.0
500	1.5197	220.40	0.35692	697.4

Pressure = 175.00 psia
Saturation temperature = 115.76°F

Temp.,* °F	Density, lb/ft³	Enthalpy, Btu/lb	Entropy, Btu/lb·°F	Vel. Sound, ft/s
Saturated				
Liquid	69.7902	50.62	0.10126	1325.3
Vapor	3.7511	117.76	0.21794	453.0
120	3.6836	118.95	0.21999	458.4
140	3.4148	124.38	0.22921	481.3
160	3.2025	129.64	0.23783	500.9
180	3.0271	134.79	0.24602	518.3
200	2.8785	139.90	0.25388	534.0
220	2.7494	144.99	0.26148	548.5
240	2.6349	150.08	0.26887	562.1
260	2.5328	155.19	0.27607	574.8
280	2.4403	160.34	0.28312	586.9
300	2.3558	165.51	0.29003	598.5
320	2.2785	170.73	0.29681	609.5
340	2.2071	176	0.30348	620.2
360	2.1411	181.32	0.31004	630.5
380	2.0795	186.69	0.31651	640.5
400	2.0216	192.11	0.32290	650.3
420	1.9675	197.59	0.32920	659.7
440	1.9164	203.12	0.33542	669.0
460	1.8683	208.71	0.34156	678.0
480	1.8228	214.36	0.34763	686.9
500	1.7797	220.05	0.35363	695.6

Pressure = 200.00 psia
Saturation temperature = 125.27°F

Temp.,* °F	Density, lb/ft³	Enthalpy, Btu/lb	Entropy, Btu/lb·°F	Vel. Sound, ft/s
Saturated				
Liquid	68.2602	54.14	0.10721	1240.5
Vapor	4.3437	118.61	0.21743	445.6
140	4.0726	122.86	0.22460	465.2
160	3.7850	128.36	0.23363	487.8
180	3.5561	133.70	0.24210	507.2
200	3.3656	138.94	0.25018	524.5
220	3.2036	144.14	0.25793	540.2
240	3.0623	149.31	0.26544	554.7
260	2.9371	154.50	0.27274	568.3
280	2.8247	159.69	0.27987	581.1
300	2.7234	164.92	0.28684	593.2
320	2.6305	170.18	0.29368	604.8
340	2.5455	175.49	0.30039	615.9
360	2.4668	180.83	0.30700	626.7
380	2.3934	186.23	0.31350	637.0
400	2.3254	191.68	0.31991	647.1
420	2.2614	197.18	0.32624	656.9
440	2.2017	202.73	0.33248	666.4
460	2.1453	208.34	0.33864	675.7
480	2.0920	214.00	0.34473	684.8
500	2.0417	219.71	0.35075	693.7

*Temperatures on ITS-90 scale

Refrigerant 134a Properties of Superheated Vapor (*Concluded*)

Pressure = 225.00 psia
Saturation temperature = 133.93 °F

Temp.,* °F	Density, lb/ft³	Enthalpy, Btu/lb	Entropy, Btu/lb·°F	Vel. Sound, ft/s
Saturated				
Liquid	66.7870	57.42	0.11266	1162.8
Vapor	4.9609	119.30	0.21690	438.1
140	4.8123	121.16	0.22002	447.3
160	4.4191	126.99	0.22959	473.6
180	4.1206	132.54	0.23840	495.5
200	3.8796	137.94	0.24671	514.6
220	3.6784	143.25	0.25465	531.6
240	3.5058	148.52	0.26229	547.2
260	3.3542	153.78	0.26970	561.6
280	3.2202	159.04	0.27691	575.1
300	3.0995	164.32	0.28395	587.9
320	2.9899	169.62	0.29084	600.0
340	2.8897	174.97	0.29761	611.7
360	2.7978	180.35	0.30425	622.8
380	2.7122	185.77	0.31079	633.6
400	2.6330	191.24	0.31723	644.0
420	2.5592	196.77	0.32358	654.0
440	2.4900	202.34	0.32984	663.9
460	2.4249	207.96	0.33603	673.4
480	2.3636	213.64	0.34213	682.8
500	2.3057	219.36	0.34816	691.9

Pressure = 250.00 psia
Saturation temperature = 141.89 °F

Temp.,* °F	Density, lb/ft³	Enthalpy, Btu/lb	Entropy, Btu/lb·°F	Vel. Sound, ft/s
Saturated				
Liquid	65.3526	60.50	0.11770	1090.7
Vapor	5.6060	119.84	0.21634	430.3
160	5.1189	125.49	0.22560	458.2
180	4.7275	131.31	0.23484	483.1
200	4.4239	136.89	0.24343	504.2
220	4.1756	142.34	0.25156	522.8
240	3.9664	147.71	0.25935	539.5
260	3.7854	153.05	0.26688	554.9
280	3.6265	158.37	0.27418	569.2
300	3.4847	163.71	0.28129	582.6
320	3.3571	169.06	0.28824	595.3
340	3.2408	174.44	0.29506	607.4
360	3.1342	179.85	0.30175	618.9
380	3.0359	185.31	0.30832	630.1
400	2.9451	190.81	0.31479	640.8
420	2.8604	196.35	0.32117	651.2
440	2.7813	201.94	0.32745	661.3
460	2.7072	207.58	0.33365	671.1
480	2.6374	213.27	0.33977	680.7
500	2.5717	219.02	0.34582	690.1

Pressure = 275.00 psia
Saturation temperature = 149.27 °F

Temp.,* °F	Density, lb/ft³	Enthalpy, Btu/lb	Entropy, Btu/lb·°F	Vel. Sound, ft/s
Saturated				
Liquid	63.9423	63.43	0.12241	1023.4
Vapor	6.2831	120.25	0.21572	422.3
160	5.9060	123.82	0.22155	441.2
180	5.3869	129.98	0.23133	469.9
200	5.0031	135.78	0.24026	493.4
220	4.6978	141.38	0.24862	513.7
240	4.4465	146.87	0.25658	531.7
260	4.2314	152.30	0.26423	548.0
280	4.0446	157.69	0.27162	563.1
300	3.8803	163.08	0.27881	577.2
320	3.7317	168.49	0.28583	590.5
340	3.5987	173.91	0.29270	603.1
360	3.4764	179.36	0.29943	615.1
380	3.3646	184.84	0.30604	626.6
400	3.2612	190.37	0.31254	637.7
420	3.1653	195.93	0.31894	648.4
440	3.0758	201.55	0.32525	658.8
460	2.9922	207.20	0.33147	668.9
480	2.9136	212.91	0.33761	678.7
500	2.8397	218.67	0.34368	688.3

Pressure = 300.00 psia
Saturation temperature = 156.16 °F

Temp.,* °F	Density, lb/ft³	Enthalpy, Btu/lb	Entropy, Btu/lb·°F	Vel. Sound, ft/s
Saturated				
Liquid	62.5436	66.23	0.12686	959.8
Vapor	6.9967	120.54	0.21505	414.2
160	6.8168	121.92	0.21730	422.0
180	6.1118	128.55	0.22782	455.8
200	5.6239	134.61	0.23715	482.1
220	5.2494	140.39	0.24578	504.3
240	4.9472	146.00	0.25393	523.7
260	4.6939	151.52	0.26171	541.1
280	4.4758	157.00	0.26921	557.0
300	4.2852	162.45	0.27649	571.8
320	4.1160	167.90	0.28357	585.7
340	3.9631	173.37	0.29049	598.8
360	3.8247	178.85	0.29727	611.2
380	3.6981	184.37	0.30392	623.1
400	3.5816	189.92	0.31045	634.6
420	3.4737	195.51	0.31688	645.6
440	3.3735	201.15	0.32321	656.3
460	3.2799	206.83	0.32945	666.6
480	3.1922	212.55	0.33561	676.7
500	3.1098	218.32	0.34169	686.5

Pressure = 325.00 psia
Saturation temperature = 162.62 °F

Temp.,* °F	Density, lb/ft³	Enthalpy, Btu/lb	Entropy, Btu/lb·°F	Vel. Sound, ft/s
Saturated				
Liquid	61.1446	68.92	0.13110	899.5
Vapor	7.7526	120.71	0.21431	405.9
180	6.9220	126.96	0.22423	440.3
200	6.2928	133.36	0.23408	470.2
220	5.8341	139.34	0.24301	494.5
240	5.4723	145.10	0.25136	515.5
260	5.1741	150.73	0.25930	534.0
280	4.9208	156.29	0.26692	550.9
300	4.7017	161.81	0.27428	566.4
320	4.5082	167.31	0.28144	580.9
340	4.3352	172.82	0.28841	594.5
360	4.1790	178.35	0.29524	607.4
380	4.0368	183.90	0.30193	619.7
400	3.9063	189.48	0.30849	631.5
420	3.7859	195.09	0.31495	642.8
440	3.6743	200.75	0.32131	653.8
460	3.5703	206.44	0.32757	664.4
480	3.4731	212.19	0.33375	674.7
500	3.3819	217.97	0.33984	684.7

Pressure = 350.00 psia
Saturation temperature = 168.71 °F

Temp.,* °F	Density, lb/ft³	Enthalpy, Btu/lb	Entropy, Btu/lb·°F	Vel. Sound, ft/s
Saturated				
Liquid	59.7334	71.54	0.13516	841.7
Vapor	8.5577	120.76	0.21349	397.5
180	7.8491	125.18	0.22046	423.2
200	7.0242	132.01	0.23098	457.6
220	6.4561	138.24	0.24029	484.4
240	6.0219	144.17	0.24888	507.1
260	5.6728	149.91	0.25698	526.9
280	5.3805	155.56	0.26472	544.7
300	5.1295	161.15	0.27218	561.0
320	4.9098	166.72	0.27941	576.1
340	4.7148	172.27	0.28644	590.2
360	4.5396	177.84	0.29332	603.6
380	4.3807	183.42	0.30005	616.3
400	4.2355	189.03	0.30665	628.4
420	4.1019	194.67	0.31313	640.1
440	3.9784	200.35	0.31952	651.4
460	3.8636	206.06	0.32580	662.2
480	3.7564	211.82	0.33199	672.8
500	3.6561	217.62	0.33811	683.0

Pressure = 375.00 psia
Saturation temperature = 174.46 °F

Temp.,* °F	Density, lb/ft³	Enthalpy, Btu/lb	Entropy, Btu/lb·°F	Vel. Sound, ft/s
Saturated				
Liquid	58.2974	74.09	0.13908	785.9
Vapor	9.4209	120.69	0.21256	389.0
180	8.9498	123.10	0.21634	403.8
200	7.8311	130.54	0.22781	444.1
220	7.1211	137.08	0.23758	474.0
240	6.6028	143.19	0.24644	498.5
260	6.1926	149.07	0.25473	519.6
280	5.8555	154.82	0.26260	538.4
300	5.5694	160.49	0.27016	555.5
320	5.3212	166.11	0.27747	571.3
340	5.1022	171.72	0.28457	586.0
360	4.9066	177.32	0.29149	599.8
380	4.7300	182.94	0.29826	612.9
400	4.5692	188.58	0.30490	625.4
420	4.4217	194.24	0.31141	637.4
440	4.2857	199.94	0.31782	648.9
460	4.1596	205.68	0.32413	660.1
480	4.0421	211.46	0.33034	670.8
500	3.9323	217.28	0.33647	681.3

Pressure = 400.00 psia
Saturation temperature = 197.93 °F

Temp.,* °F	Density, lb/ft³	Enthalpy, Btu/lb	Entropy, Btu/lb·°F	Vel. Sound, ft/s
Saturated				
Liquid	56.8213	76.60	0.14289	731.8
Vapor	10.3541	120.50	0.21152	380.4
180	10.3454	120.53	0.21158	380.6
200	8.7370	128.93	0.22451	429.5
220	7.8399	135.85	0.23484	463.0
240	7.2145	142.18	0.24403	489.7
260	6.7351	148.21	0.25252	512.3
280	6.3472	154.06	0.26055	532.1
300	6.0221	159.81	0.26821	550.0
320	5.7425	165.49	0.27560	566.5
340	5.4977	171.15	0.28277	581.7
360	5.2802	176.80	0.28975	596.0
380	5.0848	182.45	0.29656	609.5
400	4.9075	188.12	0.30323	622.4
420	4.7454	193.82	0.30978	634.7
440	4.5964	199.54	0.31621	646.5
460	4.4584	205.30	0.32254	657.9
480	4.3303	211.09	0.32878	669.0
500	4.2107	216.93	0.33492	679.6

Pressure = 600.00 psia
Saturation temperature = n/a (supercritical)

Temp.,* °F	Density, lb/ft³	Enthalpy, Btu/lb	Entropy, Btu/lb·°F	Vel. Sound, ft/s
Saturated				
Liquid				
Vapor				
220	19.6784	118.27	0.20421	340.3
240	14.2159	131.50	0.22343	409.1
260	12.2674	139.92	0.23530	449.7
280	11.0672	147.15	0.24522	480.8
300	10.2049	153.83	0.25413	506.7
320	9.5351	160.21	0.26241	529.2
340	8.9895	166.39	0.27024	549.2
360	8.5305	172.45	0.27774	567.5
380	8.1351	178.45	0.28496	584.4
400	7.7885	184.40	0.29197	600.1
420	7.4804	190.34	0.29879	615.0
440	7.2035	196.26	0.30546	629.0
460	6.9523	202.20	0.31198	642.4
480	6.7229	208.15	0.31838	655.3
500	6.5118	214.12	0.32467	667.6

*Temperatures on ITS-90 scale

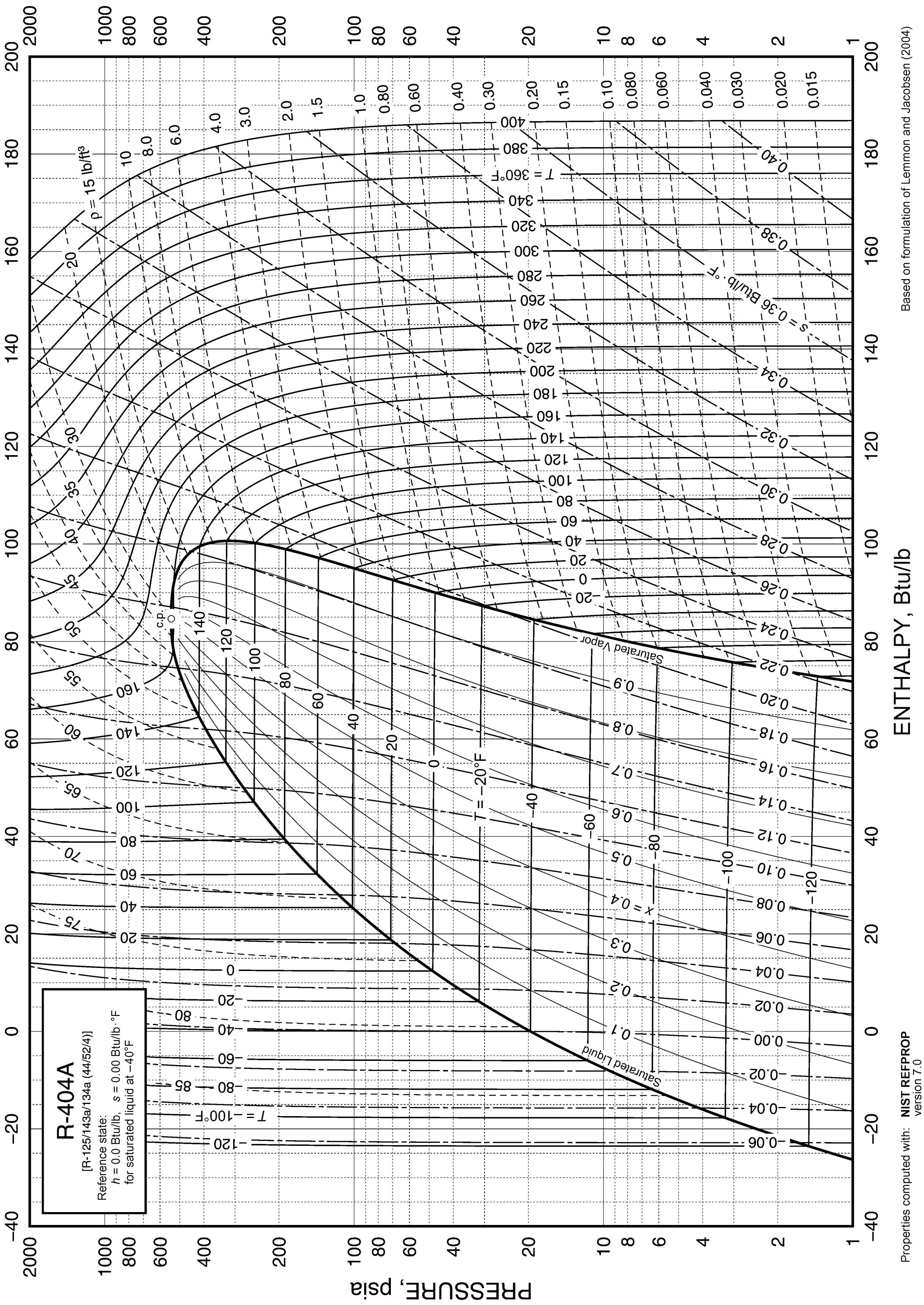


Fig. 14 Pressure-Enthalpy Diagram for Refrigerant 404A

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Refrigerant 404A [R-125/143a/134a (44/52/4)] Properties of Liquid on Bubble Line and Vapor on Dew Line

Pres-sure, psia	Temp.,* °F Bubble	Temp.,* °F Dew	Density, lb/ft³ Liquid	Volume, ft³/lb Vapor	Enthalpy, Btu/lb Liquid	Enthalpy, Btu/lb Vapor	Entropy, Btu/lb·°F Liquid	Entropy, Btu/lb·°F Vapor	Specific Heat c_p, Btu/lb·°F Liquid	Specific Heat c_p, Btu/lb·°F Vapor	c_p/c_v Vapor	Vel. of Sound, ft/s Liquid	Vel. of Sound, ft/s Vapor	Viscosity, lb_m/ft·h Liquid	Viscosity, lb_m/ft·h Vapor	Thermal Cond., Btu/h·ft·°F Liquid	Thermal Cond., Btu/h·ft·°F Vapor	Surface Tension, dyne/cm	Pres-sure, psia
1	–129.56	–127.50	89.61	36.2311	–26.33	71.76	–0.07039	0.22616	0.2907	0.1554	1.161	3173	439.8	1.695	0.0181	0.0695	0.00369	17.42	1
1.5	–120.05	–118.11	88.64	24.7754	–23.56	73.11	–0.06215	0.22201	0.2901	0.1589	1.160	3050	444.6	1.518	0.0186	0.0678	0.00388	16.92	1.5
2	–112.90	–111.03	87.92	18.9245	–21.49	74.14	–0.05611	0.21920	0.2900	0.1615	1.159	2964	448.1	1.403	0.0190	0.0666	0.00403	16.53	2
2.5	–107.10	–105.29	87.33	15.3578	–19.81	74.98	–0.05129	0.21710	0.2902	0.1637	1.159	2898	450.7	1.320	0.0193	0.0657	0.00414	16.22	2.5
3	–102.18	–100.42	86.83	12.9493	–18.38	75.69	–0.04727	0.21544	0.2905	0.1656	1.159	2845	452.9	1.255	0.0195	0.0647	0.00425	15.94	3
4	–94.08	–92.40	86.01	9.8941	–16.02	76.86	–0.04076	0.21292	0.2912	0.1688	1.159	2760	456.3	1.159	0.0199	0.0634	0.00442	15.49	4
5	–87.49	–85.87	85.33	8.0300	–14.10	77.82	–0.03555	0.21106	0.2920	0.1715	1.159	2694	458.9	1.088	0.0203	0.0623	0.00456	15.11	5
6	–81.89	–80.32	84.76	6.7705	–12.46	78.64	–0.03119	0.20960	0.2929	0.1738	1.159	2639	461.0	1.033	0.0205	0.0614	0.00468	14.79	6
7	–77.00	–75.46	84.25	5.8607	–11.02	79.35	–0.02742	0.20841	0.2937	0.1758	1.160	2592	462.7	0.989	0.0208	0.0606	0.00478	14.50	7
8	–72.64	–71.14	83.80	5.1716	–9.74	79.98	–0.02409	0.20741	0.2944	0.1777	1.161	2551	464.1	0.952	0.0210	0.0599	0.00488	14.25	8
10	–65.08	–63.64	83.01	4.1954	–7.51	81.07	–0.01839	0.20581	0.2959	0.1811	1.162	2481	466.4	0.892	0.0214	0.0587	0.00505	13.79	10
12	–58.65	–57.25	82.34	3.5353	–5.60	82.00	–0.0136	0.20457	0.2974	0.1840	1.164	2422	468.1	0.845	0.0217	0.0577	0.00519	13.41	12
14	–53.01	–51.65	81.74	3.0582	–3.91	82.81	–0.00944	0.20357	0.2987	0.1866	1.166	2372	469.4	0.806	0.0220	0.0568	0.00532	13.06	14
14.7[b]	–51.20	–49.85	81.55	2.9217	–3.37	83.07	–0.00812	0.20326	0.2991	0.1875	1.166	2355	469.8	0.795	0.0221	0.0566	0.00536	12.95	14.7
16	–47.98	–46.65	81.20	2.6968	–2.41	83.53	–0.00577	0.20273	0.3000	0.1891	1.167	2327	470.4	0.774	0.0222	0.0561	0.00544	12.75	16
18	–43.42	–42.11	80.71	2.4132	–1.03	84.18	–0.00246	0.20203	0.3012	0.1913	1.169	2286	471.2	0.747	0.0225	0.0554	0.00554	12.47	18
20	–39.24	–37.96	80.26	2.1845	0.23	84.78	0.00055	0.20141	0.3024	0.1935	1.171	2249	471.9	0.723	0.0227	0.0548	0.00564	12.20	20
22	–35.37	–34.11	79.83	1.9960	1.40	85.32	0.00332	0.20088	0.3035	0.1955	1.173	2215	472.4	0.701	0.0229	0.0542	0.00573	11.96	22
24	–31.77	–30.53	79.44	1.8379	2.50	85.83	0.00588	0.20041	0.3046	0.1974	1.175	2184	472.8	0.682	0.0230	0.0537	0.00582	11.73	24
26	–28.39	–27.17	79.06	1.7033	3.53	86.30	0.00827	0.19998	0.3056	0.1992	1.176	2154	473.1	0.665	0.0232	0.0532	0.00590	11.52	26
28	–25.21	–24.01	78.71	1.5873	4.51	86.75	0.01051	0.19960	0.3067	0.2010	1.178	2127	473.3	0.649	0.0234	0.0527	0.00598	11.31	28
30	–22.20	–21.02	78.37	1.4863	5.44	87.16	0.01263	0.19925	0.3077	0.2027	1.180	2101	473.5	0.634	0.0235	0.0523	0.00605	11.12	30
32	–19.34	–18.17	78.05	1.3974	6.32	87.56	0.01463	0.19894	0.3086	0.2043	1.182	2076	473.6	0.621	0.0237	0.0519	0.00612	10.94	32
34	–16.62	–15.46	77.74	1.3187	7.16	87.93	0.01653	0.19864	0.3096	0.2059	1.184	2052	473.6	0.608	0.0238	0.0515	0.00619	10.76	34
36	–14.01	–12.87	77.44	1.2484	7.97	88.29	0.01834	0.19838	0.3105	0.2074	1.186	2030	473.6	0.597	0.0239	0.0511	0.00625	10.59	36
38	–11.52	–10.39	77.15	1.1852	8.75	88.62	0.02007	0.19813	0.3115	0.2089	1.188	2008	473.5	0.586	0.0241	0.0507	0.00632	10.43	38
40	–9.12	–8.01	76.87	1.1281	9.50	88.95	0.02172	0.19790	0.3124	0.2104	1.190	1987	473.4	0.576	0.0242	0.0504	0.00638	10.27	40
42	–6.81	–5.71	76.60	1.0763	10.22	89.26	0.02331	0.19768	0.3133	0.2119	1.192	1967	473.3	0.566	0.0243	0.0501	0.00644	10.12	42
44	–4.59	–3.50	76.34	1.0290	10.92	89.56	0.02484	0.19748	0.3141	0.2133	1.194	1948	473.1	0.557	0.0244	0.0497	0.00649	9.97	44
46	–2.44	–1.36	76.09	0.9857	11.60	89.84	0.02632	0.19729	0.3150	0.2146	1.196	1930	472.9	0.548	0.0245	0.0494	0.00655	9.83	46
48	–0.36	0.71	75.84	0.9459	12.25	90.12	0.02774	0.19711	0.3158	0.2160	1.198	1912	472.7	0.540	0.0246	0.0492	0.00660	9.70	48
50	1.65	2.71	75.60	0.9091	12.89	90.38	0.02911	0.19694	0.3167	0.2173	1.200	1894	472.5	0.532	0.0247	0.0489	0.00665	9.56	50
55	6.43	7.47	75.03	0.8285	14.41	91.01	0.03237	0.19655	0.3188	0.2206	1.205	1853	471.8	0.514	0.0250	0.0482	0.00678	9.25	55
60	10.89	11.90	74.48	0.7609	15.84	91.58	0.03539	0.19621	0.3208	0.2237	1.210	1814	471.0	0.498	0.0252	0.0476	0.00690	8.95	60
65	15.07	16.07	73.97	0.7033	17.19	92.11	0.03822	0.19590	0.3228	0.2267	1.215	1778	470.1	0.483	0.0254	0.0470	0.00701	8.67	65
70	19.02	20.00	73.47	0.6537	18.47	92.61	0.04088	0.19562	0.3247	0.2297	1.220	1744	469.2	0.470	0.0257	0.0465	0.00712	8.41	70
75	22.76	23.72	72.99	0.6104	19.69	93.07	0.04339	0.19537	0.3267	0.2325	1.226	1712	468.1	0.457	0.0259	0.0460	0.00723	8.16	75
80	26.32	27.27	72.54	0.5724	20.86	93.50	0.04578	0.19514	0.3286	0.2354	1.231	1681	467.0	0.446	0.0261	0.0455	0.00733	7.92	80
85	29.71	30.64	72.09	0.5387	21.98	93.91	0.04804	0.19492	0.3305	0.2382	1.236	1651	465.9	0.435	0.0263	0.0450	0.00742	7.70	85
90	32.96	33.88	71.67	0.5085	23.05	94.30	0.05021	0.19471	0.3324	0.2409	1.242	1623	464.7	0.425	0.0264	0.0446	0.00753	7.48	90
95	36.07	36.98	71.25	0.4815	24.09	94.66	0.05229	0.19452	0.3342	0.2436	1.248	1596	463.5	0.416	0.0266	0.0442	0.00763	7.27	95
100	39.07	39.96	70.84	0.4570	25.10	95.00	0.05428	0.19434	0.3361	0.2464	1.254	1569	462.2	0.407	0.0268	0.0438	0.00772	7.07	100
110	44.73	45.60	70.06	0.4145	27.01	95.64	0.05804	0.19400	0.3399	0.2518	1.266	1520	459.6	0.391	0.0271	0.0430	0.00792	6.69	110
120	50.02	50.86	69.32	0.3789	28.82	96.21	0.06155	0.19368	0.3437	0.2572	1.279	1473	456.8	0.376	0.0275	0.0423	0.00810	6.34	120
130	54.99	55.81	68.60	0.3485	30.53	96.73	0.06485	0.19338	0.3475	0.2626	1.292	1429	454.0	0.363	0.0278	0.0416	0.00829	6.01	130
140	59.68	60.48	67.90	0.3222	32.16	97.20	0.06795	0.19309	0.3514	0.2682	1.306	1387	451.1	0.351	0.0281	0.0410	0.00848	5.69	140
150	64.13	64.91	67.23	0.2994	33.73	97.62	0.07090	0.19281	0.3553	0.2739	1.321	1347	448.2	0.339	0.0284	0.0404	0.00866	5.4	150
160	68.36	69.13	66.57	0.2793	35.23	98.01	0.07371	0.19253	0.3594	0.2797	1.336	1309	445.2	0.329	0.0288	0.0399	0.00885	5.12	160
170	72.40	73.15	65.93	0.2614	36.68	98.37	0.07639	0.19226	0.3635	0.2857	1.353	1273	442.1	0.319	0.0291	0.0394	0.00904	4.85	170
180	76.26	76.99	65.30	0.2454	38.08	98.69	0.07896	0.19198	0.3678	0.2919	1.370	1238	439.0	0.310	0.0294	0.0388	0.00922	4.60	180
190	79.97	80.68	64.68	0.2311	39.44	98.98	0.08143	0.19170	0.3722	0.2984	1.388	1204	435.8	0.301	0.0297	0.0384	0.00941	4.36	190
200	83.53	84.23	64.07	0.2181	40.76	99.25	0.08381	0.19143	0.3767	0.3051	1.408	1171	432.6	0.293	0.0300	0.0379	0.00961	4.13	200
220	90.27	90.94	62.87	0.1955	43.29	99.70	0.08833	0.19085	0.3864	0.3194	1.450	1108	426.1	0.277	0.0307	0.0370	0.01000	3.70	220
240	96.57	97.21	61.70	0.1764	45.70	100.05	0.09259	0.19026	0.3969	0.3353	1.498	1048	419.4	0.263	0.0313	0.0362	0.01041	3.30	240
260	102.48	103.09	60.53	0.1601	48.02	100.32	0.09663	0.18962	0.4086	0.3530	1.553	991	412.6	0.250	0.0320	0.0354	0.01084	2.93	260
280	108.06	108.64	59.37	0.1460	50.25	100.51	0.10047	0.18895	0.4216	0.3730	1.616	936	405.7	0.238	0.0328	0.0347	0.01131	2.59	280
300	113.34	113.90	58.20	0.1336	52.42	100.61	0.10417	0.18823	0.4364	0.3959	1.690	884	398.7	0.227	0.0335	0.0340	0.01180	2.28	300
320	118.36	118.89	57.03	0.1226	54.54	100.64	0.10773	0.18745	0.4534	0.4226	1.778	832	391.5	0.216	0.0343	0.0333	0.01235	1.98	320
340	123.14	123.65	55.83	0.1127	56.61	100.58	0.11118	0.18660	0.4733	0.4543	1.883	783	384.2	0.206	0.0352	0.0326	0.01294	1.71	340
360	127.71	128.19	54.61	0.1038	58.65	100.43	0.11456	0.18566	0.4972	0.4927	2.013	734	376.8	0.196	0.0362	0.0320	0.01360	1.46	360
380	132.09	132.54	53.35	0.0956	60.67	100.20	0.11787	0.18464	0.5265	0.5404	2.174	685	369.2	0.187	0.0373	0.0315	0.01435	1.22	380
400	136.28	136.71	52.03	0.0881	62.68	99.85	0.12114	0.18349	0.5635	0.6014	2.383	638	361.5	0.177	0.0385	0.0309	0.01520	1.01	400
450	146.07	146.42	48.36	0.0713	67.80	98.42	0.12934	0.17987	0.7246	0.8714	3.313	519	341.6	0.154	0.0423	0.0298	0.01806	0.54	450
500	154.97	155.22	43.51	0.0556	73.49	95.51	0.13833	0.17416	1.2912	1.8068	6.526	396	320.1	0.128	0.0488	0.0299	0.02348	0.18	500
548.24[c]	162.50	162.50	35.84	0.0279	80.85	80.85	0.14987	0.14987	—	—	—	—	—	—	—	—	—	0.00	548.24

*Temperatures on ITS-90 scale [b]Bubble and dew points at one standard atmosphere [c]Critical point

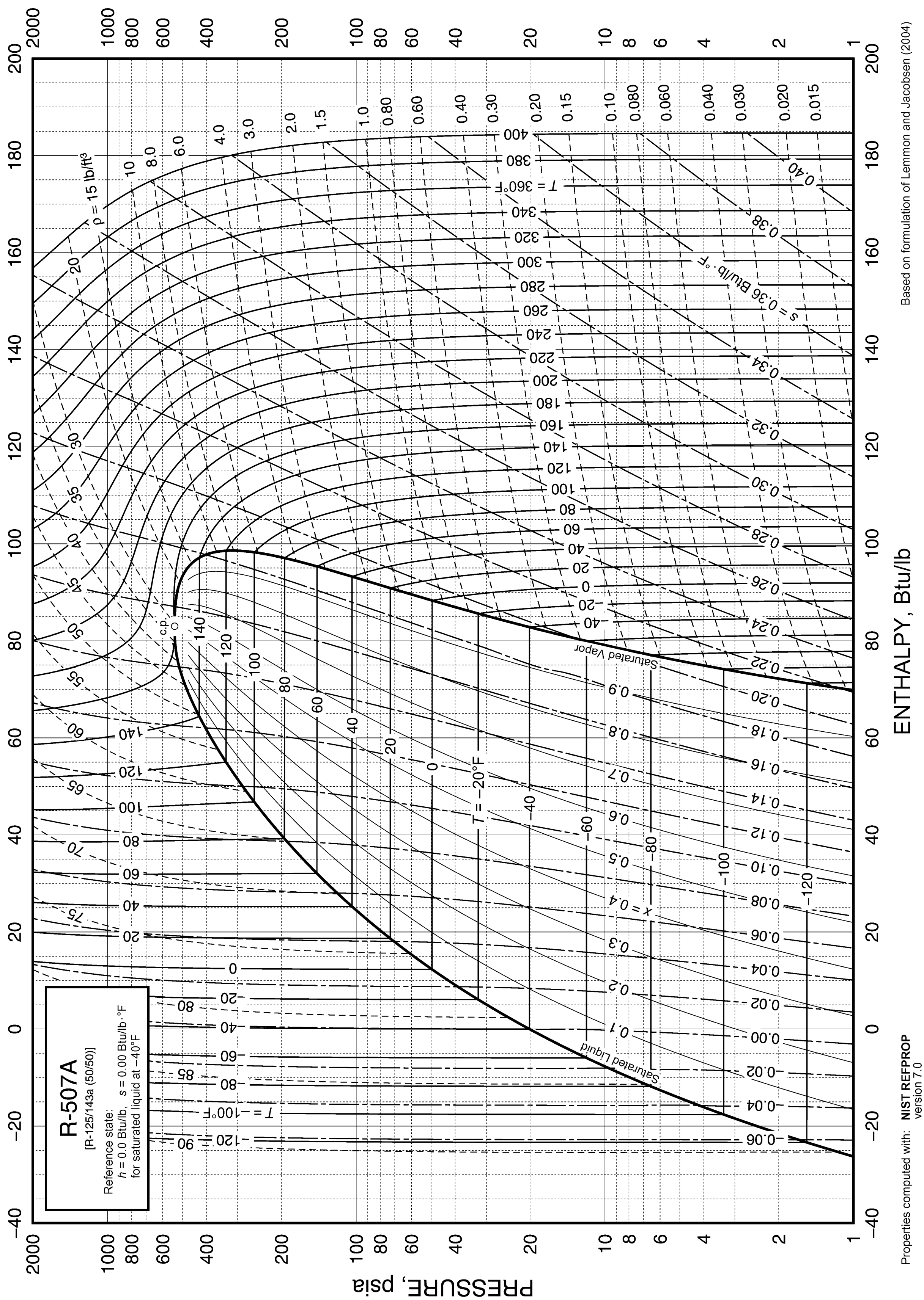

Fig. 17 Pressure-Enthalpy Diagram for Refrigerant 507A

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Refrigerant 507A [R-125/143a (50/50)] Properties of Saturated Liquid and Saturated Vapor

Temp.,* °F	Pressure,** psia	Density, lb/ft³ Liquid	Volume, ft³/lb Vapor	Enthalpy, Btu/lb Liquid	Enthalpy, Btu/lb Vapor	Entropy, Btu/lb·°F Liquid	Entropy, Btu/lb·°F Vapor	Specific Heat c_p, Btu/lb·°F Liquid	Specific Heat c_p, Btu/lb·°F Vapor	c_p/c_v Vapor	Vel. of Sound, ft/s Liquid	Vel. of Sound, ft/s Vapor	Viscosity, $lb_m/ft·h$ Liquid	Viscosity, $lb_m/ft·h$ Vapor	Thermal Cond., Btu/h·ft·°F Liquid	Thermal Cond., Btu/h·ft·°F Vapor	Surface Tension, dyne/cm	Temp.,* °F
–150	0.386	92.41	86.952	–32.027	67.009	–0.08831	0.23154	0.2919	0.1470	1.1650	3468	424.1	—	—	0.0724	0.00330	18.45	–150
–145	0.497	91.88	68.522	–30.571	67.711	–0.08365	0.22872	0.2904	0.1487	1.1637	3379	427.0	2.053	—	0.0715	0.00339	18.20	–145
–140	0.634	91.36	54.501	–29.121	68.416	–0.07908	0.22607	0.2893	0.1504	1.1626	3298	429.8	1.922	0.0176	0.0705	0.00349	17.94	–140
–135	0.801	90.84	43.729	–27.677	69.126	–0.07460	0.22358	0.2885	0.1522	1.1616	3222	432.5	1.804	0.0179	0.0696	0.00358	17.67	–135
–130	1.004	90.32	35.377	–26.235	69.838	–0.07019	0.22125	0.2879	0.1540	1.1607	3151	435.2	1.697	0.0181	0.0687	0.00368	17.41	–130
–125	1.249	89.80	28.844	–24.796	70.554	–0.06586	0.21906	0.2876	0.1558	1.1599	3084	437.8	1.600	0.0184	0.0678	0.00378	17.14	–125
–120	1.541	89.29	23.692	–23.359	71.272	–0.06160	0.21701	0.2874	0.1576	1.1593	3021	440.3	1.512	0.0186	0.0670	0.00388	16.87	–120
–115	1.887	88.77	19.596	–21.921	71.993	–0.05740	0.21509	0.2874	0.1595	1.1588	2961	442.7	1.431	0.0189	0.0661	0.00398	16.59	–115
–110	2.295	88.26	16.315	–20.484	72.716	–0.05326	0.21328	0.2875	0.1614	1.1584	2904	445.1	1.356	0.0192	0.0652	0.00408	16.31	–110
–105	2.773	87.75	13.669	–19.045	73.440	–0.04918	0.21159	0.2878	0.1633	1.1581	2848	447.4	1.288	0.0194	0.0644	0.00418	16.03	–105
–100	3.329	87.23	11.521	–17.604	74.166	–0.04515	0.21001	0.2882	0.1652	1.1580	2795	449.6	1.225	0.0197	0.0636	0.00429	15.75	–100
–95	3.974	86.72	9.7644	–16.161	74.892	–0.04117	0.20852	0.2887	0.1672	1.1581	2743	451.7	1.166	0.0199	0.0627	0.00439	15.46	–95
–90	4.715	86.20	8.3201	–14.716	75.619	–0.03723	0.20713	0.2893	0.1692	1.1583	2692	453.7	1.112	0.0202	0.0619	0.00450	15.17	–90
–85	5.566	85.68	7.1254	–13.266	76.346	–0.03335	0.20583	0.2900	0.1712	1.1586	2643	455.6	1.061	0.0205	0.0611	0.00461	14.88	–85
–80	6.535	85.16	6.1316	–11.813	77.073	–0.02950	0.20462	0.2908	0.1733	1.1592	2595	457.4	1.014	0.0207	0.0603	0.00471	14.58	–80
–75	7.636	84.64	5.3004	–10.356	77.800	–0.02569	0.20348	0.2917	0.1754	1.1599	2547	459.0	0.969	0.0210	0.0595	0.00482	14.28	–75
–70	8.879	84.11	4.6018	–8.894	78.525	–0.02192	0.20242	0.2926	0.1776	1.1607	2501	460.6	0.928	0.0212	0.0587	0.00493	13.98	–70
–65	10.280	83.58	4.0116	–7.427	79.248	–0.01819	0.20143	0.2937	0.1798	1.1618	2454	462.1	0.889	0.0215	0.0579	0.00504	13.68	–65
–60	11.849	83.05	3.5108	–5.954	79.970	–0.01449	0.20050	0.2948	0.1821	1.1631	2409	463.4	0.852	0.0217	0.0572	0.00516	13.37	–60
–55	13.603	82.51	3.0839	–4.475	80.690	–0.01082	0.19963	0.2960	0.1844	1.1646	2364	464.6	0.818	0.0220	0.0564	0.00527	13.06	–55
–52.13[b]	14.696	82.20	2.8676	–3.625	81.101	–0.00873	0.19916	0.2967	0.1858	1.1655	2338	465.2	0.799	0.0221	0.0560	0.00534	12.88	–52.13
–50	15.554	81.97	2.7184	–2.990	81.406	–0.00719	0.19882	0.2972	0.1868	1.1663	2319	465.6	0.785	0.0222	0.0557	0.00538	12.75	–50
–45	17.719	81.43	2.4043	–1.499	82.119	–0.00358	0.19807	0.2985	0.1893	1.1682	2275	466.6	0.754	0.0225	0.0549	0.00550	12.43	–45
–40	20.112	80.88	2.1331	0.000	82.829	0.00000	0.19737	0.30000	0.1918	1.1704	2231	467.4	0.725	0.0227	0.0542	0.00562	12.12	–40
–35	22.750	80.33	1.8983	1.506	83.534	0.00355	0.19671	0.3014	0.1944	1.1728	2187	468.0	0.697	0.0230	0.0534	0.00574	11.80	–35
–30	25.649	79.77	1.6941	3.020	84.235	0.00708	0.19610	0.3030	0.1971	1.1755	2143	468.5	0.671	0.0232	0.0527	0.00585	11.48	–30
–25	28.827	79.20	1.5160	4.541	84.931	0.01058	0.19553	0.3046	0.1998	1.1785	2100	468.8	0.646	0.0235	0.0520	0.00598	11.15	–25
–20	32.300	78.63	1.3601	6.071	85.621	0.01407	0.19500	0.3063	0.2026	1.1818	2056	469.0	0.622	0.0238	0.0512	0.00610	10.83	–20
–15	36.086	78.05	1.2231	7.610	86.304	0.01753	0.19450	0.3081	0.2056	1.1854	2013	469.0	0.599	0.0240	0.0505	0.00622	10.50	–15
–10	40.203	77.46	1.1025	9.158	86.981	0.02097	0.19404	0.3100	0.2086	1.1894	1970	468.9	0.578	0.0243	0.0498	0.00635	10.17	–10
–5	44.671	76.87	0.9960	10.716	87.651	0.02439	0.19360	0.3119	0.2117	1.1938	1926	468.5	0.557	0.0245	0.0491	0.00647	9.84	–5
0	49.508	76.27	0.9016	12.284	88.313	0.02779	0.19319	0.3140	0.2149	1.1986	1883	468.0	0.537	0.0248	0.0484	0.00660	9.51	0
5	54.733	75.66	0.8177	13.862	88.966	0.03118	0.19281	0.3161	0.2183	1.2038	1840	467.3	0.518	0.0250	0.0477	0.00673	9.18	5
10	60.367	75.04	0.7430	15.452	89.610	0.03455	0.19245	0.3184	0.2218	1.2095	1797	466.4	0.499	0.0253	0.0470	0.00687	8.85	10
15	66.429	74.41	0.6763	17.052	90.245	0.03791	0.19211	0.3208	0.2254	1.2157	1753	465.3	0.482	0.0256	0.0463	0.00700	8.51	15
20	72.941	73.77	0.6165	18.665	90.868	0.04126	0.19179	0.3233	0.2291	1.2226	1710	464.0	0.464	0.0258	0.0457	0.00714	8.18	20
25	79.923	73.12	0.5629	20.290	91.480	0.04459	0.19148	0.3260	0.2330	1.2301	1666	462.5	0.448	0.0261	0.0450	0.00728	7.84	25
30	87.396	72.45	0.5146	21.929	92.079	0.04791	0.19118	0.3288	0.2371	1.2384	1623	460.8	0.432	0.0264	0.0443	0.00743	7.51	30
35	95.384	71.78	0.4711	23.581	92.664	0.05123	0.19089	0.3318	0.2414	1.2476	1579	458.8	0.417	0.0267	0.0436	0.00759	7.17	35
40	103.91	71.09	0.4318	25.249	93.234	0.05454	0.19061	0.3350	0.2460	1.2577	1535	456.6	0.402	0.0270	0.0430	0.00775	6.84	40
45	112.99	70.38	0.3962	26.931	93.788	0.05784	0.19032	0.3384	0.2508	1.2690	1491	454.2	0.388	0.0273	0.0423	0.00792	6.50	45
50	122.65	69.66	0.3638	28.630	94.324	0.06114	0.19004	0.3421	0.2560	1.2816	1447	451.6	0.374	0.0276	0.0416	0.00810	6.17	50
55	132.92	68.92	0.3344	30.346	94.840	0.06444	0.18976	0.3460	0.2616	1.2956	1403	448.7	0.360	0.0280	0.0410	0.00829	5.83	55
60	143.82	68.16	0.3076	32.080	95.336	0.06773	0.18946	0.3503	0.2676	1.3113	1358	445.5	0.347	0.0283	0.0403	0.00849	5.50	60
65	155.38	67.39	0.2832	33.834	95.808	0.07103	0.18916	0.3549	0.2742	1.3289	1313	442.0	0.334	0.0287	0.0397	0.00871	5.17	65
70	167.62	66.58	0.2608	35.609	96.255	0.07434	0.18884	0.3599	0.2814	1.3488	1268	438.3	0.322	0.0291	0.0390	0.00893	4.84	70
75	180.56	65.76	0.2403	37.406	96.675	0.07764	0.18850	0.3654	0.2894	1.3713	1222	434.3	0.310	0.0295	0.0384	0.00918	4.52	75
80	194.24	64.90	0.2214	39.228	97.065	0.08096	0.18814	0.3715	0.2983	1.3970	1176	430.0	0.298	0.0300	0.0377	0.00943	4.19	80
85	208.68	64.02	0.2041	41.076	97.421	0.08429	0.18775	0.3783	0.3083	1.4265	1130	425.3	0.286	0.0304	0.0371	0.00971	3.87	85
90	223.92	63.10	0.1880	42.952	97.740	0.08764	0.18732	0.3858	0.3196	1.4606	1083	420.3	0.275	0.0309	0.0364	0.01002	3.55	90
95	239.97	62.14	0.1732	44.860	98.019	0.09101	0.18686	0.3944	0.3325	1.5003	1035	414.9	0.264	0.0315	0.0358	0.01035	3.24	95
100	256.88	61.14	0.1595	46.803	98.251	0.09441	0.18634	0.4043	0.3475	1.5471	987	409.2	0.253	0.0321	0.0351	0.01071	2.93	100
105	274.68	60.09	0.1468	48.784	98.431	0.09784	0.18576	0.4157	0.3650	1.6029	938	403.1	0.242	0.0327	0.0344	0.01112	2.62	105
110	293.40	58.99	0.1349	50.809	98.551	0.10130	0.18511	0.4291	0.3858	1.6706	888	396.5	0.231	0.0334	0.0338	0.01158	2.32	110
115	313.08	57.82	0.1238	52.885	98.600	0.10482	0.18438	0.4453	0.4112	1.7541	838	389.5	0.220	0.0343	0.0331	0.01210	2.03	115
120	333.77	56.57	0.1134	55.018	98.568	0.10840	0.18354	0.4652	0.4427	1.8597	786	382.0	0.209	0.0352	0.0325	0.01270	1.74	120
125	355.50	55.22	0.1036	57.221	98.435	0.11206	0.18256	0.4904	0.4833	1.9972	732	373.9	0.198	0.0362	0.0318	0.01341	1.47	125
130	378.33	53.76	0.0943	59.509	98.177	0.11583	0.18141	0.5237	0.5375	2.1831	677	365.3	0.187	0.0375	0.0311	0.01425	1.20	130
135	402.31	52.15	0.0855	61.903	97.759	0.11973	0.18003	0.5700	0.6142	2.4480	620	356.1	0.176	0.0389	0.0305	0.01530	0.94	135
140	427.52	50.32	0.0769	64.439	97.125	0.12382	0.17833	0.6399	0.7313	2.8546	560	346.1	0.164	0.0408	0.0299	0.01664	0.70	140
145	454.04	48.19	0.0684	67.182	96.173	0.12821	0.17616	0.7590	0.9326	3.5556	497	335.3	0.151	0.0432	0.0294	0.01846	0.48	145
150	481.99	45.55	0.0597	70.265	94.697	0.13311	0.17318	1.0130	1.3606	5.0420	429	323.4	0.137	0.0466	0.0293	0.02122	0.27	150
155	511.55	41.76	0.0499	74.107	92.081	0.13918	0.16842	1.9550	2.8693	10.2379	353	309.4	0.119	0.0524	0.0305	0.02681	0.10	155
159.12[c]	537.40	30.64	0.0326	83.010	83.010	0.15339	0.15339	∞	∞	∞	0	0.0	—	—	∞	∞	0.00	159.12

*Temperatures on ITS-90 scale

**Small deviations from azeotropic behavior occur at some conditions; tabulated pressures are average of bubble and dew-point pressures

[b]Normal boiling point

[c]Critical point

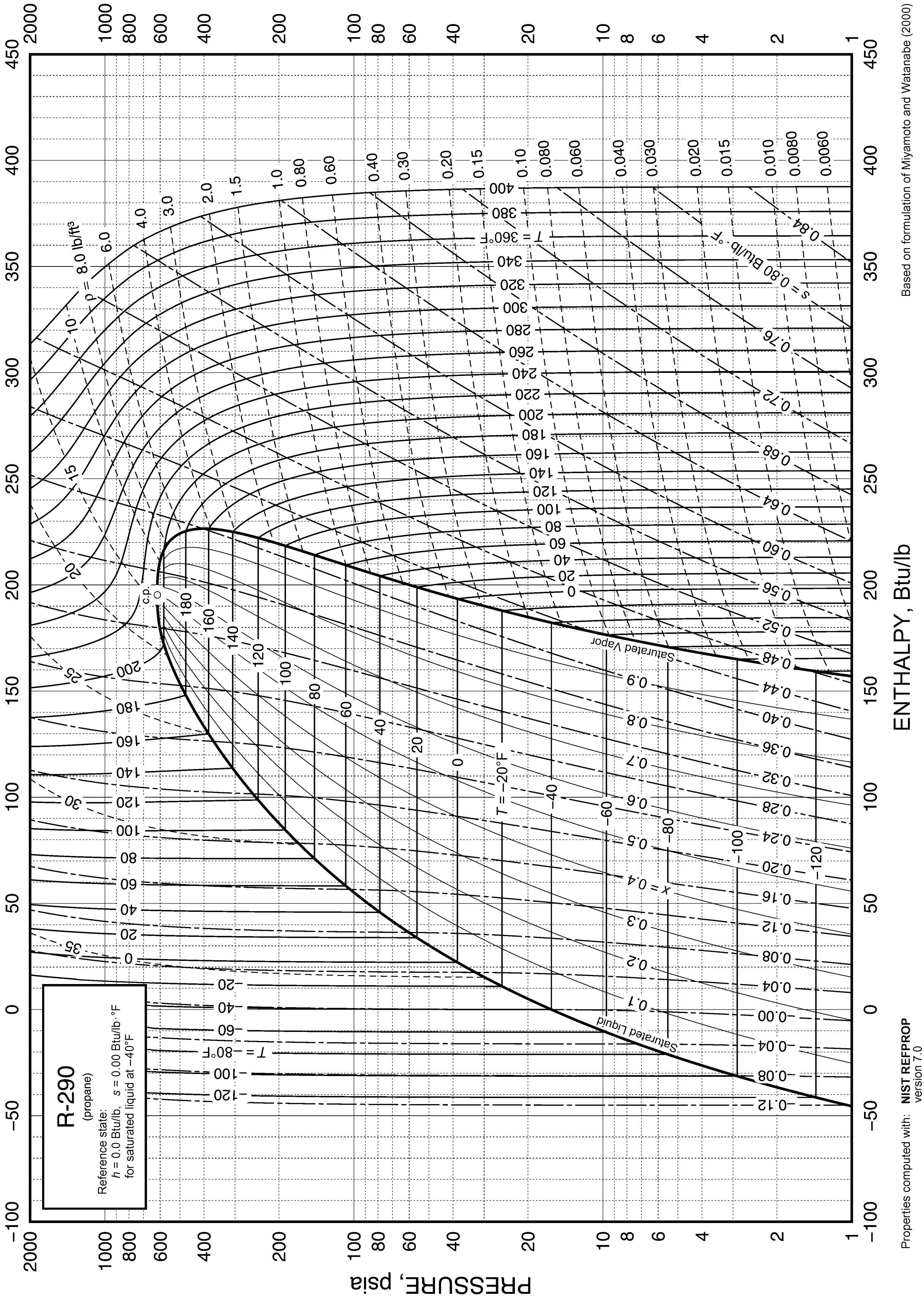

Fig. 23 Pressure-Enthalpy Diagram for Refrigerant 290 (Propane)

Refrigerant 290 (Propane) Properties of Saturated Liquid and Saturated Vapor

Temp., °F	Pressure, psia	Density, lb/ft³	Volume, ft³/lb	Enthalpy, Btu/lb		Entropy, Btu/lb·°F		Specific Heat c_p, Btu/lb·°F		c_p/c_v	Vel. of Sound, ft/s		Viscosity, lb_m/ft·h		Thermal Cond., Btu/h·ft·°F		Surface Tension, dyne/cm	Temp., °F
		Liquid	Vapor	Liquid	Vapor	Liquid	Vapor	Liquid	Vapor	Vapor	Liquid	Vapor	Liquid	Vapor	Liquid	Vapor		
–200	0.020	42.03	3122.3	–80.510	137.326	–0.24019	0.59871	0.4770	0.2606	1.2094	5702	594.9	1.795	0.0099	0.1050	0.00287	28.59	–200
–190	0.040	41.68	1630.8	–75.728	139.945	–0.22212	0.57765	0.4794	0.2648	1.2055	5580	605.2	1.586	0.0102	0.1031	0.00308	27.75	–190
–180	0.076	41.33	898.92	–70.922	142.601	–0.20462	0.55886	0.4819	0.2691	1.2019	5459	615.2	1.415	0.0106	0.1012	0.00330	26.90	–180
–170	0.135	40.97	519.81	–66.090	145.294	–0.18764	0.54209	0.4845	0.2734	1.1985	5337	625.0	1.272	0.0109	0.0993	0.00351	26.06	–170
–160	0.232	40.62	313.69	–61.230	148.019	–0.17115	0.52711	0.4873	0.2777	1.1954	5215	634.5	1.152	0.0113	0.0974	0.00374	25.23	–160
–150	0.382	40.26	196.68	–56.342	150.774	–0.15511	0.51372	0.4903	0.2822	1.1925	5093	643.7	1.049	0.0116	0.0954	0.00397	24.39	–150
–145	0.484	40.08	157.78	–53.887	152.162	–0.14725	0.50756	0.4918	0.2845	1.1912	5032	648.2	1.003	0.0118	0.0944	0.00408	23.98	–145
–140	0.608	39.90	127.61	–51.423	153.557	–0.13948	0.50174	0.4934	0.2868	1.1899	4971	652.6	0.960	0.0119	0.0935	0.00420	23.57	–140
–135	0.757	39.72	104.00	–48.952	154.957	–0.13181	0.49624	0.4950	0.2892	1.1887	4910	656.9	0.919	0.0121	0.0925	0.00432	23.15	–135
–130	0.935	39.54	85.379	–46.472	156.364	–0.12423	0.49103	0.4967	0.2916	1.1876	4849	661.2	0.882	0.0123	0.0915	0.00444	22.74	–130
–125	1.147	39.35	70.580	–43.983	157.775	–0.11674	0.48611	0.4985	0.2940	1.1866	4788	665.3	0.846	0.0125	0.0905	0.00456	22.33	–125
–120	1.398	39.17	58.730	–41.485	159.191	–0.10934	0.48146	0.5003	0.2966	1.1856	4727	669.4	0.813	0.0126	0.0895	0.00468	21.92	–120
–115	1.693	38.99	49.176	–38.978	160.611	–0.10202	0.47706	0.5022	0.2992	1.1848	4666	673.3	0.782	0.0128	0.0885	0.00480	21.51	–115
–110	2.036	38.80	41.421	–36.461	162.036	–0.09477	0.47290	0.5041	0.3018	1.1840	4606	677.2	0.753	0.0130	0.0875	0.00493	21.10	–110
–105	2.435	38.62	35.086	–33.935	163.463	–0.08760	0.46897	0.5061	0.3045	1.1833	4545	680.9	0.725	0.0132	0.0865	0.00505	20.70	–105
–100	2.896	38.43	29.880	–31.398	164.894	–0.08050	0.46525	0.5082	0.3073	1.1827	4484	684.6	0.698	0.0133	0.0855	0.00518	20.29	–100
–95	3.425	38.24	25.577	–28.850	166.327	–0.07348	0.46174	0.5103	0.3102	1.1822	4423	688.1	0.673	0.0135	0.0846	0.00531	19.89	–95
–90	4.030	38.06	22.000	–26.291	167.762	–0.06652	0.45842	0.5125	0.3132	1.1818	4363	691.5	0.650	0.0137	0.0836	0.00544	19.49	–90
–85	4.718	37.87	19.010	–23.721	169.199	–0.05962	0.45529	0.5148	0.3162	1.1814	4303	694.8	0.627	0.0138	0.0826	0.00557	19.09	–85
–80	5.497	37.68	16.500	–21.138	170.638	–0.05278	0.45233	0.5172	0.3193	1.1812	4242	697.9	0.606	0.0140	0.0816	0.00570	18.69	–80
–75	6.376	37.49	14.381	–18.544	172.077	–0.04600	0.44954	0.5196	0.3225	1.1811	4182	700.9	0.585	0.0142	0.0806	0.00583	18.29	–75
–70	7.364	37.29	12.584	–15.936	173.516	–0.03928	0.44690	0.5222	0.3257	1.1812	4122	703.8	0.566	0.0144	0.0797	0.00596	17.89	–70
–65	8.470	37.10	11.054	–13.316	174.955	–0.03261	0.44442	0.5248	0.3291	1.1813	4062	706.5	0.547	0.0145	0.0787	0.00610	17.49	–65
–60	9.704	36.90	9.7455	–10.682	176.394	–0.02600	0.44208	0.5275	0.3325	1.1816	4002	709.1	0.529	0.0147	0.0778	0.00624	17.10	–60
–55	11.075	36.71	8.6215	–8.034	177.831	–0.01943	0.43987	0.5302	0.3360	1.1820	3942	711.6	0.513	0.0149	0.0768	0.00637	16.71	–55
–50	12.593	36.51	7.6522	–5.371	179.267	–0.01291	0.43779	0.5331	0.3397	1.1825	3882	713.9	0.496	0.0150	0.0759	0.00651	16.31	–50
–45	14.270	36.31	6.8133	–2.693	180.701	–0.00643	0.43583	0.5361	0.3434	1.1831	3823	716.0	0.481	0.0152	0.0749	0.00665	15.92	–45
–43.80[b]	14.696	36.26	6.6298	–2.051	181.043	–0.00489	0.43538	0.5368	0.3443	1.1833	3809	716.5	0.477	0.0153	0.0747	0.00669	15.83	–43.80
–40	16.117	36.11	6.0846	0.000	182.132	0.00000	0.43399	0.5392	0.3472	1.1840	3763	718.0	0.466	0.0154	0.0740	0.00680	15.54	–40
–35	18.144	35.91	5.4494	2.709	183.560	0.00639	0.43225	0.5423	0.3511	1.1849	3704	719.8	0.451	0.0156	0.0730	0.00694	15.15	–35
–30	20.363	35.70	4.8938	5.435	184.984	0.01275	0.43062	0.5456	0.3551	1.1861	3644	721.5	0.438	0.0157	0.0721	0.00709	14.76	–30
–25	22.785	35.50	4.4064	8.177	186.404	0.01906	0.42909	0.5489	0.3592	1.1874	3585	723.0	0.425	0.0159	0.0712	0.00724	14.38	–25
–20	25.424	35.29	3.9773	10.937	187.819	0.02534	0.42765	0.5524	0.3634	1.1888	3525	724.3	0.412	0.0161	0.0703	0.00739	14.00	–20
–15	28.291	35.08	3.5985	13.715	189.229	0.03159	0.42630	0.5560	0.3677	1.1905	3466	725.4	0.400	0.0163	0.0694	0.00754	13.62	–15
–10	31.399	34.87	3.2632	16.512	190.632	0.03781	0.42503	0.5597	0.3722	1.1924	3406	726.3	0.388	0.0164	0.0685	0.00769	13.24	–10
–5	34.760	34.66	2.9655	19.327	192.029	0.04400	0.42384	0.5635	0.3768	1.1945	3347	727.0	0.377	0.0166	0.0676	0.00785	12.86	–5
0	38.389	34.44	2.7005	22.163	193.419	0.05016	0.42272	0.5674	0.3815	1.1968	3287	727.6	0.366	0.0168	0.0667	0.00801	12.49	0
5	42.296	34.22	2.4639	25.018	194.800	0.05629	0.42167	0.5715	0.3863	1.1993	3228	727.9	0.355	0.0170	0.0659	0.00817	12.11	5
10	46.497	34.00	2.2523	27.895	196.173	0.06240	0.42069	0.5757	0.3914	1.2021	3168	728.0	0.345	0.0172	0.0650	0.00834	11.74	10
15	51.005	33.78	2.0625	30.793	197.536	0.06848	0.41977	0.5800	0.3965	1.2052	3109	728.0	0.335	0.0174	0.0641	0.00850	11.37	15
20	55.834	33.55	1.8919	33.713	198.889	0.07455	0.41890	0.5845	0.4019	1.2086	3049	727.7	0.325	0.0175	0.0633	0.00868	11.00	20
25	60.997	33.32	1.7381	36.656	200.231	0.08059	0.41809	0.5891	0.4074	1.2123	2989	727.1	0.316	0.0177	0.0624	0.00885	10.64	25
30	66.509	33.09	1.5993	39.623	201.560	0.08662	0.41733	0.5939	0.4132	1.2164	2929	726.4	0.307	0.0179	0.0616	0.00903	10.28	30
35	72.383	32.86	1.4737	42.615	202.877	0.09263	0.41661	0.5989	0.4192	1.2208	2869	725.4	0.299	0.0181	0.0608	0.00921	9.92	35
40	78.636	32.62	1.3599	45.631	204.179	0.09863	0.41593	0.6041	0.4254	1.2256	2809	724.2	0.290	0.0183	0.0600	0.00940	9.56	40
45	85.280	32.38	1.2564	48.674	205.466	0.10461	0.41529	0.6094	0.4319	1.2309	2749	722.7	0.282	0.0185	0.0592	0.00959	9.20	45
50	92.331	32.13	1.1622	51.743	206.737	0.11058	0.41469	0.6150	0.4386	1.2367	2688	721.0	0.274	0.0188	0.0584	0.00979	8.85	50
55	99.804	31.88	1.0763	54.840	207.991	0.11655	0.41412	0.6209	0.4457	1.2429	2628	719.1	0.267	0.0190	0.0576	0.00999	8.50	55
60	107.71	31.63	0.9979	57.967	209.226	0.12250	0.41357	0.6269	0.4532	1.2498	2567	716.8	0.259	0.0192	0.0568	0.01020	8.15	60
65	116.08	31.37	0.9260	61.123	210.440	0.12845	0.41305	0.6333	0.4610	1.2573	2507	714.3	0.252	0.0194	0.0560	0.01042	7.80	65
70	124.91	31.11	0.8602	64.310	211.633	0.13440	0.41254	0.6399	0.4692	1.2656	2446	711.5	0.245	0.0197	0.0552	0.01064	7.46	70
75	134.22	30.85	0.7997	67.529	212.802	0.14034	0.41205	0.6469	0.4779	1.2746	2384	708.4	0.238	0.0199	0.0545	0.01087	7.12	75
80	144.04	30.57	0.7441	70.782	213.947	0.14629	0.41157	0.6543	0.4871	1.2846	2323	705.0	0.231	0.0202	0.0537	0.01111	6.78	80
85	154.37	30.30	0.6928	74.070	215.063	0.15224	0.41110	0.6620	0.4969	1.2955	2261	701.3	0.224	0.0204	0.0530	0.01135	6.45	85
90	165.23	30.01	0.6455	77.394	216.151	0.15819	0.41063	0.6703	0.5074	1.3076	2199	697.3	0.218	0.0207	0.0523	0.01161	6.12	90
95	176.64	29.72	0.6018	80.757	217.206	0.16415	0.41015	0.6790	0.5186	1.3209	2137	693.0	0.212	0.0210	0.0515	0.01188	5.79	95
100	188.62	29.43	0.5613	84.160	218.227	0.17013	0.40967	0.6883	0.5306	1.3358	2075	688.3	0.205	0.0213	0.0508	0.01216	5.47	100
110	214.34	28.81	0.4889	91.096	220.152	0.18212	0.40866	0.7089	0.5577	1.3707	1948	677.9	0.193	0.0219	0.0494	0.01276	4.83	110
120	242.54	28.16	0.4262	98.220	221.896	0.19420	0.40755	0.7330	0.5900	1.4148	1820	665.9	0.181	0.0226	0.0480	0.01342	4.21	120
130	273.38	27.46	0.3716	105.560	223.420	0.20640	0.40627	0.7619	0.6294	1.4717	1689	652.2	0.170	0.0234	0.0467	0.01417	3.61	130
140	307.01	26.72	0.3237	113.151	224.672	0.21878	0.40475	0.7977	0.6791	1.5477	1556	636.7	0.159	0.0243	0.0453	0.01503	3.02	140
150	343.62	25.91	0.2812	121.039	225.573	0.23140	0.40286	0.8439	0.7453	1.6537	1419	619.3	0.148	0.0253	0.0440	0.01604	2.46	150
160	383.40	25.01	0.2434	129.299	226.011	0.24436	0.40043	0.9072	0.8399	1.8099	1277	599.7	0.137	0.0265	0.0427	0.01727	1.92	160
170	426.58	23.99	0.2090	138.045	225.808	0.25784	0.39722	1.002	0.9880	2.0578	1127	577.6	0.125	0.0281	0.0414	0.01886	1.41	170
180	473.45	22.80	0.1773	147.486	224.658	0.27213	0.39277	1.163	1.2515	2.5014	968	552.5	0.113	0.0301	0.0401	0.02108	0.94	180
190	524.34	21.29	0.1469	158.074	221.895	0.28789	0.38613	1.517	1.8458	3.5048	793	523.4	0.100	0.0329	0.0390	0.02468	0.51	190
200	579.80	19.02	0.1146	171.336	215.315	0.30736	0.37403	3.062	4.4472	7.8310	590	487.5	0.083	0.0381	0.0398	0.03308	0.15	200
206.13[c]	616.58	13.76	0.0727	193.643	193.643	0.34037	0.34037	∞	∞	∞	0	0.0	—	—	∞	∞	0.00	206.13

[b]Normal boiling point

[c]Critical point

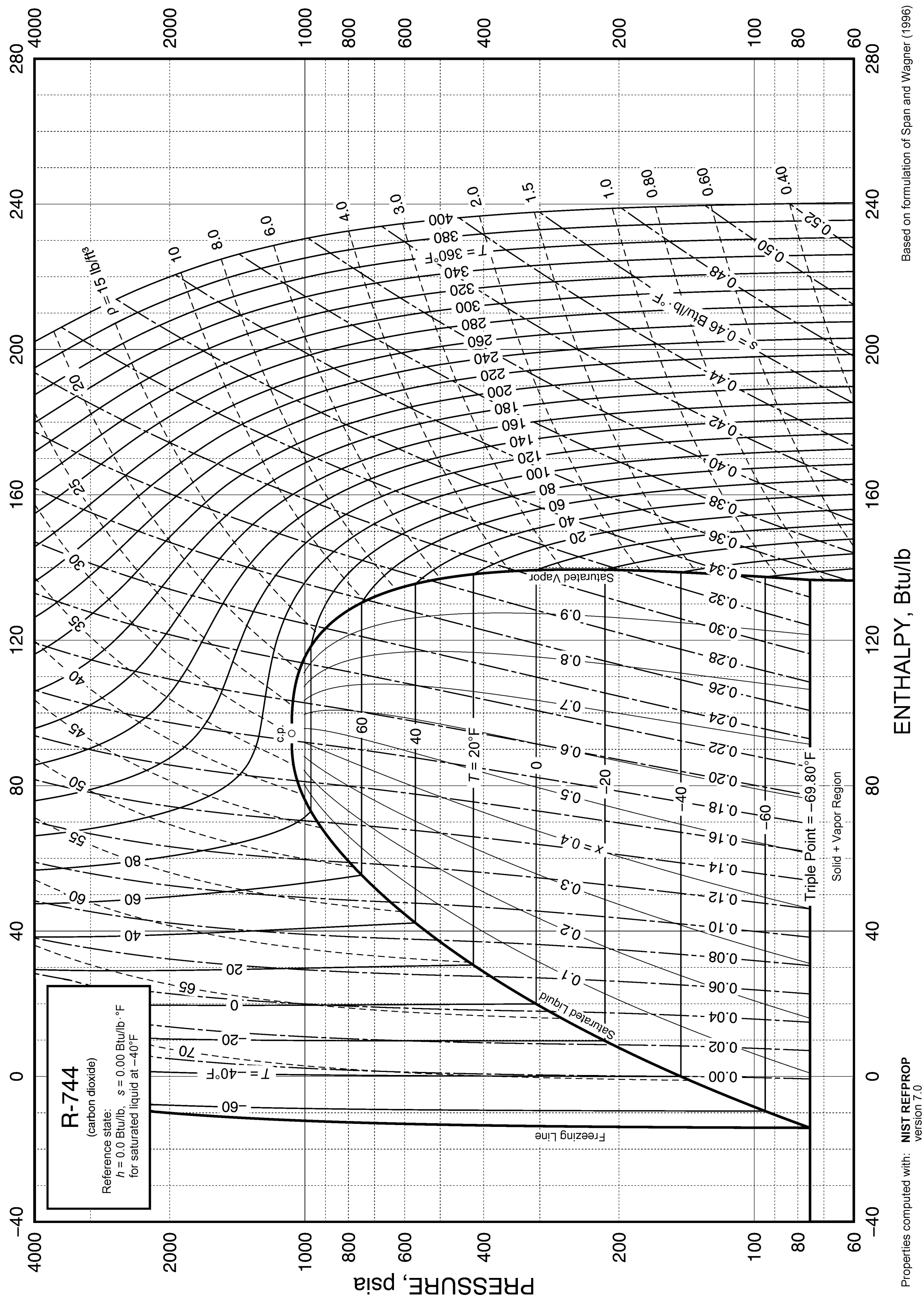

Fig. 20 Pressure-Enthalpy Diagram for Refrigerant 744 (Carbon Dioxide)

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Refrigerant 744 (Carbon Dioxide) Properties of Saturated Liquid and Saturated Vapor

Temp.,* °F	Pres-sure, psia	Density, lb/ft³	Volume, ft³/lb	Enthalpy, Btu/lb		Entropy, Btu/lb·°F		Specific Heat c_p, Btu/lb·°F		c_p/c_v	Vel. of Sound, ft/s		Viscosity, lb_m/ft·h		Thermal Cond., Btu/h·ft·°F		Surface Tension, dyne/cm	Temp.,* °F
		Liquid	Vapor	Liquid	Vapor	Liquid	Vapor	Liquid	Vapor	Vapor	Liquid	Vapor	Liquid	Vapor	Liquid	Vapor		
–69.80[a]	75.124	73.57	1.1641	–14.140	136.598	–0.03449	0.35215	0.4668	0.2172	1.4442	3202	730.9	0.621	0.0265	0.1044	0.00637	17.16	–69.80
–65	84.234	72.97	1.0434	–11.886	137.013	–0.02881	0.34847	0.4684	0.2212	1.4534	3138	731.9	0.593	0.0268	0.1024	0.00650	16.49	–65
–60	94.573	72.33	0.9336	–9.532	137.417	–0.02294	0.34473	0.4703	0.2257	1.4638	3073	732.7	0.565	0.0272	0.1003	0.00664	15.81	–60
–55	105.84	71.69	0.8375	–7.167	137.790	–0.01714	0.34107	0.4724	0.2304	1.4754	3007	733.2	0.539	0.0276	0.0982	0.00678	15.12	–55
–50	118.08	71.04	0.7532	–4.791	138.130	–0.01138	0.33749	0.4749	0.2355	1.4882	2941	733.5	0.514	0.0279	0.0962	0.00693	14.45	–50
–48	123.26	70.77	0.7224	–3.837	138.257	–0.00909	0.33608	0.4760	0.2377	1.4937	2915	733.5	0.505	0.0281	0.0954	0.00699	14.18	–48
–46	128.61	70.51	0.6930	–2.881	138.379	–0.00681	0.33467	0.4771	0.2399	1.4994	2889	733.5	0.496	0.0283	0.0945	0.00706	13.91	–46
–44	134.13	70.24	0.6651	–1.923	138.494	–0.00453	0.33328	0.4783	0.2422	1.5054	2862	733.5	0.486	0.0284	0.0937	0.00712	13.65	–44
–42	139.82	69.97	0.6386	–0.963	138.604	–0.00226	0.33189	0.4795	0.2445	1.5116	2836	733.4	0.477	0.0286	0.0929	0.00718	13.38	–42
–40	145.69	69.70	0.6132	0.000	138.708	0.00000	0.33052	0.4808	0.2470	1.5180	2809	733.3	0.469	0.0287	0.0921	0.00725	13.12	–40
–38	151.74	69.42	0.5891	0.965	138.806	0.00226	0.32915	0.4821	0.2495	1.5247	2783	733.1	0.460	0.0289	0.0913	0.00732	12.86	–38
–36	157.98	69.15	0.5661	1.933	138.898	0.00451	0.32779	0.4836	0.2520	1.5317	2756	732.9	0.452	0.0290	0.0905	0.00739	12.60	–36
–34	164.40	68.87	0.5442	2.904	138.983	0.00675	0.32643	0.4850	0.2547	1.5390	2730	732.6	0.443	0.0292	0.0897	0.00746	12.34	–34
–32	171.02	68.59	0.5233	3.877	139.062	0.00899	0.32509	0.4866	0.2574	1.5466	2703	732.3	0.435	0.0293	0.0889	0.00753	12.08	–32
–30	177.83	68.31	0.5033	4.854	139.134	0.01123	0.32375	0.4882	0.2603	1.5545	2677	732.0	0.427	0.0295	0.0881	0.00760	11.82	–30
–28	184.83	68.02	0.4842	5.833	139.199	0.01346	0.32241	0.4899	0.2632	1.5628	2650	731.6	0.420	0.0297	0.0873	0.00768	11.56	–28
–26	192.04	67.74	0.4659	6.816	139.258	0.01568	0.32108	0.4917	0.2662	1.5714	2623	731.1	0.412	0.0298	0.0865	0.00775	11.31	–26
–24	199.46	67.45	0.4485	7.802	139.309	0.01790	0.31975	0.4935	0.2694	1.5804	2596	730.6	0.405	0.0300	0.0857	0.00783	11.06	–24
–22	207.08	67.16	0.4318	8.791	139.353	0.02012	0.31843	0.4955	0.2726	1.5898	2569	730.1	0.397	0.0302	0.0849	0.00791	10.80	–22
–20	214.91	66.86	0.4158	9.784	139.389	0.02234	0.31711	0.4975	0.2760	1.5996	2542	729.5	0.390	0.0303	0.0841	0.00799	10.55	–20
–18	222.97	66.56	0.4005	10.781	139.418	0.02455	0.31580	0.4996	0.2795	1.6099	2515	728.9	0.383	0.0305	0.0833	0.00807	10.30	–18
–16	231.24	66.27	0.3859	11.781	139.438	0.02675	0.31448	0.5018	0.2831	1.6206	2488	728.2	0.376	0.0307	0.0825	0.00816	10.05	–16
–14	239.73	65.96	0.3718	12.786	139.451	0.02896	0.31317	0.5042	0.2869	1.6318	2461	727.5	0.369	0.0308	0.0818	0.00825	9.81	–14
–12	248.45	65.66	0.3584	13.794	139.455	0.03116	0.31186	0.5066	0.2908	1.6435	2433	726.7	0.363	0.0310	0.0810	0.00834	9.56	–12
–10	257.40	65.35	0.3455	14.807	139.450	0.03336	0.31055	0.5091	0.2949	1.6557	2405	725.9	0.356	0.0312	0.0802	0.00843	9.32	–10
–8	266.58	65.04	0.3331	15.824	139.437	0.03556	0.30924	0.5118	0.2991	1.6685	2378	725.0	0.350	0.0314	0.0794	0.00853	9.07	–8
–6	276.01	64.72	0.3212	16.846	139.415	0.03776	0.30793	0.5146	0.3035	1.6820	2350	724.1	0.343	0.0315	0.0786	0.00863	8.83	–6
–4	285.67	64.40	0.3098	17.873	139.383	0.03996	0.30662	0.5175	0.3082	1.6960	2321	723.1	0.337	0.0317	0.0778	0.00873	8.59	–4
–2	295.58	64.08	0.2989	18.905	139.342	0.04216	0.30531	0.5206	0.3130	1.7108	2293	722.1	0.331	0.0319	0.0771	0.00883	8.35	–2
0	305.74	63.76	0.2884	19.942	139.291	0.04435	0.30399	0.5238	0.3180	1.7262	2264	721.0	0.325	0.0321	0.0763	0.00894	8.11	0
2	316.15	63.43	0.2782	20.985	139.230	0.04655	0.30267	0.5272	0.3233	1.7425	2235	719.8	0.319	0.0323	0.0755	0.00905	7.88	2
4	326.82	63.09	0.2685	22.033	139.158	0.04875	0.30135	0.5307	0.3288	1.7596	2206	718.6	0.313	0.0325	0.0747	0.00916	7.64	4
6	337.75	62.76	0.2591	23.088	139.075	0.05095	0.30003	0.5345	0.3346	1.7776	2176	717.4	0.307	0.0327	0.0740	0.00928	7.41	6
8	348.94	62.42	0.2501	24.148	138.981	0.05315	0.29869	0.5384	0.3406	1.7965	2146	716.1	0.302	0.0329	0.0732	0.00941	7.18	8
10	360.41	62.07	0.2414	25.215	138.876	0.05535	0.29736	0.5425	0.3470	1.8166	2116	714.7	0.296	0.0331	0.0724	0.00953	6.95	10
12	372.14	61.72	0.2331	26.289	138.758	0.05756	0.29601	0.5469	0.3537	1.8377	2085	713.2	0.291	0.0333	0.0716	0.00967	6.72	12
14	384.16	61.36	0.2250	27.369	138.628	0.05977	0.29466	0.5514	0.3607	1.8601	2054	711.8	0.286	0.0335	0.0709	0.00981	6.50	14
16	396.45	61.00	0.2173	28.457	138.485	0.06198	0.29329	0.5563	0.3681	1.8837	2023	710.2	0.280	0.0338	0.0701	0.00995	6.27	16
18	409.03	60.63	0.2098	29.552	138.328	0.06420	0.29192	0.5614	0.3759	1.9089	1991	708.6	0.275	0.0340	0.0693	0.01010	6.05	18
20	421.91	60.26	0.2025	30.656	138.158	0.06642	0.29054	0.5669	0.3841	1.9356	1959	706.9	0.270	0.0342	0.0685	0.01026	5.83	20
22	435.07	59.89	0.1956	31.768	137.973	0.06865	0.28915	0.5726	0.3928	1.9640	1926	705.2	0.265	0.0345	0.0677	0.01042	5.61	22
24	448.54	59.50	0.1888	32.889	137.772	0.07089	0.28774	0.5787	0.4021	1.9942	1894	703.4	0.260	0.0347	0.0670	0.01059	5.39	24
26	462.30	59.11	0.1823	34.019	137.556	0.07313	0.28632	0.5853	0.4120	2.0266	1861	701.6	0.255	0.0350	0.0662	0.01077	5.17	26
28	476.38	58.71	0.1760	35.159	137.323	0.07538	0.28488	0.5922	0.4225	2.0611	1827	699.7	0.250	0.0352	0.0654	0.01096	4.96	28
30	490.77	58.31	0.1699	36.309	137.072	0.07764	0.28342	0.5997	0.4337	2.0982	1794	697.7	0.245	0.0355	0.0646	0.01116	4.75	30
32	505.48	57.90	0.1640	37.470	136.803	0.07991	0.28195	0.6076	0.4457	2.1380	1760	695.7	0.240	0.0358	0.0638	0.01137	4.54	32
34	520.51	57.48	0.1583	38.643	136.514	0.08220	0.28045	0.6162	0.4586	2.1808	1726	693.6	0.236	0.0361	0.0631	0.01160	4.33	34
36	535.86	57.05	0.1528	39.828	136.206	0.08449	0.27893	0.6254	0.4725	2.2271	1692	691.4	0.231	0.0364	0.0623	0.01183	4.13	36
38	551.55	56.61	0.1475	41.025	135.875	0.08680	0.27739	0.6353	0.4875	2.2771	1657	689.1	0.227	0.0367	0.0615	0.01208	3.92	38
40	567.58	56.16	0.1423	42.237	135.522	0.08912	0.27582	0.6460	0.5038	2.3314	1623	686.8	0.222	0.0370	0.0607	0.01235	3.72	40
42	583.95	55.71	0.1373	43.464	135.145	0.09147	0.27422	0.6577	0.5215	2.3905	1588	684.4	0.217	0.0373	0.0599	0.01263	3.53	42
44	600.67	55.24	0.1324	44.706	134.741	0.09383	0.27259	0.6704	0.5408	2.4551	1553	681.9	0.213	0.0377	0.0591	0.01294	3.33	44
46	617.75	54.76	0.1276	45.965	134.310	0.09621	0.27092	0.6843	0.5620	2.5260	1518	679.3	0.209	0.0381	0.0583	0.01326	3.14	46
48	635.18	54.27	0.1230	47.242	133.850	0.09861	0.26921	0.6996	0.5854	2.6040	1482	676.7	0.204	0.0384	0.0575	0.01362	2.94	48
50	652.99	53.76	0.1185	48.539	133.357	0.10104	0.26746	0.7164	0.6113	2.6903	1447	673.9	0.200	0.0388	0.0567	0.01400	2.76	50
52	671.16	53.24	0.1141	49.858	132.830	0.10350	0.26566	0.7352	0.6402	2.7863	1411	671.0	0.195	0.0393	0.0559	0.01441	2.57	52
54	689.72	52.70	0.1099	51.200	132.266	0.10599	0.26381	0.7562	0.6725	2.8937	1375	668.1	0.191	0.0397	0.0551	0.01485	2.39	54
56	708.67	52.14	0.1057	52.568	131.661	0.10852	0.26190	0.7798	0.7091	3.0147	1338	665.0	0.187	0.0402	0.0543	0.01534	2.21	56
58	728.01	51.56	0.1017	53.964	131.012	0.11109	0.25992	0.8065	0.7507	3.1519	1302	661.8	0.182	0.0407	0.0535	0.01588	2.03	58
60	747.75	50.96	0.0977	55.392	130.313	0.11370	0.25787	0.8370	0.7984	3.3088	1264	658.4	0.178	0.0413	0.0527	0.01647	1.86	60
62	767.91	50.34	0.0938	56.855	129.560	0.11637	0.25574	0.8722	0.8538	3.4899	1227	654.9	0.173	0.0419	0.0519	0.01713	1.69	62
64	788.48	49.69	0.0900	58.358	128.745	0.11910	0.25351	0.9131	0.9188	3.7014	1188	651.3	0.169	0.0425	0.0511	0.01786	1.52	64
66	809.48	49.00	0.0862	59.906	127.860	0.12190	0.25117	0.9613	0.9962	3.9514	1148	647.4	0.165	0.0432	0.0503	0.01869	1.36	66
68	830.93	48.28	0.0825	61.505	126.896	0.12478	0.24871	1.019	1.090	4.252	1108	643.4	0.160	0.0440	0.0495	0.01963	1.20	68
70	852.82	47.52	0.0788	63.165	125.840	0.12776	0.24609	1.089	1.205	4.618	1066	639.0	0.155	0.0448	0.0488	0.02070	1.05	70
75	909.62	45.36	0.0697	67.656	122.671	0.13578	0.23867	1.363	1.659	6.027	951	626.5	0.143	0.0474	0.0472	0.02430	0.69	75
80	969.57	42.62	0.0603	72.945	118.309	0.14515	0.22921	2.005	2.726	9.198	816	609.5	0.129	0.0512	0.0466	0.03046	0.36	80
85	1033.07	38.41	0.0493	80.262	111.006	0.15811	0.21455	5.226	8.106	23.712	636	576.6	0.111	0.0582	0.0510	0.04701	0.10	85
87.76[c]	1069.99	29.19	0.0343	94.364	94.364	0.18355	0.18355	∞	∞	∞	0	0.0	—	—	∞	∞	0.00	87.76

*Temperatures on ITS-90 scale   [a]Triple point   [c]Critical point

TECHNICAL RESOURCES

Evaporative Condenser Engineering Manual

Introduction

The objective of a mechanical refrigeration system is to remove heat from a space or product, and to reject that heat to the environment in some acceptable manner. Evaporative condensers are frequently used to reject heat from mechanical refrigeration systems. The evaporative condenser is essentially a combination of a water-cooled condenser and an air-cooled condenser, utilizing the principle of heat rejection by the evaporation of water into an air stream traveling across the condensing coil.

Evaporative condensers offer important cost-saving benefits for most refrigeration and air-conditioning systems. They eliminate the problems of pumping and treating large quantities of water associated with water-cooled systems. They require substantially less fan horsepower than air-cooled condensers of comparable capacity and cost. And most importantly, systems utilizing evaporative condensers can be designed for a lower condensing temperature and subsequently lower compressor energy input, at lower first cost, than systems utilizing conventional air-cooled or water-cooled condensers.

The Refrigeration System

A schematic of a basic vapor compression system is shown in **Figure 1**. The corresponding heat transfer processes can be represented on a plot of pressure versus enthalpy as shown in **Figure 2**.

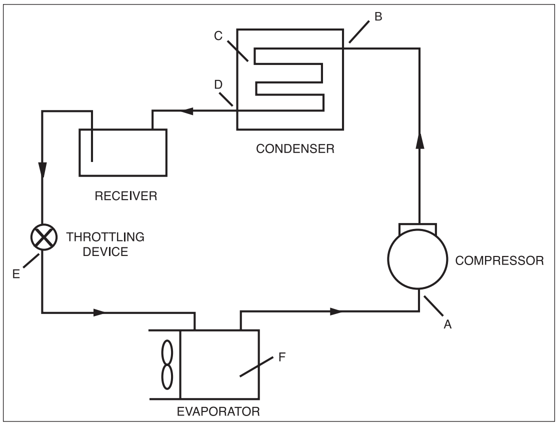

Figure 1. Vapor Compression Refrigeration System

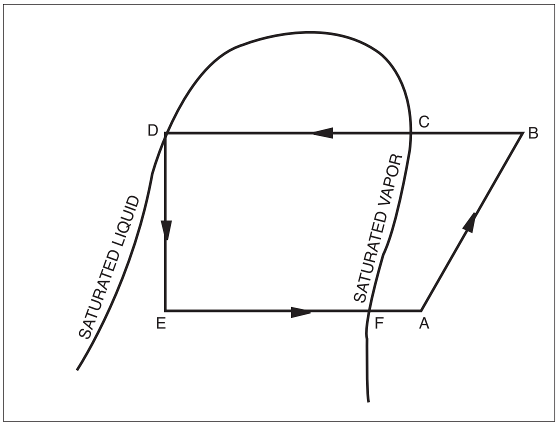

Figure 2. Pressure-Enthalpy Diagram for Compression Refrigeration System

Refrigerant vapor enters the compressor from the evaporator at a slightly superheated condition (A) and is compressed to the condensing pressure (B). The amount of suction gas superheat (F-A) is a function of the type of evaporator and the heat absorbed from the atmosphere as the gas travels along the suction line from evaporator to the compressor.

The compressed and further superheated vapor enters the heat rejection device (condenser) at Point B, where the superheat is quickly removed and the saturated vapor state (Point C) is reached. From Point C to Point D, condensation of the refrigerant occurs at constant pressure until the refrigerant reaches a saturated liquid state at Point D.

There may be some subcooling of the liquid refrigerant near the outlet of the evaporative condenser, but this is quickly dissipated in the drain line from the condenser to the receiver, and in the receiver itself. The drain line and the receiver contain both refrigerant liquid and vapor, and where these two phases coexist, it is impossible for the liquid temperature to remain below the saturation temperature. Therefore, the lower heat content of the subcooled liquid condenses some of the refrigerant vapor until an equilibrium condition is reached at a saturated temperature corresponding to the condensing pressure. So, from a practical standpoint, the refrigerant liquid going to the evaporator should be saturated as represented by Point D. The only exception to this is when a separate subcooling device is used to subcool the liquid after it leaves the receiver.

The refrigerant liquid at Point D is passed through a throttling device (orifice, capillary, or valve) where the pressure is reduced at constant enthalpy to the system suction pressure at Point E. The refrigerant at Point E consists of liquid and vapor, the vapor resulting from the "flashing" of some of the liquid in order to cool the remaining liquid from condensing temperature (Point D) to the evaporating temperature (Point E). The evaporation of the remaining liquid from Point E to Point F represents the useful work of heat pickup in the evaporator.

Refrigeration Heat Rejection Systems

"Once-Through" Condensing System

Water, because of its availability and heat transfer characteristics, has long been the principal medium used for heat rejection from refrigeration and air conditioning systems.

The simplest heat rejection system is one using city, well or surface water directly through a refrigerant condenser and then dumping that water into the sewer, to the ground, or back to the surface water source. The heat removed in the condenser is dependent upon the temperature rise and the flow rate of the water. For an average heat rejection of 15,000 BTUH/TR of refrigeration and a water temperature rise of 20°F in the condenser, approximately 1.5 USGPM of water per ton must be supplied to and wasted from the refrigerant condenser.

This "once-through" type of system at one time was used almost universally for refrigerant condensing. However, the increasing cost of water, high sewerage charges, and restrictions on thermal pollution have made this type of system uneconomical and obsolete.

Refrigerant Condenser and Cooling Tower

One of the early modifications to the "once-through" system was the addition of a cooling tower to permit recirculation of the cooling water and thus conserve water. In a cooling tower, the heated water from the condenser is brought in contact with air, and a small portion of the water is evaporated into the airstream. For each pound of water evaporated, approximately 1,000 BTU are removed from the remainder of the recirculated water. Therefore, only 15 lb/hr, or 0.03 USGPM of water is used per ton of refrigeration, a theoretical savings of 98% of the water required by the "once-through" system. In actual practice, however, the savings is approximately 95%, because a small amount of water must be "bled off" from the system in order to control the concentration of impurities in the recirculated water.

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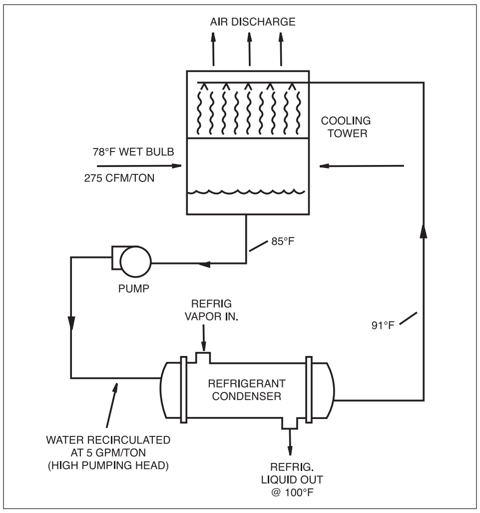

Figure 3. Refrigerant Condenser with Cooling Tower

The temperature of the water leaving the cooling tower is determined by the ambient air wet-bulb temperature. In most areas, design wet-bulb temperatures are such that the temperature of the water leaving the cooling tower is substantially higher than well or surface water temperatures (see **page J8** for geographical wet-bulb data). Therefore, to compensate for the higher cooling water temperature and the additional step of heat exchange introduced by the cooling tower, the condenser water circulation rate and the design condensing temperature often must be increased in comparison to a "once-through" system.

Figure 3 shows a typical arrangement for a cooling tower/refrigerant condenser system. The recirculated water flow rate of 5 USGPM/TR of refrigeration and the 6°F water temperature increase are representative of those existing in an ammonia refrigeration system. The 100°F condensing temperature is about the practical minimum that could be obtained at a 78°F design wet-bulb temperature. Since the pump must circulate water through the refrigerant condenser, cooling tower and interconnecting piping, relatively high pumping head is required.

Halocarbon refrigerant systems may be and usually are designed for somewhat higher condensing temperatures than ammonia systems. This permits a higher water temperature rise through the condenser, but increases the compressor horsepower. Water circulation is normally 3 USGPM/TR versus 5 to 6 USGPM/TR required for an ammonia system.

Air-Cooled Condensers

The air-cooled condenser is another type of heat rejection device used for refrigeration and air conditioning systems.

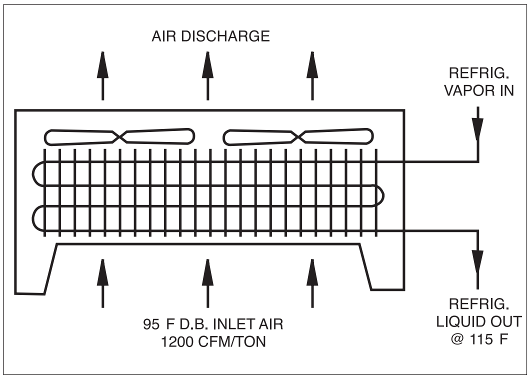

Figure 4. Air-Cooled Condenser

Figure 4 shows a typical air-cooled condenser. Since it does not utilize the evaporative principle, the amount of cooling in the air-cooled condenser is a function of the ambient dry-bulb temperature. Design dry-bulb temperatures are normally 15°F to 25°F higher than design wet-bulb temperatures, so condensing temperatures using air-cooled equipment will be at least that much higher than condensing temperatures using evaporative cooling, resulting in increased compressor horsepower.

Air-cooled condensers reject heat from the refrigerant by sensible heating of the ambient air that flows through them. The low specific heat of air results in a large volume flow rate of air required (approximately four times that of evaporative cooling equipment), with corresponding high fan horsepower and large condenser plan area. The net result of the use of an air-cooled condenser is a savings of water, but at the expense of increased power consumption by the compressor and the condenser.

Evaporative Condensers

Evaporative condensers reject heat from refrigeration and air conditioning systems while using minimum quantities of energy and water. As shown in **Figure 5**, water is pumped from the basin section and is distributed over the exterior of the condensing coil by a series of distribution troughs or spray nozzles. The flow rate of water need only be enough to thoroughly wet the condensing coil to provide uniform water distribution and prevent accumulation of scale. Therefore, minimum pumping horsepower is required.

A fan system forces air through the falling water and over the coil surface. A small portion of the water is evaporated, removing heat from the refrigerant, and condensing it inside the coil. Therefore, like the cooling tower, all of the heat rejection is by evaporation, thus saving about 95% of the water normally required by a "once-through" system.

The evaporative condenser essentially combines a cooling tower and a refrigerant condenser in one piece of equipment. It eliminates the sensible heat transfer step of the condenser water which is required in the cooling tower/refrigerant condenser system. This permits a condensing temperature substantially closer to design wet-bulb temperature, and consequently, minimum compressor energy input.

The temperatures and water flow rate shown in F**igure 5** are typical of an evaporative condenser applied to a refrigeration or air conditioning system at the designated design wet-bulb temperature with either ammonia or a halocarbon refrigerant. These conditions result in an economical evaporative condenser selection. However, a lower condensing temperature and lower compressor energy input could be obtained with a larger condenser at this same wet-bulb temperature.

The evaporative condenser offers a number of important advantages over other condensing systems:

1. **Low System Operating Costs –** Condensing temperatures within 15°F of design wet-bulb are practical and economical, resulting in compressor horsepower savings of 10% or more over cooling tower/condenser systems and more than 30% over air-cooled systems. Fan horsepower is comparable to cooling tower/condenser systems and is about one-third that of an equivalent air-cooled unit. Because of the low pumping head and reduced water flow, water pumping horsepower is approximately 25% of that required for the normal cooling tower/condenser installation.

2. **Initial Cost Savings –**The evaporative condenser combines the cooling tower, condenser surface, water circulating pump, and water piping one assembled piece of equipment. This reduces the cost of handling installing separate components of the cooling tower/condenser system.

   Since the evaporative condenser utilizes the efficiency of evaporative cooling, less heat transfer surface, fewer fans, and fewer fan motors required resulting in an initial material cost savings of 30 to 50% over comparable air-cooled condenser.

3. **Space Saving –** The evaporative condenser saves valuable space by combining the condensing coil and cooling tower into one piece equipment, and eliminating the need for large water pumps piping associated with the cooling tower/condenser system.

   Evaporative condensers require only about 50% of the plan area of a comparable sized air-cooled installation.

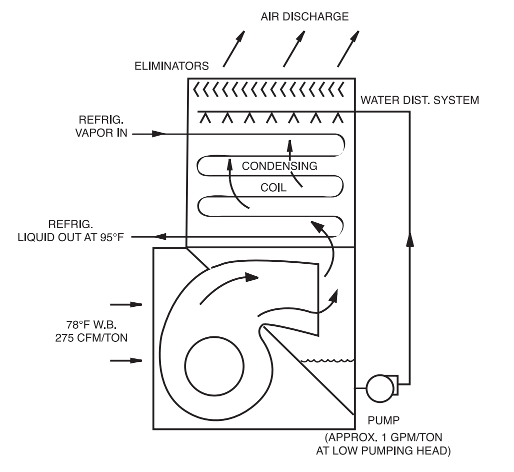

Figure 5. Evaporative Condenser

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Evaporative Condenser Operation and Installation Recommendations

Winterization

Most evaporative condenser installations operate year-round so consideration must be given to protect against freezing of the recirculated water in locations where the ambient temperature falls below 32°F. There are several protection methods that can be used.

Remote Sump

One method involves the use of an auxiliary sump tank with a spray water recirculating pump located within a heated space. **Figure 6** shows a typical arrangement of an evaporative condenser with a remote sump tank. All of the water in the condenser basin drains to the indoor sump whenever the recirculating pump is not operating. The indoor remote sump must be sized to provide an operating suction head for the pump and a surge volume above this operating level to hold all the water that will drain back when the pump is shut down. This includes water in suspension in the condenser and the water in the condenser basin during normal operation, plus that in the pipe lines between the condenser and sump. The amount of water in suspension plus the amount of water in the condenser basin during remote sump operation for BAC condensers is available on **page J226** or from your local BAC Representative.

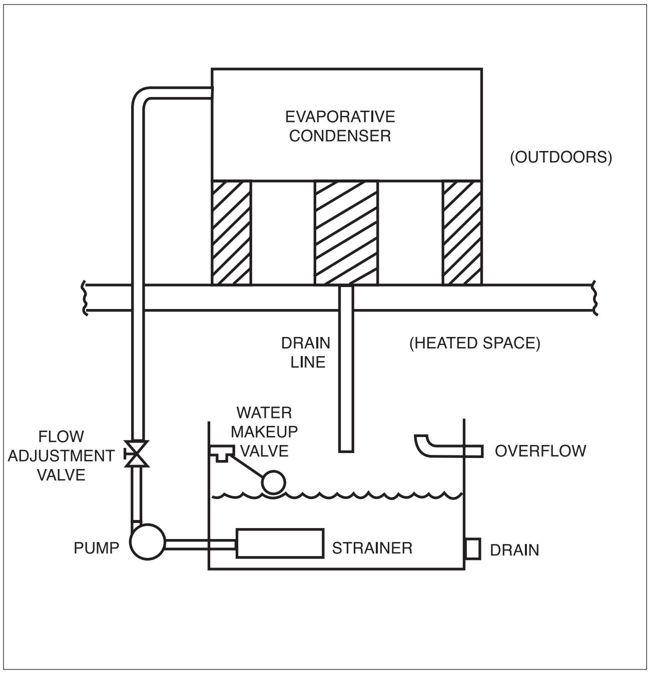

Figure 6. Evaporative Condenser With Remote Sump Tank

Recirculating water pumps for remote sump applications must be selected for the required flow at a total head which includes the vertical lift, pipe friction (in supply and suction lines) plus the specified pressure required at the inlet header of the water distribution system (should not exceed 2.0 psig for all evaporative condensers). A balancing valve must always be installed in the discharge line from the pump to permit adjusting flow to the condenser.

Basin Heaters

Occasionally, because of the condenser location or space limitations, a remote sump application may be impractical. In such cases, electric heaters or steam coils can be installed in the condenser basin to prevent freezing at low ambient temperatures when the condenser is completely idle. In addition, the pump suction line, pump, and pump discharge pipe (up to overflow connection) should be traced with heating tape and insulated.

Capacity Control

Most refrigeration and air conditioning systems are subject to wide load variations and substantial changes in ambient temperature conditions. Where refrigerant control requires a reasonably constant condensing pressure, some form of capacity control is required.

Fan Cycling

Fan cycling is the simplest method of capacity control on evaporative condensers. This method can result in relatively large fluctuations in condensing pressures, however. On ammonia systems, most evaporators are fed by high pressure or low pressure float valves or float switches which are less sensitive to variations in head pressure. On this type of system, fan cycling of the evaporative condenser will usually provide satisfactory capacity control on the high side of the system. This is particularly true on larger ammonia systems, where the evaporative condenser may have several fan motors which can be cycled in steps.

Halocarbon systems generally utilize evaporators controlled by thermal expansion valves. A reasonably constant pressure differential across the thermal expansion valve is required for its proper operation. Therefore, this type of system requires a closer degree of evaporative condenser capacity control than can be obtained with fan cycling.

Two-Speed Fan Motors

The number of steps of capacity control can be doubled by using two-speed fan motors in conjunction with fan cycling. This is particularly useful on single fan motor units which normally have only one step of capacity control using simple fan cycling.

Normally the two-speed fan motor will be selected so that the low speed is half of the full speed, such as 1800/900 rpm. An evaporative condenser will deliver approximately 58% of its rated capacity at half speed operation.

An additional benefit of two-speed fan motors is reduced fan horsepower at low speed. Brake horsepower varies as the cube of the fan speed, so the unit will use only about one eighth of the full load brake horsepower when operating at low speed. Maximum load and maximum wet-bulb temperature occur infrequently, so the unit will be operating at half speed and hence sharply reduced brake horsepower much of the time.

Another benefit of two speed motors is that when an evaporative condenser is operating at low speed it will have substantially lower operating sound levels. The sound pressure levels of both centrifugal and propeller fan evaporative condensers will be reduced by four to ten decibels, depending on the sound frequency.

BALTIGUARD™ Fan System

The BALTIGUARD™ Fan System consists of two standard single-speed fan motor and drive assemblies. One drive assembly is sized for full speed and load, and the other is sized approximately 2/3 speed and consumes only 1/3 the design horsepower. This configuration allows the system to be operated like a two-speed motor, but with the reserve capacity of a standby motor in the event of failure. As a minimum, approximately 70% capacity will be available from the low horsepower motor, even on a design wet-bulb day. Controls and wiring are the same as those required for a two-speed, two-winding motor. Significant energy savings are achieved when operating at low speed during periods of reduced load and/or low wet-bulb temperatures.

BALTIGUARD PLUS™ Fan System

The BALTIGUARD PLUS™ Fan System builds on the advantages of the BALTIGUARD™ Fan System by adding a VFD on one motor.

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Independent Fan Operation

The independent fan option consists of one fan motor and drive assembly for each fan to allow independent operation, adding redundancy and an additional step of fan cycling and capacity control to models with more than one fan.

Variable Frequency Drives

Precise capacity control and energy savings are achieved with the BAC variable frequency drive (VFD) option. VFDs offer a more efficient and durable way to reduce fan speed compared to fan cycling, fan discharge dampers, or mechanical speed changers. The inherent ability for VFDs to provide soft starts, stops, and smooth accelerations prolongs the mechanical system life (fans, motors, belts, bearings, etc.). Sound levels are also reduced at lower fan speeds, and start-up noise is eliminated with the soft start feature. See section E for information on BAC's enclosed control and variable frequency drive offerings.

NOTE: An inverter duty motor is required for all models operating with a variable frequency drive.

Modulating Fan Discharge Dampers

Modulating fan dampers, located in the fan discharge of centrifugal fan units, provide an infinite number of capacity control steps. Modulating dampers also affect a reduction in fan motor horsepower which is approximately proportional to the reduction in CFM as the dampers move toward the closed position.

- **Single Coil Circuit Units** – On a single circuit condenser, a condensing pressure sensing element is located in the compressor discharge line or in the receiver (see **Figure 7**). The pressure controller is electrically connected to a damper motor, and when condensing pressure changes, a signal is sent to the damper motors to reposition the dampers and provide more or less airflow as required.
- **Multiple Coil Circuit Units** – On multiple circuit condensers where it is necessary to control condensing pressures for two or more circuits, a spray water temperature sensing controller, located in the basin, is substituted for the condensing pressure controller. Maintaining spray water at approximately summertime temperatures will indirectly provide control of condensing pressures on the multiple condenser circuits. Even with a very light load on one circuit, the condensing temperature in that circuit cannot fall below the spray water temperature.

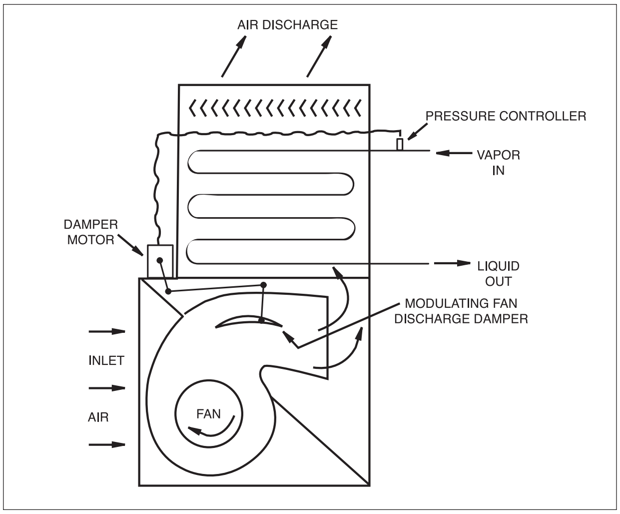

Figure 7. Evaporative Condenser With Modulating Fan Discharge Dampers (Single Coil Circuit Unit)

NOTE: This system will not provide control if the basin is drained for dry condenser operation in winter.

Dry Operation

During winter operation, when the refrigeration load may be reduced and the ambient air temperature is far below the design conditions, the evaporative condenser may be operated dry, i.e., without recirculated water flow. This reduces the capacity of the unit to more nearly match the reduced load.

Dry operation of an evaporative condenser is intended to be a seasonal process. Water pump cycling should not be used for capacity control. Condenser capacity changes greatly with and without spray water, so that this method of control often results in short cycling of the recirculating pump. In addition, alternate wetting and drying of the condenser coil promotes formation of scale on the condensing surface.

Evaporative condensers should not be operated dry in sub-freezing ambient temperatures while the recirculated water is stored in the basin of the unit. The flow of cold air through the unit may freeze the water, even if electric heaters or steam coils have been provided for freeze protection. These heaters are designed to prevent freezing only when the pumps and fans are idle. Furthermore, air turbulence created by the fans will blow water throughout the interior of the unit, and cause icing on the cold surfaces. It is recommended that the evaporative condenser be completely drained of water when dry operation is desired.

Condenser Piping

See **page J181**.

Purging and Purge Piping

Source of Non-Condensables

Air and other non-condensable gases collect in refrigeration systems from several sources:

1. Poor evacuation of a new system prior to charging.
2. A leak into the system low side if operation is at pressures below atmospheric.
3. Failure to evacuate completely after part of a system has been open for repair.
4. Chemical breakdown of oil and/or refrigerant.

If permitted to accumulate, non-condensables in the system cause high condensing pressures and, therefore increased power input to the compressors.

Checking the System for Non-Condensables

To check the system for non-condensable gases, first close the valve in the liquid line running from the receiver to the evaporator (king valve), then pump down the system slightly, enough to assure that if any non-condensables are present they are pumped over to the high side. Immediately after pump-down, close the discharge valve on the compressor. Operate the evaporative condenser for at least two hours or until the water temperature in the basin or remote sump is the same as the entering wet-bulb temperature. Then the temperature corresponding to the pressure in the evaporative condenser should correspond, or nearly so, to the wet-bulb temperature of the entering air. If this temperature is higher than the wet-bulb temperature by more than 2°F, the system has an excessive amount of non-condensables. (Be sure that all gauges are accurate when checking for non-condensables.)

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Purge Connections

Purging at the high point of the system can only be effective when the system is down. During normal operation the non-condensables are dispersed throughout the high velocity refrigerant vapor and too much refrigerant would be lost when purging from this high point.

However, purging at the condenser coil outlet can be effectively accomplished during system operation. The non-condensables will carry through the condensing coil with the refrigerant liquid and vapor and tend to accumulate in the condensing coil outlet header and connection where the temperature and velocity are relatively low.

In the BAC condenser coil design, the refrigerant outlet connection is tangent to the top of the coil header so non-condensables cannot trap in the header. A 1/2" or 3/4" purge connection should be cut into the top of the liquid outlet along the horizontal run (for a refrigerant connection size less than 4", a purge valve may be provided with the BAC condenser; contact your local BAC Representative for confirmation). Each connection must be valved so that each coil can be purged separately.

Purge Piping

All of the purge connections on the condenser coils plus the purge connection in the receiver may be cross connected to a single purge line, which is connected to an automatic purger. However, only one purge valve should be open at a time. Opening two or more valves tied together equalizes the coil outlet pressures and the effect of the vertical drop legs is lost.

Location

In order to obtain specified performance from an evaporative condenser installation, it is essential that the unit or units be located so as to guarantee design airflow to each unit while minimizing recirculation of the discharge air.

A single condenser located outdoors will seldom pose any layout problem. However, multiple units or a single unit with a fan side facing an adjoining building or wall must be located with reference to the wall (or to each other) to allow ample space for airflow to the fans. **Figure 8** illustrates those dimensions which must be taken into consideration when locating evaporative condensers. BAC Representatives can provide specific location recommendations for the various models of BAC evaporative condensers that are available. Refer to layout guidelines on **page J88**. For PCC layout guidelines refer to **page J108**.

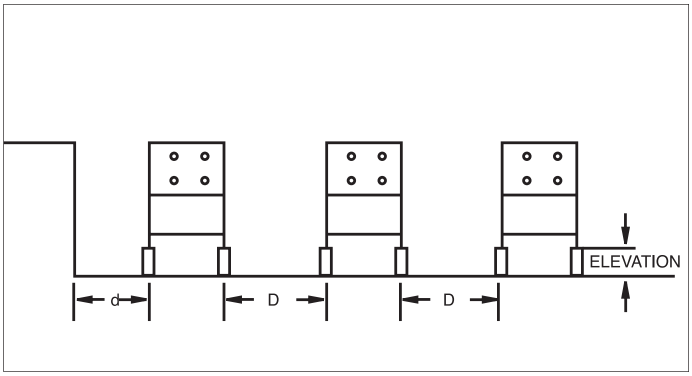

Figure 8. Condenser Spacing Parameters

NOTE: In **Figure 8**, the top (discharge) of the condenser should be at the same or higher level than an adjoining building or wall in order to minimize recirculation caused by down draft between the condenser and wall. Such a down draft might be created by winds blowing across the condenser discharge towards the wall. If for some reason, it is not possible to raise the condenser to the level of the top of an adjoining building or wall, a discharge hood can be used on centrifugal fan condensers (see **Figure 9**). The hood increases the discharge air velocity and elevates the point of discharge to a height where recirculation is minimized. Elevating the condenser increases the area for airflow from beneath the unit and permits placing the condensers closer together or closer to an adjoining wall. However, there is no spacing advantage to elevations greater than 10 feet in this respect.

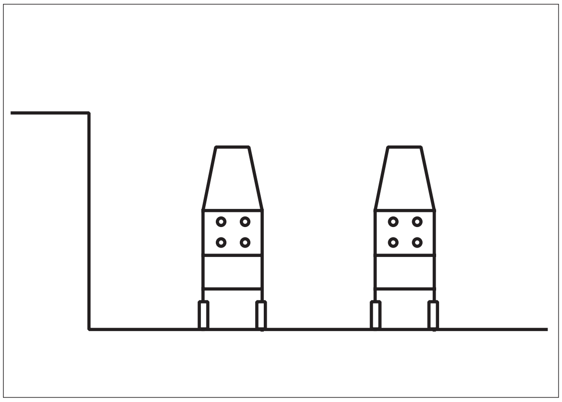

Figure 9. Discharge Hoods to Increase Discharge Air Velocity

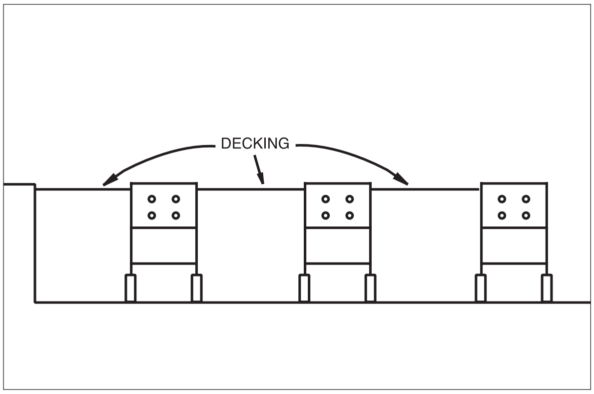

Figure 10. Decking Between Condenser and Wall or Between Condensers

Occasionally, the minimum spacing cannot be provided. By "decking over" between the condensers or between a condenser and an adjoining wall (providing a solid surface between the air discharge and air intakes, **Figure 10**), the condenser spacing can be decreased accordingly.

Condenser installations involving large capacities and/or multiple units do not lend themselves to the application of rigid layout guidelines. Some such installations virtually create their own environment and all potential problems of airflow and recirculation are magnified. In some cases, it may be necessary to increase the design wet-bulb temperature for which the condensers are selected. It is recommended that the layout parameters of any installation other than a single unit on an open roof be reviewed by the local BAC Representative.

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Recirculated Water System

An evaporative condenser obtains its ability to condense the refrigerant by evaporating a portion of the water recirculated over the condensing coil. As the water evaporates, any impurities present in the supply water remain in the unit. The concentration of impurities increases rapidly, and continues as long as the unit is in operation.

In addition, any impurities in the air (such as chemical fumes in an industrial area or salt air near the coastline) will be absorbed by the recirculated water, resulting in a corrosive solution.

To prevent an excessive build-up of impurities in the recirculated water, it is recommended that water be removed or “bled” from the unit at a rate at least equal to the amount of water being evaporated. In many localities this constant bleed and replacement with fresh water will keep the concentration of impurities in the system at an acceptable level. Note: In addition to any bleed or chemical treatment, all systems must be treated for biological contaminants.

An evaporative condenser will evaporate approximately 3 USGPM of water per 100 tons of refrigeration. Allowing an equal quantity for bleed, total water consumption is approximately 6 USGPM per 100 tons of refrigeration.

Most evaporative condensers that are furnished with a factory-installed recirculating pump (or pumps) are also furnished with a water bleed line and flow adjusting valve. Units furnished for remote sump application must have a bleed line and valve installed at the remote sump. It is important to keep the bleed lines operative and properly adjusted through periodic inspection. The water removed through the bleed line will more than pay for itself through increased unit life.

If the condition of the water and/or the air is such that continuous bleed will not control scaling or corrosion, the recirculated water must be treated. A reputable local water treatment company should be consulted to analyze the system water and recommend proper treatment. See the appropriate *Operation and Maintenance Manual* available at www.BaltimoreAircoil.com.

Most evaporative condensers are constructed of galvanized (zinc-coated) steel, and any chemical treatment must be compatible with this material. Chemicals should be fed into the recirculated water on a continuous metered basis to avoid localized high concentration which may cause corrosion. Batch feeding of chemicals does not afford adequate control of water quality, and is not recommended.

When acid treatment is required, it is essential that the acid be accurately metered into the recirculated water, and the concentration properly controlled. Acid should not be fed directly into the cold water basin; it must be fed into the recirculated water piping so it will mix thoroughly before reaching the basin.

Special Applications

Desuperheaters

A desuperheater is an air-cooled finned coil usually installed in the discharge airstream of an evaporative condenser. **Figure 11** shows a typical arrangement. Its primary function is to increase the condenser capacity by removing some of the superheat from the discharge vapor before the vapor enters the wetted condensing coil. The amount of superheat removed is a function of the desuperheater surface, condenser airflow and the temperature difference between refrigerant temperature and the temperature of the air leaving the condenser. Practically, the application of a desuperheater is limited to reciprocating compressor ammonia installations where discharge temperatures are relatively high (250°F to 300°F).

It is economically impractical to provide a desuperheater on an evaporative condenser with enough heat transfer surface to remove all of the superheat in the ammonia refrigerant. Therefore, complete superheat removal is never attained under design conditions of load and ambient wet-bulb temperature with the standard desuperheater coils furnished by evaporative condenser manufacturers. The anticipated capacity increase on an ammonia condenser with a standard desuperheater is in the area of 10% rather than the 16% theoretically possible.

Occasionally, where condenser space is limited, the addition of a desuperheater may permit a smaller plan area unit. However, with the numerous size increments available in today's evaporative condensers, such instances are rare. The air-cooled desuperheater is not as efficient as wetted condenser surface, so it is more economical to select a condenser with additional wetted surface to achieve greater capacity.

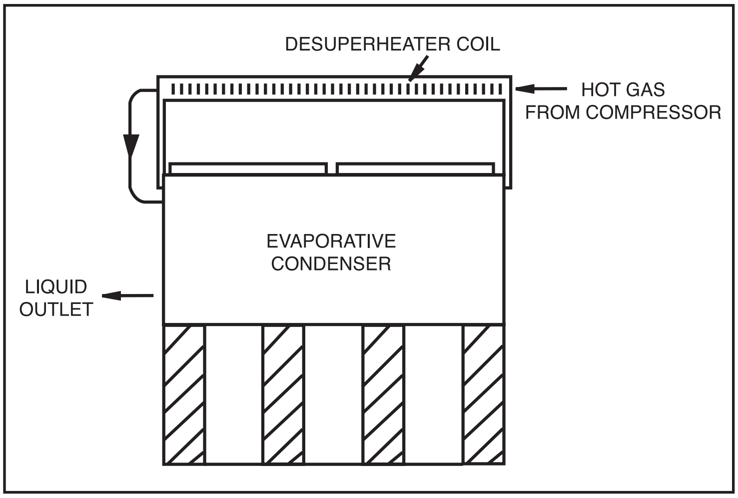


Figure 11. Evaporative Condenser with Desuperheater Coil

Desuperheaters have been recommended by some manufacturers to assist in oil removal from the ammonia vapor and also to minimize scaling of the upper tubes of the wetted condensing coil by reducing entering refrigerant gas temperatures to the wetted coil.

For oil removal, an oil separator is installed between the desuperheater coil and the wetted condenser coil. The theory is that cooling of the hot discharge refrigerant vapor will promote condensation of the oil vapor from the refrigerant-oil mixture and separation of oil from the refrigerant in the oil separator. This claim has merit. However, there is normally no control over the amount of heat removed from the refrigerant vapor in the desuperheater coil. At less than design load or wet-bulb temperature, the desuperheater coil often becomes a condensing coil, and when liquid refrigerant mixes with liquid oil, separation becomes quite difficult.

Evaporative Condenser Engineering Manual

Today there are many oil separators with high efficiencies for removing oil from the hot discharge vapor as it leaves the compressor. The oil separator can be located in the engine room where it can be monitored by the operating engineer and where it is not exposed to the ambient temperatures that would cause refrigerant condensation. From the scaling standpoint, the presence or absence of a desuperheater is immaterial. The primary factor that determines the tendency to form scale on the wetted coil of an evaporative condenser is the external surface temperature of the coil. At the inlet of the wetted coil where only hot refrigerant vapor exists, the internal heat transfer coefficient is quite low. Despite the high vapor temperatures at the inlet (250°F to 300°F), the low internal coefficient reduces the rate of heat transfer through the coil/tubes at that point. The resulting coil surface temperature at the inlet is not appreciably different from the coil surface temperature in the condensing portion of the coil. Therefore, scaling in an evaporative condenser becomes primarily a function of adequate water distribution over the coil, proper bleed-off to prevent concentration of solids, and proper water treatment where water conditions are particularly bad.

The increasing use of screw compressors for industrial refrigeration systems further obsoletes the use of a desuperheater. The screw compressor is an oil seal, oil cooled unit, with the cooled oil injected into the compressor in contact with the refrigerant vapor. Larger, efficient, de-mister type oil traps furnished as part of the screw compressor package minimize problems of oil carryover. Because the cooled oil is in direct contact with the refrigerant vapor, discharge temperatures are relatively low on water-cooled screw compressors (160°F to 190°F), and even lower on refrigerant liquid injected screw compressors (approximately 120°F). Consequently, any capacity gain of a desuperheater used on a screw compressor installation is negligible.

Refrigerant Liquid Subcooling (Halocarbon Systems)

In the case of air conditioning or refrigeration systems, the pressure at the expansion device feeding the evaporator(s) can be substantially lower than the receiver pressure due to liquid line pressure losses. If the evaporator is above the receiver, the static head at the evaporator is less than at the receiver, which further reduces the pressure at the expansion device.

A refrigerant remains in liquid form only as long as the liquid pressure is at or higher than the saturation pressure corresponding to its temperature. Any pressure reduction in the liquid line between the receiver and the expansion device causes flashing or vaporization of some of the liquid. The presence of this flash gas will cause erratic operation of the thermal expansion valve and reduce the valve capacity, sometimes to the point of starving the evaporator.

To avoid liquid line flashing where the above conditions exist, it is necessary to subcool the liquid refrigerant after it leaves the receiver. The minimum amount of subcooling required is the temperature difference between the condensing temperature and the saturation temperature corresponding to the pressure at the expansion valve. To determine the degree of subcooling required, it is necessary to calculate the liquid line pressure drop including valves, ells, tees, strainers, etc., and add to it the pressure drop equivalent to the static head loss between the receiver and the thermal valve at the evaporator, if the evaporator is located above the receiver.

The static head loss due to a vertical rise in the liquid line is a function of the refrigerant density. At normal condensing temperatures, the static head loss is approximately 0.50 psi per foot rise for R-22.

As an example of the calculation to determine the amount of subcooling required, assume an R-22 system designed for 105°F condensing temperature (210.7 psig) with a thermal valve fed evaporator 25 feet above the refrigerant receiver.

Assume that detailed calculations of friction pressure drop indicate a line loss of 8.0 psi. The static head loss for a vertical rise of 25 feet (12.5 psi), plus 8 psi friction pressure drop, results in a total pressure drop of 20.5 psi. So the pressure at the expansion valve is 210.7 - 20.5, or 190.2 psig, and the saturation temperature corresponding to 190.2 psig is 98°F. Therefore, the minimum amount of subcooling to prevent flashing is 105°F (condensing temperature) minus 98°F, or 7°F.

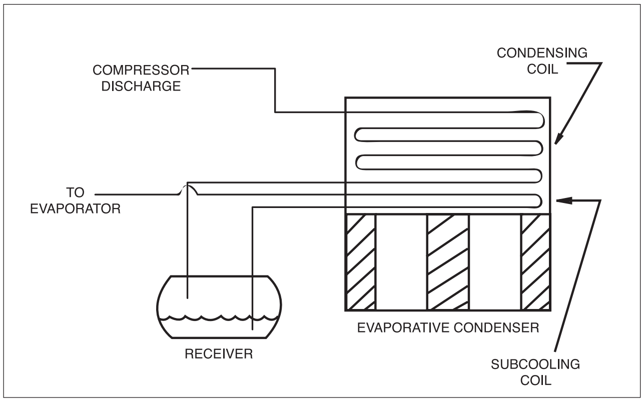


Figure 12. Recommended Piping for Evaporative Condenser with Liquid Subcooling Coil

Some compressor manufacturers publish their compressor ratings based on a fixed amount of subcooling at the thermal expansion valve. Subcooled liquid at the expansion valve of the evaporator does increase system capacity since it increases the refrigeration effect per pound of refrigerant circulated. But the increase is relatively small and seldom justifies the cost of the subcooling device and piping for this reason alone. However, where compressor ratings based on subcooled liquid are used, the specified amount of subcooling must be added to that required for liquid line pressure drop and static head loss.

One method commonly used for supplying subcooled liquid for halocarbon systems is to provide a subcooling coil section in the evaporative condenser, located below the condensing coil (see **Figure 12**). Depending upon the design wet-bulb temperature, condensing temperature, and subcooling coil surface, these sections will normally furnish approximately 10°F of liquid cooling. However, to be effective, the subcooling coil must be piped between the receiver and evaporator as shown in **Figure 12**.

NOTE: Increasing the evaporative condenser size over the capacity required for the system will not produce liquid subcooling. The increased condenser capacity will result only in lower operating condensing temperatures. The same result will occur if the condensing coil is piped directly to the subcooling coil.

Low temperature, multistage ammonia refrigeration systems often use liquid subcooling between stages for more economical operation. However, subcooling coils in an evaporative condenser are seldom, if ever, used with an ammonia refrigeration system for several reasons:

1. Design condensing temperatures are generally lower with ammonia, thus limiting the amount of subcooling that can be obtained.
2. The density of ammonia liquid is approximately 37 LBS/ft^3, less than half that of the normally used halocarbons, and static head losses are proportionately less.
3. The expansion devices and system designs normally used for ammonia systems are less sensitive to small amounts of flash gas.
4. The high latent heat of ammonia (approximately 480 BTU/lb versus 70 BTU/lb for R-22) results in comparatively small amounts of flash gas with a liquid line properly sized for low pressure drop.

Evaporative Condenser Engineering Manual

Multiple Circuit Condenser Coils

The coil in a single condenser can be split in sections to provide a number of individual circuits. A multiple circuit coil is used primarily with the common halocarbon refrigerant (R-134a, R-22, R-404A, R-507) on small air-conditioning or refrigeration systems with two or more reciprocating compressors. The reason for this is that proper oil return to the compressors can be a problem on these systems, and it is good design practice to isolate each compressor.

In general, the halocarbon refrigerant are highly miscible with oil, the degree of miscibility being a function of the refrigerant, the type of oil, the pressure and temperature of the mixture. During normal operation, some oil is lost from the crankcase of the reciprocating compressor and this oil travels around the refrigerant circuit with the refrigerant. It is essential that the oil lost from the compressor be returned to it.

In order to avoid oil return problems, it is common practice on the smaller (200 tons and below) halocarbon refrigeration and air-conditioning systems to design independent refrigerant circuits where two or more reciprocating compressor systems are involved. In order to use a single evaporative condenser, the condenser coils can be split internally to accommodate the capacities of the individual systems.

This practice is not followed with R-717 (ammonia) systems. Oil and ammonia are practically immiscible so that most of the oil carried over from the reciprocating compressors can be removed with discharge line oil separators and returned either directly to the individual compressor crankcase or to an oil receiver and then to the compressor crankcase.

If multiple compressor halocarbon systems are not designed with isolated circuits, an oil return system must be provided to return oil to each compressor crankcase.

Auxiliary Cooling Using Condenser Basin Water

During normal evaporative condenser operation, the recirculated spray water is maintained at a temperature some point higher than the inlet air wet-bulb temperature and lower than the condensing temperature. The exact recirculated water temperature is determined by these two operating parameters. Therefore, this water can be considered as a source of relatively cool fluid for auxiliary cooling requirements on refrigeration plants, such as jacket cooling for reciprocating and rotary compressors, jacket cooling for air compressors and vacuum pumps, and oil cooling for screw compressors.

Water is taken from the basin of the condenser or the remote sump and is pumped to the source of heat, usually by a separate pump (see **Figure 13**). In most cases, only a fraction of the evaporative condenser flow rate is required for cooling purposes. The water flows through the heat source, increases in temperature, and is then returned to the condenser basin or remote sump. The heated water then mixes with the basin water producing a mixture temperature somewhat higher than the normal recirculated water temperature. An increase in temperature of the recirculated water by virtue of an external cooling load has the effect of reducing condensing capacity, but the penalty is relatively small. Consult your local BAC Representative for specific evaporative condenser performance data on systems utilizing basin water for auxiliary cooling.

Using a portion of the recirculated spray water for external cooling purposes is an effective and simple concept. However, there is a significant drawback to this cooling system that does not always make it desirable. An evaporative condenser characteristically behaves as an air washer, stripping dirt and dust particles from the air circulating through it, and holding them in suspension in the recirculated water. Consequently, this can create serious clogging of compressor jackets or heat exchanger tubes. Frequent cleaning of the heat exchanger or sophisticated filtering equipment is usually required.

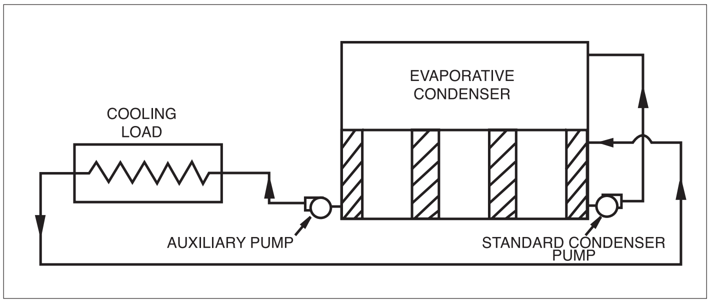


Figure 13. Auxiliary Cooling Using Condenser Basin Water

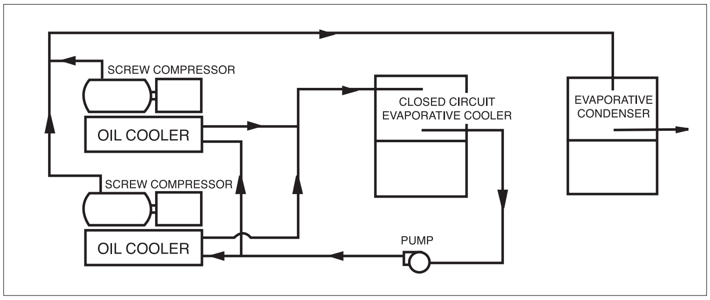


Figure 14. Evaporative Condenser With Closed Circuit Cooling Tower for Fluid Cooling: Cooling Oil Coolers for Refrigeration Screw Compressors

Closed Circuit Fluid Cooling

To eliminate the problem of system contamination associated with using spray water for auxiliary cooling, BAC recommends that a closed system be used for that cooling whenever possible. A separate closed circuit cooling tower, or a split circuit coil in the evaporative condenser, with one circuit for condensing the refrigerant and the other for cooling the liquid, are two good solutions.

As an example, a closed circuit cooling tower could be used to cool water or glycol solution for oil coolers of refrigeration screw compressors. **Figure 14** shows a typical arrangement. This is the ideal cooling system because it provides the following important advantages:

1. Provides closed loop cooling, which precludes the contamination of system fluid.
2. Provides independent control of the condensing and water-cooling systems by separating these two functions into two or more units.
3. Permits the evaporative condenser to be operated as an air-cooled condenser in cold weather, thus minimizing freeze up problems.

It is important to note that if the closed circuit cooling tower is installed in a freezing climate, an antifreeze (glycol) solution must be used instead of water. If a closed circuit cooling tower coil containing water is not provided with a supplementary heat load after shutdown, and is exposed to ambient temperature below 32°F, the water could freeze and rupture the coil. Other winterizing precautions similar to those described earlier in this manual for evaporative condensers apply equally to closed circuit cooling towers.

A separate closed circuit cooling tower for fluid cooling cannot always be justified, particularly on smaller installations. For instance, on refrigerated plants involving only one or two water-cooled screw compressors, it may be more economical to furnish an evaporative condenser with a split circuit coil, with one circuit for condensing refrigerant and the other isolated for fluid cooling. This approach lacks one of the features of the separate unit arrangement, i.e., the fluid cooling and condensing functions cannot be controlled independently. Both functions are handled within the same unit, but the heat rejection capacity of the unit must be controlled by either the condensing pressure or the leaving fluid temperature. Consequently it is necessary to sacrifice close control of one of these parameters, usually the leaving fluid temperature.

Using an evaporative condenser for both condensing and fluid cooling also limits the permissible inlet and outlet fluid temperatures on the fluid cooling circuit. Careful engineering analysis is required to establish satisfactory temperature criteria and properly select the evaporative condenser. Consult your local BAC representative for specific recommendations on split circuit evaporative condensers.

Evaporative Condenser Engineering Manual

Thermosyphon Oil Coolers

Thermosyphon oil coolers (TSOC) operate as unique high-temperature chillers using high-pressure liquid ammonia saturated at 70°F to 95°F (21°C to 35°C), and evaporating in the TSOC at the system condensing pressure 70°F to 95°F (21°C to 35°C). This is made possible by using a gravity feed recirculation refrigerant system based on drawing liquid ammonia from a receiver or auxiliary liquid supply. The liquid source is at condensing pressure and located about 6 to 8 ft (1.8 to 2.4 m) above the TSOC. This source is connected directly via low-pressure drop piping to the tube side of the TSOC shell and tube heat exchanger (see Figure 1).

The oil to be cooled is piped through the shell-side of the cooler. When the oil entering the cooler is warmer than the saturated liquid temperature, some of the ammonia liquid will boil at the saturated temperature within the tubes, cooling the oil. Vapor generated in the TSOC tubes will rise through the refrigerant return line, which is connected to the liquid receiver above the liquid level.

The vapor bubbles in the return line lower the density of the return liquid/vapor to approximately 3 lb/ft^3 (48 kg/m^3). The supply liquid line, which contains only liquid ammonia, is heavier, weighing about 37 lb/ft^3 (592 kg/m^3).

The weight imbalance between the two legs induces a thermosyphon refrigerant flow that will be in excess of the oil cooler load requirement. The excess liquid returns with the vapor up to the receiver vessel. The liquid drops into the receiver and the vapor is vented to the condenser inlet.

When a TSOC is operating properly, the refrigerant inlet and return lines will be at the same temperature.

Two problems that can cause the TSOC to lose oil-cooling capacity and/or stop cooling entirely.

The first problem, the gradual loss of cooling capacity, may occur on any TSOC application, but is generally found on those ammonia systems that have screw compressors and some older reciprocating compressors with less efficient (non-coalescer) mesh-type oil separators. Coalescing oil separators typically permit minimal oil carryover of 5 to 10 ppm by weight (pound of oil per pound of ammonia pumped). Mesh oil separators will allow more carryover, on the order of 30 to 100 ppm, which may result in 6 to 20 times the oil carryover as with screw compressors.

Oil is virtually immiscible with ammonia. Because it is heavier than liquid ammonia, it will be located at the bottom of any ammonia liquid vessel, including the ammonia in high-pressure receivers and auxiliary TSOC receivers. If the supply of ammonia for TSOCs is taken from the bottom of these vessels, then some oil may be drawn into the TSOC, where it will settle to the bottom, logging the lower tubes and reducing the TSOC capacity by preventing these tubes from participating in the cooling process.

When cooling loss occurs, close the liquid supply to the TSOC, pump out the remaining liquid ammonia, then close the return line. Next, stop the unit and drain the oil from the bottom drain connections on the TSOC heads, but not the shell that contains the oil being cooled. This should clear the problem, but it may require periodic draining every few months or so.

When the problem requires weekly draining, then more serious action is indicated. The oil carryover rate is out of control and the low-side evaporators, level switches and pressure regulators are probably also oil logged. When this occurs, evaluate the oil carryover, track the amount added to reciprocating and screw compressors and the amount drained from the low side of the system. Chances are that oil carry over is extreme and an oil management system is indicated.

An oil management system can include a special “downstream coalescing separator” located between the reciprocating compressors and the condenser. This separator can be designed to remove oil in the range of 5 to 10 ppm carryover, equivalent to that of screw compressors. The oil can be collected in an oil receiver, properly filtered and directed back to the reciprocating compressor crankcases via float level control for automatic handling. This method will rapidly pay for itself considering the savings of the cost of labor, the cost of new oil and the disposal of used oil.

The second problem is that the TSOC units work well for months and then, all at once, one or more coolers in a large plant with many TSOCs connected to a single supply source stop cooling. Obviously, the oil overheats and the screw compressors shut down on high oil temperature. Generally, this occurs with a season change—even mild season changes.

The problem is neither with the TSOC nor with the oil. It is because the TSOC is tied into the same receiver with any number of other TSOCs. This is not bad. It is done all the time. However, the piping for the return lines to the receiver must be respected. The premise is that the thermosyphon principle operates on minimal pressure differences (the 6 to 8 ft [1.8 to 2.4 m] height). One of the primary rules is that the vapor generated in the TSOC must return to the condenser inlet at the same condensing pressure.

Figure 2 shows the proper way to pipe the return on multiple TSOC systems. It is imperative that each TSOC return reaches the receiver return header without influence from the other coolers or they may interfere with each other. This may result in spilling liquid refrigerant down a neighbor's return line, causing the fine pressure balance to be upset and stopping the TSOC refrigerant flow.

If there are multiple TSOCs and one unit quits cooling, look up at the TSOC return lines. It may be that several of the TSOC returns are manifolded into a horizontal line that rises several feet before entering the auxiliary receiver. This is the problem.

The returns will have to be repiped in accordance with the intent of Figure 2. Each TSOC return is individually connected into a return header, located above the receiver liquid level and sloping toward the receiver. Each return must connected to the header by entering from above, so that the liquid return from one TSOC cannot interfere with any other.

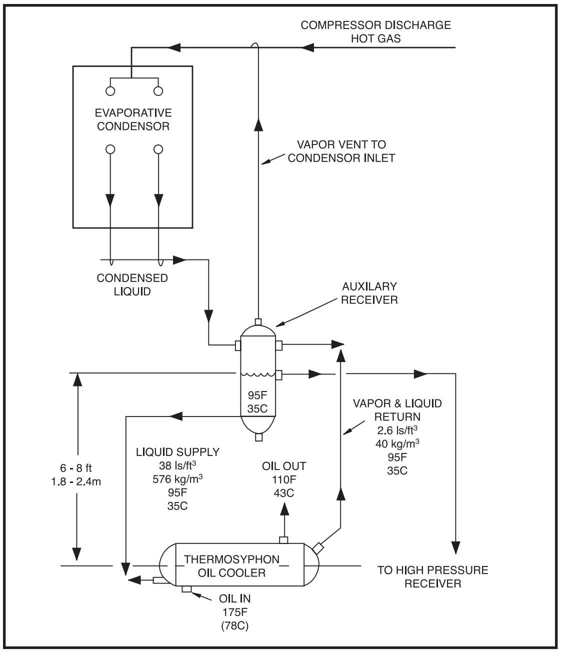


Figure 1. A Basic Flow Diagram of a TSOC

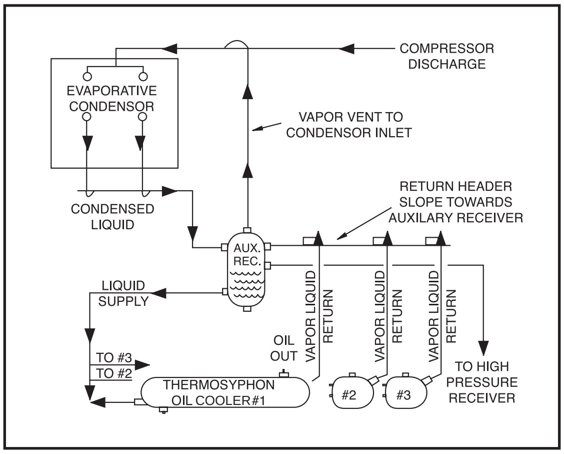


Figure 2. Multiple Thermosyphon Piping

NOTE: Rudy Stegmann, P.E., President of The Enthalpy Exchange. Williamsburg, VA.

Remote Sump Tank Selection for a Closed Circuit Cooling Tower or Evaporative Condenser

NOTE: This section provides instruction in the selection of a remote sump tank for a closed circuit cooling tower or evaporative condenser only. For information on sizing a remote sump tank for an open circuit cooling tower, see **page J178**.

Remote sump tanks are used on evaporative cooling systems to provide a means of cold water basin freeze protection during cold weather operation. The remote sump tank is usually located in a heated, indoor space, and may preclude the need to winterize the cold water basin. A remote sump tank must provide sufficient storage to accommodate the suction head for the pump plus a surge volume to hold all of the water that will drain back to the tank when the pump is shut down. The surge volume includes:

- Piping Volume: Water in the piping between the unit and the remote sump.
- Water in Suspension: Water within the spray distribution system and water falling through the coil/fill section.
- Cold Water Basin Volume: Water in the cold water basin during normal operation.

Tables 2 through **7** provide the volume of water in suspension plus the water volume in the cold water basin, labeled as Spray Water Volume. **Table 8** can be used to calculate the volume of water in the piping between the unit and the remote sump, including riser and drain piping for applications where piping is Schedule 40 PVC. For specific information for your application, contact your local BAC Representative.

On remote sump applications, the standard float valve(s) and strainer(s) and pump are omitted from the cold water basin and a properly sized outlet connection is added. The end user should supply a pump that meets the following factors:

- Total static head from the remote sump tank operating level to the inlet of the evaporative equipment.
- Pipe and valve friction losses.
- The required water pressure at the inlet of the spray distribution system should not exceed 2.0 psig for all Closed Circuit Cooling Towers and Evaporative Condensers.
- Required flow rate as shown in **Tables 2** through **7**.

A valve should always be installed in the pump discharge line so that the water flow can be adjusted to the proper flow rate and pressure. Inlet water pressure should be measured with a pressure gauge installed in the water supply riser near the equipment inlet. The valve should be adjusted to permit the specified inlet pressure, which results in the design water flow rate.
Accurate inlet water pressure and flow rate are important for proper evaporative equipment operation. Higher pressure (in excess of 10 psig) can damage to the spray distribution system. Lower pressure or low flow may cause improper wetting of the coils, which will negatively affect thermal performance, promote scaling, and may also cause excessive drift.

Tables 2 through **7** include the proper outlet size for each model. The remote sump outlet connection is located on the bottom of most units. On smaller Series V units, the connection is located on the end of the unit. To clarify the location of the remote sump outlet connection, refer to the appropriate unit print, available from your local BAC Representative.
Another effect of using a remote sump is that the operating weight of the evaporative unit is reduced (design changes, the omission of the integral spray pump, and/or changes in cold water basin volume can contribute to this deduct). Please refer to the **Table 1** on the following page for the operating weight deduct associated with a remote sump application.

Safety Factor

When selecting a remote sump tank, select a model with a net available volume that is 5% greater than the above defined surge volume. Engineering data on BAC's RS Remote Sump Tanks is provided below see **page H1** for more information on Remote Sumps. Note that the minimum operating level must be maintained in the remote sump tank to prevent vortexing of air through the tank's suction connection.

Model Number	Shipping Weights (lbs)	Maximum Weight (lbs)[1]	Maximum Storage Volume (gal)	"X" Minimum Operating Level[2]	Net Available Volume (gal)
RS 94	240	1,070	94	8 1/2"	72
RS 212	350	2,220	212	8 1/2"	163
RS 335	470	3,410	335	8 1/2"	257
RS 457	610	4,630	457	8 1/2"	351
RS 702	800	6,970	702	8 1/2"	539
RS 946	1,030	9,340	946	8 1/2"	727
RS 1390	1,260	13,470	1,390	8 1/2"	1,068

Table 1: RS Remote Sump Tank Engineering Data

NOTES:

1. Maximum weight is for tank filled with water to spillout.
2. Minimum operating level "X" is measured from inside bottom of tank.

Remote Sump Tank Selection for a Closed Circuit Cooling Tower or Evaporative Condenser

Closed Circuit Cooling Tower Model	Evaporative Condenser Model	Spray Water Volume[1,2] (gal)	Required Flow Rate (GPM)	Outlet Size[3] (in)	Weight Deduct (lbs)
FXV-0806x-x-x	CXVB-x-0806-x	303	290	6	110
FXV-0809x-x-x	CXVB-x-0809-x	466	500	8	220
FXV-0812x-x-x	CXVB-x-0812-x	628	719	10	210
FXV-0818x-x-x	CXVB-x-0818-x	953	859	10	260
FXV-1212x-x-x	CXVB-x-1212-x	908	859	10	260
FXV-1218x-x-x	CXVB-x-1218-x	1,378	1,300	12	480
—	CXVB-x-1224-x	1,816	1,718	(2) 10	520
—	CXVB-x-1236-x	2,756	2,600	(2) 12	960
FXV-288x-x-x	CXVT-x-1224-x and XECXVTx-1224-x	1,625	1,900	12	1,400
FXV-364x-x-x	CXVT-x-1426-x and XECXVTx-1426-x	2,000	1,900	12	1,400
—	CXVT-x-2424-x and XECXVTx-2424-x	3,250	3,800	(2) 12	2,800
—	CXVT-x-2826-x and XECXVTx-2826-x	4,000	3,800	(2) 12	2,800

Table 2. FXV/CXVB and CXVT Remote Sump Data

Hybrid Closed Circuit Cooling Tower Model	Spray Water Volume[1,2] (gal)	Required Flow Rate (GPM)	Outlet Size[3] (in)	Weight Deduct (lbs)
HXV-64X	600	715	10	560
HXV-66X	750	900	10	560

Table 3. HXV Remote Sump Data

Evaporative Condenser Model	Spray Water Volume[1,2] (gal)	Required Flow Rate (GPM)	Outlet Size[3] (in)	Weight Deduct (lbs)
VCA-122A to 191A	350	260	6	2,000
VCA-174A to 259A	425	330	8	3,220
VCA-261A to 322A	496	400	8	3,680
VCA-323A to 446A	753	600	10	5,560
VCA-300A to 512A	683	500	8	4,600
VCA-460A to 779A	1,037	760	10	7,020
VCA-662A to 1024A	1,367	1,020	(2)8	9,030
VCA-S700A to S884A	1,367	1,020	(2)8	9,030
VCA-920A to 1558A	2,073	1,540	(2)10	13,870
VCA-302A to 661A	871	610	8	4,720
VCA-526A to 1010A	1,322	920	10	7,450
VCA-605A to 1321A	1,743	1,240	(2)8	9,430
VCA-S870A to S1204A	1,743	1,240	(2)8	9,430
VCA-930A to 2019A	2,644	1,860	(2)10	14,870

Table 4. VCA Remote Sump Data

Closed Circuit Cooling Tower Model	Evaporative Condenser Model	Spray Water Volume - End Connection[1,2] (gal)	Spray Water Volume - Bottom Connection[1,2] (gal)	Required Flow Rate (GPM)	Outlet Size[3] (in)	Weight Deduct (lbs)
VF1-009-X	VC1- 10 to 25	25	—	35	2.5	180
VF1-018-X	VC1- 30 to 65	50	—	75	3	310
VF1-027-X	VC1-72 to 90	75	—	115	4	440
VF1-036-X	VC1-100 to 135	105	—	150	4	590
VF1-048-X	VC1-150 to 205	140	—	220	6	850
VF1-072-X	VC1-N208 to N230	360	—	305	6	2,250
VF1-096-X	VC1-N243 to N315	360	—	385	6	2,100
VF1-144N-X	VC1-N338 to N470	520	—	580	6	3,250
VF1-192-X	—	—	720	770	(2) 6	4,200[4]
VF1-288-N	—	—	1,040	1,160	(2) 6	6,500[4]
VF1-144-X	VC1-386 to 516	—	600	585	8	4,510[4]
VF1-216-X	VC1-540 to 804	—	710	835	10	6,560[4]
VF1-288-X	VC1-772 to 1032	—	1,360	1,170	10	8,170[4]
VF1-432-X	VC1-1158 to 1608	—	2,090	1,670	12	13,270[4]
—	VC1-C216 to C320	360	—	385	6	2,100
—	VC1-C339 to C469	520	—	580	6	3,250

Table 5. VF1 and VC1 Remote Sump Data

Closed Circuit Cooling Tower Model	Evaporative Condenser Model	Spray Water Volume[1,2] (gal)	Required Flow Rate (GPM)	Outlet Size[3] (in)	Weight Deduct (lbs)
VFL-012-X	VCL-016 to 035	40	45	3	350
VFL-024-X	VCL-038 to 079	95	94	4	550
VFL-036-X	VCL-087 to 120	200	142	4	290
VFL-048-X	VCL-134 to 155	250	192	6	600
VFL-072-X	VCL-167 to 234	385	284	6	720
VFL-096-X	VCL-257 to 299	405	384	8	1,740

Table 6. VFL and VCL Remote Sump Data

NOTES:

1. The spray water volume is based on the maximum operating water level in the cold water basin with no net drop leg included in the piping system below the unit outlet.
2. All remote sump unit volumes are based on bottom outlets sized except for VF1 and VC1 units as noted.
3. Outlet size is for remote sump applications only.
4. Weigh deduct based on bottom connection.

Remote Sump Tank Selection for a Closed Circuit Cooling Tower or Evaporative Condenser

Evaporative Condenser Model	Spray Water Volume [1,2] (gal)	Required Flow Rate (GPM)	Outlet Size[3] (in)	Weight Deduct (lbs)
PCC-x-0406x	133	100	4	720
PCC-x-0412x	265	200	6	1,130
PCC-x-0709x	389	270	8	2,230
PCC-x-0718x	793	560	10	3,530
PCC-x-1012x	675	500	8	3,070
PCC-x-1212x	798	610	10	3,070
PCC-x-1218x	1,207	920	12	4,220
PCC-x-1220x	1,341	1,025	12	3,770
PCC-x-1024x	1,350	1,000	(2) 8	6,140
PCC-x-2012x	1,350	1,000	(2) 8	6,140
PCC-x-1224x	1,596	1,220	(2) 10	6,140
PCC-x-1236x	2,414	1,840	(2) 12	8,450
PCC-x-1240x	2,682	2,050	(2) 12	7,540
PCC-x-2412x	1,596	1,220	(2) 10	6,140
PCC-x-2418x	2,414	1,840	(2) 12	8,450
PCC-x-2420x	2,682	2,050	(2) 12	7,540
PCC-x-2424x	3,192	2,440	(4) 10	12,280
PCC-x-2436x	4,828	3,680	(4) 12	16,920
PCC-x-2440x	5,364	4,100	(4) 12	15,080

Table 7. PCC Remote Sump Data

Closed Circuit Cooling Tower Model	Spray Water Volume [1,2] (gal)	Required Flow Rate (GPM)	Outlet Size[3] (in)	Weight Deduct (lbs)
PFi-0406N	117	60	4	210
PFi-0412N	210	130	6	560
PFi-0709N	205	180	6	980
PFi-0718N	446	370	10	1,470
PFi-1012N	381	340	8	1,180
PFi-1212N	490	410	10	2,680
PFi-1218N	861	610	12	3,400
PFi-1024N	763	680	(2) 8	5,490
PFi-2012N	763	680	(2) 8	5,490
PFi-1224N	980	820	(2) 10	5,370
PFi-2412N	980	820	(2) 10	5,370
PFi-1236N	1,721	1,220	(2) 12	6,800
PFi-2418N	1,721	1,220	(2) 12	6,810

Table 8. PFi Remote Sump Data

Nominal Pipe Size (in)	Gallons Per Linear Foot
2	0.174
3	0.384
4	0.662
6	1.503
8	2.603
10	4.101
12	5.822
14	7.04
16	9.193
18	11.636
20	14.461
24	20.916

Table 9. Schedule 40 Pipe Capacities - Not Applicable for Other Types of Piping

NOTES:

1. The spray water volume is based on the maximum operating water level in the cold water basin with no net drop leg included in the piping system below the unit outlet.
2. All remote sump unit volumes are based on bottom outlets sized as noted, except those models with separate columns, which are based on an end outlet sized as noted.
3. Outlet size is for remote sump applications only.

Example

An FXV-0806A-12D-K will be installed on a system that will also utilize an RS Remote Sump Tank. The system has been designed with 40 feet of 6" pipe that will be above the operating level of the remote sump tank. What is the correct RS Remote Sump Tank selection?

Solution: From **Table 2**, the spray water volume for an FXV-0806A-12D-K is 303 gallons.

From **Table 8**, the 6" pipe will contain 1.503 gallons of water per linear foot. The total volume contained in the 6" pipe is 40 feet x 1.503 gallons/foot = 60 gallons.

The total volume required is:

	Spray Water Volume	303 gallons
+	System Piping Volume	60 gallons
=	Total Volume	363 gallons

363 gallons x 1.05 (safety factor) = 381 gallons required.

From the remote sump tank engineering data available on **page H5**, the correct RS Remote Sump Tank selection is an RS-702, which has a net available volume of 539 gallons.

The Value of Maintaining Evaporative Cooling Equipment

Cooling Tower Maintenance and Upgrades Saves Time, Money, Energy, and Extends the Life of the Unit?

Evaporative cooling equipment enables owners and operators to take advantage of the operating cost savings inherent in water cooled systems. A well maintained cooling tower enables the entire cooling system to perform at optimum efficiency by conserving both energy and water.

A cooling tower is selected to provide a fluid (usually water) to a system at a design temperature and flow rate (USGPM). If the delivered temperature of the fluid to the system is higher than desired, system performance suffers.

Owners gain operating cost benefits when they implement a regular, comprehensive cooling tower maintenance program.

Today's building owners are constantly challenged to keep operating costs down. Therefore, owners are motivated to purchase system equipment that is energy efficient, reliable, and maintenance friendly. When properly maintained, water-cooled systems meet these objectives.

Series 3000 Cooling Tower

The cooling tower is often the forgotten component of the system when it comes to maintenance. A newly installed cooling tower reliably delivers the design fluid temperature and flow rate. However, the cooling tower needs routine inspection and maintenance to continue performing as designed, while extending the life of the cooling tower.

A Cost-Saving Opportunity

Owners and operators who have a working knowledge of cooling tower preventive maintenance and upgrade technology will get the most out of their cooling towers. Their efforts can yield beneficial results, including:

- Smooth and reliable operation
- Longer cooling tower life expectancy
- Consistent performance
- Increased thermal performance
- Lost performance restoration
- Less down time
- Water and energy savings

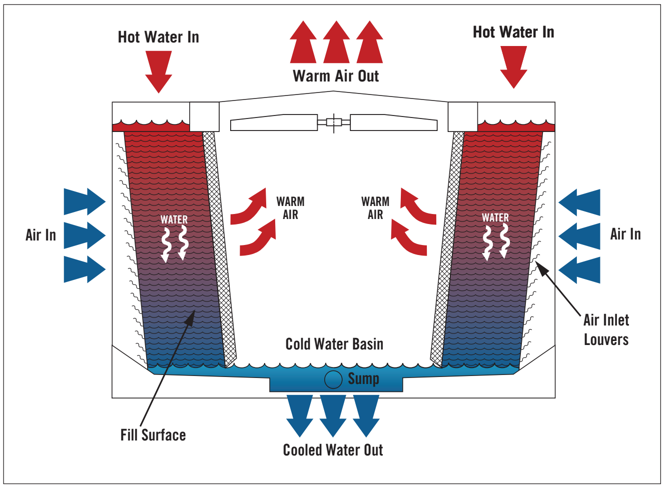
FXV Closed Circuit Cooling Towers

This document will explore routine maintenance and suggest ways to improve cooling tower performance.

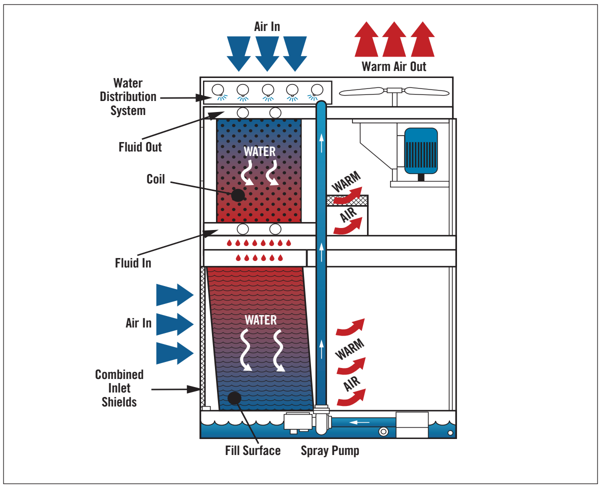
Cooling Tower Basics

In a cooling tower, warm water from the system is evenly distributed via a gravity or pressurized nozzle system directly over a heat transfer surface called "fill", while air is simultaneously forced or drawn through the fill, causing a small percentage of the water to evaporate. The evaporation process removes heat and cools the remaining water, which is collected in the tower's cold water basin and returned to the system (typically a water cooled condenser or other heat exchanger).

Similarly, in a closed circuit cooling tower/evaporative condenser, the heat is rejected indirectly from a fluid/vapor flowing through the coil section by spraying re-circulated water over the coil section, again evaporating a small percentage of the water in the process.



Cooling Tower



Closed Circuit Cooling Tower

The temperature at which the cooled fluid is returned to the system measures tower performance. This temperature can vary depending upon the actual cooling load, water flow, airflow, and the entering air conditions.

Preventive Maintenance

Performing routine preventive maintenance is paramount for consistently achieving the desired temperature and flow rate and plays an important role in maximizing cooling tower operating life.

To perform properly, all tower components must be kept clean and free of obstructions. Maintenance frequency depends mainly on the condition of the circulating water and the environment in which the tower is operating.

The Value of Maintaining Evaporative Cooling Equipment

Strainer

Strainers are important to cooling tower performance since they minimize contact between debris and the system components, preventing debris from reaching the condenser loop and pump. Strainers should be routinely inspected and cleaned. Some tower designs allow external access to strainers, permitting inspection during tower operation. All units except remote sump units are factory equipped with strainers. Be sure to contact your local BAC representative should you need a replacement strainer.

Inspecting a Cold Water Basin Strainer

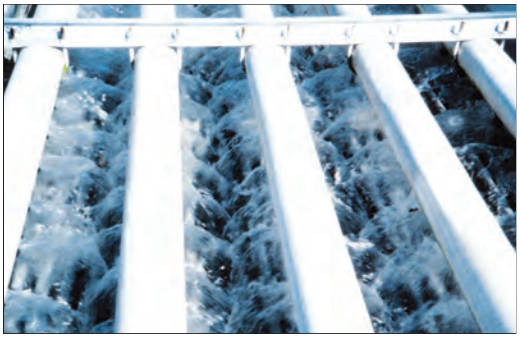
Hot Water Basin Strainer Cleaning (Series 1500 Cooling Towers Only)

Water Distribution

The water distribution system's role is to evenly distribute water over the fill or coil section via either a gravity distribution system or a pressurized spray system. If the heat transfer surface is not fully wetted, the nozzles need to be checked, cleaned, and if need be replaced.

In a gravity distribution system, the nozzles can be externally accessed, visually inspected, and cleaned by removing the hot water basin covers on the fan deck. Most pressurized spray distribution systems use nozzles and branches held in place by rubber grommets, which allow easy removal to clean and flush debris.

Gravity Water Distribution



Pressurized Spray Water Distribution

Cold Water Basin

Smart cooling tower design should facilitate debris removal from the cold water basin, since some debris will eventually make its way into the cooling tower. A well designed cold water basin is sloped toward the strainer to keep dirt from accumulating. The basin should be kept clean by occasionally flushing the dirt out of the system through the tower drain. Alternatively, you can install basin sweeper piping in conjunction with a filtration system, which automatically performs this maintenance. Water filtration saves maintenance costs by removing debris and unwanted particulates in the cooling water system, which in turn reduces the time required to clean the cold water basin. It also reduces water treatment cost, as water treatment chemicals tend to work more effectively in clean water. Foreign particles can absorb treatment chemicals, thus requiring the distribution of even more chemicals to properly treat the tower water.

Make-up Water Supply

Cooling tower water level is critical to reducing air entrainment, as well as conserving water. Though most of the water in the system is recirculated, some water must be added to replace the percentage lost by evaporation and bleed. Bleed is defined as the water that is discharged to prevent the accumulation of solids in the recirculated water. The make-up water system replaces the lost water via a mechanical float ball and valve assembly or an electric water level probe assembly (with solenoid valve). The make-up water supply pressure should typically be maintained between 15 psig and 50 psig to ensure proper valve shut-off and avoid "chatter." If the supply pressure is higher than 50 psig, install a pressure reducing valve.

Mechanical Water Level Control

Electric Water Level Control

The operating water level of the cooling tower will vary with system thermal load (evaporation rate), the bleed rate employed, and the make-up water supply pressure.

Bleed

To prevent the accumulation of solids in the recirculating water, the tower should be equipped with a bleed line, including a metering connection and globe valve, that is connected to a nearby drain. In a closed circuit cooling tower or evaporative condenser with a spray water pump, a metering valve to control the bleed rate should be provided at the pump discharge. While a manually adjusted bleed valve is the simplest system, getting the proper bleed rate can be a problem, as cooling tower loads vary throughout the day. A conductivity meter connected to a solenoid valve solves this problem by maintaining the proper cycles of concentration at all times. Also, it is recommended that a separate meter is installed to measure bleed volume, since less water is discharged to drain than supplied to the cooling tower. This may reduce sewer water charges.

The bleed rate should be adjusted to prevent an excessive build-up of impurities in the recirculating water. This is largely dependent upon the local water quality and the evaporation rate. Constant bleed and replacement with fresh water will prevent the accumulation of impurities. To obtain specific recommendations, contact a competent water treatment professional for your area.

Mechanical Drive System

The mechanical fan drive system has several components operating at high speed that should be checked regularly. Follow proper lock-out/tag-out procedures including locking out all motor disconnect switches before working on the mechanical system.

Mechanical Belt Drive System

The Value of Maintaining Evaporative Cooling Equipment

Cooling tower fans are typically driven by belt or gear drive systems. Both require routine maintenance to ensure reliable, trouble-free performance. Belt drive systems are popular, reliable, and offer single point adjustment. Proper belt tension is critical to ensure reliable operation. Gear drives also provide reliable operation, when properly maintained. However if a problem occurs, resolution may be more involved if a gear box rebuild or replacement is required. Oil level, oil quality, and shaft alignment should be checked regularly in accordance with the gear box manufacturer's recommendations. BAC offers both systems to meet user needs or preferences.

When starting up a new unit, lubrication for the fan shaft bearings is typically not necessary, since all units leave the factory already greased. However, for seasonal start-up, purge the fan shaft bearings with new grease (per manufacturer's recommendations). Fan shaft bearings should be lubricated every three months at a minimum. BAC's Automatic Bearing Greasers can be easily installed to enhance the life of the bearing and provide labor savings by eliminating monthly bearing maintenance. BAC's Cooling Tower Duty Motors have permanently sealed bearings, never requiring lubrication. Other non-BAC fan motors may require motor bearing lubrication as recommended by the manufacturer's instructions. For maximum life resulting in less motor failures, downtime and replacements, it is best to install motors with a "cooling tower duty" rating like that of BAC Cooling Tower Duty Motors. Motor bearings should be lubricated as recommended by the manufacturer's instructions.

The Importance of Clean Operation

Cooling tower components must be kept clean and free of obstructions. Neglecting the cooling tower will lead to higher than desired return water temperatures to the system, which will result in higher energy usage from two perspectives. First, the system (chiller) will consume more energy because it must operate at a higher than necessary condensing pressure (head) to satisfy the load. Due to the higher fluid temperatures provided by the cooling tower, as little as 2˚F (1.1˚C) higher temperature can result in 6% more energy consumption by the chiller. Second, the tower must operate longer at higher fan horsepower while trying to attain the design leaving water temperature.

Common Problems: Causes, Effects, and Solutions

Regardless of how often routine maintenance is performed, like any other mechanical component, problems may eventually arise. These include elevated leaving water temperatures, drift, and corrosion. Should any of these problems occur, follow the actions listed and contact your local BAC Representative or water treatment supplier for assistance.

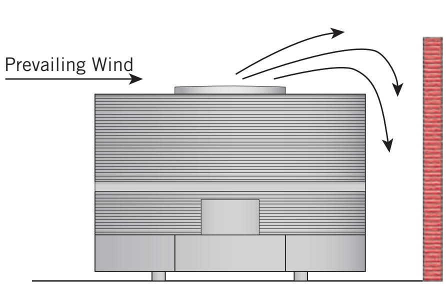
Check Cooling Load: If the actual cooling load exceeds the design load for which the tower was selected, the leaving water temperature will exceed the design specification.

Check Water Flow and Distribution: Visually inspect the water distribution system to ensure the spray nozzles are clean, are correctly installed, and are uniformly distributing the water over the fill. In counterflow towers, measure the pressure at the cooling tower inlet connection and compare it to the design pressure provided by BAC. For towers with a gravity distribution system, the operating level in the hot water basin (typically between 2 and 5 inches) will correlate to a specific flow rate.

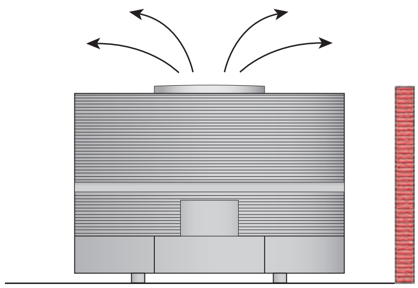
Inspecting Spray Nozzles

Check Air Flow: Cooling tower air inlets should be located in an unimpeded supply of fresh air. The cooling tower air discharge should also be at least as high as any surrounding walls to reduce the possibility of hot, moist discharge air being recirculated into the air inlets, creating artificially elevated entering wet-bulb and leaving water temperatures. To insure full design air flow, the cooling tower drive system must be adjusted according to the BAC's Operation and Maintenance Manual.

The cooling tower and surrounding area should be examined for air flow restrictions which may cause blockage of the air inlets. Check for clogging or improper distribution of water across the tower fill.



Incorrect Orientation of Tower and Neighboring Walls



Proper Orientation of Tower and Neighboring Walls

Check Ambient Conditions: Cooling towers are selected to produce the required leaving water temperature at the design cooling load and entering wet-bulb temperature. Whenever the actual entering wet-bulb temperature is higher than design conditions, the leaving water temperature will also be higher, which results in decreased efficiency.

Drift occurs as air flows through the cooling tower and carries water droplets out of the tower. Drift eliminators are installed in the discharge stream to remove water droplets from the air. In a properly maintained system, efficient eliminators will reduce drift loss to a negligible percentage of the design flow rate.

If excess drift occurs, check drift eliminators for proper installation, spacing, and overall condition. Examine the fill for even spacing to ensure there is no clogging or blockage, and check water and air flow as described above. Repair or replace eliminators as necessary.

Inspecting Coil

Inspecting Drift Eliminator

The Value of Maintaining Evaporative Cooling Equipment

Corrosion: Corrosion is always a concern with cooling towers because of their ability to wash the air of impurities. These impurities cause scale, corrosion, and can damage system components after long-term exposure.

If a constant bleed of the system is ineffective to combat scale or corrosion, water treatment may be necessary. A successful water treatment program should satisfy the specific guidelines set by the manufacturer, provide effective microbiological control, and be compatible with the system's materials of construction.

Potential airborne impurities and biological contamination (such as Legionella) should be controlled through the use of biocides, and such treatment should be initiated at system start-up and continued regularly. ASHRAE has taken proactive steps to understand and deal with Legionella through its popular publication, ASHRAE Guideline 12 – 2000, entitled "Minimizing the Risk of Legionellosis Associated with Building Water Systems". Visit www.BaltimoreAircoil.com to secure a copy of this important document. To obtain specific recommendations of water treatment programs, contact a competent water treatment supplier.

Performance Improvements

To enhance performance and longevity of the unit, structurally sound cooling towers can be retrofitted with upgrade kits to:

- Conserve energy
- Control capacity and redundancy
- Restore performance
- Facilitate easier and safer maintenance
- Increase capacity
- Reduce sound levels

To conserve energy, variable frequency drives (VFDs) can be added to control the fan motor speed and use only the amount of energy necessary to meet current operating requirements, thus reducing overall energy consumption. Installing an Energy-Miser®/Baltiguard™ Fan System by adding a second single speed motor to the drive system will maximize up time and also provide you with energy savings by operating at approximately 1/3 of the main motor horsepower. The Energy-Miser®/Baltiguard™ Fan System provides you with capacity control similar to a two speed motor. To improve water distribution performance, retrofit nozzle and grommet kits are available to replace older, smaller nozzles or troughs with large-orifice, clog-free nozzles. Access options such as platforms, ladders, and walkways can be added to facilitate easier and safer access for maintenance. BAC's OEM replacement fill kits easily replace the original fill that may be clogged with scale or debris. BAC's fill kits are designed to enhance thermal performance or to restore the lost thermal performance of your cooling tower. For sound sensitive applications, intake and discharge sound attenuation packages can be installed to reduce sound levels.

Installing Retrofit VersaCross Fill Kit

Access Platform and Ladder

Conclusion

Paying regular attention to the forgotten system component, the cooling tower, through a regular, comprehensive maintenance program can save time, money, and energy while increasing the tower's life expectancy. A well maintained tower is a candidate for retrofit kits designed to enhance performance and lengthen its life. Owners and operators can save time and money through preventative maintenance technology. If you are not regularly performing routine maintenance on your cooling tower, implement a comprehensive maintenance program today. For more information on how to get started, please contact your local BAC Representative.

In addition to maintaining your cooling equipment, please feel free to contact your local BAC Representative for:

- Free inspections
- Provide training on maintaining your cooling equipment
- Replacement parts
- Capacity upgrades
- Safety and access options
- Performance restoration
- Replacement units

TECHNICAL RESOURCES

Maintenance Checklist for:

Cooling Towers, Closed Circuit Cooling Towers, and Evaporative Condensers[1]

WARNING: Do not perform any service on or near the fans, motors, and drives, or inside the unit without first ensuring that the fans and pumps are disconnected, locked out, and tagged out.

Inspect and clean as necessary:	Start-Up	Monthly	Quarterly	Annually	Shutdown
Inspect general condition of the unit[2] and check unit for unusual noise or vibration	✓	✓			
Inspect cold water basin	✓		✓		
Flush water distribution system/inspect spray nozzles	✓		✓		
Drain basin and piping			✓		✓
Inspect air inlet louvers/combined inlet shields	✓	✓			
Check and adjust water level in basins	✓	✓			
Check operation of make-up valve	✓	✓			
Check and adjust bleed rate	✓	✓			
Inspect unit finish				✓	
Mechanical equipment system:	**Start-Up**	**Monthly**	**Quarterly**	**Annually**	**Shutdown**
Check belt condition	✓	✓			
Adjust belt tension[3]	✓		✓		
Lubricate fan shaft bearings	✓		✓		✓
Lubricate motor base adjusting screw	✓		✓		✓
Check and lubricate optional gear drive	See product specific O&M Manual for detailed instructions and schedule				
Check drive alignment				✓	
Check motor voltage and current	✓		✓		
Clean fan motor exterior	✓		✓		
Check fan motor for proper rotation	✓				
Check general condition of the fan	✓		✓		
Check and unplug fan drain holes (hollow blade fans)	✓		✓		
Check fan for uniform pitch			✓		
Check fan for rotation without obstruction	✓		✓		
Check and recoat steel shafts with RUST VETO®	✓		✓		✓

NOTES:

1. **Consult your product specific O&M Manual before conducting maintenance on the unit**. Recommended service intervals are the minimum for typical installations. Different environmental conditions may dictate more frequent servicing.
2. When operating in ambient temperatures below freezing, the unit should be inspected more frequently. Refer to the "Cold Weather Operation" section of the Operation and Maintenance Manual for more details.
3. Tension on new belts must be readjusted after the first 24 hours of operation and quarterly, thereafter.

Filtration Guide

Introduction

Often, owners and operators overlook the impact that evaporative cooling equipment efficiency can have on profits. Even a marginal improvement in the efficiency of evaporative cooling equipment, heat exchangers, and chillers can offer owners significant savings over the lifespan of the cooling system. Improving the water quality in the cooling loop is a simple, cost effective method of realizing efficiency gains.

In evaporative cooling equipment, airborne debris like silt is entrained in the fluid flow. Dirty make-up water can also contribute to the build-up of contaminants. Other issues may arise from scale that builds up and flakes off inside the tower, treatment chemical residue, and algae that can build-up and contaminate the circulation water. These are just a few sources of unwanted contaminants that can build-up over time and lead to poor water quality.

BAC recommends a mechanical filtration system and a water treatment program specifically tailored for each installation to ensure high water quality. Both must be used in order to effectively treat the water in a cooling system. Properly treating water in a cooling system leads to cost savings and higher efficiencies allowing evaporative cooling equipment to operate as specified by the manufacturer.

Benefits of Clean Water

1. **Reduced energy consumption**
   As little as a 1/16" layer of dirt, scale, or biological deposits on heat transfer surfaces results in a loss of cooling tower efficiency, increasing energy costs.
2. **Improved chemical performance**
   Dirty water requires more chemicals to treat than clean water because a build-up of solid contaminants provides a buffer that reduces the effects of treatment chemicals. Additional chemicals are then necessary.
3. **Lower maintenance cost**
   Frequently draining a tower and cleaning sediment increases labor requirements, and results in added costs to replace lost water in the system and provide additional chemicals.
4. **Improved productivity and less downtime**
   Fouling a cooling system slows production because machines cannot run efficiently. A fouled heat exchanger could take a system down for an extended period of time until repairs are complete, resulting in less production per day and lost profits.
5. **Control of biological growth that can lead to health problems**
   Legionella, bacteria that thrives in improperly maintained cooling tower environments, is particularly important to control because it poses significant health risks. Reducing outbreaks of the disease Legionellosis is discussed in ASHRAE Guideline 12-2000, entitled "Minimizing the Risk of Legionellosis Associated with Building Water Systems." Visit www.BaltimoreAircoil.com to secure a copy of this important document.

NOTE: Ultimately, achieving clean water on a daily basis when using a filtration system requires routine water analysis, an effective water treatment program, and a training program for maintenance employees. Water treatment programs are application specific, please contact your local water treatment specialist to diagnose the needs of a system.

Filtration Guide

Successful Filtration

A typical 200 ton cooling tower operating 1,000 hours a year may assimilate upwards of 600 lbs. of particulate matter into the water supply from airborne dust and makeup water. The tower basin or remote sump provides a perfect environment for unwanted particulate matter to settle and accumulate (ASHRAE handbook, 2008 Ch 39.13). The wet and warm conditions of the basin or remote sump encourage bacteria growth. Chemical water treatment does control the effects of these microbial organisms, but alone it does not serve to eliminate the habitat that promotes the proliferation of organisms. Using a mechanical filtration system does not supplant chemical treatment. Nonetheless, chemicals cannot reduce particle build-up. Reducing the build-up of particulate contamination, the breeding grounds for microbial organisms, can be achieved via proper mechanical filtration.

Successfully filtering cooling tower water depends on the system designed. Successful design is dependent on how well the owners and system designers understand their contaminant problems. Understanding the contaminant problem is a function of knowing the size and type of contaminants that must be filtered in order to achieve system protection. The method of filtration is generally cost driven; there exists a clear best choice in method but sometimes at a cost premium. Once the method of filtration is known, the most appropriate filtration equipment to filter the system can then be determined based on the properties of the contaminant.

NOTE: Mechanical filtration systems are not to be used alone. In addition to filtration, water treatment is necessary to ensure high water quality. For more information please see the "Water Quality Guidelines" section on **page J253.**

Methods of Filtration

The following methods of filtration are not to be confused with the use of pump suction strainers, which must be used on every cooling tower. Pump suction strainers are standard on properly designed cooling towers and are just the beginning of filtration for a system. Pump suction strainers are located on the outlets of units and prevent large debris, such as sticks and stones, from entering the system. BAC provides pump suction strainers standard on all units with the exception of remote sump applications.

Basin Cleaning

Basin cleaning is a common method of filtration that directly prevents solids accumulation in the unit basin or remote sump. One method of applying basin cleaning as a means of filtration involves drawing water from the unit basin/sump to the filter package and then pumping the filtered water directly back to the tower basin (**Figure 1**).

Without a mechanical system, basin cleaning is often done by hand using maintenance crews. This requires a high level of maintenance and is not as efficient as using a mechanical system. Furthermore, a mechanical system provides continuous maintenance while a maintenance crew can only provide interval maintenance; continuous maintenance ensures a cleaner system. Also, the maintenance crew faces health risks if the crew is cleaning a contaminated system. Basin cleaning is best achieved via a pattern of specialized nozzles that create a directed turbulence of flow designed to influence particles toward the basin cleaning package's pump intake. An important element to making this approach work effectively is adhering to the flow and pressure requirements (20 psi or 1.4 bar minimum at the nozzle header) of the chosen nozzles in order to achieve the necessary flow to sweep the solids in the basin/sump and prevent troublesome accumulation. Inadequate flow/pressure to these nozzles dramatically reduces their effectiveness and the ability of the system to direct solids toward the pump intake and into the filter. The size of a basin sweeping filtration package is based on the planned area of the unit's basin or remote sump.

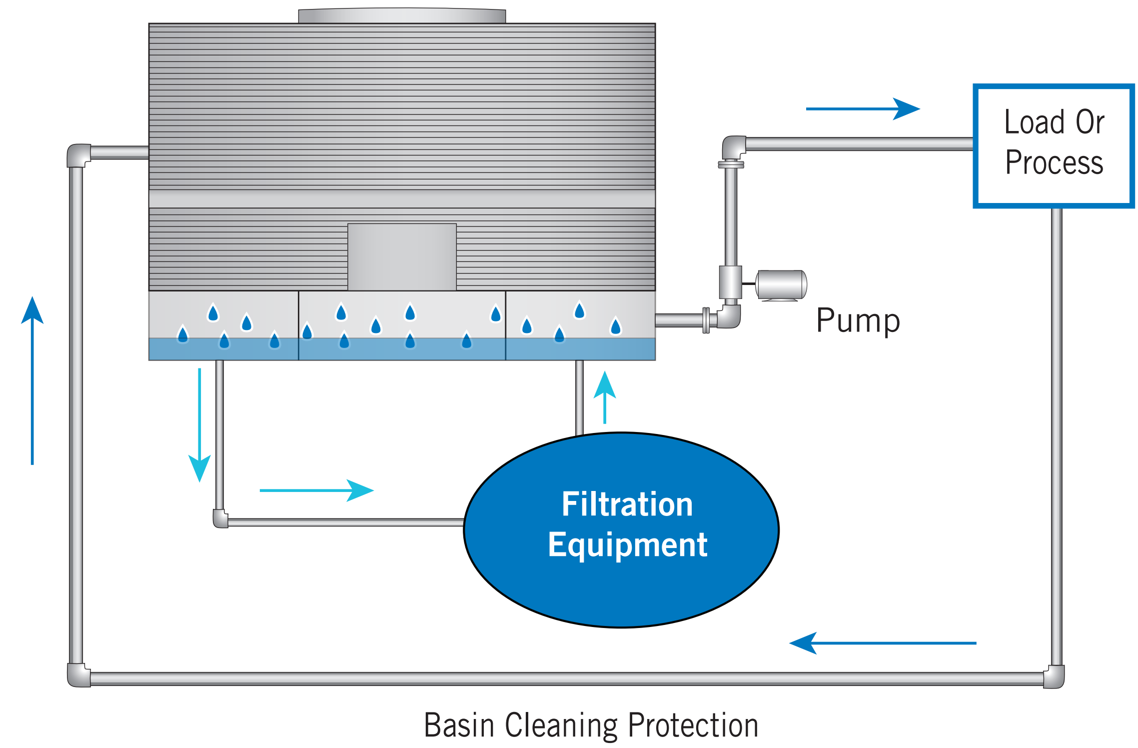


Figure 1. Basin Cleaning

Filtration Guide

A simple guideline is:

Water Depths	USGPM Filtration Flow Rate[1]
Less than 3 feet or 0.9 meters	1 USGPM per square ft (2.44 m^3/hr per m^2)
Greater than 3 feet or 0.9 meters	1.5 USGPM per square ft (3.66 m^3/hr per m^2)

NOTE:
1. **Refer to the submittal for the product specific flow rate.**

This approach takes control of getting the solids to the filtration system and virtually eliminates solids build up in the tower basin. However, basin cleaning does not directly filter the water that is pumped into the heat exchangers and chillers. From a maintenance standpoint, basin cleaning improves the cycles of maintenance for cooling towers but does not address maintenance issues in the heat exchangers or chillers. Full flow and side stream filtration are methods that do provide direct protection to the heat exchanger and chillers, but do not prevent solids accumulation in the tower basin.

Full Flow and Side Stream Filtration

Full flow and side stream filtration are the two most common methods that are used to directly protect the heat exchangers and chillers. Full flow filtration utilizes a filter installed after the cooling tower on the discharge side of the pump. This filter continuously filters the entire system flow, meaning that the filter must be sized to handle the system's design flow rate. Thus, a flow rate of 300 USGPM requires a filter sized to treat 300 USGPM. Full flow filtration reduces heat exchanger and chiller maintenance significantly and improves the operating cycles of the equipment as well. Full flow filtration is the preferred method of filtration but is not cost effective for systems with high flow rates. For example, a 400 ton cooling tower with a flow rate of 1,200 USGPM would require a filter sized to treat 1,200 USGPM. This requires a system that must be very large to accommodate the 1,200 USGPM flow rate; a system this large will incur high expenses. Also, for a system this large, decreases in flow rates may not be detected easily. This decrease could result in an increase in pressure on the pump discharge and not allow fluid to flow to the heat exchanger properly, leading to a decrease in heat transfer. Furthermore, full flow systems cannot run and be cleaned at the same time, which means that maintenance results in some planned downtime. Although full flow filtration reduces the overall solids concentration in the water pumped to the heat exchangers and chillers, this method does not address the problem of solids accumulation in the tower basin or remote sump.

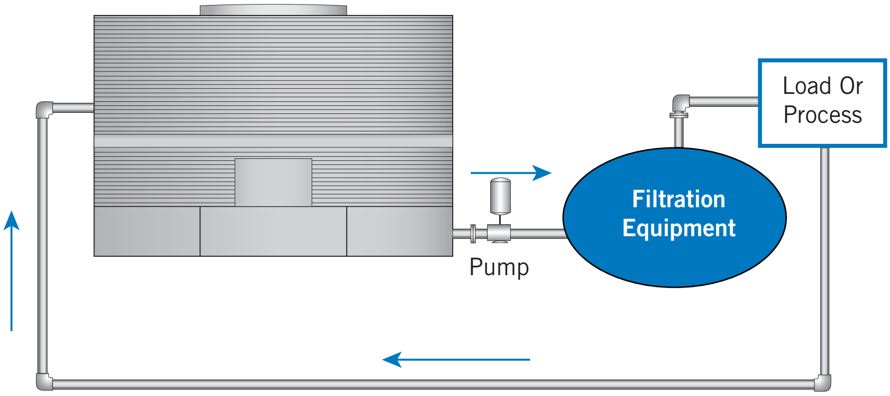


Figure 3. Full Stream Filtration

Side stream filtration is a cost-effective alternative to full flow filtration because it continuously filters a percentage of the flow instead of the entire flow. Side stream filtration can reduce maintenance and improve operating cycles of equipment in the cooling loop. This method involves removing particles at a higher rate than accumulation. The water is pumped from the cooling tower cold water basin, through the side stream filtration system, into the heat exchangers and chillers, and then returned back to the cooling tower basin. This method is used most often when full flow is extremely high, causing full flow filtration to be financially infeasible. One key advantage over full flow filtration is that the side stream filtration system can be cleaned without having to go offline, resulting in no planned downtime for maintenance. Like full flow filtration, this method reduces the overall solids concentration but does not address the problem of solids accumulation in the tower basin or remote sump.

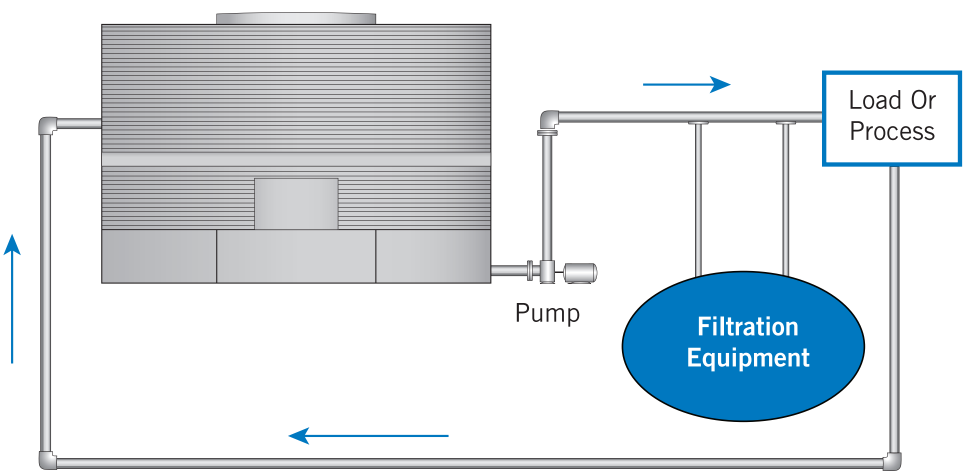


Figure 4. Side Stream Filtration

Properly sizing a side stream filtration system is critical to achieve optimum filter performance. An often used guideline is to size a filter that can handle a flow rate that turns the system volume over once an hour. This flow rate generally ranges from as low as 3% up to 10% and is typically determined by the turnover rate of the system volume per hour. For example, consider a 400 ton cooling tower with a flow rate of 1,200 USGPM. The estimated system volume will be approximately 3,500 gallons. In order to turn this system volume over once an hour, a 58 USGPM flow rate will be required, as demonstrated below.

Approximate system volume = 3,500 gallons

In order to turn the entire 3,500 gallon system volume over once an hour: 3,500 gallons/hr * 1 hr/60 min = 58 USGPM side stream flow rate.

A 58 USGPM side stream flow rate is 4.83% of the 1,200 USGPM flow rate for a 400 ton cooling tower (58 USGPM/ 1,200 USGPM * 100 = 4.833%). Side stream filtration percentages at 3% or less of the total circulation flow rate have been shown to severely damage HVAC systems, promoting fouling throughout the cooling loop. Therefore, the best designs avoid using low filter specifications. For the same level of purity, side stream filtration does bring the water to the same level of purity that full flow filtration does but the process just takes longer. Since only a percentage of the water is filtered at a time, some solids do bypass the filter and remain in the fluid flow, but eventually these solids reach the filter again and are removed as water is re-circulated through the cooling loop. Keeping in mind that the entire system volume is turned over once an hour, particulates that escape the filter the first time are caught in subsequent rounds of filtration.

Filtration Guide

At first glance it would seem that full flow is preferable over side stream filtration because full flow filtration, comparatively, reduces heat exchanger and chiller maintenance more significantly and creates larger improvements in the operating cycles of this evaporative cooling equipment. However, full flow filtration cannot be justified financially for systems with high flow rates and requires planned downtime for maintenance of the filtration equipment, making side stream filtration a more desirable choice in most applications. Regardless, side stream filtration easily improves the water quality to an acceptable level that will ensure proper protection of the heat exchangers and chillers. Neither the full flow nor side stream method of filtration addresses solids accumulation in the tower basin or remote sump.

The very best filtration practice is to employ basin cleaning (as discussed on **page J243**) along with full flow or side stream filtration. Basin cleaning ensures that particulates are directed towards the filter inlet and that these solids do not accumulate in the cooling tower basin. Once the particulates reach the filter inlet, the equipment chosen for full flow or side stream filtration will remove the remaining unwanted particulates, thus providing clean water to the heat exchangers and chillers. Using basin cleaning with full flow or side stream filtration directly protects the cooling tower, heat exchangers, and chillers, providing the ultimate reduction in maintenance while improving the efficiency of equipment in the evaporative cooling loop.

Common Filtration Equipment

Common filtration technologies that are applied to full flow and side stream HVAC applications include screen (self cleaning filters), centrifugal separators, cartridge filters, bag filters, sand media filters, and disc filters. Aside from proper filtration, the best filters require the least maintenance and use the least energy, satisfying cost efficiency.

Screen (Self Cleaning) Filters

Also known as self cleaning filters, strainers are used often in full flow filtration. Screen filters employ steel mesh screens that remove large, heavy particulates such as sediment. Bypass piping needs to be installed with screen filters to allow the screen to be removed for cleaning. In areas of poor water quality, screens should be oversized to provide a larger surface area to operate, which minimizes the frequency of maintenance related to not having a large enough screen. Screen filters have moving parts that allow a backwash cycle to self clean the filter. Because of these moving parts and how the screen filters are designed, they require frequent maintenance.

Centrifugal Separators

Centrifugal separators, commonly known as separators, are often used in full flow filtration. Separators create a vortex that spins particle contaminants out of the entering fluid. A downside to this turbulent spinning is that it causes separators to operate at a pressure loss, usually about 5 to 10 psi. A separator does not need to be replaced often because it is not trapping any particles that clog or damage its system, making separators an economical option for filtration. In the HVAC industry, separators are preferred over screen filters because separators require less maintenance and replacement, but are just as effective at achieving the proper level of filtration.

Cartridge, Bag, and Sand Filters

Cartridge filters, made of polypropylene (a plastic), trap particle contaminants as water passes through the filter media. One advantage of cartridge filters is that once the filter becomes dirty, an automatic backwash cycle is initiated to clean the filter. Nonetheless, these cartridge filters must be replaced over time as they wear out. Bag filters, generally made of polyester, are widely used in the HVAC industry because bag filters are low in cost. Like cartridge filters, bag filters must often be replaced. Sand media filters distribute contaminated water over a sand medium bed capable of filtering out particles. The sand filter steel media does not require regular replacement. Sand filters use an automatic backwash cycle to clean the filter media, which lends to fewer maintenance intervals.

Cartridge and bag filters are relatively inexpensive, but their filter elements are consumable and require regular replacement. This incurs high costs, as the owner must continuously replace the cartridges and bags along with paying for labor each time. In comparison, the media of sand filters does not have to be replaced as often, making sand filters less expensive in the long run. The sturdiness and self cleaning feature of sand filters further eliminate maintenance errors related to not replacing filters often enough or at the right time, a problem that can plague owners of cartridge and bag filters.

Disc Filters

Another side stream filtration technology is a disc filter. Disc filters, made of polypropylene, use a series of stacked discs compressed together that are grooved to filter a specific micron size. Like screen and sand filters, disc filters have an automatic backwash cycle for self cleaning, which provides reduced maintenance. Another advantage to using a disc filter is that it uses much less water than other self cleaning filters that utilize backwash cycles. These energy savings can be offset, however, by a comparatively higher pump horsepower required for disc filter backwash cycles. Furthermore, the discs are consumable elements that have to be replaced often. Nonetheless, disc filters are a viable option for side stream filtration.

Summary

The remainder of the article will focus on the specific characteristics of centrifugal separators and sand filters, currently the most commonly used filtration equipment in the HVAC industry. Due to the reduced maintenance requirements (resulting in lower operating costs) of separators, sand filters, and disc filters, owners typically prefer these filters over others. The disc filter is a newer technology that has proven successful and could eventually become as popular as separators and sand filters in the industry. Screen, cartridge, and bag filters have been found to require a high level of maintenance, which makes it difficult to justify these options as long term filtration solutions.

NOTE: Mechanical filtration systems are not to be used alone. In addition to filtration, water treatment is necessary to ensure high water quality.

Filtration Guide

Particle Size: Separators vs. Sand Filters

Centrifugal separators work well for both full flow and side stream applications. Sand filters are generally used for side stream applications as sand filters used for full flow can come at a considerable cost for high flow rate systems. The determination of whether to use a centrifugal separator or sand filter typically depends on the size of the particles to be removed, amongst other economic and design factors. The comparison between centrifugal separators and sand filters is addressed in greater detail in the **Appendix**.

When making a decision on which equipment to use, one item of focus is the size of the particles to be removed, because the two types of filtration equipment discussed here have distinct capabilities in this regard. Centrifugal separators, for example, are proven capable of removing relatively large (over 40 micron) particles, but not lightweight contaminants. Centrifugal separators remove suspended particles out of fluid by relying on the velocity of a vortex that exerts force on the suspended particles to remove them from the fluid. The effectiveness of this process depends on the size and density (measured in specific gravity) of the particle relative to the density and viscosity of the fluid. As particles become smaller than 40 micron, the particles require too much force for a centrifugal separator to efficiently remove them. Sand filters, on the other hand, perform well at removing these lightweight particles. However, particles larger than 25 micron can be problematic for sand filters because these larger particles are difficult to remove from the media bed. The efficiency of a sand filter is affected by particle size only, ignoring the effects of specific gravity.

Use of either centrifugal separators or sand filters is application specific. Applications involving larger, heavier particles (based on their specific gravities) typically dictate the use of a centrifugal separator. When particles that are less than 25 micron in size need to be removed, use of a sand filter is recommended. Consult a water treatment specialist to help determine what options are available for a specific application.

NOTE: A simple method to determine the size of contaminants in a system is to take a water sample from the system, put the sample into a clear container, and then shake the water up. If the particles settle in three minutes or less, then a centrifugal separator can be used. If the particles settle in over three minutes then it is better to use a sand filter.

Particle Removal Analysis

Knowing the size of particle contaminants in the system is important, and it is necessary to differentiate between the size of particles and the quantity of particles. To clarify, designing a filtration system to remove less than 1% of the total particle volume would not be effective, even if a large quantity of particles are removed. It becomes clear why understanding the site specific characteristics of the water being pumped is crucial to specifying the proper equipment, separators or filters, to use in a filtration system. Therefore, when analyzing the size of particles found in a system, it is important to know the total volume of particle matter that needs to be eliminated, not the total number of particles. When it comes to mechanical filtration, a very small percentage of larger particles (10 to 75 microns in size) are of more concern than a high percentage of smaller particles (5 microns or less). Even the Water Quality Association, an authority on drinking water standards in the U.S., recognizes that any contaminants below 5 microns in size are most commonly identified as bacteria, a contaminant that is not removed by filtration, but by disinfection.

Table 1 below offers a comparative and hypothetical example, taking a sample of one trillion particles, and shows the portions of that sample for several particle sizes. As can be seen, if only 15% of the total numerical count of particles is greater than 10 microns, those 15% represent over 99% of the total volume. In an actual cooling water loop, there may be many times this amount, but the relative ratio is still valid and important to consider in terms of which contaminants to be most concerned about. This example shows that even a relatively small quantity of particles 10-75 microns in size can represent a very large total volume of particles. This fact should be considered when determining the particles that are capable of fouling a heat exchanger's small orifice, clogging a nozzle or accumulating in a unit's fill, basin or remote sump.

Size of Particle	Quantity of Particle	Total Volume
0.45 microns	212.5 billion particles	0.006 cubic inches
1 micron	212.5 billion particles	0.007 cubic inches
3 microns	212.5 billion particles	0.190 cubic inches
5 microns	212.5 billion particles	0.890 cubic inches
Sub-total:	**850 billion particles**	**1.088 cubic inches**
10 microns	37.5 billion particles	1.3 cubic inches
25 microns	37.5 billion particles	18.5 cubic inches
50 microns	37.5 billion particles	150.1 cubic inches
75 microns	37.5 billion particles	504.1 cubic inches
Sub-total:	**150 billion particles**	**674.0 cubic inches**

Table 1. Particle Size vs. Volume for a Sample of Particles

Aside from the size of particles to be removed, there are other economic and design factors related to determining the right equipment for filtration. These factors can often influence the equipment purchasing decision depending on the circumstances. The economic factors are the cost of replacement parts, maintenance requirements, space requirements, and the training of personnel. The design factors include the size of the particles to be removed and the allowable levels of the filtration equipment's flow range, pressure loss, and liquid loss. These economic and design factors are highly variable and change dramatically for any given cooling tower application. Whether or not certain factors influence a purchasing decision is based on the application.

Conclusion

As noted earlier, high water quality can only be achieved with the use of a professional water treatment program used alongside a properly designed mechanical filtration system. Determining the right equipment and method for filtration is a key component of designing a mechanical filtration system that works. Proper filtration can reduce energy consumption, improve chemical performance, reduce the amount of necessary maintenance, improve machine productivity, and limit bacterial growth. The system improvements that result from a good water treatment program will lead to cost savings. Deciding on the type of filtration equipment to use depends on the application and economic desires of the purchaser.

Acknowledgement:

BAC extends its sincere appreciation to Kathy Colby of LAKOS Separators and Filtration Solutions for her contributions to this article.

Filtration Guide

Appendix: Common HVAC Filtration Equipment

Sand Filters

Widely known, sand filters direct fluid into the top of their tank(s) and onto the surface of a bed of specified sand or other media. As the fluid passes through the bed of sand media, the contaminants are captured within the upper layer of media. The fluid ultimately makes its way downward, passing into some form of under drain at the bottom of the filter tank and discharging through an outlet pipe or manifold. The cleaning procedure reverses flow upward from the outlet/manifold (either from other filter tanks in the system or from the main system flow), fluidizing the sand media and back washing the contaminants through the tank's inlet to a backwash line for disposal discharge. Sand filters are most commonly installed in side stream applications. Care must be taken before installing a full flow or basin sweeping configuration because of the potential for interrupted flow during backwash or fouling of the media.

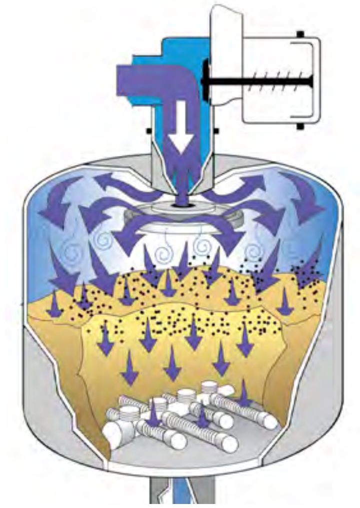


Figure 5. Sand Filter Principle of Operation

Solids Removal – This type of device is most appropriate for lightweight solids, organics and other floating contaminants. Though capable of removing heavier solids, the cleaning/backwash procedure makes it very difficult to rid the sand filter of these solids which may result in a residual build-up and an increasing pressure differential across the filter or excessive back washing frequency. When specified for removing very fine solids, sand filters must either be oversized to reduce the flow rate per-square-foot or the sand media must be upgraded, adding cost and increasing pressure loss through the filter.

Flow Range – The total surface area of a sand filter's media bed and the specified flow rate per-square-inch (20 USGPM/sq ft is typical) dictate the size (diameter) and/or quantity of tanks in a sand filter system. Though some makers use only one large tank, others use multiple smaller diameter tanks. Unlimited flow range capability is offset by the logistics of the size and/or configuration of the overall sand filter system.

Pressure Loss – Pressure loss varies from low (1 psi typical) to high (11 psi). A very low pressure loss through a clean sand filter can be rapidly lost in high solids loading applications.

Liquid Loss – It is not uncommon to lose hundreds or even thousands of gallons of fluid during a backwash cycle. Significant make-up water may also require significant chemical treatment. As a general rule, some sand media is also regularly lost during back washing, resulting in periodic media replacement.

Solids Handling – Solids handling is usually automated as the solids are carried away in the backwash water. Due to the high liquid content handled during a backwash cycle, increasing the concentration of solids in the water is not usually practical.

Replacement Parts – Typical parts manuals for sand filters number eight or more pages. The moving parts and electromechanical hardware for automatic back washing account for most of this requirement. Sand media must be monitored and periodically disposed and replaced. Improper back washing can also lead to contaminant build-up in the sand bed, providing the opportunity for troublesome bacteria to breed and/or accumulate. If oils or grease are present in the system, frequent sand media replacement will be necessary and may be designated as hazardous waste, complicating disposal procedures.

Maintenance Requirements – Back washing can be manually initiated or automatic. Manual operation creates the risk that pressure differential may become excessive and disruptive to the system if not performed regularly and at appropriate intervals. Additionally, infrequent back washing drives the contaminants deeper into the sand bed, making it more difficult to completely backwash the sand filter and resulting in residual build-up, which increases the frequency of back washing/liquid loss.

Periodically, even when properly monitored, it is necessary to shutdown the system and dispose and replace the sand media. In high calcium (hard water) content waters it is also not unusual for mineral build-up to induce the sand media to become a hardened cake, incapable of back washing.

Inspection is recommended monthly in order to sustain proper operating conditions.

Space Requirement – Expect sand filters to demand 10 to 20 times more space than other types of filtration for a given flow rate. Sand filter configurations are also limited for specific ceiling or piping restrictions.

Advantages:

- Sand filters remove fine and light particles
- Improved water clarity
- Easily automated
- Requires no solids handling
- Wide range of particles removed
- Effective over a wide range of flows and pressures

Disadvantages:

- Prone to changing or interrupted flow with solids collection
- Handling of backwash water volume
- Can be maintenance intensive
- Heavy, or precipitated solids pack into sand requiring frequent changing of the sand
- Space can become an issue
- Backwash water volume can be excessive in high solids loading applications

Separators

Separators use centrifugal action to remove solids that are heavier than water by use of a tangential inlet that starts the centrifugal action. More efficient designs utilize internal accelerating slots to increase the velocity, and then allow for settling in a low flow area necessary for the removal of the separable solids. Separated particle matter spirals downward along the perimeter of the inner separation barrel and into the solids collection chamber, located below the vortex deflector plate. Solids removal performance varies widely depending on the design.

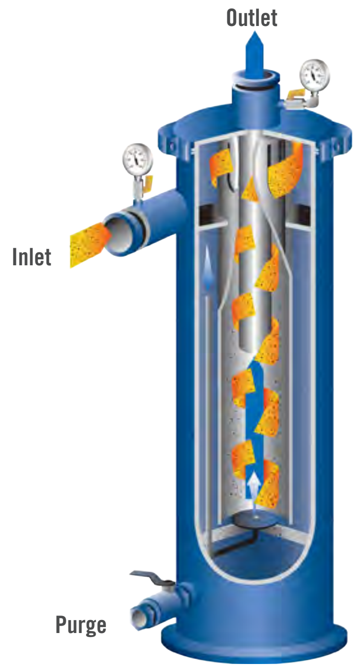


Figure 6. Centrifugal Separator Principle of Operation

Filtration Guide

Solids Removal – Separators are proven capable of 5-75 micron performance for particles that are heavier than water. Since the tested performance of centrifugal action separators varies widely among different manufacturers, we encourage third party testing to confirm actual performance at flow rates representing particular site requirements.

Flow Range – Separators feature individual units for 3 USGPM (0.7 m^3/hr) up to 12,750 USGPM (2895 m^3/hr). They can be designed for even higher (or variable) flow rates.

Pressure Loss – Separators operate continuously (no fluctuations) at a steady pressure loss of only 3-12 psi (0.2-0.8 bar). This is an acceptable loss compared to screens and barrier filters, which build-up to very high pressure losses.

Liquid Loss – Separators require no back washing. Low-flow periodic purging or a controlled bleed technique can achieve zero liquid loss. Selected solids collection options ensure minimum liquid waste and easy disposal/recovery of solids collected.

Solids Handling – Evacuation of separated solids should be accomplished automatically by the use of an electrically-actuated valve programmed at appropriate intervals and duration in order to efficiently and regularly purge solids from the separator's collection chamber. Solids can also be concentrated by the use of a solids recovery vessel. In a solids recovery vessel, separated solids are continuously purged under controlled flow into a vessel equipped with one (or three, depending on the separator size needed) 1-50 micron fiber-felt solids collection bag(s). The bags are then manually removed and cleaned or discarded.

Replacement Parts – Separators have no moving parts, and no filter elements or sand media to clean or replace. The purge options (bag filter, or motorized ball valve) for the separator may have replacement parts.

Maintenance Requirements – Separators are purged of separated solids without system interruption. They are easily automated, require no filter cleaning, and no duplicate equipment is needed.

Space requirements – Separators are compact. Larger models may be specified at low or vertical profile and/or with alternate inlet/outlet configurations to accommodate limited space or piping needs.

Advantages:

- Removes a wide range of particles
- No moving parts
- Very minimal to no maintenance requirements;
- Constant pressure drop is better for basin sweeping applications
- Can be installed full flow with low risk for interrupting flow to the main heat exchangers
- Can be automated

Disadvantages:

- Primarily removes only solids that are heavier than water

	Particle Size Removal	Pressure Loss	Maintenance Requirements	Liquid Loss
Sand Filters	Best for fine light particles; avoid heavy coarse particle applications	Low, variable	Back washing; periodic inspection; sand replacement, electromechanical parts	Potentially excessive
Separators	Fine to coarse inorganics only with a specific gravity greater than water	Low and steady	Purge components only - periodic inspection/servicing	None to minimal

Table 2. Advantages and Limitations of Sand Filters and Separators

Water Quality Guidelines

Water Treatment

A proper water treatment program, administered under the supervision of a competent water treatment specialist, is an essential part of routine maintenance to ensure the safe operation and longevity of evaporative cooling equipment, as well as other system components.

In evaporative cooling products, cooling is accomplished by evaporating a small portion of the recirculating water as it flows through the unit. As the water evaporates, the dissolved solids originally present in the water remain behind and if not controlled, the concentration of dissolved solids will increase rapidly. This can lead to corrosion, scale or biological fouling which may negatively affect heat transfer as well as the longevity of system components.

- **Corrosion** – Red rust on steel components and white rust on galvanized surfaces may affect the longevity of system components.
- **Scale Formation** – Scale, typically a calcium or magnesium based build-up, not only reduces heat transfer and system efficiency, but also may lead to under deposit corrosion. If scale is not controlled, it may continue building on critical components such as the fill and severely impact thermal performance.
- **Biological Fouling** – Slime and algae formations may reduce heat transfer, promote corrosion, and harbor pathogens such as Legionella.

For more information on water treatment, please see the Filtration Guide section in the previous section.

NOTE:
Since the quality of the ambient air and make-up water varies significantly from job site to job site, BAC strongly recommends obtaining the services of a competent water treatment specialist prior to the initial start-up of the evaporative cooling equipment. Additionally, to protect against the risk of Legionella contamination, never operate the cooling equipment without adequate biological control.

Corrosion and Scale Control

To control corrosion and scale, maintain the water chemistry of the recirculating water within the parameters listed in **Table 1** on the following page. The specific measures required vary from system to system and are dependent on the chemistry of the make-up water, the metallurgy of the piping and heat transfer devices exposed to the recirculating water, and the temperatures at which the system will be operating. Bleed/blowdown, the continuous flow of a small portion of the recirculating water to a drain, is used to control the concentration of dissolved solids. On rare occasions, this may be adequate to control scale and corrosion. More often, chemical scale and corrosion inhibitors are necessary, which raise the allowable level of dissolved solids without the risk of scale and corrosion.

Keep the chemically treated water within the guidelines given in **Table 1**. In cases where bleed/blowdown alone is being employed for corrosion and scale control without chemical treatment your water treatment specialist may recommend more conservative limits than those shown in **Table 1.**

Water Quality Guidelines

Property of Water	Recommended Levels for Various Materials of Construction			
	Galvanized Steel	Thermosetting Hybrid Polymer	Type 304 Stainless Steel	TriArmor® Corrosion Protection System or Type 316 Stainless Steel
pH	6.5 to 9.0[1]	6.5 to 9.2[1]	6.5 to 9.2 [1]	6.5 to 9.5[1]
Total Suspended Solids	25 ppm	25 ppm	25 ppm	25 ppm
Total Dissolved Solids (TDS)	1,500 ppm	2,050 ppm	2,050 ppm	2,500 ppm
Conductivity	2,400 (microohms/cm)	3,300 (microohms/cm)	3,300 (microohms/cm)	4,000 (microohms/cm)
Alkalinity as $CaCO_3$	500 ppm[2]	600 ppm[2]	600 ppm[2]	600 ppm[2]
Calcium Hardness as $CaCO_3$	50 to 600 ppm[2]	50 to 750 ppm[2]	50 to 750 ppm[2]	50 to 750 ppm[2]
Chlorides (CL)	250 ppm	300 ppm	300 ppm	750 ppm
Sulfates	250 ppm	350 ppm	350 ppm	750 ppm
Silica	150 ppm	150 ppm	150 ppm	150 ppm

Table 1. Quality Guidelines for Treated Circulating Water

NOTES:

1. Galvanized steel units require passivation in order to prevent white rust (refer to "Passivation").
2. Hardness and alkalinity limits may be exceeded under certain circumstances. Consult your water treatment specialist for recommendations.
3. The conversion factor used to determine conductivity is 0.625 (TDS = 0.625 x Conductivity).
4. EVERTOUGH™ Construction units have a TriArmor® Corrosion Protection System basin.
5. The guidelines above refer to the materials used in construction. Different combinations of materials may be used on the same unit.
6. Water chemistry will change with operating temperatures. The recommended guidelines listed in Table 1 refers to water temperature at 95˚F.

Chemical Treatment Requirements

Chemical treatment programs must meet the following requirements:

- The chemicals must be compatible with the unit materials of construction as well as other materials used in the system (pipe, heat exchanger, etc.).
- BAC discourages acid dosing as means of scale control except for open circuit cooling towers with remote sump applications or towers constructed from stainless steel. This should be done at a point in the system where total mixing and dilution occur before reaching the evaporative cooling equipment. The preferred injection point for chemical scale and corrosion inhibitors is on the discharge side of the system circulating pump(s). These chemicals should not be batch fed directly into the unit's cold water basin or water distribution system, as this can severely damage areas directly contacted.
- When chlorine is added to the system, free residual chlorine should not exceed 1 ppm, except as noted in start-up and shutdown section. Exceeding this limit may accelerate corrosion.

Passivation

When new systems are first commissioned, special measures should be taken to ensure that galvanized steel surfaces are properly passivated to provide maximum protection from corrosion. Passivation is the formation of a protective, passive, oxide layer on galvanized steel surfaces. To ensure the galvanized steel surfaces are passivated, the pH of circulating water should be kept between 6.5 and 9.0 and calcium hardness between 50 and 600 ppm (as $CaCO_3$) for four to eight weeks after start-up, or until new zinc surfaces turn dull gray in color. If white deposits form on galvanized steel surfaces after the pH is returned to normal service levels, it may be necessary to repeat the passivation process. In case the pH can't be kept below 8.2, a secondary approach is to conduct a chemical passivation using inorganic phosphate or film-forming passivation agents. Consult your water treatment specialist for specific recommendation.

NOTE: Stainless steel cold water basins and basins protected by the TriArmor® Corrosion Protection System or thermosetting hybrid polymer do not require passivation. However, if the upper structure is galvanized steel, passivation is required. Closed circuit cooling towers and evaporative condensers with galvanized coil require passivation.

Biological Control

The warm, oxygen and nutrient rich environment inside evaporative cooling equipment provides an ideal environment conducive to the growth of algae, slime, and other micro-organisms. Uncontrolled, this can reduce heat transfer, promote corrosion, and promote the growth of potentially harmful organisms such as Legionella. **To avoid biological contamination and minimize the risk of Legionella, initiate the biocide treatment program at start-up and continue on a regular basis thereafter in accordance with the treatment supplier's instructions.** Bleed/blowdown or chemical treatment used for corrosion and scale control alone is not adequate for control of biological contamination. Introduce solid or granular biocides through a chemical "pot" feeder installed in parallel with the system circulating pump. Diluted liquid biocides may be added directly to the cold water basin.

Initial Start-up and Start-up Following a Shutdown Period

To minimize the risk of biological contamination during a shut-down period of three days or more, it is recommended that the entire system (evaporative cooling equipment, system piping, heat exchangers, etc.) be drained. To resume operation of a drained system and at initial start-up, clean all debris from the cold water basin and fill the system with fresh water. Then execute one of the following biocide treatment programs while operating the circulating pump and prior to operating the unit fans:

- Resume treatment with the biocide that was used prior to shut-down. Operate the pump only while maintaining the maximum recommended biocide residual for a sufficient duration (residual and time will vary with the biocide) as recommended by the water treatment supplier. Start the fan only after this treatment period is completed.
- Check the pH of the circulating water and, if necessary, adjust it to 7.0 - 7.6 pH. Then, running the pump only, treat the system with sodium hypochlorite to maintain a level of 4 to 5 mg/l (ppm) free chlorine (as Cl_2) over a six hour period. Test kits for measuring the free residual of chlorine are commercially available. Start the fan only after this treatment period is completed.

When it is not practical to drain the system during shut-down periods, install a by-pass line with shut-off valves to permit the recirculating water to circulate throughout the system, including the unit basin, while bypassing the fill section of the evaporative cooling equipment (fans should remain off). Treat the system as per one of the above-described methods prior to restarting the unit.

Water Quality Guidelines

System Cleaning for Coil Products

This section is applicable to BAC Closed Circuit Cooling Towers and Evaporative Condensers only.

The outside of the heat exchange coil may require occasional cleaning. The chemicals used must be compatible with the materials being treated. For example, the standard coil is galvanized steel on the outside. The inside of the coil is black carbon steel. For finned coils, the coil cleaning must be careful not to damage the fins (outside of the coils) and the coils themselves. For specific recommendations on coil cleaning, contact a qualified consultant.

Closed Circuit Cooling Towers

With proper precautions, prior to start-up circulate an alkaline solution which can be used to clean condenser water systems through a closed circuit cooling tower. The necessary precautions include:

- Limit the duration of the cleaning to one day or at the most two days.
- The temperature of the solution should never exceed 100ºF (37.8°C).
- The maximum concentration of chemicals in the circulation solution should not exceed any of the following:
  - 5% Sodium Hydroxide
  - 5% Sodium Metasilicate
  - 2% Sodium Carbonate
  - 2% Tetra Sodium Pyrophosphate
  - 0.5% Trisodium Phosphate
  - 0.5% Sodium Nitrate
  - 5-10% Butyl Cellosolve

Evaporative Condensers

The installation and manufacturing processes commonly used for field assembly of steel-piped systems may leave weld byproducts inside coils and connecting piping (especially in refrigeration systems). It is common practice to install filters and/or strainers that remove contaminants during initial system operation. Shortly after system startup, the filters and/or strainers should be cleaned or replaced.

Materials Of Construction

Determining the appropriate material of construction for a project depends on several factors, including water quality, climate and environmental conditions, availability of time and manpower for maintenance, unit lifetime requirements, and budget. BAC provides the widest variety of material of construction options in the industry and has the ability to provide a solution to meet all conditions and budgets. Options such as EVERTOUGH™ Construction and the TriArmor® Corrosion Protection System provide superior corrosion resistance and durability at a tremendous value. To determine the best material options for your specific project, consult your local BAC Representative.

EVERTOUGH™ Construction

EVERTOUGH™ Construction combines a number of BAC's innovative corrosion protection features in a single cost-effective package.

TriArmor® Corrosion Protection System

TriArmor® Corrosion Protection System is a proprietary polyurethane barrier that offers a level of corrosion protection for cold water basins that is superior to conventional stainless steels. The TriArmor® Corrosion Protection System was specifically designed for evaporative cooling applications and has undergone accelerated testing to simulate years of operation in the harshest environments.

Corrosion Resistant Distribution System

For Series 3000 Cooling Towers, pultruded fiberglass reinforced polyester (PFRP) hot water basins provide a lightweight and high strength alternative to conventional stainless steel with an added level of corrosion resistance. BAC's fiberglass reinforced panels are impervious to a wide variety of chemical and atmospheric contaminants.

For the PT2, PFi, PCC, VCA, FXV, CXVT and CXVB the distribution system is constructed of corrosion resistant PVC.

Thermosetting Hybrid Polymer

A manufacturing process fuse bonds a hybrid polymer to heavy-gauge G-235 galvanized steel providing superior corrosion protection. Over the past 25 years, this corrosion protection system has been installed on thousands of units worldwide.

Warranty

Backed by a comprehensive Louver-to-Louver℠ 5-year warranty.

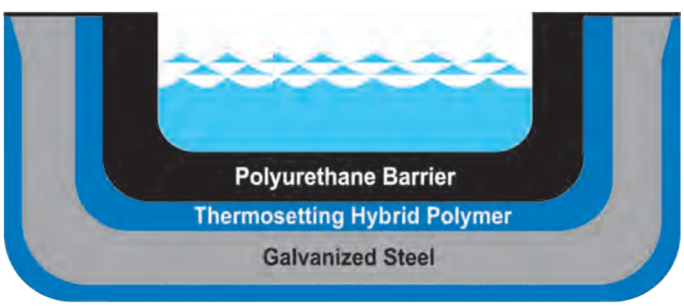
Materials Of Construction

TriArmor® Corrosion Protection System

The TriArmor® Corrosion Protection System is a triple protection process consisting of:

- **G-235 Galvanized Steel** - the heaviest commercially available galvanized steel which provides a durable structure to the cold water basin.
- **Thermosetting Hybrid Polymer** - electrostatically applied to both sides of the G-235 galvanized steel, providing a second layer of protection from corrosion. This material also serves as a mechanical and chemical bonding agent between the polyurethane barrier and the galvanized steel.
- **Polyurethane Barrier** - factory applied, corrosion resistant impermeable armor that completes the system and creates a seamless basin.

TriArmor®
Corrosion Protection System

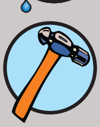


TriArmor® Corrosion Protection System Spray Booth

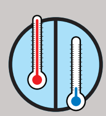
Ultimate in Material Advancement

The TriArmor® Corrosion Protection System was introduced after a decade of extensive R&D and field testing. This new material has consistently demonstrated the following characteristics:


✓ Leak free


✓ Tough and durable


✓ Slip resistant


✓ Resistant to thermal shock


✓ Self extinguishing

Compare the Factory Installed TriArmor® Corrosion Protection System Advantages:

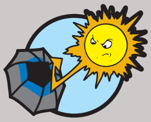
	Test	Galvanized Steel	Type 304 Stainless Steel	Type 316 Stainless Steel	TriArmor™ Corrosion Protection System
Corrosion	Acid Test pH=4	Good	Excellent	Excellent	Superior
	Alkaline Test pH=11	Good	Excellent	Excellent	Superior
	Chloride Levels	Good	Better	Excellent	Superior
	5% Salt Spray Test	Good	Better	Excellent	Superior
Environmental	UV Resistance	Superior	Superior	Superior	Superior
	Thermal Shock	Superior	Superior	Superior	Superior

Good
Better
Excellent
Superior

The TriArmor® Corrosion Protection System has been specifically designed for evaporative cooling applications to provide the best corrosion resistant material available in the marketplace.

This revolutionary material of construction has been subjected to accelerated testing to simulate years of operation in the harshest environments. Additionally, this system has performed successfully for a decade at customer installations. The TriArmor® Corrosion Protection System is:

√ **Unsurpassed in corrosion resistance**
Impervious to chloride attack



√ **Formulated to resist UV damage**

√ **Backed by a 5-year leak and corrosion warranty**

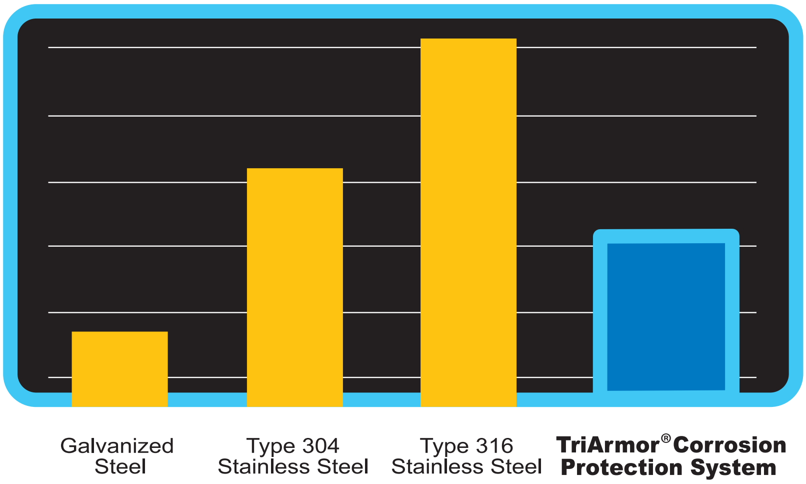
√ **Environmentally friendly, containing no solvents, volatile organic compounds (VOC), or chlorofluorocarbons (CFC).**

The TriArmor® Corrosion Protection System offers superior corrosion resistance compared to Stainless Steel, but at a lower first cost.

- Factory applying the TriArmor® Corrosion Protection System using BAC's lean, ISO certified manufacturing process reduces manufacturing costs while maintaining high product quality.
- Triple protection provides extended material life which is backed by a 5-year leak and corrosion warranty.
- Tough and durable finish won't crack, peel or warp under harsh conditions, minimizing the cost of ownership.

Materials Of Construction

Average Cold Water Basin Material Price

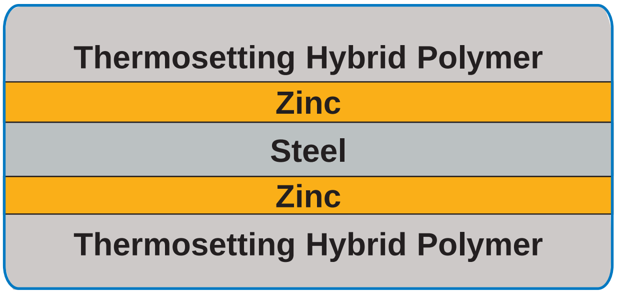


Galvanized Steel

G-235 (Z700 metric) mill galvanized steel is the heaviest commercially available galvanized steel, universally recognized for its strength and corrosion resistance. To assure long-life, G-235 (Z700 metric) hot-dip galvanized steel is used as the base material for all steel products and parts, and all exposed cut edges are protected with a zinc-rich coating after fabrication. With good maintenance and proper water treatment, G-235 (Z700 metric) galvanized steel products will provide excellent service life under the operating conditions normally encountered in comfort cooling and industrial applications.

Thermosetting Hybrid Polymer

A thermosetting hybrid polymer, used to extend equipment life, is applied to select G-235 mill galvanized steel components of the unit. The polymerized coating is baked onto the G-235 mill galvanized steel and creates a barrier to the already corrosion resistant galvanized steel. The thermosetting hybrid polymer has been tested to withstand 6,000 hours in a 5% salt spray without blistering, chipping, or losing adhesion.



Closed Circuit Cooling Tower with the Optional Thermosetting Hybrid Polymer

Stainless Steel

Stainless steel is the industry's traditional alternative to galvanized steel when elevated levels of corrosion resistance are required. Stainless steel materials can be provided in lieu of standard materials for unit structure, as well as many auxiliary components.

Component Construction

In addition to the various materials available for the structure of its units, BAC carefully selects the materials used for all components of its products. Additional materials such as fiberglass reinforced polyester (FRP), polyvinyl chloride (PVC), aluminum and copper are used for components when necessary to provide the corrosion resistance required on a unit providing evaporative cooling service.

Which Material Option is Right for My Project?

Included within the product sections of this handbook is a discussion on construction options. These sections define the availability of certain materials and combinations of materials for each product. Refer to these sections for specific product information. Your local BAC Representative can provide guidance on the proper unit construction for your project.

Research and Development

Introduction

Research and development is a necessary component of any major supplier of evaporative equipment. Companies with strong research and development teams are better able to improve the energy efficiency of their evaporative equipment products, increase thermal performance by creating more efficient heat transfer designs, and develop better water distribution systems. These are all innovations that only the brightest minds and strongest research facilities in the evaporative equipment industry can achieve.

As the worldwide leader in heat transfer technology, BAC prides itself on having a world-class research and development facility to complement corporate operations at headquarters in Jessup, MD. The test facility covers 70,000 square feet, representing a spacious area that can handle a large number of projects as BAC continues to bring cutting-edge evaporative equipment to market. The facility houses several labs (including a new state-of-the-art Ammonia Test Lab) designed to test the smallest to the largest evaporative equipment along with the materials used to construct them, such as fill and fans.

Unit and Component Testing

The test facility accelerates a thorough process of analyzing and testing full size BAC units. Analyses are performed by detailed computer models that fully describe the performance of units. The research and development team then performs tests on full size units to verify the computer algorithms. Testing full size units is an important process in the research and development of evaporative equipment because it provides BAC with the ability to thoroughly analyze a complete unit. This contributes to understanding how units are likely to perform in the field and equips BAC with deep product knowledge in theory, practice, and application.

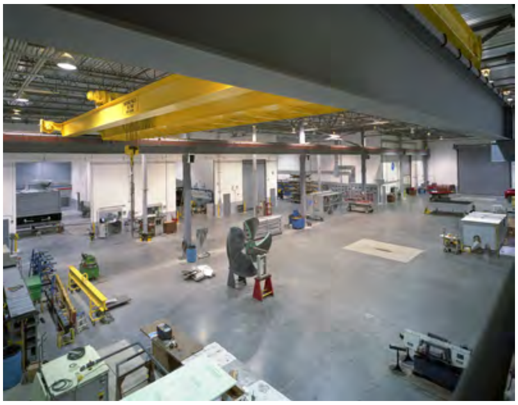


Figure 1. BAC's Research and Development Facility

The research and development facility also tests each component of a unit in order to bring the most efficient, best designed products to market. Component testing includes the research and development of vital evaporative equipment parts such as fans, fill, motors, bearings, and gears. The team puts each part through a rigorous procedure consisting of tensile, shear, and corrosion testing. BAC learns about the best materials to use in its products through its materials testing process, which consists of abrasion, acid, and coating tests.

Supporting Independent Certification

Today's industry expects evaporative equipment to achieve independent certification from veritable agencies such as the Cooling Technology Institute (CTI). BAC exceeds certification qualifications by structurally testing its products to meet a high level of mechanical qualification. This in-house process includes strain gauge testing, fatigue testing, and structural analysis. The lab uses the most current practices in the industry, such as using wireless strain gauges to test the strength of fans in motion. Such practices allow BAC to understand how well certain materials can be trusted to perform.

The research and development facility at BAC is well known for its ability to support the independent certification process, even to the point of serving as an independent testing lab for other companies. The CTI, perhaps, institutes the most rigorous certification process in the industry, requiring one evaporative cooling tower of each product line to be certified for thermal performance each year. BAC offers the most extensive product line in the industry, potentially making this a daunting task. However, the well-equipped BAC research and development facility makes the company more than capable of meeting certification requirements for more than 9 products requiring certification. In addition to performing tests to maximize thermal performance, sound testing is performed with regularity in the research and development labs. BAC continues to employ research that promises to bring the lowest sound levels to the industry. Another facet of the design process includes seismic testing. The BAC research team models BAC evaporative equipment to meet the requirements set forth by the International Building Code (IBC). These designs are then verified by a third party via shake table testing; BAC was the first in the industry to implement seismic testing to meet design requirements.

Continuously Innovating

The research and development facility continuously innovates and improves the evaporative equipment industry. BAC has developed a variety of specialized rigging techniques that make it easier for customers to install their units in the field. As a result of research on rigging units, BAC has developed single piece and modular rigs. Further, the research and development team develops processes designed to improve the maintenance of evaporative equipment as well. The lab thoroughly tests the durability of product offerings such as the TriArmor® Corrosion Protection System, thermosetting hybrid polymer, and stainless steel. Products with these protection systems are tested in a process that mimics harsh environmental conditions. Using a state of the art corrosion testing process, the research and development facility is capable of analyzing the wear of these systems in days for a process that typically requires years to fully study.

Figure 2. Shake Table Test Facility

The efforts of the research team at BAC have led to the company obtaining hundreds of patents. These patents include the recently re-introduced coil technology for the FXV/CXVB products. This advanced coil technology increased the thermal performance of these product lines up to 50% over the previous generation. BAC offers a patented crossflow fill, BACross®, which increased the performance of its products line 7-10% over the previous generation of products. For ice thermal storage units, BAC's coil spacing patent allows ice coils to prevent bridging and optimize ice building. TriArmor®, developed in the research lab, is one of the most revolutionary and cost effective materials of construction in the market. This material offers the same benefits of stainless steel such as a leak proof basin and nearly identical corrosion protection, amazingly at a lower cost in almost every application.

These patents are but a few achievements that reveal the strength of BAC's research and development facility. Customers are highly encouraged to schedule a visit to BAC's headquarters to explore this cutting edge facility.

Formulas and Tables

Fan Laws

The fan laws can be used to predict the performance of a tower with a non-standard motor.

$RPM_2 = RPM_1\ (CFM_2) / (CFM_1)$

$\text{Static Pressure}_2 = \text{Static Pressure}_1\ (CFM_2/CFM_1)^2$

$\text{Horsepower}_2 = \text{Horsepower}_1\ (CFM_2 / CFM_1)^3$

DID YOU KNOW?
Cooling tower tons account for the heat of compression imposed by the chiller in addition to the building load. The heat of compression is typically assumed to be a 25% addition, or 3,000 BTUH per ton.

Formulas

Range = Entering Water Temperature - Leaving Water Temperature

Approach = Leaving Water Temperature - Ambient Wet-Bulb Temperature

Heat Rejected by a Cooling Tower:

BTUH = (Flow) X (Range) X 500 X (SG) X (SH)

Note: SG = SH = 1 for water

MBH = 1000 BTUH

Refrigeration Tons:

$$\textbf{Tons} = \frac{BTUH}{12{,}000}$$

Cooling Tower Tons:

$$\textbf{Tons} = \frac{BTUH}{15{,}000}$$

Basic Electrical:

E = I x R

P = I x E

Where: E = voltage (volts) I = current (amps)

R = resistance (ohms) P = power (watts)

AC Line Current in a Single Phase Supply

$$I = \frac{P}{E * PF * EFF}$$

AC Line Current in a Three Phase Supply

$$I = \frac{P}{(\sqrt{3}) * E * PF * EFF}$$

Where:
I is the RMS line current in Amps
P is the average output power in Watts
E is the AC line voltage in Volts
PF is the input power factor
EFF is the efficiency of the supply

Refrigerant Pressue Temperature Table

˚F Temp	R-717 psig	R-404a psig	R-507 psig	R-134a psig	R-22 psig	R-744 psig
-50	**14.4**	0.6	1	**18.4**	**6.2**	102.1
-45	**11.8**	2.7	3	**16.6**	**2.7**	116.3
-40	**8.8**	5	5.5	**14.7**	0.5	130.6
-35	**5.5**	7.6	8.2	**12.3**	2.6	146.1
-30	**1.7**	10.4	11.1	**9.7**	4.9	162.7
-25	1.2	13.4	14.3	**6.8**	7.4	180.6
-20	3.5	16.8	17.8	**3.6**	10.1	199.7
-15	6.2	20.5	21.7	**0.1**	13.2	220.2
-10	9	24.5	25.8	2	16.4	242.1
-5	12.3	28.8	30.3	4.1	20	265.5
0	15.6	33.5	35.2	6.5	24	290.3
5	19.5	38.6	40.5	9.1	28.2	316.8
10	23.7	44	46.1	11.9	32.7	344.9
15	28.3	49.9	52.2	15.1	37.7	374.8
20	33.4	56.2	58.8	18.4	43	406.4
25	38.8	63	65.8	22.1	48.7	439.8
30	44.9	70.3	73.3	26.1	54.9	475.2
35	51.4	78.1	81.3	30.4	61.4	512.5
40	58.4	86.4	89.8	35.1	68.5	551.9
45	66.1	95.2	98.9	40	76	593.5
50	74.3	104.7	109	45.4	84	637.2
55	83.2	114.7	119	51.2	92.5	683.3
60	92.6	125.3	130	57.4	101.6	731.8
65	102.8	136.6	141	64	111	782.9
70	113.8	148.6	154	71.1	121.4	836.7
75	125.5	161.2	167	78.6	132	893.4
80	138	174.6	180	86.7	144	953.2
85	151.4	188.8	195	95.1	156	1017
90	165.5	203.7	210	104.2	168.4	
95	180.6	219.4	226	113.8	182	
100	196.7	235.9	244	124.1	196	
105	213.9	253.4	252	134.9	211	
110	231.8	271.7	281	146.3	226.4	
115	251	290.9	301	158.4	243	
120	271.1	311.1	322	171.1	260	
125	292.5	332.3	344	184.5	278.4	
130	314.9	354.5	368	198.7	296.8	
135	338.8	377.8	393	213.6	317	
140	363.5	402.2	419	229.3	337.3	
145	390.2	427.7	446	245.7	359	
150	417.4	454.4	475	263	381	

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