Chiltrix Chiller With Psychrologix™ Controller

Ultra-High Efficiency Chiller Heat Pump With Dynamic Humidity Control

PATENT PENDING

Introduction

The Chiltrix chillers employ a unique design utilizing a special capacity control approach coupled with variable speed compressors, variable speed pumps, and variable speed fans, further combined with dynamically variable control parameters that continuously adjust to meet operating conditions and considerations. The Chiltrix chillers match capacity to changing cooling loads precisely enough that often buffer tanks are not needed. A dynamic psychrometric controller manages humidity, prevents over-dehumidification, and saves energy by operating the chiller in the most efficient possible manner at all times. The new CX34 is extraordinarily efficient and offers a record-setting official AHRI IPLV rating of EER 23. With DHC active, EER (NPLV) is as high as EER 30.7 or above.

Chillers vs. Air Conditioners

First, a word about chillers. Chillers use a compressor and refrigerant to provide cooling. A chiller is defined as an air conditioning system that cools water (or a glycol-water mix). The cold water is circulated through a water distribution “loop” and ultimately through one or more indoor fan coil units to cool indoor air before returning the water back to the chiller. The Chiltrix system is a heat pump chiller. A common misperception is that chillers consume water, however, that is not the case with Chiltrix. Others may think that chillers require a cooling tower – however the Chiltrix chillers are air-cooled and do not use a cooling tower. Pumping water for cooling may seem old-fashioned, but it is more efficient than pumping refrigerant, for one reason, because the water can be pumped at a much lower pressure. This is different from a standard air conditioner because a regular air conditioner circulates a high pressure refrigerant such as Freon through a distribution loop. Basic physics tells us that it takes less energy to pump a fluid at lower pressure. Another thing to consider is that water is better, pound for pound, than Freon and other refrigerants at carrying heat (except for ammonia, which is too dangerous for most applications). In a regular air conditioner, the compressor not only creates the cooling, it also must power the distribution circuit by pumping high pressure refrigerant through the entire loop. In a chiller, a separate low wattage pump is used for pumping low pressure water through the loop and the compressor is only used for cooling. For these and other reasons, chillers are inherently more efficient than regular air conditioners.

Dehumidification

A side benefit of all standard air conditioning systems is dehumidification (humidity removal). Dehumidification occurs when a fan blows air across cooling coils to condition an indoor space, when the coils operate at a temperature below the dew point of the air. This is generally the case for the coils of an air conditioner or chiller indoor air handler. Dehumidification is an excellent benefit, when needed, as it can protect against mold, dust mites, fungus, and corrosion of mechanical systems. Lower humidity can also make warm air feel cooler than it really is, this effect is sometimes referred to as “feels like temperature” or “apparent temperature”. However, over-dehumidification can also cause problems and unnecessary dehumidification wastes a large amount of electrical energy.

Dry Climate Conditions

There are often cases where too much humidity can be removed from the air by air conditioners resulting in over-dehumidification. For example, you may see air conditioning users in dry climate conditions operating a humidifier to add humidity back into the air because the air conditioning system has over-dehumidified the air. Overly dry air can result in dry skin, irritated sinuses and throat, nosebleeds, and itchy eyes. Repeated exposure to low humidity can dry out and inflame respiratory tract mucous membranes which can increase the risk of colds or flu. Static electricity is an annoyance that is increased when humidity is low. For human comfort and health it is important to have a proper level of indoor humidity – not too high or too low. The recommended humidity levels for human health and comfort are generally in the range of 50-65% relative humidity (Per ASHRAE 62.1-2003).

Computer / Server Rooms

An area where we nearly always see humidity lower than recommended is in computer or server room cooling applications. In this application, air conditioners run non-stop around the clock to reject heat from electronic equipment. Ideally the room is a mostly closed environment to protect equipment from contamination, therefore, the same air is cooled over and over again. All or nearly all of the cooling load in a computer server room is generated as dry heat, or more properly, “sensible heat” because it is derived from the electrical resistance of processors, circuit boards, power supplies, etc. Unlike latent heat (humid heat), sensible heat sources do not add humidity to the air. The continuous operation of a server room air conditioner repeatedly cooling the same air often lowers the humidity much further than is needed or desirable which is very wasteful of energy. And when humidity is too low, the risk of potentially harmful static discharge (up to 10 kV/cm) is dramatically increased.

Humidity Control in Residential Applications

For the most part, dehumidification in small office/home applications is haphazard. The air conditioning system is controlled by a thermostat which measures sensible temperature to decide when to start and stop, providing a hit or miss level of dehumidification. Dehumidification generally occurs whenever the unit is running. The humidity therefore rises and falls randomly, is not monitored or controlled, and is rarely at the most comfortable or most energy efficient point. For most users, any accurate control of humidity for comfort or health purposes would have to be provided by purchasing, installing, and operating a separate humidifier and/or dehumidifier system that essentially fights with the air conditioner and wastes energy.

Wasted Capacity

A large amount of a systems total capacity can be used in the process of dehumidification or “latent heat removal”. Unnecessary latent heat removal is wasteful of net system capacity because each pint (lb.) of water removed from a room adds more than 1,000 BTU to the cooling load of the room. Preventing unnecessary dehumidification can increase the net effective cooling capacity of an air conditioner. A system controlled such as Chiltrix that only dehumidifies when, and to the proper extent that dehumidification is needed, can produce much more total cooling with the same compressor and same energy usage.

Wasted Energy

Generally speaking, the rate of dehumidification is a factor of the temperature difference (ΔT) between the dew point of the indoor air and the coil temperature of the air conditioner indoor unit. The colder the coil in relationship to the dew point, the more dehumidification is performed. In a standard air conditioner using refrigerant such as R410a, R22, “Freon” etc., the system has little or no ability to modulate the coil temperature, which is very cold and generally well below the dew point. Therefore, a standard air conditioner is nearly always performing or attempting to perform dehumidification regardless of whether or not dehumidification is needed.

A system such as the Chiltrix chiller with Dynamic Humidity Control activated can modulate the temperature of the cooling coils such that the coils are at the proper ΔT below the dew point when dehumidification is needed but can operate above the dew point when dehumidification is not needed. This feature can prevent the disadvantage of wasted energy or discomfort due to over-dehumidification and maintain the correct level of humidity with less energy usage.

What is IPLV?

IPLV means "integrated part load value", a concept similar to SEER. IPLV is an official AHRI standardized testing and rating methodology which provides an average EER rating under real-world conditions. "Part load" refers to times when the system is larger than it needs to be at that moment, which is nearly all of the time for a properly sized system, since a system must be sized for the hottest possible day of the year which is the actual condition only about 1% of the time. NPLV is the same concept, but with non-standard operating conditions. IPLV and NPLV are to chillers, what SEER is to standard air conditioners.

Carnot Analysis / Energy Efficiency (EER)

EER is the energy efficiency ratio, a measure of how much energy is needed to perform a BTU of cooling. In a chiller system, the thermodynamic process is one of removing heat; a chiller in cooling mode is essentially a machine that removes heat from water. An elementary Carnot analysis (or even simple common sense) shows that the warmer the water, the less energy or work is needed to remove heat from it, therefore operating a chiller with a warmer loop will unquestionably increase the EER. As an example of this, our newest Chiltrix (CX34) chiller tested at AHRI 550/590 conditions achieves an IPLV EER of 23 at 44F LWT, and an NPLV EER of 30.7 at 55F LWT, in this case, an EER increase of 33%. The CX34 can operate above NPLV, at times, with average EER rising up to 50% above IPLV.

By running the loop/coils no colder than needed within a range that allows humidity targets to be satisfied, the dynamically controlled system will have a higher average EER using less electrical energy per BTU of cooling. Part load performance numbers show a 33-50% difference. The Chiltrix system loop & coil temperature target can dynamically adjust itself from ~40°F to 62°F, the system will run no cooler than needed, while at the same time, automatically modulate its loop temperature downward when necessary to satisfy dehumidification requirements.

Dynamic Humidity Control (DHC)

The Chiltrix chiller with DHC has the ability to dynamically adjust the loop water temperature, and thus modulate the coil temperature in response to indoor relative humidity and dew point conditions. A control algorithm reads input from indoor sensors and adjusts the temperature of the water/coils such that the water loop and coil temperatures can be equal to, just above, well above, just below, or well below, the dew point, resulting in controllable dehumidification and controllable humidity. This allows the system to operate the coils above the dew point when the humidity is at an acceptable level (no dehumidification performed) and drop below the dew point when dehumidification is needed. The Chiltrix system is designed to operate the loop at the warmest possible temperature that will allow proper cooling of the space and allow the user-defined humidity levels to be maintained.

How the Chiltrix Chiller Works with DHC

The Chiltrix chiller can react very rapidly to humidity condition changes. The Chiltrix chiller uses a variable speed DC Inverter compressor, and a variable speed DC Inverter water pump, and DC inverter fan. By controlling the compressor speed, the system regulates the leaving/exit loop temperature. By controlling the speed of the pump the Chiltrix chiller maintains a constant ΔT between its entering and leaving temperature and provides the correct flow rate to match the capacity requirements. Controlling the pump and compressor together in this manner, the variable capacity Chiltrix output is always matched to the current cooling load. Because the Chiltrix chiller can dynamically match the load, there is often no need for a buffer tank. Because there is no buffer tank, the Chiltrix chiller can rapidly execute commands received from the DHC to adjust the loop temperature in real time for purposes of accurate and responsive humidity control.

Chiltrix Psychrometric Controls

As mentioned, the control of the Chiltrix system is such that a constant ΔT is maintained between entering water temperature (EWT) and leaving water temperature (LWT) and the compressor speed is dynamically managed to maintain a LWT set point. In this manner, the capacity is matched in real-time to the cooling or heating load. For example, at a baseline operating condition in cooling mode the system may have parameters such as EWT 54F, LWT 44F (ΔT of 10F), and a 2.4 GPM flow, meaning that the capacity and load are both 12,000 BTU. An increase in EWT (Increase in ΔT) would indicate an increased load. For example, a change in sensed conditions to ΔT 13F would indicate an increase in cooling load from 12,000 BTU to 15,600 BTU. The Chiltrix system would dynamically respond by increasing compressor and pump speed to match the new load, i.e., the system would produce a higher compressor speed to match the new BTU requirement and flow would increase to 3.12 GPM producing a return to 10F ΔT at the new higher compressor speed. The new conditions would then be EWT 54, LWT44, and based on this, 3.12x10x500=15,600 BTU. In this manner, the chiller capacity is always directly targeted to the load and flow is maintained at 2.4 GPM/ton.

The controls system dynamically and continuously varies the LWT target based on conditions, to control dehumidification and to operate the chiller at the highest possible Carnot efficiency. For example, if indoor sensors indicate that no dehumidification is needed, the LWT target can be dynamically adjusted upwards to produce a far more efficient operating state. However, if a door opens and humid air enters the conditioned space, and humidity rises above its set point, the system will lower the LWT below the dew point to an extent and until such time as humidity is under control. Then, as conditions allow, it will recover back to the most efficient state. As mentioned, the Chiltrix chiller EER is substantially higher when operating at NPLV conditions (55F LWT) as opposed to IPLV conditions (44 LWT).

An often-missed aspect of indoor humidity is that indoor humidity is “event based”. In other words, humidity does not increase on its own or enter the indoor space through walls, or increase due to solar gain or from the use of electronics or lighting. Indoor humidity increases only when some event occurs, such as an exterior door opening that allows humid outdoor air to enter the space, or someone taking a hot shower, etc. Once humidity rises to a user-defined level, the Chiltrix DHC controller reacts to it by changing its operating parameters to enable or increase dehumidification. After the humidity has been handled, the Chiltrix unit will move back to its more efficient operating state where it will remain until dehumidification is needed again.

Vacation/Dry Mode

Residential users may also wish to set the Chiltrix chiller system in “vacation mode” at appropriate times. In vacation mode the system will ignore indoor temperature and focus only on keeping humidity under a preset level saving a large amount of electrical energy while the home is unoccupied, yet the home is still being protected from humidity and moisture damage. This mode of operation may also be suitable for climate controlled storage such as needed for textiles, documents, etc. A wintertime vacation mode can prevent freezing and save energy by operating the heating loop at a far lower temperature than would be needed for human health or comfort.

Geothermal Comparison

The Chiltrix chiller is air-cooled, but can be compared to many water-to-water (geothermal) units as far as efficiency. Of course a price comparison would show the Chiltrix unit to have a far lower installed cost. While Energy Star currently has no program for air-to-water chillers, it's interesting to note that the Chiltrix air cooled chiller exceeds the efficiency (EER) requirements that are needed for a variable speed geothermal unit to earn an Energy Star label.

Hardware Considerations

A basic thermodynamic analysis explains that running a warmer loop during cooling mode requires indoor coil equipment to be configured such that it has enough sensible capacity at times when the loop is operating at warmer temperatures. Simply put, the cooling capacity of an indoor fan coil unit is a function of air flow, coil surface area, and ΔT (between the air and the coil). If due to a warmer coil the ΔT is to be lower, then fan speed and/or coil surface area must be increased to compensate. Chiltrix chiller system design is such that indoor fan coil units are sized a little larger than they would need to be for strictly standard operating conditions, they are sized to achieve the needed sensible cooling capacity while supporting a wide range of loop water temperatures at or above standard conditions. In the Chiltrix chiller system design, indoor equipment is sized to accommodate sensible cooling loads at 55 LWT or above. While this approach may at times slightly increase indoor fan energy, a far larger reduction in compressor energy makes this an exceptionally favorable trade-off.

Summary

The Chiltrix use of capacity matching controls and variable speed components, combined with continuously variable operating parameters, offers an unprecedented level of cooling energy savings. The system design maximizes part load energy efficiency and saves additional energy by controlling the energy expended on latent heat removal. The system prevents over-dehumidification. The Chiltrix chiller is, without DHC, already more efficient than any other system in its class. And with DHC enabled, it further lowers energy costs and gains up to 50% additional EER increase. The Chiltrix chiller is perfect for a wide variety of applications including homes and offices in climates with high humidity, low humidity, frequent humidity swings, as well as any applications with variable sensible and latent cooling loads such as equipment cooling, structures with variable occupancy or usage, storage facilities, etc.

Editor's Note-

This document mainly describes operation of the Chiltrix chiller in cooling mode, however, further Carnot analysis easily explains that heating mode energy efficiency is also significantly improved by use of the Chiltrix dynamic capacity matching, variable speed technology, and by taking advantage a more efficient heating LWT parameters made possible by the larger indoor equipment.

Appendix 1.
DEW POINT & HUMIDITY ANALYSIS

TEMP (°F)	RH%	DP (Dew Point)(°F)
80	60	65
80	55	62
80	50	60
80	45	57
80	40	53
78	60	63
78	55	61
78	50	58
78	45	55
78	40	52
76	60	61
76	55	58
76	50	56
76	45	53
76	40	50
74	60	59
74	55	57
74	50	54
74	45	51
74	40	48
72	60	57
72	55	55
72	50	52
72	45	49
72	40	46
70	60	55
70	55	53
70	50	50
70	45	47
70	40	44

The Chiltrix indoor units increase or decrease their fan speed (CFM) to control temperature based on user thermostat settings. In certain applications, the chiller controller also Controls indoor fan speed.

The Chiltrix DHC function monitors indoor humidity and adjusts the indoor unit coil temperature to keep RH% within the user defined allowable range by regulating the loop temperature.

Dehumidification occurs when the coil temperature is below the DP. No dehumidification occurs when the coil temperature is above the DP. When operating below the DP, the rate of dehumidification increases with increased ΔT.

For example, if humidity begins to rise slowly, the DHC controller may lower the system temperature a few °F below the DP. If RH continues to rise, or rises rapidly, the DHC may reduce the coil temperatures to an even lower setting.

As humidity stabilizes within the desired RH range, the DHC will slowly raise the coil temperatures to the highest temperature that allows RH targets to be maintained.

It is critical to maintain proper humidity levels.

Operating the system/coil temperatures as warm as possible, while maintaining RF% targets, allows the system to run at its highest level of total electrical efficiency.

For computer/server rooms: The Class A-1 ASHRAE recommended maximum temperature is 80°F with a maximum RH of 60%. For details, see:
http://www.chiltrix.com/documents/HP-ASHRAE.pdf

Residential:
For residential comfort, health, and protection against microbial growth, ASHRAE Standard 62.1-2013 recommends indoor RH up to but not exceeding 65%.