Engineering Bulletin

Condenser Water Temperature Control

Optimus™ Water-Cooled Chillers
Model RTHD

⚠SAFETY WARNING

Only qualified personnel should install and service the equipment. The installation, starting up, and servicing of heating, ventilating, and air-conditioning equipment can be hazardous and requires specific knowledge and training. Improperly installed, adjusted or altered equipment by an unqualified person could result in death or serious injury. When working on the equipment, observe all precautions in the literature and on the tags, stickers, and labels that are attached to the equipment.

August 2014

RLC-PRB017D-EN

Introduction

Read this manual thoroughly before operating or servicing this unit.

Warnings, Cautions, and Notices

Safety advisories appear throughout this manual as required. Your personal safety and the proper operation of this machine depend upon the strict observance of these precautions.

The three types of advisories are defined as follows:

WARNING	Indicates a potentially hazardous situation which, if not avoided, could result in death or serious injury.
CAUTION	Indicates a potentially hazardous situation which, if not avoided, could result in minor or moderate injury. It could also be used to alert against unsafe practices.
NOTICE	Indicates a situation that could result in equipment or property-damage only accidents.

Important Environmental Concerns

Scientific research has shown that certain man-made chemicals can affect the earth's naturally occurring stratospheric ozone layer when released to the atmosphere. In particular, several of the identified chemicals that may affect the ozone layer are refrigerants that contain Chlorine, Fluorine and Carbon (CFCs) and those containing Hydrogen, Chlorine, Fluorine and Carbon (HCFCs). Not all refrigerants containing these compounds have the same potential impact to the environment. Trane advocates the responsible handling of all refrigerants-including industry replacements for CFCs such as HCFCs and HFCs.

Important Responsible Refrigerant Practices

Trane believes that responsible refrigerant practices are important to the environment, our customers, and the air conditioning industry. All technicians who handle refrigerants must be certified. The Federal Clean Air Act (Section 608) sets forth the requirements for handling, reclaiming, recovering and recycling of certain refrigerants and the equipment that is used in these service procedures. In addition, some states or municipalities may have additional requirements that must also be adhered to for responsible management of refrigerants. Know the applicable laws and follow them.

WARNING

Proper Field Wiring and Grounding Required!

Failure to follow code could result in death or serious injury. All field wiring MUST be performed by qualified personnel. Improperly installed and grounded field wiring poses FIRE and ELECTROCUTION hazards. To avoid these hazards, you MUST follow requirements for field wiring installation and grounding as described in NEC and your local/state electrical codes.

WARNING

Personal Protective Equipment (PPE) Required!

Installing/servicing this unit could result in exposure to electrical, mechanical and chemical hazards.

- **Before installing/servicing this unit, technicians MUST put on all PPE required for the work being undertaken (Examples; cut resistant gloves/sleeves, butyl gloves, safety glasses, hard hat/bump cap, fall protection, electrical PPE and arc flash clothing). ALWAYS refer to appropriate Material Safety Data Sheets (MSDS)/Safety Data Sheets (SDS) and OSHA guidelines for proper PPE.**
- **When working with or around hazardous chemicals, ALWAYS refer to the appropriate MSDS/SDS and OSHA/GHS (Global Harmonized System of Classification and Labelling of Chemicals) guidelines for information on allowable personal exposure levels, proper respiratory protection and handling instructions.**
- **If there is a risk of energized electrical contact, arc, or flash, technicians MUST put on all PPE in accordance with OSHA, NFPA 70E, or other country-specific requirements for arc flash protection, PRIOR to servicing the unit. NEVER PERFORM ANY SWITCHING, DISCONNECTING, OR VOLTAGE TESTING WITHOUT PROPER ELECTRICAL PPE AND ARC FLASH CLOTHING. ENSURE ELECTRICAL METERS AND EQUIPMENT ARE PROPERLY RATED FOR INTENDED VOLTAGE.**

Failure to follow instructions could result in death or serious injury.

Copyright

Trademarks

Revision History

RLC-PRB017D-EN (05 Aug 2014)

Updated for Optimus™ project to use UC800 controller with TD7 user interface.

Table of Contents

Condenser Water Temperature Control

This Engineering Bulletin provides information on:

- Why you need condenser water temperature control on Optimus™ chillers.
- Minimum pressure differential requirements of Optimus chillers.
- Methods of condenser water temperature control.
- Unit control (Tracer™ UC800) condenser water control features.

Trane Optimus chillers start and operate satisfactorily over a range of load conditions with controlled entering condenser water temperature. Reducing the condenser water temperature is an effective method of lowering the chiller's power consumption. The leaving chilled water temperature and the current cooling load have the most direct impact on the optimum condenser water temperature. From a system perspective, improved chiller efficiency may be offset by increased tower fan and pumping costs. In order to achieve system optimization, each subsystem must be operated in the most efficient manner possible while continuing to satisfy the current building load.

To enable the reliable control of unit operating conditions and reduce installation cost the Optimus unit controller (UC800) is equipped with control functions and options to assist in the control of condenser water flow and therefore temperature. These functions and options are discussed in this Engineering Bulletin.

Section 1

Why You Need Condenser Water Temperature Control

Satisfy oil protection safeties

Optimus™ chillers rely on differential pressure between the compressor discharge and suction to move oil through the compressor rotors and bearings for cooling and lubrication. In addition, the Optimus also requires an oil pressure differential in order to load the compressor. Lower temperature and pressure in the condenser (and higher temperature and pressure in the evaporator) can reduce the chiller's differential pressure below the minimum required for proper cooling, lubrication, and loading. Optimus chillers are protected from compressor damage by the UC800 control system; however, an inadequate pressure differential will keep the chiller from operating. Differential refrigerant temperatures low enough to cause unit operation issues typically occur only immediately following a morning cold start when the condenser water temperature may be very low and the chilled water temperature is elevated. The most effective way to maintain the required differential pressure during chiller startup and operation is to apply condenser water temperature or flow control.

Maximize energy efficiency

Power consumption of Optimus chillers can be minimized by operating at the lowest possible pressure differential. From a system energy use perspective, the chiller energy savings may not justify the increased cooling tower and pumping energy use required to obtain lower condenser temperature and pressure. A control scheme that monitors and controls the chilled water system based on the energy use of all system components will minimize the total system power consumption during all modes of operation. The system energy efficiency is seldom optimized by operating the condenser water system (cooling tower) at a temperature that results in chiller operation at its minimum refrigerant differential pressure.

Section 2

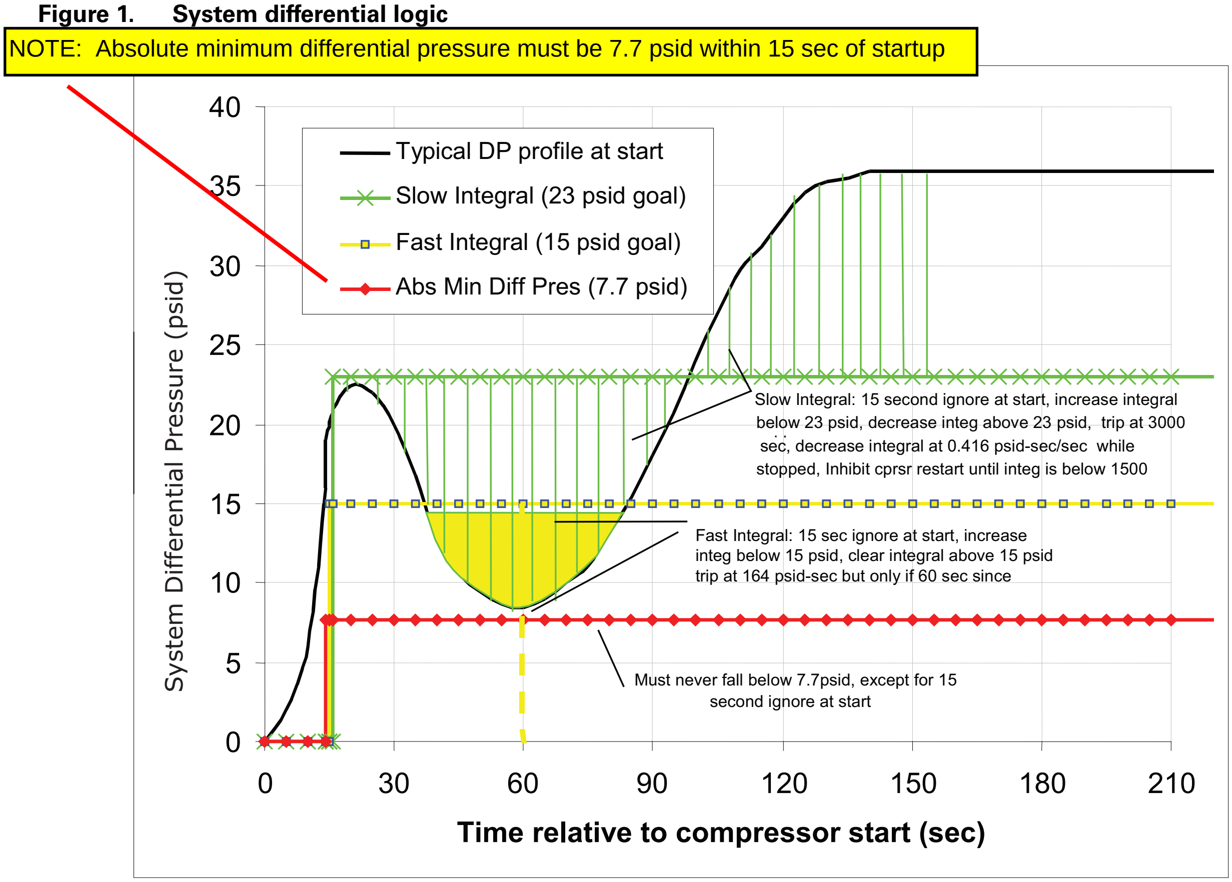
Minimum Pressure Differential Requirements

It is important to understand that the controls for adequate oil circulation is based on refrigerant differential pressure. These pressure requirements are summarized below:

1. During normal operation:
   a. The Optimus™ chiller requires a minimum pressure differential of 23 psid (158.6 kPa) at all load conditions in order to ensure adequate oil circulation.
2. Following unit start-up:
   a. Within 2 minutes of start-up a minimum pressure differential of 15 psid (103.4 kPa) must be achieved.
   b. Control should continue to achieve a minimum pressure differential of 23 psid (158.6 kPa) as soon as possible following attaining the initial 15 psid (103.4 kPa) requirement, but in no longer than 10 minutes.

Note: *If the above guidelines cannot be reliably met, then some form of condenser water temperature control must be used.*

Figure 1. System differential logic



Temperature References

With any chiller the **LEAVING** condenser and evaporator fluid temperature can be used as a good indicator of the refrigerant pressure in the respective heat exchanger. For this reason the **LEAVING** fluid temperatures can be used as an estimate/reference for direct refrigerant differential pressure measurement and control. For this reason alternate leaving fluid temperature requirements are provided below.

The following are temperature references to help ensure adequate oil circulation throughout the chiller.

1. During normal operation:
   a. The Optimus™ chiller requires a minimum refrigerant pressure differential of 23 psid (158.6 kPa) at all load conditions in order to ensure adequate oil circulation.
2. Following unit start-up:
   a. Within 2 minutes of start-up a minimum pressure differential of 15 psid (103.4 kPa) must be achieved.
      i. Water in the evaporator - regardless of the specific temperature in the evaporator, on start up the chiller will keep the evaporator refrigerant pressure as low as possible to maximize the unit refrigerant differential pressure. The temperature reference for this pressure requirement is: the **leaving** condenser water temperature must be at least 45°F (7.2°C) or it must be 14°F (7.8°C) degrees higher than the **leaving** evaporator water temperature within 2 minutes of start-up. This is only valid for a system with water in the evaporator.
      ii. Glycol in the evaporator - The temperature reference for the leaving condenser water temperature varies depending on the type of glycol in the evaporator and the concentration of glycol, so there is no set temperature reference for this case. The leaving condenser temperature should be at least 14°F (7.8°C) degrees higher than the **leaving** evaporator temperature, which means the **leaving** condenser temperature can be below 45°F (7.2°C) if the leaving evaporator temperature is low.
   b. Control should continue to achieve a minimum pressure differential of 23 psid (158.6 kPa) as soon as possible following attaining the initial 15 psid (103.4 kPa) requirement, but in no longer than 10 minutes.
      i. Water in the evaporator - The temperature reference for this pressure requirement is the **leaving** condenser water temperature must be above 45°F (7.2°C) following the initial requirement above and rise to at least 55°F (12.8°C) in no greater than 10 minutes.
      ii. Glycol in the evaporator - The temperature references vary based on the fluid type and concentration in the evaporator.

Note: *Installations with a continuous supply of cold condenser water such as well water, river water, or lake water would be considered a glycol application in the above references for start up and should have condenser water temperature control.*

TOPSS Performance Prediction References

The performance prediction tool TOPSS™ only models steady state operating conditions. It should not be used to reference start up conditions. Entering condenser temperature are required to be above 55°F (12.8°C) and leaving condenser temperature must be above 60°F (15.6°C) to get a selection.

TOPSS checks for a differential pressure of 24 psid (165.5 kPa), slightly more conservative than the controls limit, at full load and part load. The part load screen sometimes shows leaving condenser and leaving evaporator temperature differences that are less than the 14°F (7.8°C) temperature difference referenced above. TOPSS checks the pressure differential at the part load points to make sure the 24 psid (165.5 kPa) limit is met.

In addition, TOPSS has some temperature limits in place to try and help ensure a good design point is selected.

- Entering condenser temperature should be 15°F (8.4°C) or more above the leaving evaporator temperature at full load.
- Entering condenser temperature should be 5°F (2.8°C) or more above the entering evaporator temperature at full load.

Section 3

Methods of Chiller Refrigerant Differential Pressure Control

Five general methods are available to control unit operating conditions for the purpose of refrigerant differential pressure control. All methods indirectly impact the unit leaving condenser water temperature which in turn affects the unit condenser pressure. The five methods fall into two control classifications:

1. Condenser Entering Water Temperature Control
   a. Cooling tower fan control
   b. Cooling tower bypass (run-around loop)
2. Condenser Water Flow Control
   a. Throttling valve
   b. Chiller condenser bypass
   c. Variable speed condenser pump

Note: *It is beyond the scope of this Engineering Bulletin to detail all the possible condenser system water configurations and their required control logic. It is the responsibility of the design engineer and control contractor to consider the system design and control to ensure condenser water temperature or flow can be adequately controlled in all system operating modes to ensure adequate refrigerant differential pressure control for all operating units.*

Important: *In order to achieve and maintain the required refrigerant differential pressure with very cold condenser water temperatures and low chiller loads, the flow through the unit condenser will be modulated to very low levels. This can result in fluttering or opening of lower accuracy condenser water proof-of-flow paddle or pressure differential switches. A better proof-of-flow device in such applications may be a "thermal dispersion" flow switch such as the IFM effector U40100. If a pressure differential switch is to be used care must be taken to select a switch range compatible with the low heat exchanger pressure drop at low flow. Paddle type flow switch use is not recommended with modulating condenser water flow.*

The condenser water temperature should be controlled to the guidelines in "Section 2," p. 7. Each method has certain advantages and disadvantages which are discussed below.

1a. Cooling tower fan control

By turning the cooling tower fans on and off, or modulating the fan cfm, the tower water temperature entering the condenser can be varied. Tower capacity is usually controlled by sensing the tower water sump or basin temperature. This allows a single control system to furnish the proper water temperature to more than one chiller.

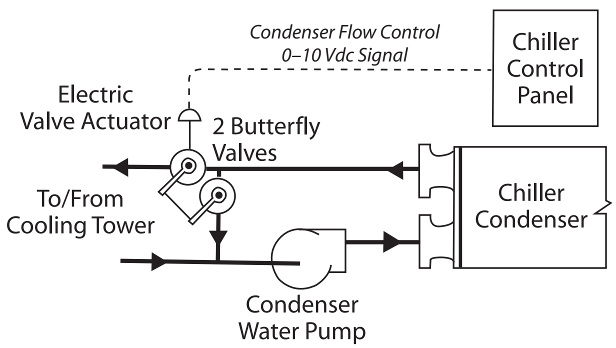
THIS METHOD IS NOT RECOMMENDED FOR OPTIMUS CHILLERS DUE TO THE MORE AGGRESSIVE PRESSURE CONTROL WHICH IS REQUIRED.

Due to the large volume of water in most cooling tower systems, this type of control cannot raise the condensing water temperature fast enough to satisfy chiller safeties. The control system might also be unable to maintain minimum permissible temperatures under certain weather conditions. The resulting unstable system can cause a range of effects from nuisance trips and one hour chiller lockouts up to compressor failures. Pneumatic valves can be used instead of electric valves if the customer prefers their use or existing pneumatic controls already exist. A field supplied electric-to-pressure transducer will be required to convert the 0–10 Vdc condenser water control signal for the pneumatic valve actuator.

1b. Cooling tower bypass (run-around loop)

This design option, shown in Figure 2, elevates the condenser refrigerant pressure by mixing leaving condenser water with entering condenser water from the cooling tower. A suitable bypass piping arrangement connects two butterfly valves with a common actuator linkage to a flanged tee, or uses a single three-way valve. The control signal used to position the valve(s) should be the condenser water control as explained in "Section 4," p. 12.

Figure 2. Cooling tower bypass



Advantage:

- Good unit control with constant water flow through the condenser

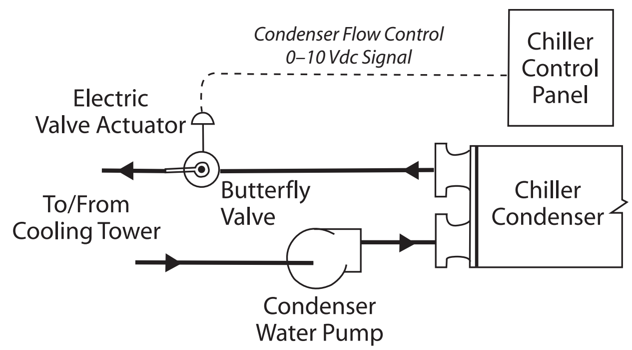
Disadvantages:

- If by-pass is located close to the tower or into to the tower sump this method may NOT provide adequate response due to condenser system water volume between chiller(s) and tower(s).
- 3-way valved bypass may be more expensive than other system design options.
- Control complexity is higher in multiple chiller systems.
- May vary the cooling tower water flow below the tower's minimum limit.

2a. Throttling valve (optionally supplied by Trane for field installation)

This system, shown in Figure 3, elevates the refrigerant pressure by using a butterfly valve to modulate water flow though the condenser. If a throttling valve is provided in the field, make sure the selected valve actuator can close off against the full pump head and the modulating range can stably maintain the minimum condenser flow down to approximately 10% of design flow. The throttling valve can be modulated by the unit control (UC800) condenser water control signal as explained in "Section 4," p. 12.

Figure 3. Throttling valve



Advantages:

- Good control with proper valve sizing at relatively low cost
- Rapid flow/temperature control response
- Pumping cost can be reduced (no VFD required)
- Dedicated valves and control per each individual chiller simplifies the control (particularly in systems that manifold pumps)

Disadvantages:

- May vary the cooling tower water flow below the tower's minimum limit

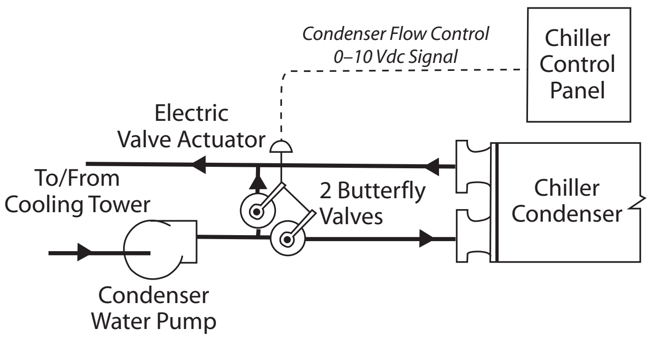
Note: *This is typically not a concern when flow reduction exists for a short period during unit start but may become an issue if reduced tower flow exists for an extended period of time*

- Requires pumps that can accommodate variable flow

2b. Chiller condenser bypass

This option, show in Figure 4, elevates the refrigerant pressure by redirecting condenser supply water back to the cooling tower. A suitable bypass piping arrangement connects two butterfly valves with a common actuator linkage to a flanged tee, or uses a single three-way valve. The control signal used to position the valve(s) should be the condenser water control as explained in "Section 4," p. 12.

Figure 4. Chiller condenser bypass



Advantages:

- Maintains a constant cooling tower flow rate
- Faster flow/temperature response than cooling tower bypass

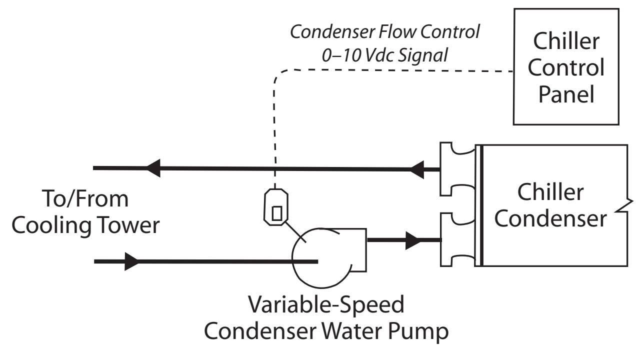
Disadvantages:

- 3-way valved bypass may be more expensive than other system design options
- Control complexity is higher in multiple chiller systems if single valve is used to serve multiple chillers

2c. Variable speed condenser pump

This system also modulates water flow through the condenser, controlling pressure by increasing the difference between the entering and leaving water temperatures. This system, shown in Figure 5, requires a variable speed drive pump on the condenser loop. The control output signal used to vary the water flow should be the condenser water control as explained in "Section 4," p. 12.

Figure 5. Condenser water pump with variable frequency drive



Note: *The pumps and drives must be sized such that the individual unit flow can be modulated down to at least 20% of unit design flow or less. This can be difficult if the condenser pump(s) are oversized or if individual pumps are sized to serve multiple units. If sufficiently low minimum flow cannot be achieved then other action may be required.*

One of the other control methods may be required in addition to pump speed modulation.

The drives may have to be allowed to operate at below the normal 20 hz limit for short periods of time, which is often permissible since it is a variable torque application. Allowance to run the motor/drive below the cataloged minimum speed must be provided by the motor and drive manufacture(s).

Advantages:

- Good flow/temperature control at relatively low cost
- Can reduce pumping cost

Disadvantages:

- Control complexity is higher in manifolded pump condenser water systems.
- May vary the cooling tower water flow below the cooling tower's minimum limit
- Requires a suitable pump, motor, and drive combination

Section 4

Unit Control Features

The unit controller (UC800) provides several hardware and software features/options that can assist in the control of chiller refrigerant differential control.

Condenser pump relay (standard hardware)

As standard, a "condenser water pump starter" contact closure is provided that indicates when the compressor is going to start/run and that condenser water flow is required. The contact opens only after compressor operation is stopped and condenser water flow is no longer required. The contact can be used to start and stop a condenser water pump, initiate the opening of a condenser isolation valve, or signal other controls to initiate the operation of a more complex field supplied condenser water control system i.e. manifolded pumps

Condenser water pump pre-run (standard software function)

In addition to the condenser pump relay, there is an user defined option to delay the compressor start for a specific time after the closing of the "condenser water pump starter" contact. The purpose of this time delay is to allow the water in the condenser system to mix. In systems with long runs of condenser piping inside the building and the cooling tower sump outside the building the chiller may be supplied relatively warm condenser water sitting in the piping for a period of time after start up followed by then a very cold dose of water from the tower sump. This condition can occur during colder weather when a building's HVAC system shuts down in the evening and restarts in the morning. The minimum refrigerant differential/condenser water temperature controls may not be able to react to the dramatic temperature change rapidly enough and an oil flow safety may shut down the chiller due to a rapid decrease in the refrigerant pressure differential. By delaying the compressor start, the condenser water is allowed to circulate throughout the system; equalizing the temperature and even warming it up slightly due to added pump heat. After the condenser water pump pre-run time has expired, the compressor is allowed to initiate a start per the normal startup sequence. The condenser water pump pre-run feature has an adjustable time setting of 0–30 minutes.

Condenser control output (optional hardware/software)

The Optimus™ chiller can be ordered with a "condenser control output" to assist in the control of the unit minimum refrigerant differential pressure. This option provides an analog output that can be field configured for: condenser flow control (fully field adjustable 0-10 Vdc), condenser pressure output, or refrigerant differential pressure output (the last two are transmitter type outputs: 2-10 Vdc fixed).

Note: *An additional (transmitter type 2-10 Vdc fixed) analog output that indicates compressor load as a percentage of the maximum RLA is also provided when this option is ordered.*

Following is a description of the three field selectable functions.

Condenser regulating valve control (optional)

When the output is configured for the "condenser regulating valve control" (also known as head pressure control) the output modulates to control an optional,Trane supplied 2-way water regulating valve (separate option), customer supplied 2 or 3-way flow regulating valve(s), or a customer supplied variable speed condenser water pump. The condenser regulating valve control function includes a PID control loop in the controller which modulates the output to maintain at least the required minimum refrigerant differential pressure required for continuous operating utilizing cold condenser water, or for producing higher temperature evaporator water. Adjustable PID control loop parameters provide flexibility in different applications while maintaining the most efficient operation of the chiller.

Condenser regulating valve control application notes:

- This function is intended to control a valve or pump dedicated to the individual chiller condenser flow control.
- If there are multiple pumps, multiple chiller and/or other condenser water system components that are shared between units a separate field supplied condenser water control system may be required to monitor and distribute the chiller(s) control requirements to the proper system component.
- If the signal is fed to another controller rather than directly to the controlled device (valve or VFD) the intermediate control must pass the signal from the controller analog output to the controlled device at an interval no slower than once every 5 seconds.
- Pneumatic valve actuators can be used if the customer prefers their use or existing pneumatic controls already exist. A field supplied electric-to pressure transducer will be required to convert the unit controller's 0-10 Vdc condenser water control signal for the pneumatic valve actuator.

Condenser pressure output signal

When the output is configured as a "condenser pressure output signal" the analog, 2–10 Vdc fixed signal indicates condenser pressure as a percentage of the High Pressure Cutout (HPC) setpoint. In this configuration a BAS or other intermediate control is required to enable the regulation of unit operating conditions to achieve condenser refrigerant differential pressure control and it is the responsibility of the control contractor to implement the proper control logic.

Chiller differential pressure

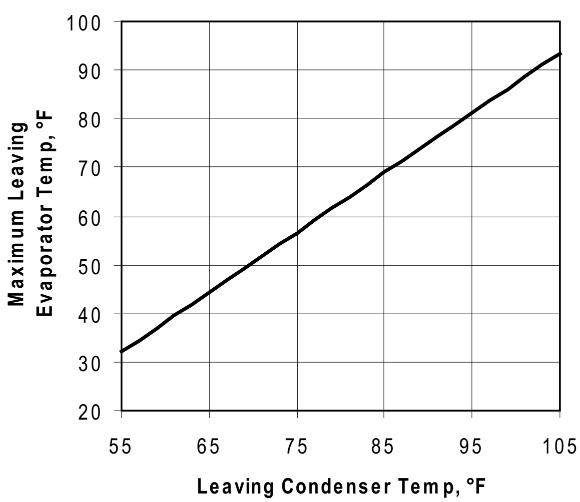
The third option is for the 2–10 Vdc fixed analog output signal to be configured to indicate the refrigerant pressure differential between the evaporator and condenser in psid. The refrigerant pressure differential signal primarily provides data to a building automation system. In this configuration a BAS or other intermediate control is required to enable the regulation of unit operating conditions to achieve condenser refrigerant differential pressure control and it is the responsibility of the control contractor to implement the proper control logic.

Trane supplied 2-way water regulating valve (optional)

For condenser water regulation a field-installed, 2-way butterfly-type (lug-style) valve, with integral electrical operator and factory-mounted valve actuator is available. This 2-way valve is field installed and wired. It is designed to be control led by the optional fully adjustable 0-10 Vdc Condenser Control Output configured for Condenser Regulating Valve Control. The valve actuator is a single-phase, 50 or 60 Hz reversible motor can be selected with 115 or 220 volt power. Valves are available in 6 and 8 inch (152.4 mm and 203.2 mm) sizes.

Note: *The 115 volt reversible motor can be powered directly from the control power transformer located in the starter, simplifying installation.*

Figure 6. Maximum leaving evaporator water temperature function of leaving condenser water temperature



Note: *For more information on UC800 settings for condenser water regulating valve and head pressure control you can reference RLC-SVB32A-EN.*

Condenser refrigerant pressure limit

The Condenser Refrigerant Pressure Limit is somewhat unrelated to control of minimum refrigerant differential pressure but important in the event of a control malfunction that would cause a high condenser refrigerant pressure limit. When the chiller approaches its high condensing pressure limit for any reason, the unit controller will take two simultaneous actions. First, the compressor will limit or reduce loading in order to avoid a shutdown due to high pressure cutout. Second, the controller will close the standard head relief binary output contact to signal that additional heat rejection capacity is required (cooler temperature or greater flow). The condenser water control system can take whatever actions necessary to reduce the chiller's condenser pressure. If these actions are unsuccessful, and the condenser pressure continues to rise the high pressure cutout (HPC) will shutdown the compressor when the high condenser pressure limit is exceeded in order to protect the chiller.

Trane optimizes the performance of homes and buildings around the world. A business of Ingersoll Rand, the leader in creating and sustaining safe, comfortable and energy efficient environments, Trane offers a broad portfolio of advanced controls and HVAC systems, comprehensive building services, and parts. For more information, visit www.Trane.com.

RLC-PRB017D-EN 05 Aug 2014
Supersedes RLC-PRB017-EN (01 Jan 2012)