



TRANE®

Engineering Bulletin

**Condenser Water Temperature Control
For CenTraVac® Centrifugal Chiller Systems**

CTV-PRB006-EN



Preface

Intended specifically for HVAC system designers and Trane field sales engineers, this engineering bulletin provides information on the effect of condenser water temperature on centrifugal chiller systems. It discusses various condenser water temperature control strategies for designing efficient systems and provides operating recommendations for CenTraVac® chillers.

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Optimizing The System

Condenser Flow Rate

“System power” - i.e., energy consumed by the chiller plant - comprises the power used by the chiller(s), cooling tower, and the pumps that circulate evaporator and condenser water.

While lowering the flow rate through the condenser increases chiller power consumption slightly, it allows the tower to operate more efficiently and significantly reduces condenser pumping power. Generally, this reduction more than offsets the small increase in chiller consumption; that means a lower **system** operating cost, particularly at part-load conditions.

Other benefits attributable to a lower-than-“normal” condenser flow rate are listed in the inset at right. Since some of these benefits are mutually exclusive, **clearly define the design goals of the application before conducting an analysis** to discover the optimal flow rate.

Consider these factors when determining the optimal condenser flow rate for your application:

- Pressure drop - i.e., high condenser system pressure drops favor low condenser water flow
- Chiller efficiency - i.e., more efficient selections favor low condenser water flow
- Load profile - i.e., more hours at part load favor low condenser water flow

Energy and economic analysis tools like Trane’s System Analyzer™ and TRACER® software can help you determine the right condenser flow rate for your application. For more information on this subject, review Trane Engineers Newsletter, “How Low-Flow Systems Can Help You Give Your Customers What They Want” (1997-Vol. 26, No. 2).

Potential low-flow benefits for . . .

Existing facilities:

- Lower pumping costs
- Lower leaving-tower/entering-condenser water temperature
- Low tower operating costs
- Increased chiller capacity

And new facilities:

- Lower pumping costs
- Smaller, less expensive condenser pump
- Smaller, less expensive condenser water piping
- Smaller, less expensive cooling tower
- Lower tower operating costs
- Lower leaving-tower/entering-condenser water temperature

Condenser Water Temperature

Cooling towers are generally selected to supply 85°F water to the chiller condenser at design conditions - i.e., when the ambient wet-bulb temperature equals design and the chiller is operating at full load. But these conditions rarely occur. Usually, the ambient wet-bulb temperature is below design and the chiller is running at less than full capacity. The tower can typically provide a lower condenser water temperature at these “off-design” conditions.

While chiller efficiency generally improves as the condenser water temperature decreases, the lowest tower water temperature may be not the most economical system choice. Colder tower water isn’t free ... it requires additional fan energy. Consequently, the **optimum** condenser water temperature (i.e. the temperature that minimizes **system** power) is an intermediate temperature between design and “as cold as possible.”

Note: For a more detailed discussion of condenser optimization strategies, review these Trane Engineers Newsletters: “Tower Water Temperature ... Control It How?” (1995-Vol 24 No 1) and “Chiller Plant System Performance (1989—Vol. 18, No. 2).

Optimizing The System

Economize With Outdoor Air Or Free Cooling

The best ways to economize are often the simplest. If the building load analysis reveals that cooling is needed when ambient temperatures are low, consider adding an outdoor air economizer or free cooling to the system. Both options provide inexpensive cooling and may reduce chiller operation.

Outdoor Air Economizer

In many systems, outdoor air can be used for direct space cooling, provided the sensible temperature is below 55°F and the dew point is low enough to assure that the space humidity level remains below 60% RH. To apply this option successfully, the outdoor- and exhaust-air sections of the air handling equipment must be sized to handle the increased volume of outdoor air. Equally important are a system design and control strategy that promotes proper humidity management.

Free Cooling

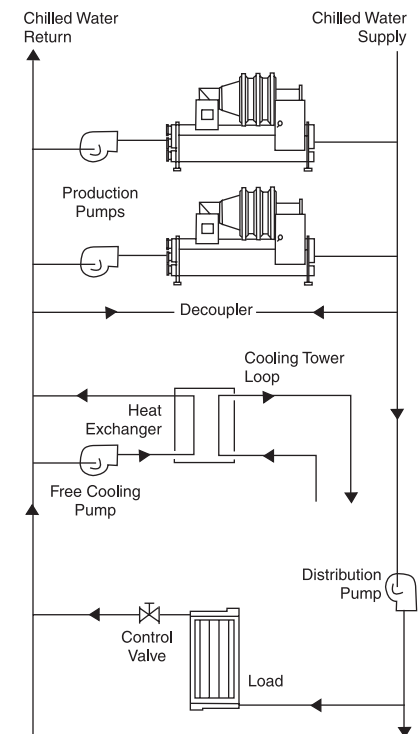
Refrigerant-loop free cooling can be provided by a chiller equipped with that option. No additional pumps or piping are necessary.

Another means of free cooling is a plate-and-frame heat exchanger installed in a "sidecar" arrangement; see Figure 1. Positioning the heat exchanger in series with the chiller(s) exposes it to the warmest water in the system, extending its operating hours and usefulness.

Note: "Sidecar" free cooling is practical when the tower sump temperature is at least 20F less than the return chilled water temperature. For more information about this design option, see the 1991 Trane Engineers Newsletter entitled "A New Era of Free Cooling" (Vol. 20, No. 3).

Regardless of the method used, combining chillers with free cooling requires consideration of the chiller manufacturer's condenser water limits. For more information, see "Operating Recommendations" on page 6 of this bulletin.

Figure 1 — "Sidecar" Free Cooling



Guidelines For CenTraVac® Chillers

Operating Recommendations

All chillers require a minimum pressure difference between the condenser and evaporator to assure proper management of oil and refrigerant, as well as hermetic motor cooling (when applicable). The control strategy used to accomplish this can be simple and indirect - i.e., maintain a fixed minimum condenser refrigerant pressure; or more sophisticated but direct - i.e. maintain the minimum condenser-evaporator refrigerant pressure differential. See "Control Strategies" on page 9.

Following are specific guidelines for CenTraVac condenser refrigerant pressure.

At start-up ...

- The condenser refrigerant pressure should reach the required minimum pressure differential within 15 minutes of starting the chiller.
- Run the chiller no less than 30 minutes at the required minimum refrigerant pressure differential to assure that the oil returns to the oil tank.

When running ...

- For CVHE models of design sequence "1A" or later (built in or after 1990), as well as CVHF and CVHG models, always maintain the minimum refrigerant pressure differential described in Figure 2 between the condenser and evaporator.

Note: For CVHE models built from 1982 to 1990, (design sequences "A" to "Z"), see Trane service bulletin CVHE-SB-26; it describes upgrades that permit operation at the conditions described in Figure 2.

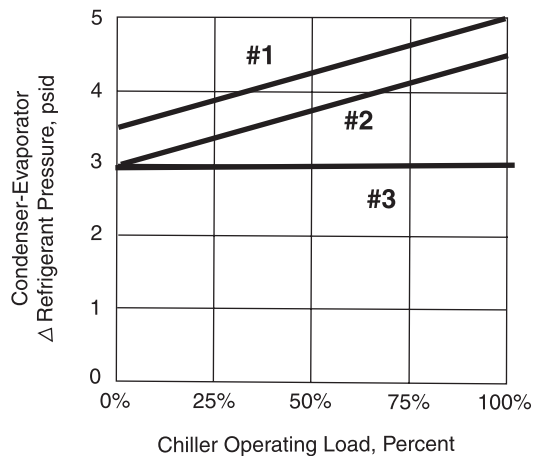
Line #1 applies to units with heat-exchanger shell designations (EVSZ, CDSZ) of 142M, 142L, 210L, 250E, 250L or 250D.

Line #2 applies to units with heat-exchanger shell designations (EVSZ, CDSZ) of 032S, 032L, 050S, 050L, 080S or 080L.

Line #3 applies to units with refrigerant pump.

Note: The "EVSZ" and "CDSZ" shell designations can be found on the Trane CenTraVac chiller selection program output report or in the chiller nameplate information.

Figure 2 — Minimum Condenser-Evaporator Refrigerant Pressure Differential



Maintaining The Minimum Refrigerant Pressure Differential

System Design Options

Regulating the refrigerant pressure difference between the condenser and evaporator typically means maintaining the condenser refrigerant pressure when necessary. There are essentially five different ways to accomplish this through system design:

- cooling tower fan control
- cooling tower bypass
- chiller bypass
- throttling valve(s)
- variable-speed condenser water pump

Brief descriptions of these methods follow, along with the primary advantages and disadvantages of each.

Cooling Tower Fan Control

One way to increase condenser refrigerant pressure is to turn off, or modulate the speed of, the cooling tower fans. Tower fan operation is usually based on the water temperature of the tower sump/basin. This strategy allows a single control system to furnish properly controlled water to more than one chiller.

Advantages ...

- Low-cost controls.
- Better system efficiency.

Disadvantages ...

- Control system may not be appropriate for the application (e.g. those that use river water, or with a tower that serves other systems).
- Many weather conditions can prevent cooling tower fan control from maintaining the leaving-tower water at or above the minimum temperature needed for proper chiller operation.
- If the tower sump contains a great deal of water, it may not be possible to comply with the CenTraVacR operating recommendations on page 6.

Cooling Tower Bypass

This design option, shown in Figure 3, elevates the condenser refrigerant pressure by mixing leaving condenser water with entering-condenser water from the cooling tower. A suitable bypass piping arrangement for this purpose connects two butterfly valves with a common actuator linkage (or a single three-way valve) to a flanged tee.

Advantage ...

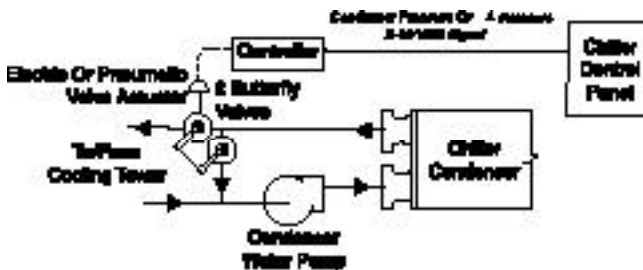
- Excellent control.

Disadvantages ...

- A valved bypass may be more expensive than other system design options.
- Requires a "dedicated" condenser water pump.
- May vary cooling tower flow below the tower flow limit.

Guidelines For CenTraVac® Chillers

Figure 3 — Cooling Tower Bypass



Chiller Bypass

Figure 4 illustrates this system design option. Using the chiller bypass to reduce condenser water flow through the chiller raises the temperature differential (ΔT) across the condenser which, in turn, maintains the condenser refrigerant pressure.

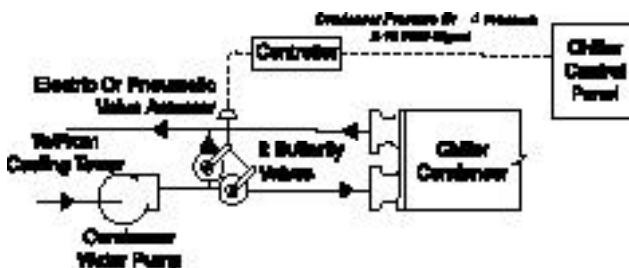
Advantages ...

- Maintains a constant cooling tower flow rate.
- Does not require a “dedicated” condenser water pump.
- The system bypass can be provided at the tower rather than at each chiller, reducing this option’s first cost.

Disadvantages ...

- Like the cooling tower bypass, a valved bypass may be more expensive than other system design options.

Figure 4 — Chiller Bypass



Guidelines For CenTraVac® Chillers

Throttling Valve(s)

Throttling valves offer another means for reducing condenser water flow to increase refrigerant pressure by creating a greater temperature differential across the condenser. There are two common variations of this design option. The first, shown in Figure 5 on page 8, requires only one butterfly valve.

Note: Be sure to select a valve with a modulating range that can maintain the minimum refrigerant pressure differential (ΔP) when the chiller is running at minimum load and at a minimum tower sump temperature.

The nonlinear flow characteristics of a butterfly valve can cause unstable control at low flow rates. To avoid this instability, consider adding a small globe valve in parallel with the butterfly valve as shown in Figure 6. Operate the valves in sequence so that the globe valve opens over the first half of the signal range and the butterfly valve begins to modulate when the globe valve is fully open. The globe valve should be large enough to prevent butterfly valve operation in an unstable region.

Advantages ...

- Provides good control at relatively low cost if the valves are properly sized.
- May reduce system pumping costs.

Disadvantages ...

- Requires a pump that can accommodate variable flow.
- Using a single butterfly valve (without a globe valve piped in parallel) may cause erratic control at low condenser flow rates.
- May vary cooling tower flow below the tower flow limit.

Figure 5 — Throttling Valve

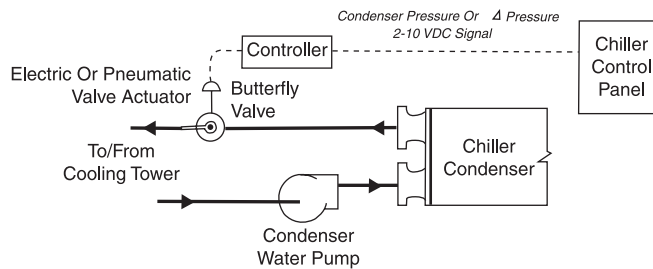
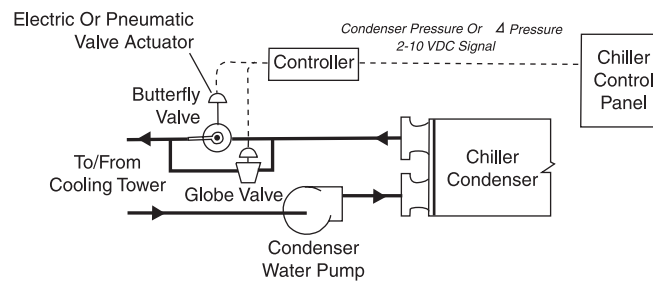


Figure 6 — Throttling Valve With Globe Valve Piped In Parallel



Guidelines For CenTraVac® Chillers

Variable-Speed Condenser Water Pump

This system option also modulates water flow through the condenser, increasing the temperature difference between the entering and leaving water and, in turn, raising the condenser refrigerant pressure. As shown in Figure 7, it requires one variable-speed condenser water pump (an inverter-duty motor may be necessary, depending on the turn-down).

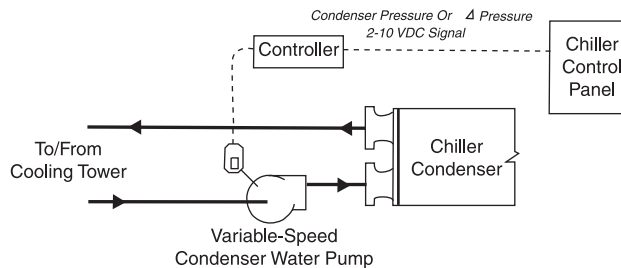
Advantages ...

- Good control at relatively low cost.
- Can reduce pumping costs.

Disadvantages ...

- Requires a suitable pump, motor and drive combination.
- May vary cooling tower flow below the tower flow limit.

Figure 7 — Variable-Speed Condenser Water Pump



Control Strategies

The system design options described in the preceding section offer ways to maintain the necessary condenser-evaporator refrigerant pressure differential by regulating condenser refrigerant pressure. Successfully implementing any of these options requires a control system that measures the refrigerant pressure differential at the chiller. Direct measurement of the condenser-evaporator refrigerant pressure differential provides the most reliable operation, though sensing condenser pressure for an indirect “measurement” offers a practical alternative.

The UCP2 control panel on Trane CenTraVac® chillers can accommodate either control strategy, as described on page 10.

Guidelines For CentraVac® Chillers

Sensing Condenser Refrigerant Pressure

If the evaporator pressure is relatively constant, the minimum refrigerant pressure differential can be maintained by sensing and regulating condenser pressure.

Note: Since this control strategy requires a constant evaporator pressure, do not use it in conjunction with chilled water reset or ice storage.

To help implement this indirect control strategy, the UCP2 control panel can provide a 2-to-10-Vdc signal proportional to the condenser refrigerant pressure; see Figure 8. If it detects a condenser pressure of 0 psia, for example, the UCP2 will produce a 2-Vdc signal. The control panel generates a 10-Vdc signal if it detects a condenser pressure that corresponds to the chiller's high-pressure cutout (HPC) setting, i.e. 15 psig for standard chillers. Figure 9 illustrates the relationship between the UCP2 output signal and condenser pressure for a standard chiller.

Typically, the UCP2's output signal is sent to a dedicated controller which modulates condenser water flow as necessary—either using valve(s) or a variable-speed drive—to maintain the minimum condenser-evaporator pressure differential; see Figure 4 (page 7) through Figure 7 (page 9). *Do not use the UCP2 signal to directly control the valve(s) or drive since this may cause unstable operation.*

Figure 8 — Monitoring Condenser Refrigerant Pressure

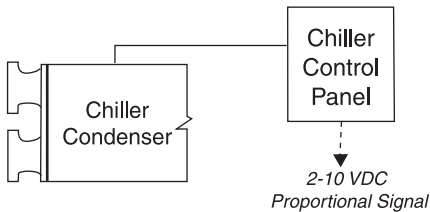
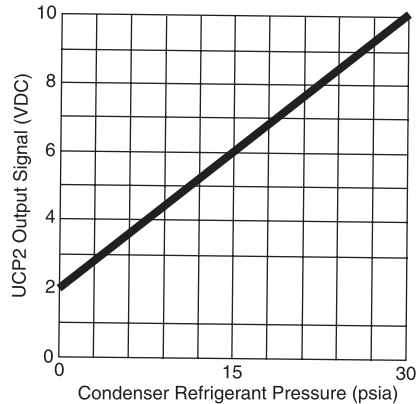


Figure 9 — Refrigerant Pressure-To-Output-Signal Relationship (Standard Chiller)



Sensing Refrigerant Pressure Differential

Directly measuring the refrigerant pressure difference that exists between the condenser and evaporator is the most reliable way to maintain the chillers minimum condenser-evaporator refrigerant pressure differential: it accounts for refrigerant pressure changes in the evaporator and the condenser. That makes this control strategy particularly appropriate for systems with chilled water reset.

As Figure 10 on page 10 implies, the UCP2 monitors the refrigerant pressures in the condenser and evaporator, and produces a 2-to-10-Vdc signal proportional to the pressure difference between them. This output signal is "scalable"; that means the chiller operator can tailor the pressure differential range for the application—i.e. the 2-Vdc signal can be set to represent any value between 0 and 400 psid, and the 10-Vdc signal to represent any value

between 1 and 400 psid. Figure 11 on page 10 illustrates typical settings for the UCP2's pressure-differential output signal.

Again, this 2-to-10-Vdc signal is usually sent to a dedicated controller that will, in turn, modulate valve(s) or a variable-speed drive to alter the condenser flow rate and maintain the minimum condenser-evaporator refrigerant pressure differential. *Do not use the UCP2 signal to directly control the valve(s) or drive since this may cause unstable operation.*

Figure 10 — Monitoring The Condenser-Evaporator Pressure Differential

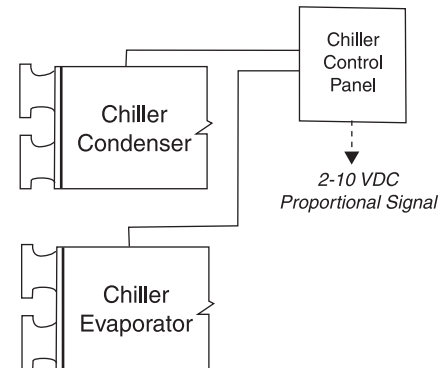
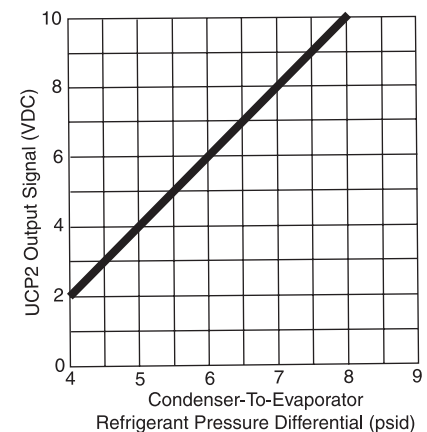


Figure 11 — Typical Settings For UCP2's Scalable Differential Pressure Output Signal



Summary

The **optimum condenser water temperature** for minimizing system power is **not** the lowest possible temperature (within the manufacturers guidelines). Rather, the optimum condenser water temperature will be some intermediate temperature i.e. between design and “as cold as possible.”

The **optimum condenser water flow** for minimizing system power is generally lower than 3 gpm/ton. The optimum flow rate will depend on tower performance, the condenser system, pumps and chiller performance. Other influencing factors are certain first-cost considerations such as smaller/less expensive condenser water pumps, smaller/less expensive cooling towers, and condenser water piping.

All chillers must maintain a minimum refrigerant pressure differential between the condenser and evaporator to assure proper oil- and refrigerant-flow management and adequate hermetic motor cooling. This engineering bulletin defines the minimum differential for CenTraVac® chillers manufactured during or since 1990; it also describes the system design options and unit control strategies that can be used to maintain this minimum differential.



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Literature Order Number	CTV-PRB006-EN
File Number	PL-RF-CTV-000-PRB006-EN-0600
Supersedes	CTV-EB-84 May 1997
Stocking Location	La Crosse

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