FREEZE PROTECTION AND NOISE REDUCTION FOR CHILLED WATER SYSTEMS

Applications for Condenserless Chillers

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TABLE OF CONTENTS

INTRODUCTION

Chilled water systems that use air-cooled outdoor chillers face several challenges.

Noise mitigation is a concern for all outdoor chillers located where noise generated by equipment may disturb building neighbors and local residents.

In addition, outdoor chillers installed in northern climates suffer the effects of cold outdoor temperatures and the costs associated with freeze protection. Antifreeze solutions can provide protection, however, there are drawbacks to be considered. Some antifreeze fluids can be hazardous. Also, the use of antifreeze increases the fluid viscosity and the associated pumping energy, reducing heat transfer capability and decreasing efficiency. Energy performance is not a feature that most building owners are willing to sacrifice, especially if they are seeking LEED® certification points.

This white paper will address the requirements of freeze protection and noise reduction in chilled water systems and demonstrate that the solution may be found in the placement of the freeze-sensitive and noise-generating components of the system.

CHILLER OPTIONS

What is the difference between an air-cooled chiller, a remote evaporator chiller, and a condenserless chiller?

One way to answer this question is to reveal where the chiller components are located, as shown in Fig. 1 through 3. In these figures, the components inside the red circle are factory assembled and tested.

Air-Cooled Chillers

All components of an air-cooled chiller are located outdoors. This means that the evaporator barrel, the device that cools the working fluid, is exposed to cold ambient temperatures. If the working fluid is water, it is very likely that the water will freeze when outdoor temperatures fall below 32 F unless special freeze protection measures are taken. In many applications, an antifreeze solution is added to the working fluid to minimize its freeze potential. As noted previously, noise transmission from the chiller and the disadvantages of antifreeze solutions are issues associated with this type of chilled water system.

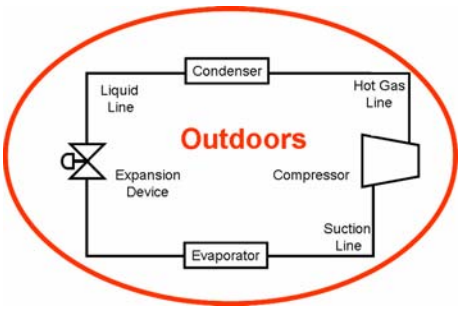


Fig. 1. Air-Cooled Chiller

Remote Evaporator Chiller

The remote evaporator chiller is an air-cooled chiller with the evaporator physically removed from the outdoor chiller and placed indoors. Suction and liquid refrigerant lines must be field designed and installed by the contractor for each project. This configuration does isolate the evaporator barrel from the cold outdoor temperatures. However, outdoor noise, field-fabricated suction lines, compressor service access and indoor space requirements all pose issues that must be considered.

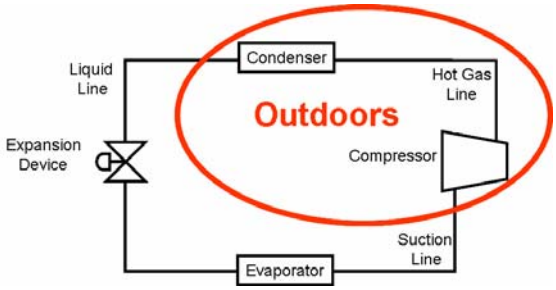


Fig. 2. Remote Evaporator Chiller

Condenserless Chiller with Remote Air-Cooled Condenser

The condenserless chiller with a remote air-cooled condenser places the evaporator and compressors indoors. This type of system isolates the evaporator barrel from the cold outdoor ambient temperatures. Locating the compressor indoors provides for easier service and noise control. The remote air-cooled condenser located outdoors is smaller in size, has lower sound levels, and is significantly lighter weight compared to an air-cooled chiller of similar capacity.

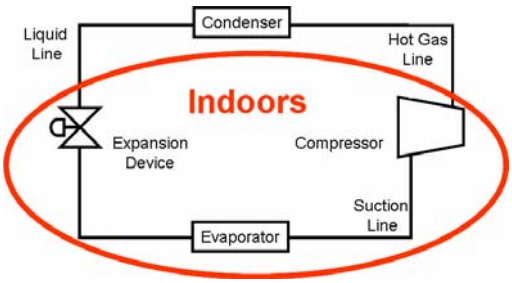


Fig. 3. Condenserless Chiller with Remote Air Cooled Condenser

THE REMOTE EVAPORATOR

Is an air-cooled chiller with remote evaporator the answer?

Remote Evaporator Chillers and Freeze Protection

As described above, one way to overcome the freeze issue is to place the chiller's evaporator barrel indoors, while the compressors and air-cooled condenser section remain outdoors. These components are connected by field-installed suction and liquid refrigerant piping located between the remote evaporator and the outdoor compressor/condenser section as shown in the Fig. 4.

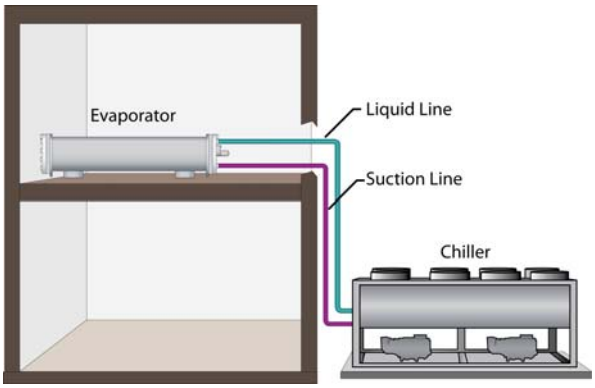


Fig. 4. Typical Air-Cooled Chiller with Remote Evaporator

Although it may be tempting to use this system to overcome the freeze issue, an examination of the design requirements and application sensitivities of this arrangement reveals several concerns.

The refrigerant suction line carries refrigerant gas and lubricating oil back to the compressor. These field-piped suction lines must be designed and installed properly to ensure sufficient refrigerant flow and oil return to the compressor. Some of the consequences of improper suction line design and installation are:

- Improper oil return - Without oil, compression efficiency will suffer and excessive wear can result. A thin film of oil is needed to create a seal between the rotors on a screw compressor. Without oil, compression efficiency suffers. The lack of oil will lead to low oil pressure nuisance alarms, equipment shut-down and, if not attended to, premature compressor failure.

- Undersized suction line – An undersized suction line will reduce chiller performance and possibly allow refrigerant to return to the compressor. With any positive displacement reciprocating or screw compressor, liquid return can cause immediate compressor failure since liquids are non-compressible.

- Oversized suction line – An oversized suction line can cause low refrigerant velocities in the pipe. The ability of the pipe to carry oil back to the compressor is a function of the refrigerant velocity. If the velocity is too low, poor oil return can result. The lack of oil can lead to nuisance alarms or compressor failures as previously described.

- Suction line losses – Any friction loss in the suction pipe translates into a loss in chiller capacity. Less capacity reduces energy efficiency and increases energy consumption. The length of suction lines in remote evaporator applications can result in a loss of capacity of up to 3% which is often not accounted for in design requirements.

- Field-applied suction accumulators - Some chiller manufacturers require the application of special field-installed suction accumulators. This field-fabricated device, which can be *hundreds of feet in length*, is required to increase the storage volume of the suction line. This is necessary to retain refrigerant in the suction line during the off-cycle. If the accumulator is undersized or overlooked, liquid refrigerant can be drawn into the compressor resulting in catastrophic compressor failure.

Application of remote evaporators relies heavily on the contractor's field expertise along with proper engineering of refrigerant piping and accumulators. If not properly engineered and carefully installed, energy penalties will result and at worst, equipment failure can result. The responsibility of a proper design rests with the consulting engineer while the responsibility of the installation rests with the contractor.

Remote Evaporator Chillers and Noise

An air-cooled chiller with remote evaporator has compressors located outdoors as previously shown in Fig. 4. These compressors will transmit noise to surrounding neighbors and adjacent building occupants. Churches, housing developments, apartments buildings, and schools located within hearing distance of the air-cooled chiller are all subject to the effects of objectionable noise levels. The sound level of an air-cooled chiller can be as much as 20 dB-A higher than the sound level of a remote air-cooled chiller, which results in a noticeable difference in comfort.

CONDENSERLESS CHILLER—THE BEST SOLUTION FOR FREEZE PROTECTION AND NOISE REDUCTION

Freeze Protection

Advantage of Locating the Compressors and Evaporator Indoors

Condenserless chillers bring the evaporator and compressors together in a single package located indoors, where the working fluid is not exposed to cold outdoor temperatures. The compressor and evaporator components are connected to hot gas and liquid line extending to a remote air-cooled condenser located outdoors. This arrangement, shown in Figure 5, eliminates the issues associated with the use of antifreeze and offers several other advantages.

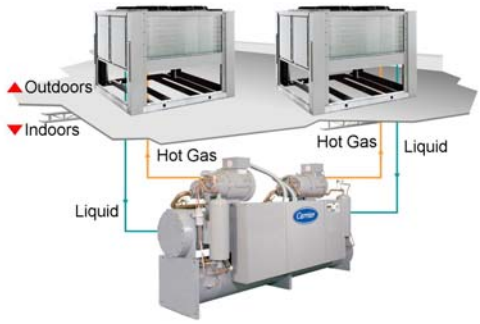


Fig. 5. Typical Condenserless Chiller with Remote Air Cooled Condenser

As a result of locating the compressor and evaporator indoors, freeze protection is provided without field-designed and installed suction lines. Condenserless chillers use hot gas and liquid lines that are sized by simply following the manufacturer's recommended pipe sizing tables. The job site variations associated with the suction line installation and suction accumulator sizing are completely eliminated. With condenserless chillers, all suction piping is factory designed and installed in a quality-controlled assembly process. This arrangement eliminates concerns over field design and installation of the suction piping that is so critical to efficient and reliable chiller operation.

Placing the compressor and evaporator indoors also allows easier access to critical chiller components for service and maintenance purposes.

Noise Reduction

Remote Air-Cooled Condensers Have Lower Sound Levels Compared to Air-Cooled Chillers

Comparing the outdoor sound pressure for a remote air-cooled condenser versus an air-cooled chiller shows a dramatic increase in sound levels as shown in Fig. 6. Air-cooled chillers are simply louder than remote air-cooled condensers, by up to 20 dB-A.

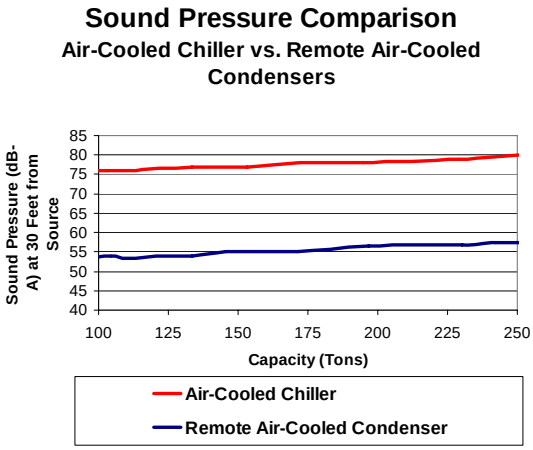


Fig. 6. Sound Pressure (db-A) for Air-Cooled Screw Chillers versus Condenserless Chiller with Remote Air-Cooled Condensers

How do we react to increased sound pressure? Table A provides a rule for the effect on hearing changes at both high and low frequency levels. With upwards of 20 dB-A difference in sound pressure levels, air-cooled chillers are certainly much louder than the remote air-cooled condensers for the same capacity chilled water system.

Table A
Effects on Hearing for High and Low Frequencies

Increased Sound Pressure (Decibel)	Effect on Hearing
High Frequencies (above 125 Hz Octave Band)	
1 dB	Not Noticeable
3 dB	Just Perceptible
5 dB	Noticeable
10 dB	Double
20 dB	Much Louder
Low Frequencies (125 Hz and Below Octave Band)	
3 dB	Noticeable
5 dB	Double
10 dB	Much Louder

ADDITIONAL BENEFITS OF CONDENSERLESS CHILLERS

Locating the compressor and evaporator indoors can provide benefits beyond freeze protection and noise reduction.

Other benefits to consider are:

- Easier serviceability – The compressor becomes much more accessible compared to outdoor or rooftop mounted chiller equipment. Technicians can walk right up to the compressor located in the mechanical room for easy access to the important chiller components.
- No antifreeze fluids required – Eliminates the hazards associated with some antifreeze solutions. Using water eliminates the energy losses associated with higher viscosity and heat transfer inefficiencies of the antifreeze solutions.
- Significantly smaller footprint – Some remote evaporator packages at 250 tons are 60 inches wide. Carrier's condenserless chiller at 270 tons can fit through a standard 36-in door way.
- Reduced roof loading – The air-cooled condensers used with condenserless chillers are lighter weight compared to air-cooled chillers with compressors, condensers, and evaporators filled with the working fluid. Some 250-ton air-cooled chillers have an operating weight in excess of 18,500 pounds, while two air-cooled condensers sized for a 250-ton system weigh less than 6,100 pounds, which is less than half the weight. With the condenserless chiller located indoors and the air-cooled condensers located outdoors, structural steel and equipment rigging costs are lower.
- Lower profile air-cooled condensers – Architects usually desire outdoor HVAC equipment with a low vertical profile to make it easier to screen the equipment from view. Some 250-ton air-cooled chillers reach upwards of 95 inches. However, remote air-cooled condensers for the same 250-ton system are only about 42 inches high—that's less than half the profile of an air-cooled chiller, making remote air-cooled condensers much easier to hide from view.
- Increased condensing surface from hot gas lines – The purpose of the air-cooled condenser is to cool the high temperature refrigerant gas to a liquid. The hot gas line actually contributes to the condensing process by cooling the hot gas before the refrigerant even enters the condenser. The hot gas line contributes to this cooling process by adding "surface area" efficiency to the condenser.

NO ANTIFREEZE SOLUTION MEANS LOWER ENERGY USAGE

Can Carrier's 30HXA condenserless chiller save energy while providing freeze protection?

One advantage of the condenserless chiller is the protection against cold ambient temperature conditions without the use of antifreeze. It is important to note that some applications will require a suitable antifreeze solution to minimize the potential of freezing. In particular, protection of the chiller from leaving fluid temperatures of 40 F or lower will require the use of an appropriate concentration of an antifreeze solution. This is necessary to protect the cooler barrel from freezing due to cold saturated suction temperatures while the chiller is producing the cold leaving fluid temperatures. Also, antifreeze solutions must be used to protect chilled water piping that may be exposed to outdoor temperatures below freezing. Antifreeze is also necessary to protect chilled water coils that may be exposed to freezing entering air temperatures or for coils installed in air handling units that are installed outdoors in areas prone to exposure to cold ambient conditions.

Energy can be saved by reducing the fluid viscosity and improving the heat transfer coefficients typically associated with antifreeze solutions. Reduced viscosity reduces the chilled water pump energy while improved heat transfer improves chiller efficiency. Both of these factors offer very desirable outcomes when system energy is considered.

Toxicity issues associated with ethylene glycol can lead to selecting less toxic antifreeze solutions such as propylene glycol. Many designers choose antifreeze solution concentrations of up to 40% for cold climate systems. Higher concentrations increase energy demands due to viscosity and heat transfer losses.

Table B shows the impact of adding a 40% propylene glycol solution to an air-cooled chiller sized for a 250-ton load with 44 F/54 F LWT/EWT and 95 F ambient air temperature. Note: A significantly larger chiller was needed to provide the required capacity when using the antifreeze solution.

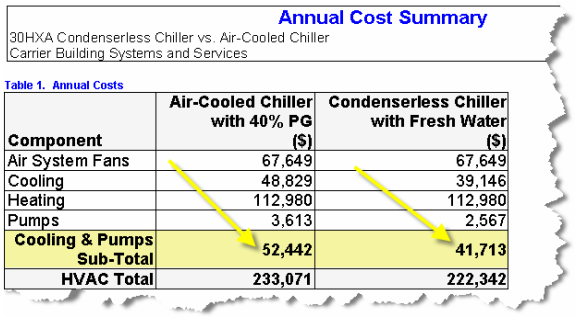
Projects seeking LEED® Certification will appreciate the ability to reduce energy costs through application of condenserless chillers, while at the same time providing a suitable means to protect the chiller from cold ambient temperatures. A comparison of an air-cooled screw chiller with an antifreeze solution to a condenserless chiller with factory matched air-cooled condenser using fresh water reveals the extent of this benefit.

If the annual energy costs are evaluated for a 250- ton condenserless chiller system, significant energy savings can be realized. Using Carrier's Hourly Analysis Program (HAP), a typical 2-story high school building in Indianapolis has an annual energy cost savings as shown in Fig 7.

Table B
Impact of Use of 40% PG Antifreeze Solution on Air-Cooled Chiller Performance

		Fresh Water	40% PG Antifreeze Solution	% Difference
Capacity	Tons	269.3	263.1	-2%
Total Power	kW	298	330	11%
Efficiency	kW/Ton	1.11	1.25	13%
Operating Weight	Lbs	15,658	17,412	11%
Minimum Circuit Amps	MCA	550	686	25%
Length	In	377	424	12%
Width	In	89	89	-
Height	In	90	90	-
Cooler Pressure Drop	Ft wg	11.5	14.1	23%
Pump Motor	Hp	15	20	33%
Pump Power	Bhp	10.0	14.9	49%

PG – Propylene Glycol



Annual Cost Summary

30HXA Condenserless Chiller vs. Air-Cooled Chiller
Carrier Building Systems and Services

Table 1. Annual Costs

Component	Air-Cooled Chiller with 40% PG ($)	Condenserless Chiller with Fresh Water ($)
Air System Fans	67,649	67,649
Cooling	48,829	39,146
Heating	112,980	112,980
Pumps	3,613	2,567
Cooling & Pumps Sub-Total	**52,442**	**41,713**
HVAC Total	**233,071**	**222,342**

Fig. 7. Annual Cost Summary for an Air-Cooled Chiller with 40% Antifreeze Solution vs. Condenserless Chiller with Fresh Water

A 20% annual energy savings can be realized for the chiller, air-cooled condenser and chilled water pumps in this example. These savings can contribute to more LEED points and a reduction in greenhouse gases such as CO_2. Reductions in energy consumption today demonstrate a willingness to preserve resources so that they may be enjoyed by future generations.

Further energy savings can be achieved by combining the condenserless chiller, located indoors, with a remote evaporative condenser that can be located outdoors. This type of condenser includes the condenser coils, acoustically tuned fans, water sump, spray nozzles, a small spray pump and essential controls. The system uses a spray mist of water to lower the refrigerant temperature through evaporation of the water. Evaporation relies on the outdoor air wet-bulb temperature which is often lower than the outdoor dry-bulb temperature. This results in lower refrigerant temperatures, lower system pressures and lower energy consumption. This white paper focuses on applications using remote air-cooled condensers. However, it is important to acknowledge the energy savings potential of this alternative type of remote condenser.

CARRIER'S 30HXA CONDENSERLESS CHILLER—THE RIGHT SIZE FOR THE PROJECT

Carrier's 30HXA chiller and matched air-cooled condenser offer a wide range of application flexibility.

Chiller Fits through Standard 36-in Doorway

Carrier's 30HXA chiller conveniently fits through a standard 36-inch doorway making rigging easier and reducing installation costs (Fig. 8).

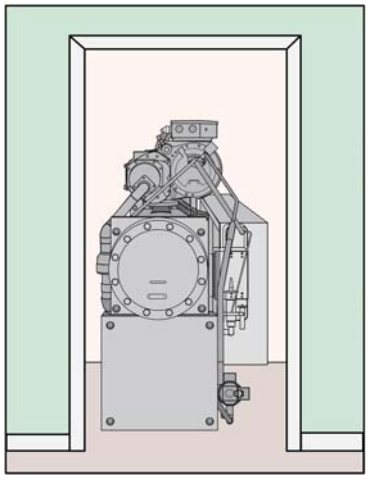


Fig. 8. Carrier's 30HXA Chiller Fits through Standard 36-in. Doorway

Smaller Footprint Compared to Remote Evaporators

With indoor mechanical space at a premium, why would a building owner want to increase the expanse of non-leasable space? The width of the 30HXA chiller is significantly smaller than a similar capacity remote evaporator system on the market today (Fig. 9).

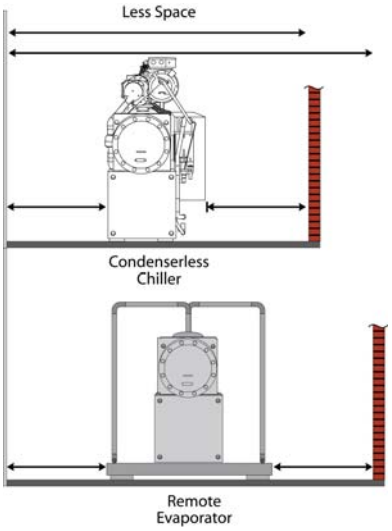


Fig. 9. Indoor Space Comparison – Carrier's 30HXA Chiller and a Remote Evaporator Chiller at 250 Tons

Lower Profile Air-Cooled Condenser

Compared to a 250-ton air-cooled chiller, the air-cooled condenser matched specifically to Carrier's 30HXA condenserless chiller is less than half the height (Fig.10).

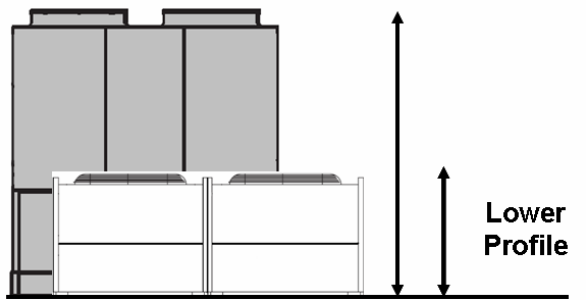


Fig. 10. Low Profile of Carrier's 30HXA Chiller Compared to an Air-Cooled Chiller

Wide Capacity Range

Carrier's 30HXA is available in capacities ranging from 70 to 270 tons to match many job requirements. Combinations of two or more chillers can further increase the chiller plant capacity.

HFC-134a for Zero Ozone Depletion

With the phase-out of HCFC-based refrigerants imminent, Carrier's 30HXA chiller with HFC-134a refrigerant offers zero ozone depletion potential and no phase-out (Fig. 11).

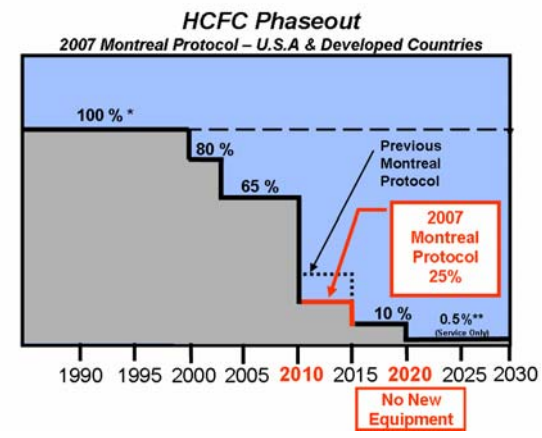


Fig. 11. Montreal Protocol Refrigerant Phase-Out

CONDENSERLESS CHILLERS OFFER MANY BENEFITS COMPARED TO REMOTE EVAPORATOR CHILLERS

Carrier's 30HXA condenserless chiller (Fig. 12.) provides many benefits beyond excellent freeze protection and easier noise reduction when compared to a remote evaporator chillers.

Fig. 12. Carrier's 30HXA Condenserless Chiller

Condenserless chillers offer:

- Easier freeze protection
- Lower outdoor sound levels—even lower with condenser fan option
- Smaller indoor footprint
- Lower outdoor profile—can be as low as 3 ft-7 in.
- Factory-tested suction piping
- Lower installed cost - no exterior sound barrier/wall required
- No hail guard required with Carrier's 09AZ condensers
- Reduced roof loading and construction cost
- Easier maintenance with indoor equipment
- Easier fit into the building
- Long-term refrigerant with zero ozone depletion HFC-134a
- Lower energy usage helps contribute to LEED® Certification

Turn to the Experts.

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