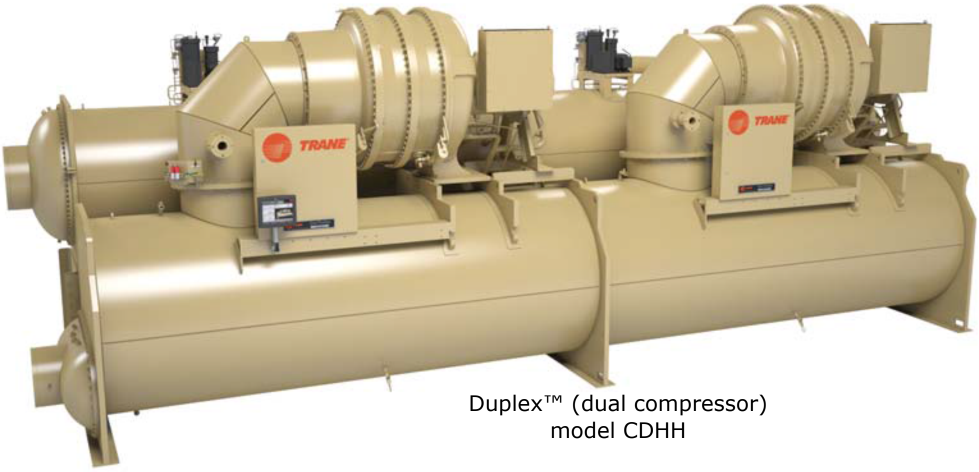
Product Catalog

Series E™ CenTraVac™ Chiller

3000 to 14000 kW (850 to 4000 tons), 50 Hz
3150 to 14000 kW (900 to 4000 tons), 60 Hz

Simplex (single compressor)
model CVHH



Duplex™ (dual compressor)
model CDHH

September 2015

CTV-PRC016B-EN

Introduction

World's Most Efficient Lowest Emissions Chiller

The Evolution Continues—Trane is proud to introduce the latest addition to the EarthWise™ CenTraVac™ product family, the Series E™ chiller, which extends the range of Trane's centrifugal chiller portfolio.

Ingersoll Rand EcoWise™ Portfolio—Building on the Trane commitment to provide the right refrigerant for the right product at the right time, the Series E uses low pressure, R-1233zd(E) and is the first CenTraVac chiller to become part of the EcoWise portfolio of products designed to lower their environmental impact through the use of next-generation, low global warming potential (GWP) refrigerants and high efficiency operation.

Environmental Product Declaration— The EarthWise™ CenTraVac centrifugal chiller was the first—and remains the only—commercial chiller in the world to earn product-specific Type III Environmental Product Declaration (EPD) verification, following the requirements of ISO 14025. Product-specific Type III EPD verification proves the environmental claims regarding chiller performance and documents conformance with the stringent third-party certification requirements of the International Standards Organization (ISO) and verified by Underwriters Laboratories in accordance with ISO 14025.

Standard of Excellence—Trane found that the straightest path to achieve the highest efficiency with the best reliability is through simplicity of design. The Series E™ CenTraVac™ chiller has only one primary moving part—a single rotating shaft supported by two bearings. This direct drive concept minimizes the chance of failure by reducing the number of critical parts—no gear boxes, couplings, extra shafts, or shaft seals. This also reduces wear and drag on parts, resulting in more sustainable, reliable, and efficient operation.

Economically and Environmentally Sound—The Series E chiller continues the CenTraVac chiller tradition as the world's most efficient, lowest emissions chiller. The full load efficiency levels of CenTraVac chillers are simply the best available, at least 10 percent more efficient than the next best centrifugal chiller available today.

Lowest Total Refrigerant Emissions in the Industry—The key to the highest energy efficiency and the lowest refrigerant leak rate is the choice of the low-GWP refrigerant R-1233zd(E). Semi-hermetic compressors—along with a low pressure refrigerant—make the industry's lowest refrigerant leak rate possible (less than 0.5 percent annually as documented in predecessor CenTraVac chiller models).

Tracer AdaptiView™ Chiller Control—Advanced digital control with patented Adaptive Control™ algorithms shorten the chiller's response time in support of energy-saving variable pumping strategies and keep the chiller running, even during the most challenging conditions when other chillers would shut down. A predictive "Feed Forward" control strategy anticipates and compensates for load changes to maintain stable leaving chilled water temperatures. The controller consists of a unit-mounted control panel, the main processor and a full color 30.5-cm (12-inch) touch screen display with animated graphics and 27 language options.

EarthWise System Design—This high-performance system design approach reduces first cost, lowers operating costs, and is substantially quieter than traditional applied systems. Central to the design are low flow, low temperature, and high efficiency for both airside and waterside systems, along with optimized control algorithms for sustainable performance.

Tracer AdaptiView controls provide the system intelligence required to manage the performance and document the benefits.

Smaller equipment and ductwork means supplying less airflow at colder temperatures and enables quieter operation. This also reduces relative humidity in the building, improving indoor air quality.

Compared to conventional designs, an EarthWise chilled water system reduces the total cost of ownership by lowering installation and operating costs. For more information, visit: www.trane.com/commercial/north-america/us/en/products-systems/earthwise-systems.html

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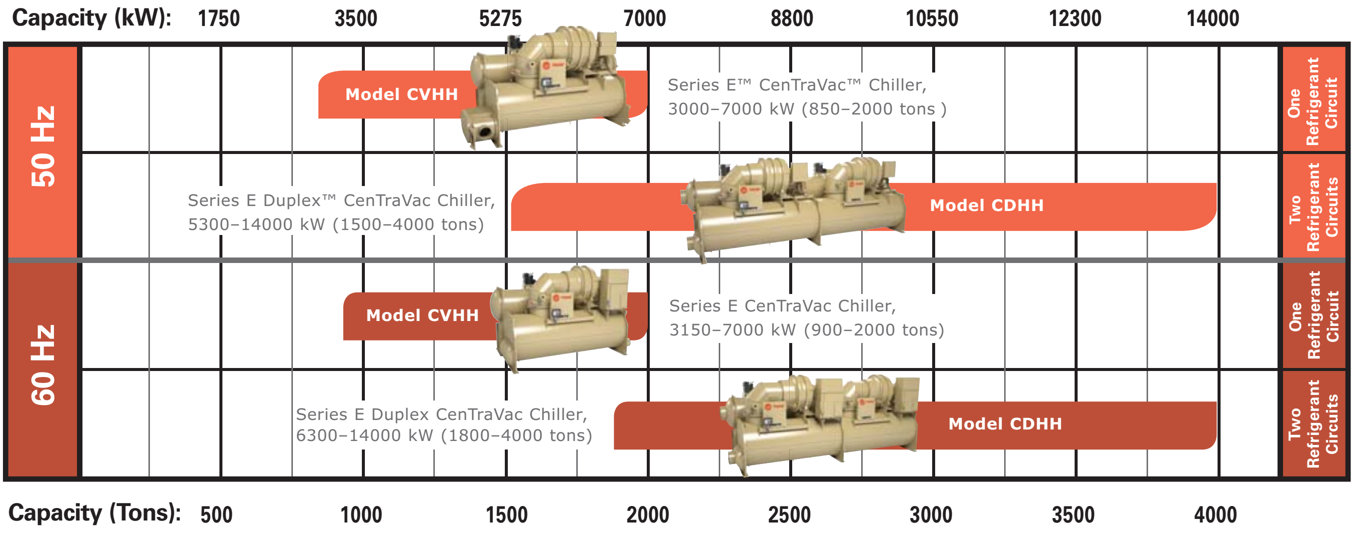
Tonnage Ranges by Series E CenTraVac Chiller Model Number



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Revision History

CTV-PRC016B-EN (14 Sep 2015)

- Added data for new 50 Hz models: CVHH (950 and 1050) and CDHH (1750 and 2250).
- Added new options: Free Cooling, and Partial Heat Recovery.
- Updated unit weights for all models.
- Updated minimum and maximum evaporator flow rates for all models.

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General Information

Unmatched Local Expertise

The performance and reliability of a Series E CenTraVac™ chiller is backed by a local team of engineers. These engineers can help answer your questions or solve your problems regarding system design application, installation, or evaluation of equipment alternatives. No other manufacturer can offer that degree of support to its customers.

ISO 9001 Certification

The quality management system used by the Trane CenTraVac chiller manufacturing facility is ISO 9001 certified. The system documents office, manufacturing, and testing procedures for maximum consistency in meeting or exceeding customer expectations. ISO 9001 requires extensive documentation on how quality assurance activities are managed, performed, and continuously monitored. Included in the system are verification checkpoints from the time the order is entered until final shipment. In addition, product development is subjected to formal planning, review, and validation.

Certified AHRI Performance

Trane® centrifugal chillers are rated within the scope of the Air-Conditioning, Heating & Refrigeration Institute (AHRI) Certification Program and display the AHRI Certified® mark as a visual confirmation of conformance to the certification sections of AHRI Standard 550/590 (I-P) and ANSI/AHRI Standard 551/591 (SI). The EarthWise™ purge is rated in accordance with AHRI Standard 580.

The applications in this catalog specifically excluded from the AHRI certification program are:

- Low temperature applications, including ice storage
- 60 Hz chillers larger than 10550 kW (3000 tons) and/or greater than 15000 volts
- 50 Hz chillers larger than 10550 kW (3000 tons) and/or greater than 15000 volts
- Heat recovery and heat pump ratings
- Glycol and brines

District Cooling

Trane Adaptive Control™ algorithms and the multi-stage design allow all CenTraVac™ chillers to operate at low leaving water temperatures without the use of glycol or other freeze inhibitors. This reduces the cost of delivering cooling capacity over long distances. Pre-engineered thermal storage systems using Trane chillers extend the chillers exceptional reliability to the rest of the district cooling plant.

Turbine Inlet Cooling

Trane chillers are frequently used in conjunction with combustion turbines to increase the power capacity, efficiency, and life of the turbine. Turbine inlet cooling can eliminate the need for inlet water spray to reduce NO_X emissions. With turbine inlet cooling, plants can delay or even avoid the need for additional turbines because more capacity can be obtained from existing turbines.

The Ingersoll Rand Climate Commitment

The Ingersoll Rand EcoWise™ portfolio is a demonstration of Ingersoll Rand's commitment to reducing the environmental impact of our products and providing more sustainable product choices for our customers. The Series E™ CenTraVac™ chiller was the first Trane product to become part of this portfolio.

EcoWise products are designed to lower their environmental impact with next-generation, low global warming potential refrigerants and high efficiency operation.

Next-Generation Refrigerant

Trane has always taken a balanced approach to selecting refrigerants, considering factors such as safety, sustainability, efficiency, sound, reliability and overall lifecycle impact. The selection of low pressure R-1233zd(E) enables Trane to continue this commitment as the industry evolves through its next refrigerant transition, from HCFCs and HFCs to next-generation, low-GWP refrigerants, like R-1233zd(E).

Classified as an "A1" refrigerant per ASHRAE Standard 34, R-1233zd(E) is one of the few non-flammable olefin options available today. It has near-zero global warming potential and enables best-in-class chiller efficiencies. Low pressure refrigerants have been a key element of the Trane centrifugal chiller design since its introduction in 1938, and the Series E CenTraVac chiller continues this tradition with its low pressure, leak-tight design.

Comparing Low and Medium Pressure Chiller Operation

Consider the benefits of a low-pressure Series E CenTraVac chiller versus medium pressure machines:

Table 1. Low to medium pressure comparison at AHRI conditions

	Low Pressure	**Medium / High Pressure**
Evaporator	• Always at negative pressure • Air leaks inward • Refrigerant lost: (# air leak in) x purge efficiency(a) • No refrigerant loss into equipment room	• Operates at positive pressure • Refrigerant leaks outward at moderate rate • Refrigerant loss is difficult to know, performance is degraded • Refrigerant loss is into equipment room
Condenser	• At slightly positive pressure at all conditions • In the event of a leak, refrigerant could leak outward, but at a very low rate	• Always at high positive pressure • In the event of a leak, refrigerant would leak outward at a very high rate
Monitoring of leak rate	• Trane EarthWise™ purge is able to continuously monitor in leakage with the run meter. • Refrigerant monitor as required by ASHRAE. • Purge can be connected to a building automation system for notification of increased purge operation (in-leak). Similarly, the BACnet® module allows the refrigerant monitor to be connected to the building automation system.	• Only ways to monitor leak rate on medium/high pressure chiller are: - periodic leak checks - purchase refrigerant monitor • Refrigerant monitor as required by ASHRAE. • Typically, the only time a leak is detected on a medium/high pressure chiller is during spring startup. This means that a chiller which develops a leak in the summer may leak continuously until the following spring.
Typical Pressures: 3.3°C (38°F) evaporator 37.8°C (100°F) condenser	**R-1233zd(E)** Evap: -46.2 kPaG (-6.7 psig) Cond: 99.3 kPaG (14.4 psig)	**R-134a** Evap: 228.2 kPaG (33.1 psig) Cond: 855.6 kPaG (124.1 psig)

(a) Trane EarthWise purge efficiency does not exceed 0.02 units of refrigerant per unit of air.

Features and Benefits

Factory Testing for Assured Performance

Series E™ CenTraVac™ chillers that fall within the scope of AHRI Standard 550/590 (IP) and ANSI/AHRI Standard 551/591 (SI) bear the AHRI seal. All other CenTraVac chillers, and the selection software itself, are rated in accordance with the Standard. Performance testing is a key part of this program. Factory performance tests confirm that your chiller's actual performance matches what was predicted during the selection process, before the chiller is installed.

Standard AHRI tests are a well-recognized industry practice; however, a chiller's operating conditions vary significantly based on the needs of the building and its occupants. Data centers, hospitals and retail locations all have specific requirements unique to their application and location. The Trane myTest™ program offers a fully customizable portfolio of chiller test packages and proof-of-performance options, in addition to standard AHRI tests. All tests and demonstrations are done in accordance with AHRI Standard 550/590, and the testing equipment is calibrated and validated by the National Institute of Standards Technology (NIST).

AHRI allows for standard tolerances in its certified selections, however, some customers may require tighter tolerances. Selecting and testing to zero tolerance requirements ensures that the full capacity and performance benefit are realized.

To learn more, contact your local Trane account manager or visit www.trane.com/myTest.

The Series E CenTraVac Chiller Operating Cycles

Figure 1. Two-stage refrigerant flow (60 Hz)

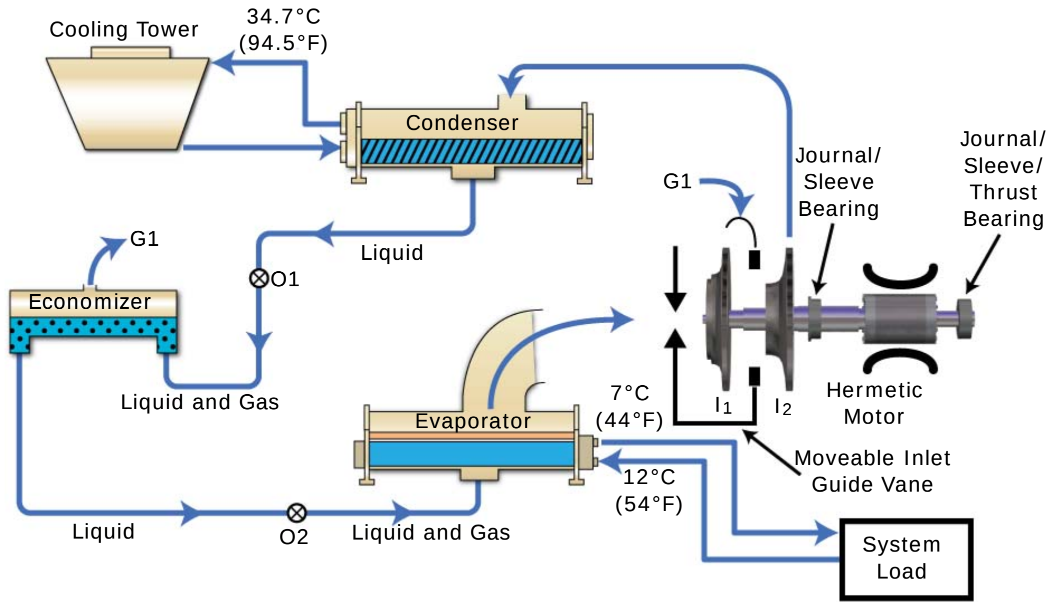
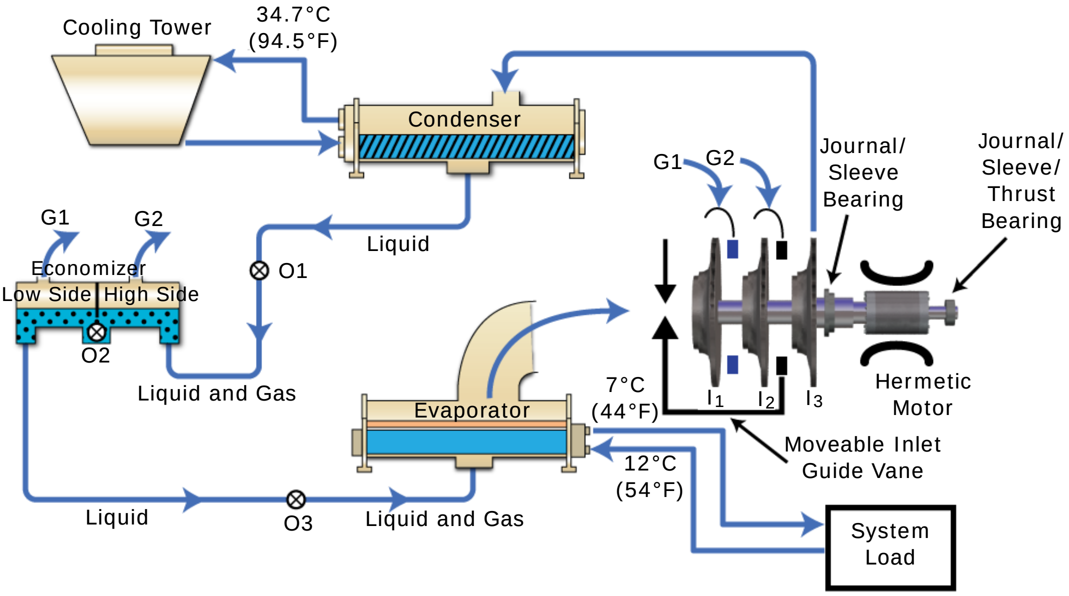


Figure 2. Three-stage refrigerant flow (50 Hz)



Compressor Motor

The motor used in the Series E™ CenTraVac™ chiller is a specially designed squirrel cage, two pole induction motor suitable for 50 or 60 hertz, three phase current. CenTraVac chiller motors are cooled by liquid refrigerant surrounding the motor windings and rotor. Using liquid refrigerant results in uniform low temperatures throughout the motor, which prolongs motor life over open designs.

Motor heat is rejected out to the cooling tower, which helps keep the equipment room at a desirable temperature.

Fixed Orifice Flow Control

For proper refrigerant flow control at all load conditions, the Series E™ CenTraVac™ chiller design incorporates the Trane patented fixed orifice system. The orifices are optimized for full- and part-load chiller performance during the selection process. It eliminates float valves, thermal expansion valves, and other moving parts. Since there are no moving parts, reliability is increased.

Low Speed, Direct Drive Compressor

With only one primary rotating component—the rotor/impeller assembly—the Trane low speed, direct drive design operates exceptionally quietly. The smoothly rotating Series E™ CenTraVac™ chiller compressor is inherently quieter than gear-driven compressors. Typical CenTraVac chiller sound measurements are among the quietest in the industry. Trane can guarantee sound levels with factory testing and measurements in accordance with ANSI/AHRI Standard 575.

The direct drive, low speed compressor with a motor shaft supported by two bearings provides quiet, reliable and more efficient operation. Compressors using gears suffer mesh losses and extra bearing losses in the range of three to five percent at full load. Since these losses are fairly constant over the load range, increasingly larger losses (as a percentage) result as the load decreases.

Multiple Stages of Compression

The multi-stage design provides a stable operating envelope to meet dynamic system needs and enables customers to reliably operate their Series E chiller in all real world conditions. It also enables the use of a flash economizer for better efficiency.

Flash Economizer

The three-stage (50 Hz) Series E™ CenTraVac™ chiller models have a two-stage economizer, providing up to 7 percent better efficiency than designs with no economizer. Since the chiller uses three impellers, it is possible to flash refrigerant gas at two intermediate pressures between the evaporator and condenser, significantly increasing chiller efficiency. This improvement in efficiency is not possible in single-stage chillers where all compression is done by one impeller.

The two-stage (60 Hz) Series E™ CenTraVac™ chiller models have a single-stage economizer, providing up to 4.5 percent better efficiency than designs with no economizer. Since the chiller uses two impellers, it is possible to flash refrigerant gas at an intermediate pressure between the evaporator and condenser, significantly increasing chiller efficiency. This improvement in efficiency is not possible in single-stage chillers where all compression is done by one impeller.

Inlet Guide Vanes

Part-load performance is further improved through the use of moveable inlet guide vanes. Inlet guide vanes improve performance by throttling refrigerant gas flow to exactly meet part-load requirements and by prerotating refrigerant gas for optimum entry into the impeller. Prerotation of refrigerant gas minimizes turbulence and increases efficiency.

Refrigerant/Oil Pump Motor

Low voltage chillers will have a 380–600V 50/60 Hz, 3-phase, 2 hp motor. Medium voltage chillers will have a 200–240V 50/60 Hz, 1-phase, 2 hp motor.

EarthWise Purge System

The EarthWise™ purge design features a high-efficiency carbon filter with an automatic regeneration cycle. The filter separates refrigerant from non-condensable gas and collects it. When the filter senses that it is full, the regeneration cycle begins, and reclaimed refrigerant is automatically returned to the chiller. This keeps the purge efficiency at its peak without the need to exchange carbon canisters.

Normal operating efficiency does not exceed 0.02 units of refrigerant lost per unit of dry air removed. The purge system can be operated at any time, independent of chiller operation, per ASHRAE Standard 147.

Integrated Rapid Restart

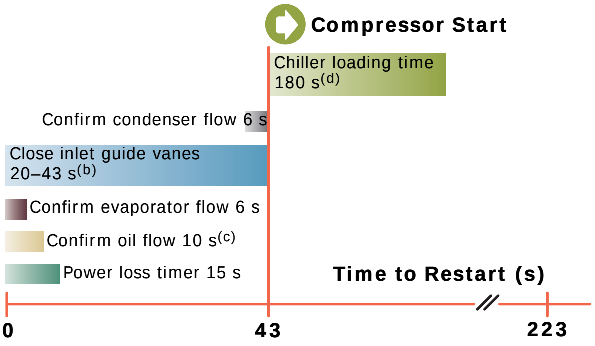
Note: *Restart times provided are based on Series E chillers with a constant speed starter. Restart times with a Trane Adaptive Frequency™ drive will vary. Contact your local Trane account manager for more information.*

A loss of cooling capacity can be costly, which is why Series E™ CenTraVac™ chillers are designed to integrate seamlessly with uninterruptible power supplies (UPS) and have the shortest restart times in the industry.

In the event of a power interruption, the chiller defaults to its rapid restart mode, optimizing electrical and mechanical variables, including guide vane position. This not only helps the chiller get back online faster, but it also provides the least amount of load on your building's electrical infrastructure, which can make a big difference if your building has a backup generator.

Even under extreme conditions, CenTraVac chiller restart times have been verified at as few as 43 seconds, as shown in Figure 3. Thanks to fast restart times like these, you can substantially minimize the risks of financially devastating damage to assets caused by overheating due to power outages. Of course, the truest test of a chiller's restart capabilities is the amount of time it takes to resume full-load cooling, and this is where the Series E CenTraVac chiller really shines. An 80 percent cooling load can be achieved in less than three minutes after power restoration—your assurance that the cooling capacity your equipment requires is just a few minutes away.

Figure 3. Tracer AdaptiView™ restart time after power loss (with UPS)—Simplex (single compressor) Series E CenTraVac chiller[a]



(a) Assumes chiller starter power restored within 120 seconds (s)
(b) Function of chiller load
(c) Oil pump on UPS
(d) Estimated time to 80 percent load

Series E CenTraVac Chiller Pressure-Enthalpy (P-H) Diagrams

Figure 4. Three-stage Series E™ CenTraVac™ chiller P-H diagram

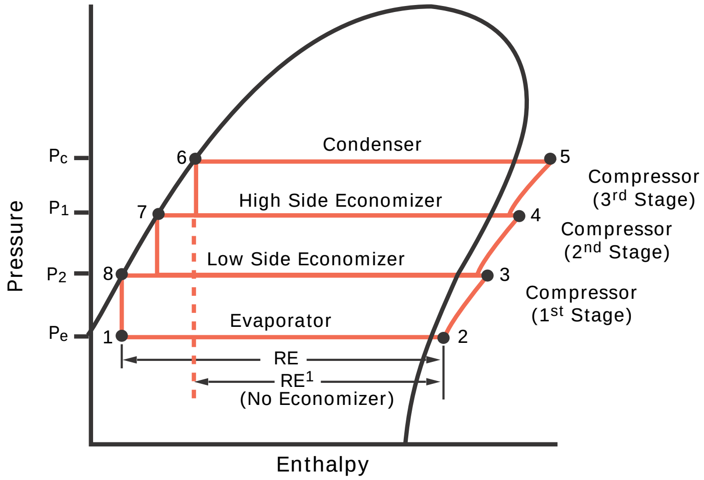
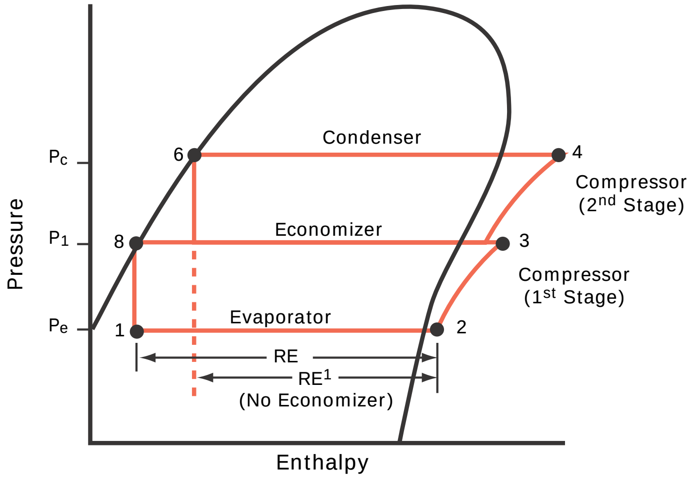


Figure 5. Two-stage Series E™ CenTraVac™ chiller P-H diagram



The pressure-enthalphy (P-H) diagrams describe refrigerant flow through the major chiller components. The diagrams confirm the superior operating cycle efficiency of the three- and two-stage compressor with economizer, respectively.

Evaporator—A liquid-gas refrigerant mixture enters the evaporator (point 1). Liquid refrigerant is vaporized (point 2) as it absorbs heat from the system cooling load. The vaporized refrigerant then flows into the compressor's first stage.

Compressor First Stage—Refrigerant gas is drawn from the evaporator into the first stage compressor. The first-stage impeller accelerates the gas, increasing its temperature and pressure into the first stage of the compressor (point 3).

Compressor Second Stage—Refrigerant gas leaving the first stage of the compressor is mixed with cooler refrigerant gas from the low pressure side of the economizer. This mixing lowers the enthalpy of the mixture entering the second stage. The second-stage impeller accelerates the gas, further increasing its temperature and pressure (point 4).

Compressor Third Stage—For Series E™ CenTraVac™ chillers with three-stage compressors, the refrigerant gas leaving the compressor's second stage is mixed with cooler refrigerant gas from the high pressure side of the two-stage economizer. This mixing lowers the enthalpy of the gas mixture entering the third stage of the compressor. The third-stage impeller accelerates the gas, further increasing its temperature and pressure (point 5), then discharges it to the condenser.

Condenser—Refrigerant gas enters the condenser where the system cooling load and heat of compression are rejected to the condenser water circuit. This heat rejection cools and condenses the refrigerant gas to a liquid (point 6).

For three-stage Series E CenTraVac chillers with the patented two-stage economizer and refrigerant orifice system, liquid refrigerant leaving the condenser (Figure 4, p. 12, point 6) flows through the first orifice and enters the high pressure side of the economizer. The purpose of this orifice and economizer is to preflash a small amount of refrigerant at an intermediate pressure (P1). Preflashing some liquid refrigerant cools the remaining liquid (point 7).

Refrigerant leaving the first stage economizer flows through the second orifice and enters the second-stage economizer. Some refrigerant is preflashed at an intermediate pressure (P2). Preflashing the liquid refrigerant cools the remaining liquid (point 8).

To complete the operating cycle, liquid refrigerant leaving the economizer (point 8) flows through a third orifice system. Here, refrigerant pressure and temperature are reduced to evaporator conditions (point 1).

For two-stage Series E CenTraVac chillers with economizer and refrigerant orifice system, liquid refrigerant leaving the condenser (Figure 5, p. 12, point 6) flows through the first orifice system and enters the economizer. The purpose of the orifice and economizer is to preflash a small amount of refrigerant at an intermediate pressure (P1) between the evaporator and condenser. Preflashing some liquid refrigerant cools the remaining liquid (point 8).

Another benefit of flashing refrigerant is to increase the total evaporator refrigeration effect from RE^1 to RE. The two-stage economizer of the three-stage Series E CenTraVac chillers provides a 7 percent better efficiency than chillers with no economizer. The single-stage economizer of the two-stage Series E CenTraVac chiller provides up to 4.5 percent better efficiency than chillers with no economizer. To complete the operating cycle, liquid refrigerant leaving the economizer (point 8) flows through a second orifice system. Here, refrigerant pressure and temperature are reduced to evaporator conditions (point 1).

Unit Options

Trane Starters and Drives

A Wide Array of Low- and Medium-Voltage Starters

Trane starters can be applied to low- or medium-voltage applications. The current draw of the compressor motor determines the size of the starter. The starter size must be greater than, or equal to, the compressor motor current draw.

Table 2. Trane Series E™ CenTraVac™ chiller starter and drive choices

Low Voltage (380–600V)		Medium Voltage (3300–6600V)		Medium Voltage (10,000–11,000V)
Remote-Mounted	**Unit-Mounted**	**Remote-Mounted**	**Unit-Mounted**	**Remote-Mounted**
Wye-Delta • Up to 1860 amps	**Wye-Delta** • Up to 935 amps	**Across-the-Line** • Up to 720 amps • Isolation switch, power fuses standard	**Across-the-Line** • Up to 360 amps • Isolation switch, power fuses standard	**Across-the-Line** • Up to 94 amps • Isolation switch, power fuses standard
Solid-State • Up to 1800 amps with circuit breaker required	**Solid-State** • Up to 1143 amps with disconnect or circuit breaker required	**Primary Reactor** • Up to 720 amps • Isolation switch, power fuses standard	**Primary Reactor** • Up to 360 amps • Isolation switch, power fuses standard	**Primary Reactor** • Up to 94 amps • Isolation switch, power fuses standard
	Adaptive Frequency™ Drive (AFD) • Up to 1210 amps • Circuit breaker standard 380–480V	**Autotransformer** • Up to 720 amps • Isolation switch, power fuses standard	**Autotransformer** • Up to 360 amps • Isolation switch, power fuses standard	**Autotransformer** • Up to 94 amps • Isolation switch, power fuses standard
		Adaptive Frequency Drive • Up to 375 amps • Isolation switch, power fuses standard		

Overview, Standard and Optional Features

All factory-installed or remote-mounted starters provided by Trane offer the following standard features for safe, efficient application and ease of installation:

Standard Features

- IP20 starter enclosure.
- Starter enclosures capable of being padlocked (unit-mounted wye-delta and solid-state starters).
- Control power transformer and oil pump motor circuit:
  - 50/60 Hz low voltage units: 4 kVA single phase control power transformer to provide power for all chiller-mounted control devices[1] with 120V secondary voltage and 3-phase line voltage 380–600 Vac to provide power to the three-phase oil pump motor circuit.
  - 50/60 Hz medium voltage units: 8 kVA single phase control power transformer with dual secondary voltage to provide power for all chiller-mounted control devices[1] with 120V secondary voltage and 200–240V secondary voltage to provide power to the single phase oil pump motor circuit.
- Three-phase incoming line terminals.
- Six output load terminals for low-voltage starters (at or below 600 Vac), three output load terminals for medium voltage (greater than 600 Vac). Unit-mounted starters are factory-connected to the motor.

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[1] Exception: Remote-mounted medium-voltage AFDs and customer-supplied starters.

- Automatic closed-transition transfer from wye to delta on any two-step starter (unit-mounted).
- One pilot relay to initiate start sequence from Series E™ CenTraVac™ chiller control circuit signal.

Optional Features

- Ground fault protection.
- Digital metering devices.
- Surge protector/lighting arrestor.
- Standard, high interrupt, and higher interrupt circuit breakers that are mechanically interlocked to disconnect line power when the starter door is open.
- Special IP52 enclosures.
- Analog ammeters and voltmeters.
- Special function pilot lights.
- Under/over voltage.

Factory-Installed Starters

- Factory-tested chiller/starter combination.
- Enhance electrical system reliability.
- Optimize control of the Series E™ CenTraVac™ chiller motor/compressor start and protection subsystem.
- Factory quality control of the starter-to-chiller electrical connections.
- Eliminate field-installed disconnect switch (when optional circuit breaker is used).
- Reduce the number of field electrical connections.
- Eliminate chiller-to-starter field wiring.
- Reduce starter installation costs 20 to 35 percent.
- Complete package available with UL or GB agency approvals.
- Eliminate starter mounting pad and required equipment room floor space.
- Eliminate starter-to-disconnect switch field wiring (when optimal circuit breaker is used).
- Reduce system design time-starter components and interconnecting wiring are pre-engineered and selected.

Standard Motor Protection

Three current transformers monitor phase current. Contactor position and various voltage signals provide extensive interlocking between the starter and the chiller controller. All logic and subsequent instruction originate in the chiller controller. Protection against the following starter detections is provided:

- Loss of phase
- Distribution fault
- Excessive accelerating time
- Incomplete starting sequence
- Phase reversal
- Improper starter circuitry
- Phase amperage unbalance
- High motor current (starting and running)

Unit Options

Figure 6. Typical equipment room layout: unit-mounted Wye-Delta starter

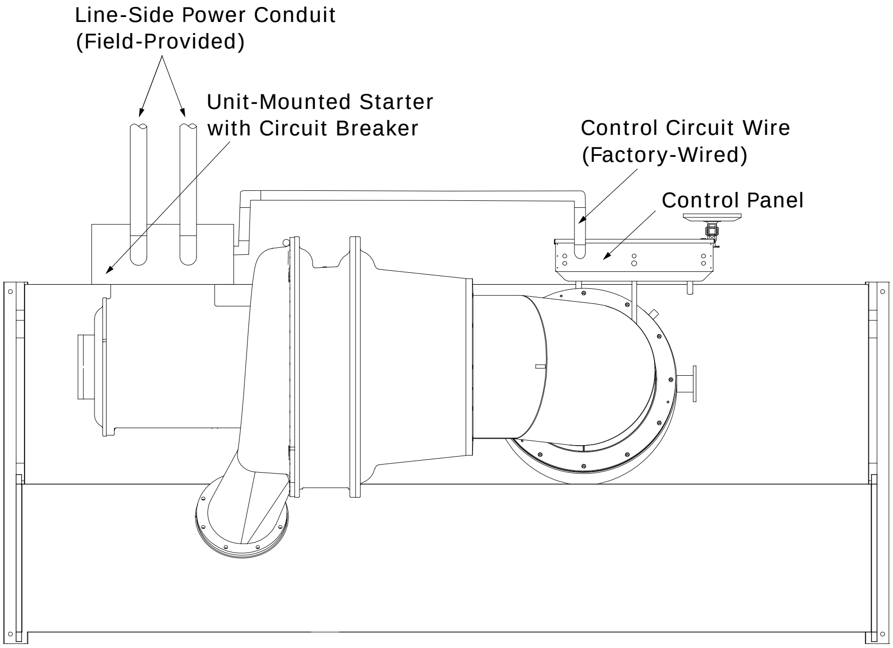
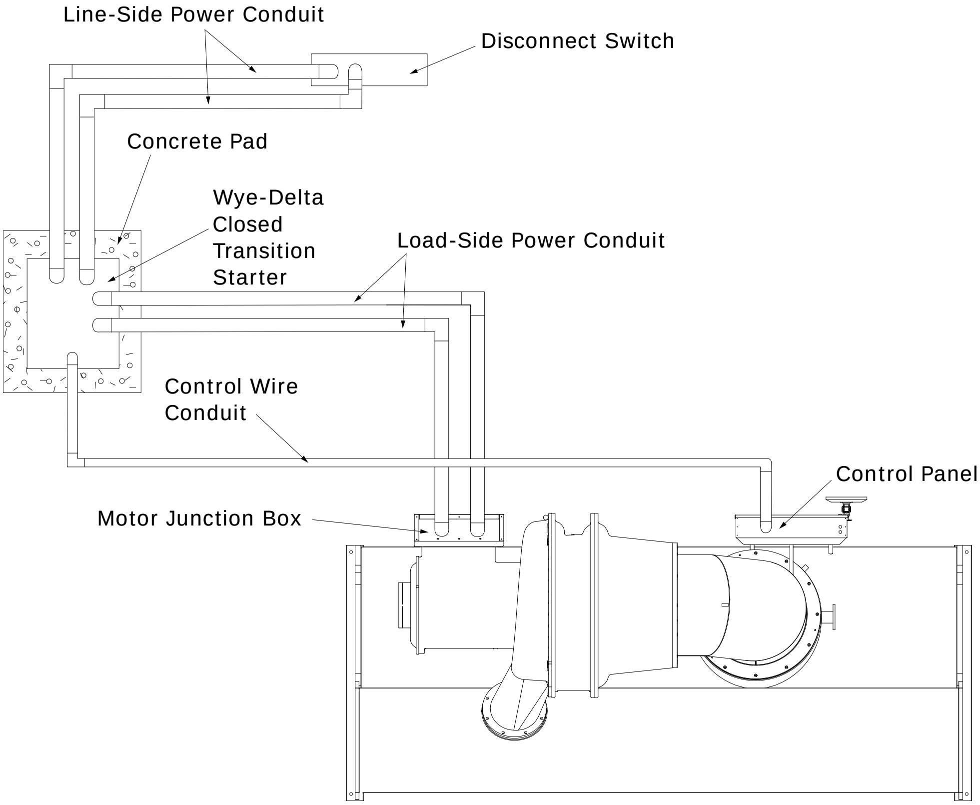


Figure 7. Typical equipment room layout: conventional remote Wye-Delta starter



Unit-Mounted Low-Voltage Wye (Star)-Delta Starters

One of the most common starters in the industry is the wye (star)-delta. It is an electromechanical starter initially set up in a “wye” or “star” configuration, which then transitions to a “delta” configuration during the starting sequence. This starter type can selected as a unit- or remote-mounted option as shown in Figure 6, p. 16 and Figure 7, p. 16. When starting and during acceleration, the motor is connected in its wye configuration. Because of this arrangement, the voltage applied to the motor windings is reduced to the inverse of the square root of three, or 0.58 times line voltage. This reduction in winding voltage results in a reduction in inrush current. The inrush current is 0.33 times the full-voltage locked rotor current rating of the motor. The accelerating torque of the motor is also reduced to 33 percent of the full-voltage torque rating, which is sufficient to fully accelerate the compressor motor. The chiller controller monitors the motor current during operation via current transformers located in the starter enclosure. During acceleration, when the line current drops to approximately 0.85 times rated load current, transition is initiated. The closed transition feature provides for a continuous motor current flow during transition by placing resistors in the circuit momentarily. This prevents the motor from losing phase to the line current during this period. With the completion of transition, the motor windings are connected in the delta configuration with full line voltage.

When a starter-mounted control power transformer is provided, the unit will have an oil pump motor circuit to drive the 3-phase oil pump motor.

Unit-Mounted Low-Voltage Solid-State Starters

A solid-state starter controls the starting characteristics of a motor by controlling the voltage to the motor. It does so through the use of Silicon Controlled Rectifiers (SCRs) and an integral bypass contactor for power control.

When a low voltage, unit mounted solid state starter is provided, it will include a starter-mounted control power transformer and an oil pump motor circuit to drive the 3-phase oil pump motor.

Silicon Controlled Rectifiers

An SCR will conduct current in one direction only when a control signal (gate signal) is applied. Because the solid-state starter is for use on alternating current (AC), two SCRs per phase are connected in parallel, opposing each other so that current may flow in both directions. For three-phase loads, a full six-SCR configuration is used.

During starting, control of current or acceleration time is achieved by gating the SCR on at different times within the half-cycle. The gate pulses are originally applied late in the half-cycle and then gradually applied sooner in the half-cycle. If the gate pulse is applied *late in the cycle*, only a *small increment of the wave form* is passed through, and the *output is low*.

If the gate pulse is applied *sooner in the cycle*, a greater increment of the wave form is passed through, and *the output is increased*. So, by controlling the SCRs output voltage, the motor’s acceleration characteristic and current inrush can be controlled.

Integral Bypass Contactors

When the SCRs are fully “phased on,” the integral bypass contactors are energized. The current flow is transferred from the power pole to the contactors. This reduces the energy loss associated with the power pole, which otherwise is about one watt per amp per phase.

When the starter is given the stop command, the bypass contactors are de-energized, which transfers the current flow from the contactors back to the power poles. The SCRs are then turned off, and the current flow stops.

Because the SCRs are turned off during normal operation, the design can be air-cooled and harmonic currents are not an issue.

Unit-Mounted Low-Voltage Adaptive Frequency Drive

The Trane Adaptive Frequency™ drive (AFD) is a refrigerant-cooled, microprocessor controlled design. The AFD is used in lieu of a constant-speed starter and is currently available for use with 460/480 volts 60 Hz or 380-415 volts 50 Hz line power only. Adaptive Frequency is a trademarked term for the Trane variable speed drive, using proprietary control logic and made to Trane specifications.

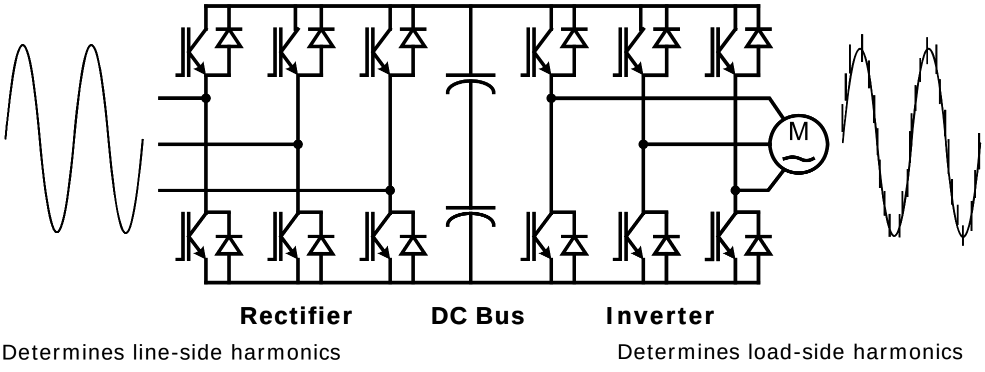
About the Trane AFD

The AFD is unit-mounted and ships completely assembled, wired, and tested from the factory. The AFD controller is designed to interface with the chiller controller. It adapts to the operating ranges and specific characteristics of the chiller. The optimum chiller efficiency is created by coordinating the compressor-motor speed with the compressor inlet guide vanes. The chiller controller and the AFD controller work together to maintain the chilled-water setpoint and avoid instability regions like low level surge. If low level surge is detected, the chiller controller's surge-avoidance logic in the chiller controller makes the proper adjustments to move the operating point away from surge. Safely operating near the instability region maximizes efficiency.

How it Works

The frequency drive regulates output voltage in proportion to output frequency to maintain ideal motor flux and constant torque-producing capability. Or put simply, a variable speed drive controls load-side frequency and voltage to adjust the compressor motor speed. The AFD is a voltage source, pulse-width modulated (PWM) design. It consists of three primary power sections as shown in Figure 8: the active rectifier, the DC bus, and the inverter.

Figure 8. AFD power sections



Rectifier (active). The rectifier (active) takes incoming AC power, filters it with an LCL filter (not shown), and then converts it to a fixed DC voltage. The insulated-gate bipolar transistor (IGBT) active rectifier significantly reduces the amount of line-side harmonic levels and the amount of ripple on the DC bus. No additional line side filters are required to meet IEEE harmonic requirements. This also simplifies the installation and avoids the optional filter efficiency losses. The active rectifier also has some traditional post-generation filtering capabilities to further smooth out remaining line-side harmonics.

DC bus. Capacitors store the DC power provided by the rectifier until it is needed by the inverter.

Inverter. Converts the DC voltage into a synthesized AC output voltage. This synthesized output controls both the voltage and the frequency. The synthesized output waveform consists of a series of pulses, hence the "pulse" in PWM.

Starting Sequence

Trane AFDs are programmed to start the compressor motor using low frequency and low voltage, thereby minimizing the inrush current. The motor is then brought up to speed by gradually increasing both frequency and voltage at the same time. Thus, current and torque are much lower during startup and motor acceleration than the high current, high torque associated with across-the-line or even reduced-voltage starters.

Patented Adaptive Control

A fourth element of AFD design is the microprocessor control logic which is the intelligence for the power section. It also includes all feedback sensors required for stability in the system and any required shutdown due to a fault.

The combination of speed control and inlet guide vane (IGV) position is optimized mathematically and controlled simultaneously. The microprocessor performance allows the chiller to operate longer at higher efficiencies and with greater stability.

Features

The standard design features of the AFD include:

- NEMA 1, ventilated enclosure with a hinged door, tested to a short circuit current rating (SCCR) of 100000 amps.
- Padlock-able, door-mounted circuit breaker/shunt trip with an Ampere Interrupting Rating (AIC) rating of 100000 amps.
- UL/CUL listed as a package.
- Simple, modular construction.
- 460/480 volt 60 Hz or 380/400/415 volt 50 Hz input power ±10 percent, with drive overload capability of 100 percent continuous to 150 percent for five seconds.
- Active input rectifier will regulate to a displacement power factor of 0.98 or better at full load and a value of 0.96 at part loads.
- Full motor voltage is applied regardless of the input voltage.
- Motor thermal overload protection 102 percent continuous, 108 percent for 60 seconds, 140 percent for 1.5 seconds.
- Minimum efficiency of 97 percent at rated load and 60 hertz.
- Soft-start, controlled acceleration, coast-to-stop.
- Adjustable frequency from 38 to 60 hertz.
- Control circuit voltages physically and electrically isolated from power circuit voltage.
- 150 percent instantaneous torque available for improved surge control.
- Output line-to-line and line-to-ground short-circuit protection.
- Ground fault protection (UL listed).

Environmental Specification

- 0°C to 40°C (32°F to 104°F) operating ambient temperature
- Altitude to 1006 m (3300 ft), amperage derate of 1 percent per every 91 m (300 ft) above 1006 m (3300 ft)
- Humidity, 95 percent non-condensing

Digital Data Display

The following points are digitally displayed at the chiller controller:

- Output frequency in hertz
- Output speed in rpm
- Input frequency
- Input/output line voltage
- Input/output kW
- Input/output current
- Average output current in percent RLA
- Load-side power factor
- AFD transistor temperature

- Fault

IEEE Standard 519

It is important to recognize that IEEE Standard 519 as a guideline relates to the entire system, not specifically to any one load or product. IEEE Standard 519 establishes requirements at the point of common coupling (PCC) where the building connects to the utility system. The Standard contains no specific requirements for the internal electrical loads. Even though Trane AFD-equipped chillers will attenuate their own harmonics, other nonlinear loads on the same system could still create harmonic problems. In buildings where harmonics might be a concern, Trane recommends conducting a power-distribution system analysis to determine if there is a need to further attenuate harmonics at the system level.

Application of Drives on Chillers

Certain system characteristics favor installation of an AFD because of energy cost savings and shorter payback. These systems include:

- Condenser water temperature relief (colder than design temperatures)
- Chilled-water reset
- Utilities with high kWh and low kW demand rates

Condenser Water Temperature Relief or Chilled-Water Reset

Compressor lift reduction is required for an AFD chiller application, both to provide stable chiller operation and to achieve greater energy savings. A reduction in lift, also referred to as "relief," assumes colder condenser inlet temperatures over the design entering temperature. Intelligent control to reduce condenser water temperature, or chilled-water reset strategies, are key to AFD savings in chiller system applications. Many believe that AFDs offer better efficiency at part load because part load values are often reported assuming condenser relief. An AFD can incrementally improve efficiency over a constant speed chiller at any load if you have substantial hours with reduced entering condenser water temperatures.

High kW Demand Charges

Electric utility bills typically include both peak-based and consumption-based energy components. The demand or distribution charges are still significant portions of the energy bill, even in deregulated markets. These charges are established by usage during utility peak hours, by individual peak usage, or a combination of peak and individual usage. This portion may or may not be influenced by installation of an AFD, because an AFD-equipped chiller draws more power at full load. If the peak chiller load coincides with utility peak hours, then the peak-based portion of the energy bill will increase. The energy or kWh portion will almost certainly be reduced because of the improved efficiency of the chiller plant during part-load and part-lift conditions throughout the year.

The greater the kWh charge, and the smaller demand or distribution charges, the shorter the payback.

Unit-Mounted AMPGARD Medium-Voltage Starters

The AMPGARD® medium-voltage starter family by Eaton Cutler-Hammer®/Boer(GB), built to Trane specifications, is available as a factory-installed option for use with Series E™ CenTraVac™ chillers. Trane mounts, wires, and tests 3300–6600 Volt for unit-mounted starters (higher voltages are remote-mount only) at the factory, so you don't have to. This reduces, or eliminates altogether, the time, expense, and any added risk associated with having the starter installed and wired at the job site.

AMPGARD reduces starter size to nearly half

Medium-voltage starters have traditionally been freestanding due to their large size and weight. With advances in contactor technology and component layout, medium-voltage starters have become small enough to make unit-mounting feasible. When this is done, the starter becomes an integral part of the chiller, saving on equipment floor space.

Across-the-Line (Full Voltage)

An across-the-line starter is the smallest medium-voltage starter option. These starters draw the highest inrush current at startup (100 percent of LRA), and have the shortest acceleration time (3–5 seconds).

Primary Reactor

Primary reactor type starters have an inrush current draw of 65 percent of LRA at startup. Their acceleration time (3–8 seconds) is slightly higher than an across-the-line starter.

Autotransformer

Autotransformer starters have the lowest inrush current draw of 45 percent of LRA at startup. They have an acceleration time of 3–8 seconds.

Standard Features

- ULor GB listed
- Factory-installed (unit-mounted only)
- Non-load-break isolation switch and current limiting fuses
- NEMA Class E2 fused interrupting ratings
- Phase voltage sensors for kW, volts/phase protection, under/overvoltage

Optional Features

- IQ150 electrical metering package
- Ground fault protection
- Factory-installed power factor correction capacitors sized specific to the motor, factory-wired and mounted inside the starter
- When a starter-mounted control power transformer is selected, it will have an oil pump motor circuit to drive the single phase oil pump motor

Starter by Others

If the Series E™ CenTraVac™ chiller starter will be provided by another manufacturer, the starter must be designed in accordance with the current Trane CVHH/CDHH Starter by Others engineering specification. It is also recommended that two copies of the interconnecting and control circuit wiring diagrams be forwarded to Trane for review. This review is intended to minimize the risk that the Series E chiller could be applied in improper starting and control systems; however, the responsibility for providing proper starting and control systems remains with the system designer and the installer.

Control Power Transformer Option

The Control Power Transformer (CPTR) option allows the customer to bring in a clean, dedicated/independent source of power to power the controls and oil pump motor. When this option is selected, the control power transformer and oil pump motor circuit are located in a separate enclosure mounted on the chiller itself, outside of the starter or drive panel, and includes the following:

- Flanged disconnect
- Three-phase customer connection with fused primary (380–600 Vac) and secondary (107–120 Vac) voltage for powering the controls and secondary voltage of 200–240 Vac for medium-voltage applications to power the single phase oil pump motor.
- UL 508A construction

The CPTR option may be selected for either low voltage or medium voltage chillers:

- The low-voltage CPTR option includes a 4 kVA control power transformer and is used with the 3-phase oil pump motor.
- The medium-voltage CPTR option includes two 4 kVA control power transformers and is used with the single phase oil pump motor.

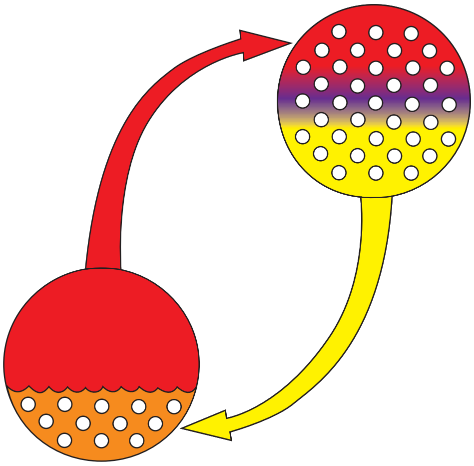
Please note that a control power transformer is always required for the chiller. If the control power transformer and oil pump motor circuit are located inside the starter/drive panel, then the CPTR option would not be needed. The CPTR option is sometimes a selectable option and, in some instances, a required item. Please contact your local Trane account manager with any questions.

Free Cooling Option

Consider a CenTraVac™ chiller option that can provide up to 45 percent of the nominal chiller capacity—without operating the compressor. Think of the significant energy and cost savings possible in many applications. This option is available on most Trane chillers, factory installed.

Free cooling operation is based on the principle that refrigerant migrates to the area of lowest temperature. When condenser water is available at temperatures lower than the required leaving chilled-water temperature, typically 50°F to 55°F (10°C to 12.8°C), the unit control panel starts the free cooling cycle automatically.

Figure 9. Free cooling schematic



When the free cooling cycle can no longer provide sufficient capacity to meet cooling requirements, mechanical cooling is restarted automatically by the unit control panel.

For example, a building with a high internal cooling load is located in a climate with cold winters. It is possible to cool the building exclusively with free cooling three to six months of the year! Free cooling payback can easily be less than a year.

Free cooling is factory installed and requires no additional floor space or piping than the standard CenTraVac chiller (unlike plate-frame heat exchangers).

Benefits

The Trane patented free cooling accessory for Series E™ CenTraVac™ chillers adapts the basic chiller so it may function as a simple heat exchanger using refrigerant as the working fluid. When condenser water is available at temperatures lower than the desired chilled liquid temperature, free cooling can provide up to 45 percent of nominal chiller capacity without operation of the compressor. This feature may result in substantial energy cost savings on many installations.

- Reliability: Two simple valves are the only moving parts.
- Single-Source Responsibility: Free cooling is Trane-engineered, -manufactured, and -installed.

- Ease of Operation: Changeover on free cooling by single switch control.
- Ease of Installation: Completely factory-installed and leak-tested components. All valve operators and controls are factory wired.

Application

Modern buildings often require some form of year-round cooling to handle interior zones, solar loads, or computer loads. As the outside air temperature decreases below the inside air design temperature, it is often possible to use an outside air economizer to satisfy the cooling requirements. There are a number of instances, however, where CenTraVac™ chiller free cooling offers a number of advantages over the use of an outside air economizer. It is possible for the free cooling chiller to satisfy the cooling load for many hours, days, or months during the fall, winter, or spring seasons without operation of the compressor motor. This method of satisfying the cooling requirement can result in significant total energy savings over other types of systems. The savings available are most easily determined through the use of a computer energy analysis and economic program, such as TRACE™ (Trane Air Conditioning Economics).

The suitability of free cooling for any particular installation depends upon a number of factors. The availability of low temperature condensing water, the quality of the outside air, the type of airside system, the temperature and humidity control requirements, and the cost of electricity all have a direct impact on the decision to use a free cooling chiller.

The use of CenTraVac chiller free cooling depends on the availability of cold condenser water from a cooling tower, river, lake, or pond. As a general rule of thumb, locations which have a substantial number of days with ambient temperatures below 45°F (7.2°C) wet bulb or more than 4000 degree-days per year are well suited to free cooling operation. A cooling tower must be winterized for off-season operation and the minimum sump temperature is limited by some cooling tower manufacturers. Cooling tower manufacturers should be consulted for recommendations on low temperature operation. With river, lake, or pond supply, condenser water temperatures down to freezing levels are possible. Areas which have fouled air may be more conducive to free cooling operation than the use of an outside air economizer.

Airside systems which both heat and cool the air can often effectively use a free cooling chiller. Dual-duct, multizone, and reheat systems fall into this general category. As the outside temperature begins to fall, the cool outside air satisfies the cooling requirements (through an outside air economizer). As the outdoor air temperature becomes very low, the outdoor air may need to be heated in order to maintain the design supply air temperature when it is mixed with return air. This “heating penalty” can be eliminated by using CenTraVac chiller free cooling. Warm chilled-water temperatures provided by the free cooling chiller would allow a warmer air temperature off the chilled-water coils, eliminating the heating energy required by using only an outside air economizer. With high cost electricity in most areas of the country, this heating penalty can be very significant.

Temperature and humidity control requirements are important considerations when evaluating the use of CenTraVac chiller free cooling. Low temperature outside air (from the outside air economizer) often requires a large amount of energy for humidification purposes. Free cooling operation helps to reduce these humidification costs on many applications.

It is important to note that those applications which require extremely precise humidity control typically cannot tolerate warmer than design chilled-water temperatures. Therefore, since free cooling chillers normally deliver warmer than design chilled water temperatures, free cooling operation is usually not applicable with systems which require precise humidity control.

Free cooling is not used in conjunction with heat recovery systems, since mechanical cooling must be used to recover heat that will be used elsewhere in the building for simultaneous heating.

Operation

Free cooling operates on the principle that refrigerant flows to the area of lowest temperature in the system. The Chiller Plant Control (CPC) application in the Tracer™ SC system controller can be used for automatic free cooling control. When condenser water is available at a temperature lower than the required leaving chilled-water temperature, the CPC starts the free cooling cycle. If the load cannot be satisfied with free cooling, the CPC or a customer-supplied system can automatically switch to the powered cooling mode. If desired, the chiller can be manually switched to the free cooling mode at the unit control panel. Upon changeover to free cooling, the shutoff valves in the liquid and gas lines are opened and a lockout circuit prevents compressor energization. Since the refrigerant temperature and pressure are higher in the evaporator than in the condenser, due to the water temperature difference, the refrigerant gas boiled off in the evaporator will flow to the condenser. The gas then condenses and flows by gravity back to the evaporator. This automatic refrigeration cycle is sustained as long as a temperature difference exists between the condenser water and evaporator water.

The difference in temperature between the condenser and evaporator determines the rate of refrigerant flow between the two shells and hence the free cooling capacity.

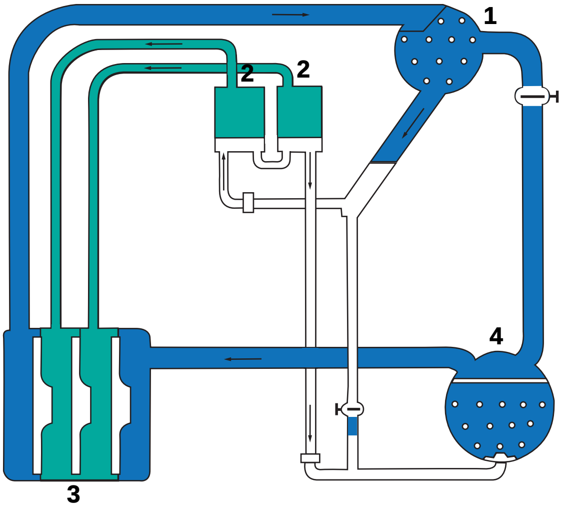
If the system load becomes greater than the free cooling capacity either the operator manually stops free cooling, a binary input from a customer-supplied system disables free cooling, or the CPC can automatically perform this function. The gas and liquid valves close and the compressor starts. Refrigerant gas is drawn out of the evaporator by the compressor, compressed, and introduced into the condenser.

The free cooling option consists of the following factory-installed or supplied components:

- Manual free cooling controls on the unit control panel
- A refrigerant gas line, including an electrically actuated shutoff valve, installed between the evaporator and condenser
- A valved-liquid return line, including an electrically activated shutoff valve, between the condenser sump and evaporator

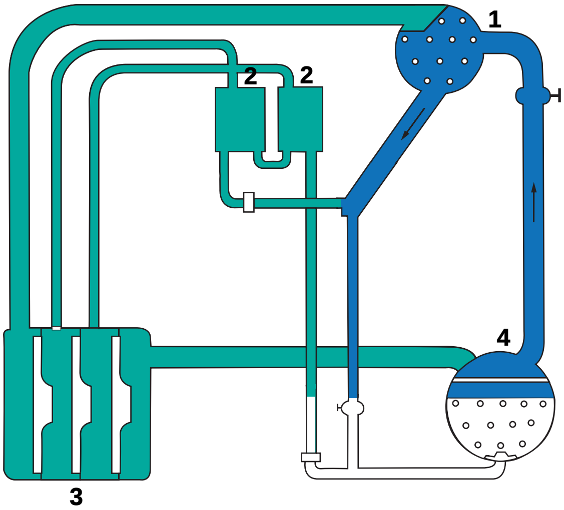
For specific information on free cooling applications, contact your local Trane sales office.

Figure 10. Compressor operation schematic



1. Condenser
2. Economizer
3. Compressor
4. Evaporator

Figure 11. Free cooling operation schematic



1. Condenser
2. Economizer
3. Compressor
4. Evaporator

System Options

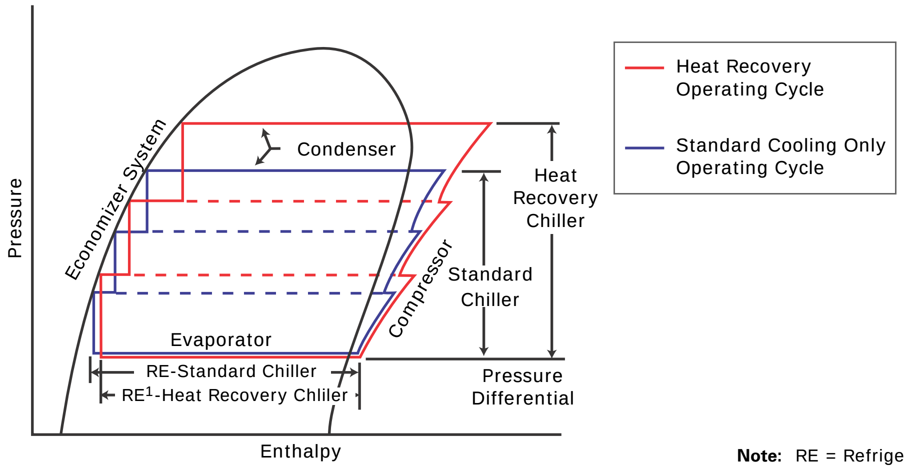
Heat Recovery

A heat recovery Series E™ CenTraVac™ chiller can significantly reduce energy costs by using heat which would normally be rejected to the atmosphere. This heat may be used for perimeter zone heating, reheat air conditioning systems, and preheating domestic hot water. Any building with a simultaneous heating and cooling load is a potential candidate.

Most heating applications require water warmer than the 29.4°C to 35°C (85°F to 95°F) typically sent to the cooling tower. Therefore, most heat recovery chillers are required to produce higher leaving condenser water temperatures, and thus will not achieve the energy efficiencies of standard, cooling-only chillers. Figure 12 illustrates the typical operating cycles of a cooling-only and a heat recovery chiller. The most noticeable differences are:

1. The pressure differential of the compressor is much greater for the heat recovery cycle.
2. The amount of heat rejected from the heat recovery condenser is greater than that which would be rejected in cooling-only operation.
3. There is a decrease in the refrigeration effect (RE). Higher condensing pressures increase the intermediate pressure in the economizer. Therefore, the liquid in the economizer has a higher enthalpy during the heat recovery mode than during standard chiller operation and the RE is slightly decreased. Because of this decreased RE, the compressor must pump more gas per ton of refrigeration.

Figure 12. Typical operating cycles



Note: RE = Refrigeration Effect

The effect of this increased pressure differential and decreased refrigeration effect is a heat recovery machine which consumes more energy during heat recovery operation.

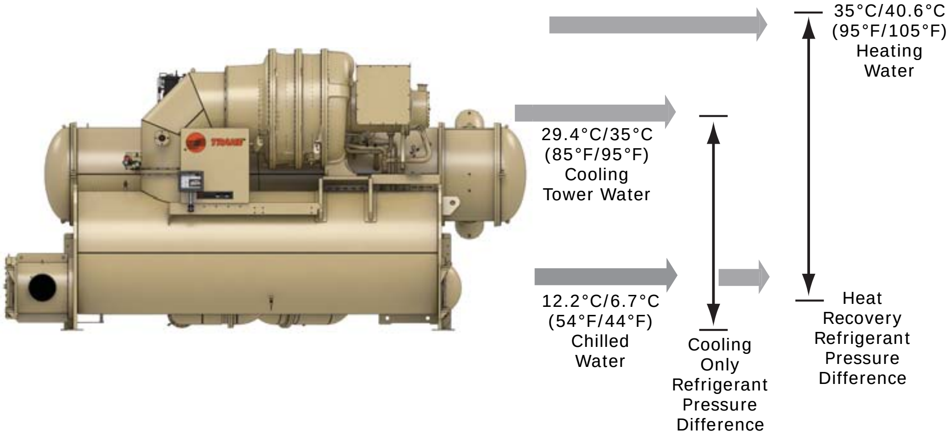
Typical catalog efficiencies for heat recovery machines operating in the heat recovery mode range from 5.49 COP to 4.18 COP (0.64 to 0.84 kW/ton) and range from 6.51 COP to 6.16 COP (0.54 to 0.57 kW/ton) for a cooling-only machine. Not only can there be an energy consumption penalty due to the inherent differences in operating cycles for heat recovery machines, but traditional chiller designs can add to that energy handicap. A heat recovery machine's operating efficiency is penalized year-round by having the capability to produce high heating water temperatures. Impellers are selected to produce the maximum refrigerant pressure difference between the evaporator and condenser, which is shown in Figure 13. This means the impeller diameters are determined by the heat recovery operating conditions.

The CenTraVac™ compressor and advanced impeller design of the Series E™ chiller reduce this costly energy penalty. The higher lift and stability of the multi-stage compressor enables a closer match of impeller size for both the cooling only and heat recovery operating conditions.

Simultaneous Heating and Cooling

The heat recovery Series E™ chiller is an excellent choice for applications requiring simultaneous heating and cooling. These chillers save energy by recovering heat that would normally be rejected to the atmosphere and using it to provide space heating, hot water for the building, or process hot water.

Figure 13. Refrigerant pressure difference



This heat is provided at a fraction of conventional heating systems cost. A heat recovery Series E chiller can provide 35°C to 59°C (95°F to 138°F) hot water depending upon the operating conditions. Two separate bundles within the same condenser shell are used in the heat recovery Series E chiller. The heating circuit and cooling tower circuit are separate, preventing cross contamination. Refrigerant gas from the compressor flows into the condenser shell allowing heat rejection to one or both condenser water circuits. This option is completely factory packaged.

Partial Heat Recovery

We are also able to offer partial heat recovery with an auxiliary condenser. This option provides economical heat recovery for applications with a small heating demand. Contact your local Trane account manager to learn more about this option.

Heating Water Temperatures and Control

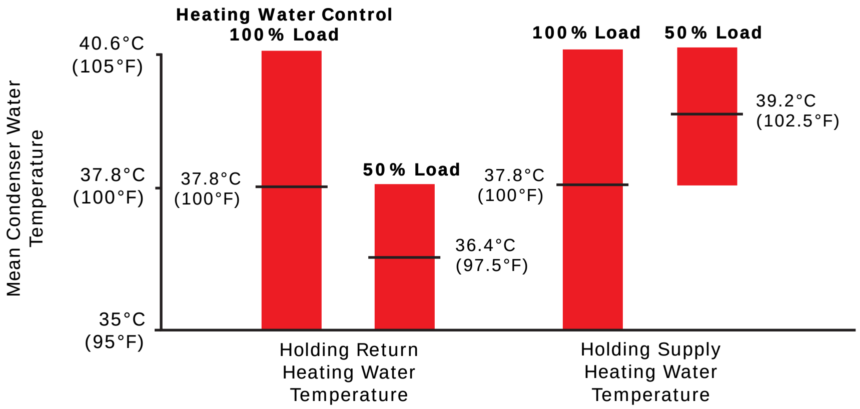
To further reduce the system energy requirements, the following design considerations should be incorporated into any heat recovery system.

It is always desirable to use the lowest heating water temperature the application allows. Experience has shown that a design heating water temperature of 40.6°C to 43.3°C (105°F to 110°F) can satisfy most heating requirements. Lower temperatures increase the chiller operating efficiency in both the heating and cooling modes. In general, the heat recovery power consumption will increase 7 to 14 percent for every -12.2°C (10°F) increase in the design heating water temperature. Equally important is how that temperature is controlled. In most cases, the heating water temperature control should maintain the return heating water temperature. By allowing the supply water temperature to float, the mean water temperature in the system drops as the chiller load decreases and less heat is rejected to the condenser. As the mean heating water temperature drops, so does the refrigerant condensing temperature and pressure difference which the compressor is required to produce at part load. This increases the unloading range of the compressor.

When the supply heating water temperature to the building system is maintained and the return heating water temperature to the condenser is allowed to float, the mean heating water temperature actually rises as the chiller load decreases and less heat is rejected to the condenser.

As Figure 14 illustrates, when the compressor unloads, the pressure difference that it must oppose to prevent surging remains essentially the same, while the compressor's ability to handle the pressure difference decreases. Therefore, the chiller's ability to unload without the use of hot gas bypass is reduced.

Figure 14. Heating water control



Hot gas bypass artificially increases the load on the compressor by diverting refrigerant gas from the condenser back to the compressor. Although hot gas bypass increases the unit's power consumption by forcing the compressor to pump more refrigerant gas, it will increase the heat available to recover for those applications where significant heating loads remain as the cooling load decreases.

Ice Storage Provides Reduced Electrical Demand

An ice storage system uses a dual-duty chiller to make ice at night when utilities charge less for electricity. The ice supplements or even replaces mechanical cooling during the day when utility rates are at their highest. This reduced need for cooling results in significant utility cost savings.

Another advantage of ice storage is standby cooling capacity. If the chiller is unable to operate, one or two days of ice may still be available to provide cooling. In that time, the chiller can be repaired before building occupants feel any loss of comfort.

The Series E™ CenTraVac™ chiller is uniquely suited for low temperature applications, like ice storage, because it uses multiple stages of compression, versus competitive designs with only one stage. This allows the chiller to produce ice efficiently with less stress on the machine. The multi-stage compressor allows the lower suction temperatures required to produce ice and the higher chiller efficiencies attributed to centrifugal chillers. Trane three-stage and two-stage centrifugal chillers produce ice by supplying ice storage vessels with a constant supply of -6.7°C to -3.9°C (20°F to 25°F) glycol solution. Series E chillers selected for these lower leaving fluid temperatures are also selected for efficient production of chilled fluid at nominal comfort cooling conditions. The ability of Trane chillers to serve "double duty" in ice production and comfort cooling greatly reduces the capital cost of ice storage systems.

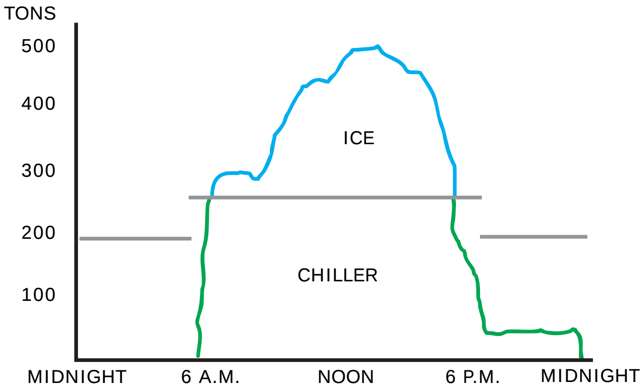
A glycol solution is used to transfer heat from the ice storage tanks to the CenTraVac chiller and from the cooling coils to either the chiller or the ice storage tanks. The use of a freeze-protected solution eliminates the design time, field construction cost, large refrigerant charges, and leaks associated with ice plants. Ice is produced by circulating -6.7°C to -3.9°C (20°F to 25°F) glycol solution through modular insulated ice storage tanks. Each tank contains a heat exchanger constructed of polyethylene tubing. Water in each tank is completely frozen with no need for agitation. The problems of ice bridging and air pumps are eliminated.

When cooling is required, ice chilled glycol solution is pumped from the ice storage tanks directly to the cooling coils. No expensive heat exchanger is required. The glycol loop is a sealed system, eliminating expensive annual chemical treatment costs. The centrifugal chiller is also available for comfort cooling duty at nominal cooling conditions and efficiencies. The modular concept of glycol ice storage systems and the proven simplicity of Trane Tracer controls allow the successful blend of reliability and energy saving performance in any ice storage application.

The ice storage system operates in six different modes, each optimized for the utility cost of the hour:

1. Off
2. Freeze ice storage
3. Provide comfort cooling with ice
4. Provide comfort cooling with chiller
5. Provide comfort cooling with ice and chiller
6. Freeze ice storage when comfort cooling is required

Figure 15. Ice storage demand cost savings



Simple and smart control strategies are another advantage the CenTraVac chiller has for ice storage applications. Trane Tracer™ building management systems can actually anticipate how much ice needs to be made at night and operate the system accordingly. The controls are integrated right into the chiller. Two wires and preprogrammed software dramatically reduce field installation cost and complex programming.

Tracer optimization software controls operation of the required equipment and accessories to easily transition from one mode of operation to another. Even with ice storage systems, there are numerous hours when ice is neither produced or consumed, but saved. In this mode, the chiller is the sole source of cooling. To cool the building after all ice is produced, but before high electrical demand charges take effect, Tracer controls set the CenTraVac chiller leaving fluid setpoint to the system's most efficient setting and start the chiller.

When electrical demand is high, the ice pump is started and the chiller is either demand-limited or shut down completely. Tracer controls have the intelligence to optimally balance the contribution of ice and chiller in meeting the cooling load.

The capacity of the chiller plant is extended by operating the chiller and ice in tandem. Tracer controls ration the ice, augmenting chiller capacity while reducing cooling costs.

When ice is produced, Tracer controls will lower the CenTraVac chiller leaving fluid setpoint and start the chiller, ice pumps, and other accessories. Any incidental loads that persist while producing ice can be addressed by starting the load pump and drawing spent cooling fluid from the ice storage tanks.

For specific information on ice storage applications, contact your local Trane sales account manager.

Application Considerations

Condenser Water Control

Trane Series E™ CenTraVac™ chillers start and operate over a range of load conditions with controlled water temperatures. Reducing the condenser water temperature is an effective way to lower the chiller power input; however, the effect of lowering the condenser water temperature may cause an increase in system power consumption. Series E chillers can typically start and operate without control of the condenser water temperature. However, for optimum system power consumption, and for multiple-chiller applications, control of the condenser water circuit is recommended. Integrated control of the chillers, pumps and towers is easily accomplished with the chiller controller and/or Tracer building controls.

Most chillers are designed for entering tower temperatures around 29.5°C (85°F), but Trane Series E CenTraVac chillers can operate at reduced lift down to a 20.7 kPaD (3 psid) pressure differential between the condenser and evaporator at any steady state load without oil loss, oil return, motor cooling, refrigerant hang-up, or purge problems. And this differential can equate to safe minimum entering condenser water temperatures at or below 12.8°C (55°F) dependent on a variety of factors such as load, leaving evaporator temperature and component combinations. Startup below this differential is possible as long as the 20.7 kPaD (3 psid) minimum pressure differential is achieved within a given amount of time.

Water Treatment

The use of untreated or improperly treated water in a chiller may result in scaling, erosion, corrosion, algae, or slime. It is recommended that the services of a qualified water treatment specialist be used to determine what treatment, if any, is advisable. Trane assumes no responsibility for the results of untreated, or improperly treated water.

Water Pumps

Avoid specifying or using 50 Hz (3000 rpm) or 60 Hz (3600 rpm) condenser and chilled-water pumps. Such pumps may operate with objectionable noises and vibrations. In addition, a low frequency beat may occur due to the slight difference in operating rpm between water pumps and CenTraVac™ chiller motors. Where noise and vibration-free operation are important, Trane encourages the use of 50 Hz (1500 rpm) or 60 Hz (1750 rpm) pumps.

Water Flow

Today's technology challenges AHRI's traditional design of 0.054 L/s·kW (3 gpm/ton) through the condenser. Reduced condenser flows are a simple and effective way to reduce both first and operating costs for the entire chiller plant. This design strategy will require more effort from the chiller. But pump and tower savings will typically offset any penalty. This is especially true when the plant is partially loaded or condenser relief is available.

In new systems, the benefits can include dramatic savings associated with:

- Size and cost of the water pumps and cooling tower
- Pump and cooling tower fan energy (30 to 35 percent reduction)
- Size and cost for condenser lines and valves

Replacement chiller plants can reap even greater benefits from low flow condensers. Because the water lines and tower are already in place, reduced flows offer tremendous energy savings. Theoretically, a 0.036 L/s·kW (2 gpm/ton) design applied to a 0.054 L/s·kW (3 gpm/ton) system would offer a 70 percent reduction in pump energy. At the same time, the original tower would require a nozzle change but would then be able to produce about two degrees colder condenser water than before. These two benefits would typically offset any extra effort required by the chiller.

Contact your local Trane account manager for information regarding optimum condenser water temperatures and flow rates for a specific application.

Selection Procedure

Selection

The Series E™ CenTraVac™ centrifugal chiller product line provides thousands of individual selections over a capacity range of 3000 through 14000 kW (850 through 4000 tons). Chiller selections and performance data can be obtained through the use of the CenTraVac chiller selection program available in local Trane sales offices. This program can provide various AHRI-certified chiller selections optimized to closely match specific project requirements. Nominal and physical data for typical compressor-evaporator-condenser combinations are given by product family.

Performance

The Series E™ CenTraVac™ chiller computer selection program provides performance data for each chiller selection at the full-load design point and part-load operating points as required.

Changing the number of water passes or water flow rates may significantly alter the performance of a particular chiller. To obtain the maximum benefit from the wide range of selections available, designers are encouraged to develop performance specifications and use the computer selection program to optimize their selections. This will allow the selection of the particular compressor-evaporator-condenser combination that most closely meets the job requirements. All selections are made using the computer selection program.

The Trane computer selection program is certified by AHRI in accordance with AHRI Standard 550/590. To ensure that the specific chiller built for your project will meet the required performance, and to ensure a more trouble-free startup, it is recommended that the chiller be performance tested on an AHRI-approved factory test loop.

Contact your local Trane account manager for more information or visit www.trane.com/myTest.

Fouling Factors

All heat exchanger tubes are subject to a certain amount of fouling during operation due to contaminants in the water and based on water treatment at the facility. Fouling impedes heat transfer and makes the chiller work harder.

AHRI Standards 550/590 (I-P) and 551/591 (SI) include a definition of the standard fouling factors to be used in water-cooled chiller ratings. The standard fouling adjustment is a 0.0001 increment from 0.0000 (“clean”) on the evaporator and 0.00025 increment from 0.0000 (“clean”) on the condenser.

Chiller specifications should be developed using the most current standard fouling factors.

Unit Performance With Fluid Media Other Than Water

Series E™ CenTraVac™ chillers can be selected with a wide variety of media other than water. Typically used media include ethylene glycol or propylene glycol either in the evaporator, condenser, or both. Chillers using media other than water are excluded from the AHRI Certification Program, but are rated in accordance with AHRI Standard 550/590. Trane factory performance tests are only performed with water as the cooling and heat rejection media. For fluid media other than water, contact your local Trane account manager for chiller selections and information regarding factory performance testing.

Flow Rate Limits

Flow rate limits for multiple pass combinations for evaporators and condensers are tabulated in the data section for the appropriate chiller family. For applications outside of these limits, please contact your local Trane account manager.

Roughing-in Dimensions

Dimensional drawings illustrate overall measurements of the chiller. The recommended space envelope indicates clearances required to easily service the Series E™ CenTraVac™ chiller. A view of the unit with its support feet is superimposed on this drawing.

All catalog dimensional drawings are subject to change. Refer to the current submittal drawings for detailed dimensional information. If the unit must be disassembled in the field, refer to CVHH-SVN001*-EN (*Installation Guide: Disassembly and Reassembly Units—CVHH and CDHH Water-Cooled CenTraVac™ Chillers*) for detailed information. Contact your local Trane account manager for submittal and template information.

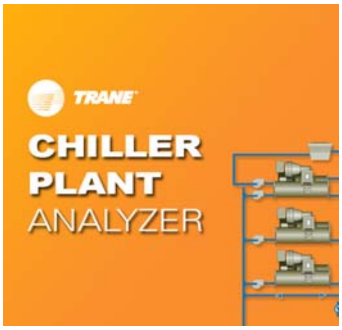
Evaporator and Condenser Data Tables

Evaporator and condenser data is shown in the Performance Data section. It includes minimum and maximum water flow limits and water connection sizes for all standard pass configurations and tube types. Pressure drops are calculated by the chiller computer selection program.

Full-Load and Part-Load Performance

The Series E™ CenTraVac™ chiller possesses excellent performance characteristics over its full range of operation. The multi-stage, direct drive compressor enables stable and efficient operation over a wide range of conditions, virtually eliminating the need for the energy-wasting hot gas bypass typically found on single-stage chillers.

An in-depth examination of project-specific conditions and energy rate structures should be performed to evaluate total energy costs over a period of time. Trane Air Conditioning Economics, or TRACE™, is a software program that helps HVAC professionals perform this type of analysis and optimize the design of a building's heating, ventilating and air conditioning system based on energy utilization and life-cycle cost. Visit www.traneCDS.com for more information.



Local utilities may offer substantial monetary rebates for centrifugal chillers with specific efficiency ratings. Contact your local utility or your local Trane account manager for further information.

The electrical rate structure is a key component of an economic evaluation. Most power bills include a significant demand charge in addition to the usage charge. The full-load power consumption of the chiller plant is likely to set the kW peak and demand charge for the billing period. This places an increased emphasis on the need to minimize the full-load power consumption of the chiller plant.

There are a number of variables that should be considered when developing a chiller load profile to compare part load performance of one chiller versus another. The use of outdoor air economizers, variations in chiller sequencing, and chiller plant load optimization strategies should be considered. Decoupled, primary/secondary water loops or variable-primary flow designs are more efficient ways to control multiple chiller water plants. These control strategies result in one chiller operating at a more fully loaded condition rather than multiple chillers operating at part load, which would require more pumping energy.

AHRI Standard 550/590 defines the entering condenser water temperatures for loads of 100, 75, 50, and 25 percent. Each point is tested, and then the Integrated Part Load Value (IPLV) can be calculated. Although some manufacturers focus on IPLV only, chiller efficiency is measured at full load and part load operation. High efficiency at full load determines the capability of the chiller to minimize the electrical infrastructure required, and reduces the impact of demand-based charges and real-time pricing during peak periods. The full load efficiency rating is required for buildings to comply with most local codes. Both full load and IPLV ratings are required for LEED® Energy and Atmosphere (EA) credits.

myPLV Chiller Performance Evaluation Tool

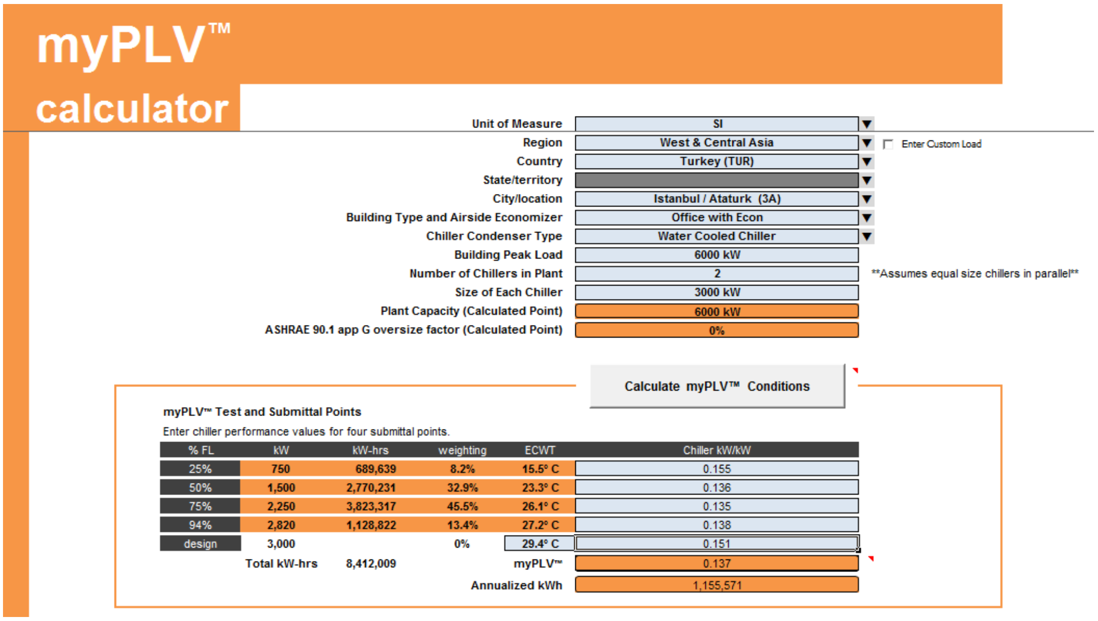
The myPLV™ tool provides a simple tool for quick and reliable chiller economic comparisons considering both full and part load ratings.

The manufacturer-agnostic tool leverages industry-standard building model data, calculating four performance points (94, 75, 50 and 25 percent) based on the specific building type, location and plant design, providing accurate weighting points and condenser temperatures. The myPLV tool also calculates the ton-hours at each of those points necessary to accurately estimate annualized energy use.

Utilizing the myPLV tool from the beginning assures that the selected chiller is appropriate for the particular application. Then, myTest™ certification confirms the chiller performs as expected.

To learn more or to download a free copy of the myPLV tool, please visit www.trane.com/myPLV.

Figure 16. myPLV—Compare chiller performance



Unit of Measure	SI
Region	West & Central Asia
Country	Turkey (TUR)
State/territory	
City/location	Istanbul / Ataturk (3A)
Building Type and Airside Economizer	Office with Econ
Chiller Condenser Type	Water Cooled Chiller
Building Peak Load	6000 kW
Number of Chillers in Plant	2
Size of Each Chiller	3000 kW
Plant Capacity (Calculated Point)	6000 kW
ASHRAE 90.1 app G oversize factor (Calculated Point)	0%

☐ Enter Custom Load

Assumes equal size chillers in parallel

myPLV™ Test and Submittal Points

Enter chiller performance values for four submittal points.

% FL	kW	kW-hrs	weighting	ECWT	Chiller kW/kW
25%	750	689,639	8.2%	15.5° C	0.155
50%	1,500	2,770,231	32.9%	23.3° C	0.136
75%	2,250	3,823,317	45.5%	26.1° C	0.135
94%	2,820	1,128,822	13.4%	27.2° C	0.138
design	3,000		0%	29.4° C	0.151
	Total kW-hrs	8,412,009		myPLV™	0.137
				Annualized kWh	1,155,571

Performance Data

Table 3. Minimum and maximum evaporator flow rates, L/s

Shell Size (EVSZ)	Bundle Size (EVBS)	Tube Type																			
		IECU						IMC1						TECU						IMCU	
		Number of Passes																			
		1		2		3		1		2		3		1		2		3		1	
		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
100M	810	48	353	25	171	17	115	48	352	25	170	17	115	45	331	23	162	16	107	—	—
	870	51	375	26	182	18	122	51	374	26	181	18	122	48	348	24	170	17	113	—	—
	1000	61	450	32	218	21	149	61	449	32	217	21	148	54	398	28	194	19	130	—	—
100L	810	48	353	25	171	17	115	48	352	25	170	17	115	45	331	23	162	16	107	—	—
	870	51	375	26	182	18	122	51	374	26	181	18	122	48	348	24	170	17	113	—	—
	1000	61	450	32	218	21	149	61	449	32	217	21	148	54	398	28	194	19	130	—	—
130M	1040	62	451	32	219	21	146	61	450	32	219	21	145	55	406	28	199	19	131	—	—
	1140	68	497	35	242	23	161	68	496	35	241	23	161	60	440	31	216	20	142	—	—
	1300	75	551	39	268	26	168	75	550	39	267	26	168	65	475	33	232	22	148	—	—
160M	1290	76	561	38	280	26	186	76	560	38	280	25	186	67	491	34	241	22	163	—	—
	1390	85	620	42	310	28	207	84	619	42	309	28	206	72	531	36	266	24	177	—	—
	1600	96	704	48	351	32	235	96	702	48	350	32	234	81	592	40	296	27	197	—	—
200L	1520	82	600	43	286	—	—	82	598	43	285	—	—	74	539	38	259	26	167	—	—
	1680	92	673	47	329	32	210	92	672	47	328	32	209	82	601	42	290	29	191	—	—
	1840	100	736	53	350	35	221	100	734	53	349	35	220	90	660	47	319	33	208	—	—
	2000	108	788	58	365	40	232	107	787	58	364	39	231	96	705	54	312	37	218	—	—
220L	1850	114	837	57	418	38	279	114	835	57	418	38	278	99	725	49	363	33	242	—	—
	2000	126	924	63	462	42	308	126	922	63	461	42	307	109	796	54	398	36	265	—	—
	2200	143	1049	72	525	48	350	143	1047	71	524	48	349	125	913	62	457	42	304	—	—
400M	3040	82	600	—	—	—	—	—	—	—	—	—	—	76	554	—	—	—	—	81	596
	3360	92	673	—	—	—	—	—	—	—	—	—	—	84	618	—	—	—	—	91	669
	3680	100	736	—	—	—	—	—	—	—	—	—	—	93	679	—	—	—	—	100	731
	4000	108	788	—	—	—	—	—	—	—	—	—	—	99	725	—	—	—	—	107	783
440M	3700	114	837	—	—	—	—	—	—	—	—	—	—	102	745	—	—	—	—	113	831
	4000	126	924	—	—	—	—	—	—	—	—	—	—	112	818	—	—	—	—	125	918
	4400	143	1049	—	—	—	—	—	—	—	—	—	—	128	939	—	—	—	—	142	1042
440X	3700	114	837	—	—	—	—	—	—	—	—	—	—	102	745	—	—	—	—	113	831
	4000	126	924	—	—	—	—	—	—	—	—	—	—	112	818	—	—	—	—	125	918
	4400	143	1049	—	—	—	—	—	—	—	—	—	—	128	939	—	—	—	—	142	1042

Performance Data

Table 4. Minimum and maximum evaporator flow rates, gpm

Shell Size (EVSZ)	Bundle Size (EVBS)	Tube Type																			
		IECU						IMC1						TECU						IMCU	
		Number of Passes																			
		1		2		3		1		2		3		1		2		3		1	
		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
100M	810	762	5589	393	2706	264	1826	761	5577	392	2701	263	1822	716	5254	367	2565	252	1703	—	—
	870	810	5941	417	2882	282	1936	808	5928	416	2876	281	1932	753	5523	385	2700	264	1792	—	—
	1000	972	7129	501	3454	330	2354	970	7114	500	3447	329	2349	860	6307	440	3081	298	2061	—	—
100L	810	762	5589	393	2706	264	1826	761	5577	392	2701	263	1822	716	5254	367	2565	252	1703	—	—
	870	810	5941	417	2882	282	1936	808	5928	416	2876	281	1932	753	5523	385	2700	264	1792	—	—
	1000	972	7129	501	3454	330	2354	970	7114	500	3447	329	2349	860	6307	440	3081	298	2061	—	—
130M	1040	975	7151	501	3476	330	2310	973	7136	500	3469	329	2306	877	6430	448	3148	296	2084	—	—
	1140	1074	7877	552	3829	363	2552	1072	7861	551	3821	362	2547	952	6979	486	3417	322	2252	—	—
	1300	1191	8735	612	4247	414	2662	1189	8717	611	4238	413	2657	1027	7528	524	3686	353	2353	—	—
160M	1290	1212	8889	606	4445	405	2948	1210	8871	605	4435	404	2942	1062	7786	541	3820	354	2588	—	—
	1390	1341	9835	672	4907	447	3278	1338	9815	671	4896	446	3272	1149	8424	574	4212	383	2801	—	—
	1600	1521	11155	762	5567	507	3718	1518	11132	761	5555	506	3711	1280	9388	640	4694	428	3126	—	—
200L	1520	1296	9505	678	4533	—	—	1293	9486	677	4523	—	—	1166	8548	606	4100	414	2655	—	—
	1680	1455	10671	744	5215	501	3322	1452	10649	743	5204	500	3316	1300	9533	674	4593	466	3025	—	—
	1840	1590	11662	834	5545	558	3498	1587	11637	832	5533	557	3491	1427	10463	738	5052	518	3294	—	—
	2000	1704	12498	915	5787	627	3674	1701	12472	913	5775	626	3667	1525	11180	849	4952	581	3450	—	—
220L	1850	1809	13268	905	6634	603	4423	1805	13240	903	6620	602	4413	1567	11494	784	5747	522	3831	—	—
	2000	1998	14654	999	7327	666	4885	1994	14624	997	7312	665	4875	1720	12614	860	6307	573	4205	—	—
	2200	2268	16634	1134	8317	756	5545	2264	16600	1132	8300	755	5533	1974	14474	987	7237	658	4825	—	—
400M	3040	1296	9505	—	—	—	—	—	—	—	—	—	—	1198	8788	—	—	—	—	1288	9444
	3360	1455	10671	—	—	—	—	—	—	—	—	—	—	1337	9801	—	—	—	—	1446	10602
	3680	1590	11662	—	—	—	—	—	—	—	—	—	—	1467	10757	—	—	—	—	1580	11586
	4000	1704	12498	—	—	—	—	—	—	—	—	—	—	1567	11494	—	—	—	—	1693	12417
440M	3700	1809	13268	—	—	—	—	—	—	—	—	—	—	1611	11817	—	—	—	—	1797	13182
	4000	1998	14654	—	—	—	—	—	—	—	—	—	—	1768	12969	—	—	—	—	1985	14559
	4400	2268	16634	—	—	—	—	—	—	—	—	—	—	2029	14881	—	—	—	—	2254	16526
440X	3700	1809	13268	—	—	—	—	—	—	—	—	—	—	1611	11817	—	—	—	—	1797	13182
	4000	1998	14654	—	—	—	—	—	—	—	—	—	—	1768	12969	—	—	—	—	1985	14559
	4400	2268	16634	—	—	—	—	—	—	—	—	—	—	2029	14881	—	—	—	—	2254	16526

Table 5. Minimum and maximum condenser flow rates, L/s

Shell Size (CDSZ)	Bundle Size (CDBS)	Tube Type											
		IECU				IMCU				TECU			
		Number of Passes											
		1		2		1		2		1		2	
		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
100M	810	131	481	66	240	133	489	67	244	117	429	58	214
	870	145	530	72	265	147	539	73	269	128	471	64	235
	1000	155	569	78	285	158	579	79	289	138	507	69	254
100L	810	131	481	66	240	133	489	67	244	117	429	58	214
	870	145	530	72	265	147	539	73	269	128	471	64	235
	1000	155	569	78	285	158	579	79	289	138	507	69	254
10HM	810	132	483	66	242	134	491	67	246	117	429	58	214
	870	144	529	72	264	147	537	73	269	128	471	64	235
	1000	155	568	77	284	157	577	79	289	140	514	70	257
130M	1040	164	600	82	300	166	609	83	305	146	535	73	268
	1140	179	658	90	329	182	669	91	334	160	588	80	294
	1300	195	714	97	357	198	725	99	363	173	635	87	318
13HM	1040	164	600	82	300	166	609	83	305	146	535	73	268
	1140	179	658	90	329	182	669	91	334	160	588	80	294
	1300	195	714	97	357	198	725	99	363	173	635	87	318
200M	1520	186	683	93	342	189	694	95	347	164	600	82	300
	1680	207	759	104	380	210	771	105	386	181	663	90	331
	1840	228	835	114	417	231	849	116	424	198	727	99	363
	2000	246	902	123	451	250	917	125	458	216	791	108	396
200L	1520	186	683	93	342	189	694	95	347	164	600	82	300
	1680	207	759	104	380	210	771	105	386	181	663	90	331
	1840	228	835	114	417	231	849	116	424	198	727	99	363
	2000	245	898	122	449	249	913	124	456	216	791	108	396
20HM	1520	186	683	93	342	189	694	95	347	164	600	82	300
	1680	207	759	104	380	210	771	105	386	180	661	90	331
	1840	228	835	114	417	231	849	116	424	198	727	99	363
	2000	237	870	119	435	241	885	121	442	207	759	104	380
220L	1850	246	902	123	451	250	917	125	458	216	791	108	396
	2000	270	991	135	495	275	1007	137	503	237	869	118	434
	2200	292	1072	146	536	297	1089	148	544	259	951	130	475
22HL	1850	246	901	123	450	250	915	125	458	216	791	108	396
	2000	270	992	135	496	275	1008	137	504	237	869	118	434
	2200	292	1070	146	535	297	1088	148	544	259	951	130	476
440M	3700	246	902	—	—	250	917	—	—	216	791	—	—
	4000	270	991	—	—	275	1007	—	—	237	869	—	—
	4400	292	1072	—	—	297	1089	—	—	259	951	—	—
440X	3700	246	902	—	—	250	917	—	—	216	791	—	—
	4000	270	991	—	—	275	1007	—	—	237	869	—	—
	4400	292	1072	—	—	297	1089	—	—	259	951	—	—

Table 6. Minimum and maximum condenser flow rates, gpm

Shell Size (CDSZ)	Bundle Size (CDBS)	Tube Type											
		IECU				IMCU				TECU			
		Number of Passes											
		1		2		1		2		1		2	
		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
100M	810	2078	7621	1039	3810	2112	7745	1056	3873	1853	6796	927	3398
	870	2292	8403	1146	4202	2329	8540	1165	4270	2034	7459	1017	3730
	1000	2461	9025	1231	4512	2501	9172	1251	4586	2193	8042	1097	4021
100L	810	2078	7621	1039	3810	2112	7745	1056	3873	1853	6796	927	3398
	870	2292	8403	1146	4202	2329	8540	1165	4270	2034	7459	1017	3730
	1000	2461	9025	1231	4512	2501	9172	1251	4586	2193	8042	1097	4021
10HM	810	2089	7661	1045	3831	2123	7786	1062	3893	1853	6796	927	3398
	870	2286	8383	1143	4192	2324	8520	1162	4260	2034	7459	1017	3730
	1000	2456	9005	1228	4502	2496	9151	1248	4576	2223	8153	1112	4076
130M	1040	2593	9506	1296	4753	2635	9661	1317	4830	2314	8485	1157	4242
	1140	2844	10429	1422	5214	2891	10599	1445	5299	2544	9329	1272	4664
	1300	3085	11311	1542	5656	3135	11495	1568	5748	2747	10073	1374	5036
13HM	1040	2593	9506	1296	4753	2635	9661	1317	4830	2314	8485	1157	4242
	1140	2844	10429	1422	5214	2891	10599	1445	5299	2544	9329	1272	4664
	1300	3085	11311	1542	5656	3135	11495	1568	5748	2747	10073	1374	5036
200M	1520	2954	10830	1477	5415	3002	11006	1501	5503	2594	9510	1297	4755
	1680	3282	12033	1641	6017	3335	12229	1668	6115	2865	10505	1433	5253
	1840	3610	13236	1805	6618	3669	13452	1834	6726	3142	11520	1571	5760
	2000	3900	14299	1950	7150	3963	14532	1982	7266	3422	12546	1711	6273
200L	1520	2954	10830	1477	5415	3002	11006	1501	5503	2594	9510	1297	4755
	1680	3282	12033	1641	6017	3335	12229	1668	6115	2865	10505	1433	5253
	1840	3610	13236	1805	6618	3669	13452	1834	6726	3142	11520	1571	5760
	2000	3883	14239	1942	7120	3947	14471	1973	7236	3422	12546	1711	6273
20HM	1520	2954	10830	1477	5415	3002	11006	1501	5503	2594	9510	1297	4755
	1680	3282	12033	1641	6017	3335	12229	1668	6115	2860	10485	1430	5243
	1840	3610	13236	1805	6618	3669	13452	1834	6726	3142	11520	1571	5760
	2000	3763	13798	1882	6899	3824	14023	1912	7011	3282	12033	1641	6017
220L	1850	3900	14299	1950	7150	3963	14532	1982	7266	3422	12546	1711	6273
	2000	4283	15703	2141	7852	4352	15959	2176	7979	3756	13772	1878	6886
	2200	4633	16987	2316	8493	4708	17263	2354	8632	4110	15069	2055	7535
22HL	1850	3894	14279	1947	7140	3958	14512	1979	7256	3422	12546	1711	6273
	2000	4288	15723	2144	7862	4358	15979	2179	7990	3756	13772	1878	6886
	2200	4627	16967	2314	8483	4703	17243	2351	8621	4112	15079	2056	7540
440M	3700	3900	14299	—	—	3963	14532	—	—	3422	12546	—	—
	4000	4283	15703	—	—	4352	15959	—	—	3756	13772	—	—
	4400	4633	16987	—	—	4708	17263	—	—	4110	15069	—	—
440X	3700	3900	14299	—	—	3963	14532	—	—	3422	12546	—	—
	4000	4283	15703	—	—	4352	15959	—	—	3756	13772	—	—
	4400	4633	16987	—	—	4708	17263	—	—	4110	15069	—	—

Job Site Considerations

Shipment and Assembly

All CenTraVac™ chillers ship as a factory assembled, factory tested package, ready to rig into place on factory-supplied isolation pads. A full oil charge is shipped in the oil sump, and a 20.7 to 34.5 kPaG (3 to 5 psig) dry nitrogen charge prevents condensation and confirms a leak-free seal before installation.

Figure 17. Shrink-wrapped Series E™ chiller, ready to ship from the factory

Figure 18. Unit control panel

Each unit is shrink-wrapped to help ensure that each Series E™ CenTraVac chiller is delivered to the customer in the same condition it left the factory. The packaging process used at Trane is industry-leading; each unit is covered with a six-sided 10 mil, military-grade recyclable film.

Controls

Tracer AdaptiView Controller

The Series E™ CenTraVac™ chiller features the Tracer AdaptiView™ controller which utilizes predictive control strategies to anticipate and compensate for changes in the chiller's operating conditions.

Feed Forward Adaptive Control

Feed Forward Adaptive Control™ is an open loop, predictive control strategy designed to anticipate and compensate for load changes. It uses the evaporator entering water temperature as an indication of load change. This allows the controller to respond faster and maintain stable leaving water temperatures.

Soft Loading

The chiller controller uses soft loading except during manual operation. Large adjustments due to load or setpoint changes are made gradually, preventing the compressor from cycling unnecessarily. It does this by internally filtering the setpoints to avoid reaching the differential-to-stop or the current limit. Soft loading applies to the leaving chilled water temperature and current limit setpoints.

Multi-Objective Limit Arbitration

There are many objectives that the controller must meet, but it cannot satisfy more than one objective at a time. Typically, the controller's primary objective is to maintain the evaporator leaving water temperature.

Whenever the controller senses that it can no longer meet its primary objective without triggering a protective shutdown, it focuses on the most critical secondary objective. When the secondary objective is no longer critical, the controller reverts back to its primary objective.

Rapid Restart

The controller allows the Series E™ CenTraVac™ chiller to restart during the postlube process. If the chiller shuts down on a nonlatching diagnostic, the diagnostic has up to 180 seconds to clear itself and initiate a fast restart. This includes momentary power losses.

Adaptive Frequency Drive (AFD) Control

The combination of speed control and inlet guide vane position is optimized mathematically and controlled simultaneously. The increased performance of the microprocessor allows the chiller to operate longer at higher efficiency, and with greater stability.

Variable-Primary Flow (VPF)

Chilled-water systems that vary the water flow through chiller evaporators have caught the attention of engineers, contractors, building owners, and operators. Varying the water flow reduces the energy consumed by pumps, while having limited affect on the chiller energy consumption. This strategy can be a significant source of energy savings, depending on the application.

Using the optional Enhanced Flow Management Package, the Tracer AdaptiView™ chiller controller reliably accommodates variable evaporator water flow and virtually eliminates its effect on the chilled water temperature.

Enhanced Flow Management

The Enhanced Flow Management Package is an optional control feature that includes water differential pressure sensor transducers.

The Enhanced Flow Management Package improves the ability of the chiller to accommodate variable flow, even in combination with an Adaptive Frequency™ Drive (AFD). For more information on this option, refer to "Enhanced Flow Management Package," p. 44.

1.1°C (34°F) Leaving Water Temperature

Another benefit of Feed Forward Adaptive Control™ is the ability to operate the Series E™ CenTraVac™ chiller at low leaving evaporator water temperatures without the use of glycol.

Colder water is generally used in wide delta-T systems, reducing the pumping energy required and making it less expensive to deliver cooling capacity over long distances. For this reason, low leaving water temperatures are frequently used in district cooling applications, but can also be used in comfort cooling applications.

Your local Trane account manager can assist in making chiller selections using 1.1°C to 2.2°C (34°F to 36°F) leaving water temperatures. Special installation procedures may be required.

Tracer AdaptiView Control and Operator Interface

The Tracer AdaptiView™ control comes with a unit-mounted operator interface that has a 30.5 centimeter (12 inch) touchscreen display. The display presents information through an intuitive navigation system. Additionally, the Tracer AdaptiView control panel allows the user to select from 27 different languages to ensure that the operator can understand how the chiller is operating.

The controller receives information from and communicates information to the other devices on the chiller's communications link. Tracer AdaptiView control performs the Leaving Chilled Water Temperature and Limit Control algorithms.

Tracer AdaptiView control can be connected to the service tool using a standard USB type B cable. The connection is located on the side of the control panel, along with a power outlet for a laptop PC power supply.

- Data graphs
- Mode overrides
- Status (all subsystems) with animated graphics
- Auto/Stop commands
- 60 diagnostics
- ASHRAE chiller log
- Setpoint adjustment (daily user points)

Field Connection

The field-connected items are important for turning the chiller on or off. This includes an emergency or external stop, pump relays, and verification that flow has been established. The optional, factory-supplied flow switch or a customer-supplied proof-of-flow device may be used.

- Emergency stop
- Chilled-water flow contacts
- Condenser-water flow contacts
- Chilled-water pump relay
- Condenser-water pump relay
- External auto stop (enable/disable)

Heat Exchanger Control

Fundamental internal variables that are necessary to control the chiller are gathered and acted upon by the heat exchanger control function.

Motor Control and Compressor Protection

This includes all functions that start, run, and stop the motor. The starter module provides the interface and control of wye-delta, across-the-line, primary reactor, autotransformer, and solid-state starters. Analog and binary signals are used to interface with the solid-state starter. The Adaptive Frequency™ drive (AFD) option includes an AFD output signal to control the drive. The motor control also provides protection to both the motor and the compressor.

EarthWise Purge Control

The purge control regulates the purge to optimize both purge and chiller efficiency. The purge controller communicates with the Tracer AdaptiView™ control over the machine bus communications link, uploading setpoints and downloading data and diagnostics.

Potential/Current Transformers—3-phase

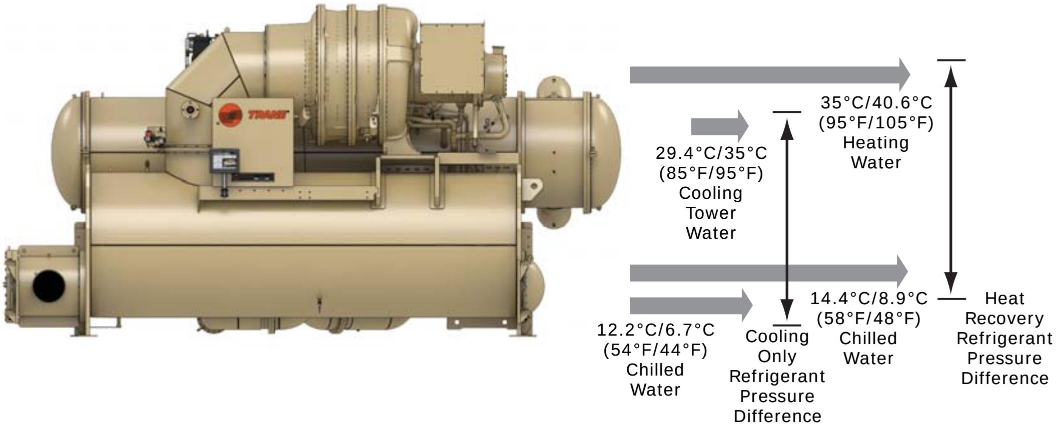
Includes factory-installed potential/current transformers in the starter for monitoring and displaying phase voltage and amperage, and provides over/undervoltage protection. Tracer AdaptiView™ control, Tracer™ TU, and Tracer building controls display the following:

- Kilowatts
- Kilowatt-hours
- Power factor (uncorrected)
- Compressor-phase amperage (a, b, c)
- Compressor-phase voltage (a-b, b-c, c-a)

Chilled-Water Reset

Chilled-water reset reduces chiller energy consumption during periods of the year when heating loads are high and cooling loads are reduced. It is based on return chilled-water temperature. Resetting the chilled-water temperature reduces the amount of work that the compressor must do by increasing the evaporator refrigerant pressure. This increased evaporator pressure reduces the pressure differential the compressor must generate while in the heat recovery mode. Chilled-water reset is also used in combination with the hot-water control. By resetting the chilled-water temperature upward, the compressor can generate a higher condenser pressure, resulting in higher leaving hot-water temperatures.

Figure 19. Chilled-water reset



Hot-Water Control

In the hot-water mode, the chiller produces hot water as its primary objective, rather than chilled water—similar to the heat recovery operation. A leaving condenser water setpoint is maintained while the leaving evaporator temperature is allowed to modulate with the load. As an option, the Extended Operation package allows an external controller to enable, disable, and modulate this mode. The hot-water mode is performed without a secondary condenser.

Ice-Making Control

For chillers that have been selected for ice-making operation, the standard control package includes the ice-making mode. As an option, the Extended Operation package allows an external controller to enable, disable, and modulate this mode.

Extended Operation Package

Select the extended-operation package for chillers that require external ice-building control, hot water control, and/or base-loading capabilities. This package also includes a 4–20 mA or 0–10 Vdc analog input for a refrigerant monitor. Package includes:

- Refrigerant monitor input
- External base-loading binary input
- External base-loading control
- External ice-building binary input
- External ice-building control
- External hot-water control binary input

Base-Loading Control

This feature allows an external controller to directly modulate the capacity of the chiller. It is typically used in applications where virtually infinite sources of evaporator load and condenser capacity are available and it is desirable to control the loading of the chiller. Two examples are industrial process applications and cogeneration plants. Industrial process applications might use this feature to impose a specific load on the facility's electrical system. Cogeneration plants might use this feature to balance the system's heating, cooling, and electrical generation.

All chiller safeties and Adaptive Control™ functions are in full effect when Base Loading is enabled. If the chiller approaches full current, the evaporator temperature drops too low, or the condenser pressure rises too high, the controller's Adaptive Control logic limits the loading of the chiller to prevent the chiller from shutting down on a safety limit. These limits may prevent the chiller from reaching the load requested by the Base Loading signal.

An alternative and less radical approach to Base Loading indirectly controls the chiller capacity. Artificially load the chiller by setting the chilled-water setpoint lower than it is capable of achieving. Then, modify the chillers load by adjusting the current limit setpoint. This approach provides greater safety and control stability because it leaves the chilled-water temperature-control logic in effect. The chilled-water temperature control responds more quickly to dramatic system changes and limits chiller loading prior to reaching an Adaptive Control limit.

Ice-Making Control

This feature allows an external controller to control the chiller in an ice-storage system. Ice storage is typically used in areas where high electrical demand charges can be offset by shifting building energy use to off-peak (typically nighttime) hours.

While the standard controller is fully capable of running the chiller in ice-making mode, installation savings and additional energy savings can be realized by using the Chiller Plant Control module of the Tracer™ building automation system. Chiller Plant Control anticipates how much ice needs to be made at night and operates the system accordingly. The controls are integrated with the chiller—two wires and pre-programmed software reduce field-installation cost and complex custom programming.

The Series E™ CenTraVac™ chiller is uniquely suited for low-temperature applications like ice storage, because it provides multiple stages of compression. This allows the chiller to produce ice efficiently, while experiencing less stress than a single-stage compression chiller.

Hot-Water Control

This feature allows an external controller to enable/disable and modulate the hot-water control mode. Occasionally, Series E™ CenTraVac™ chillers are used to provide heating as a primary operation. In this case the external controller or operator would select a hot-water temperature setpoint and the chiller capacity would be modulated to maintain the setpoint. Heating is the primary function and cooling is a waste product or a secondary function. This technique provides application flexibility, especially in multiple-chiller plants in conjunction with undersized heating plants.

The chiller needs only one condenser for hot-water control.

Refrigerant Monitor

The Extended Operation package allows for a refrigerant monitor to send a 4–20 mA signal to the Tracer AdaptiView™ control display. It can be calibrated to correspond to either 0–100 ppm or 0–1000 ppm concentration levels. The concentration level is displayed at the Tracer AdaptiView control, but the chiller will not take any action based on the input from the refrigerant monitor.

Alternatively, the BACnet® module allows the refrigerant monitor to be connected to Trane Tracer™ controls, which have the ability to increase ventilation in the equipment room in response to high refrigerant concentrations.

Enhanced Flow Management Package

This option includes transducers for the differential evaporator and condenser water pressures. Flow switches or some other means to prove flow are still required and must be field connected. One type of sensor handles all pressure ranges up to 2068.4 kPaG (300 psig).

How It Works

The Tracer™ chiller controller uses a patented, variable, water-flow compensation algorithm to maintain stable, precise capacity control.

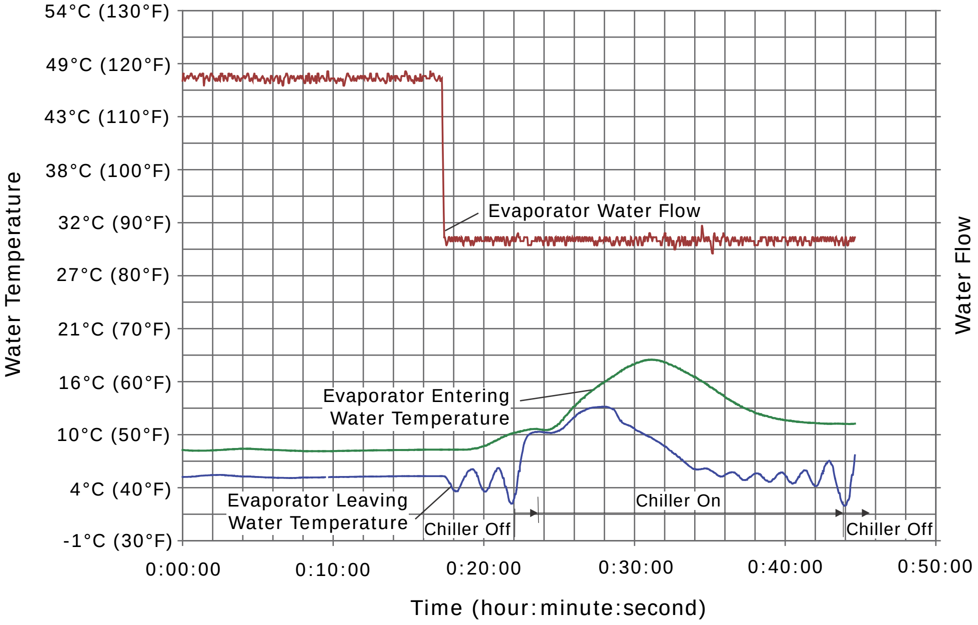
If the water-pressure transducer fails and the flow switch continues to prove flow, water-flow compensation will be disabled and the design delta-T will be used.

For applications designed to operate with variable-primary water flow, variable-flow compensation allows the chiller to respond quickly to changes in chilled-water flow rate. By automatically adjusting the control gain, large changes in the water-flow rate are accommodated.

Data shown on Figure 20 demonstrates water-temperature control without flow compensation. In contrast, Figure 21, p. 46 demonstrates water-temperature control with flow compensation enabled. The chilled-water temperature remains stable, even when the water flow rate drops 50 percent in 30 seconds.

Another benefit is disturbance rejection. Figure 22, p. 46 shows the test results from step changes in water flow with increasing magnitudes. The leaving chilled-water temperature remains largely unaffected. Even the most severe change—dropping water flow 66 percent in 30 seconds—caused only a small, 0.83°C (1.5°F) variation in chilled-water temperature. While it is unlikely that a chiller application would make water flow changes of this magnitude, the results demonstrate that the chiller is more than capable of supporting variable water flow applications.

Figure 20. Capacity control without Enhanced Flow Management Package



Variable-Flow Stability

Figure 21. Capacity control with Enhanced Flow Management Package

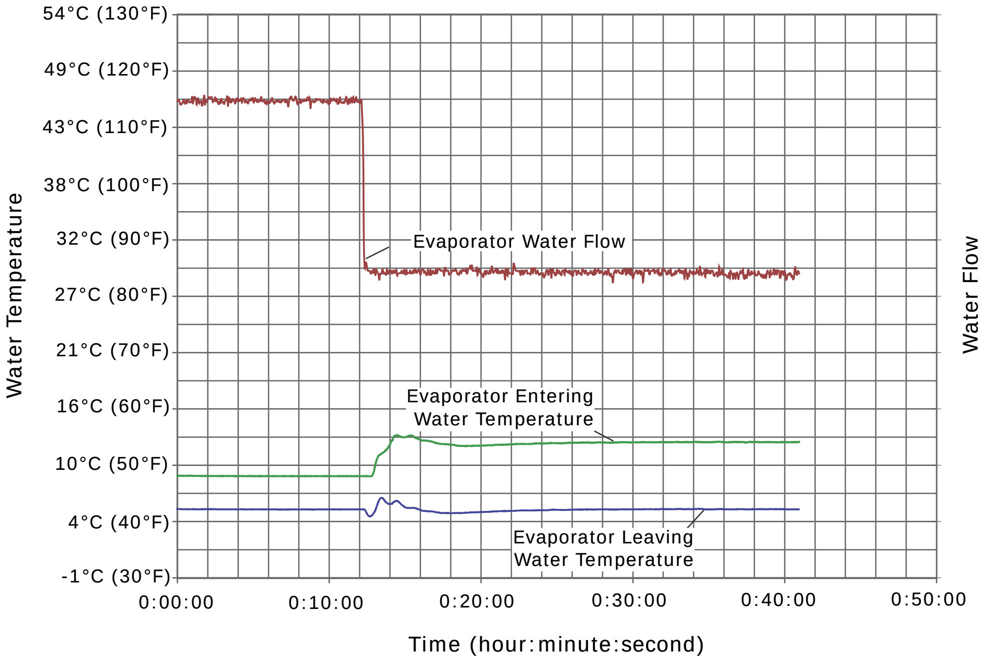
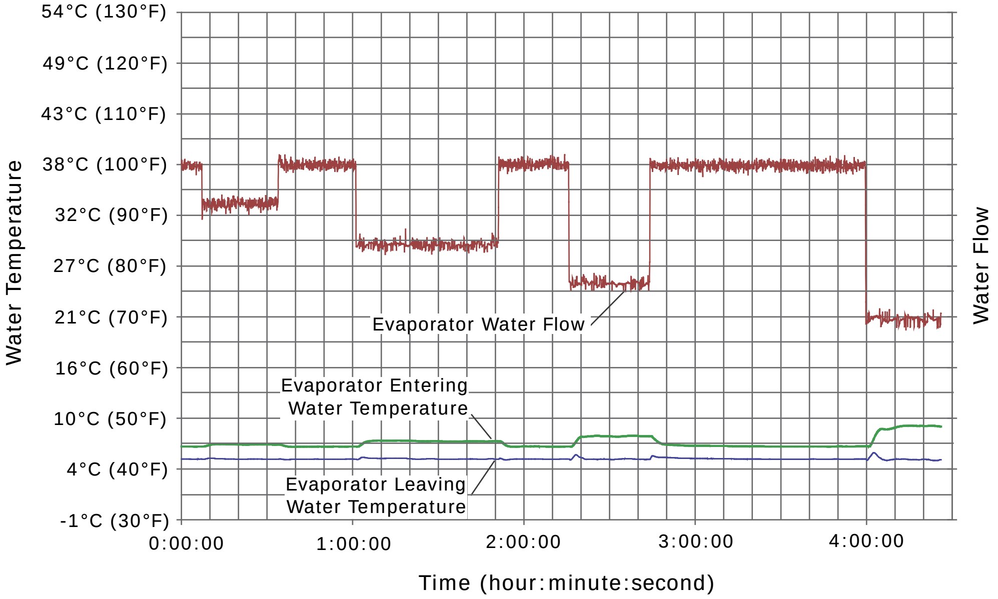


Figure 22. Capacity control with flow changes and Enhanced Flow Management Package



The following data will be shown at the Tracer AdaptiView™ control, Tracer TU displays and at the Tracer™ controls:

- Evaporator capacity (kW, tons)
- Evaporator and condenser flow rates (L/s, gpm)
- Evaporator and condenser differential water pressures (kPaD, psid)

It will automatically adjust capacity control to:

- Minimize variable-flow disturbance
- Maintain control stability at low flow

LonTalk Communications Interface (LCI-C)

The optional LonTalk® Communications Interface for Chillers (LCI-C) is available factory or field installed. It is an integrated communication board that enables the chiller controller to communicate over a LonTalk network. The LCI-C is capable of controlling and monitoring chiller setpoints, operating modes, alarms, and status. The Trane LCI-C provides additional points beyond the standard LONMARK® defined chiller profile to extend interoperability and support a broader range of system applications. These added points are referred to as open extensions. The LCI-C is certified to the LONMARK Chiller Controller Functional Profile 8040 version 1.0, and follows LonTalk FTT-10A free topology communications.

Native BACnet Communications

Tracer AdaptiView™ control can be configured for BACnet® communications at the factory or in the field. This enables the chiller controller to communicate on a BACnet MS/TP network. Chiller setpoints, operating modes, alarms, and status can be monitored and controlled through BACnet.

Tracer AdaptiView controls conform to the BACnet B-ASC profile as defined by ANSI/ASHRAE Standard 135-2004.

MODBUS Communications

Tracer AdaptiView™ control can be configured for MODBUS® communications at the factory or in the field. This enables the chiller controller to communicate as a slave device on a MODBUS network. Chiller setpoints, operating modes, alarms, and status can be monitored and controlled by a MODBUS master device.

Tracer TU Interface

The Tracer™ chiller controller adds a level of sophistication better served by a PC application to improve service technician effectiveness and minimize chiller downtime. The Tracer AdaptiView™ control's operator interface is intended to serve only typical daily tasks. The portable PC-based service-tool software, Tracer TU, supports service and maintenance tasks.

Tracer TU serves as a common interface to all UC800 and BCI-C (BACnet®) based Trane chillers, and will customize itself based on the properties of the chiller with which it is communicating. Thus, the service technician learns only one service interface.

The panel bus is easy to troubleshoot using LED sensor verification. Only the defective device is replaced. Tracer TU can communicate with individual devices or groups of devices.

All chiller status, machine configuration settings, customizable limits, and up to 100 active or historic diagnostics are displayed through the service-tool software interface.

LEDs and their respective Tracer TU indicators visually confirm the availability of each connected sensor, relay, and actuator.

Tracer TU is designed to run on a customer's laptop, connected to the Tracer AdaptiView control panel with a USB cable.

Laptop requirements for Tracer TU:

- 1 GB RAM (minimum)
- 1024 x 768 screen resolution
- CD-ROM drive

- Ethernet 10/100 LAN card
- An available USB 2.0 port
- Microsoft® Windows® operating system: Windows 7 Enterprise, Windows 8 Enterprise, or Windows Professional (32-bit or 64-bit)
- Microsoft® .NET Framework 4.0 or later

Contact your local Trane account manager for more information.

Building Automation and Chiller Plant Control

System and Chiller Plant Controls

Tracer™ SC allows you to streamline facility management without reinventing the entire system. Adding Tracer SC to your system provides a flexible, cost effective solution for building automation and climate control that can extend to lighting and energy consumption. Accessible from a personal computer, tablet or smart phone, Tracer SC eliminates the need for a dedicated computer so you can manage system performance whenever and wherever it is convenient. Tracer SC is a simplified, web-based management tool that reduces scheduling, reporting and system application chores to simple "point and click" tasks. Tracer SC strikes the perfect balance between tenant comfort and energy efficiency, resulting in operating cost savings and a better bottom line.

Area Application

The Area application coordinates groups of equipment based on tenant or occupant organization within a building, allowing for standard calculations and functions. The Area application can be configured to use multiple algorithms, along with area temperatures and humidity inputs, to make an economizing decision. Users are presented with a simplified, logical user interface with logical areas rather than directly interfacing with equipment. The Area application also supports:

- Optimal start/stop
- Humidity pulldown
- Night purge
- Unoccupied heating/cooling setpoints
- Unoccupied humidify/dehumidify
- Timed override functions

For more information, refer to BAS-APG007*-EN (*Applications Guide: Air Systems [including EarthWise™ Systems] for the Tracer® SC System Controller*).

Chiller Plant Control (CPC)

The Chiller Plant Control (CPC) application permits users to configure a chiller plant for optimal efficiency and reliability, while providing a means for monitoring and controlling the daily operation. Depending upon the chiller plant configuration and design, the CPC application can do the following:

- Provide overall chiller plant status information and alarms to local and remote Tracer SC users
- Enable or disable chiller plants
- Start, stop, and monitor the status of system chilled water pumps
- Calculate individual chilled water setpoints for chillers in series chiller plants
- Request when chillers are added or subtracted according to building load requirements and user-specified add and subtract logic
- Rotate chillers according to user-defined intervals
- Remove chillers from the rotation in the event

For more information, refer to BAS-APG012*-EN (*Applications Guide: Tracer™ SC System Controller Chiller Plant Control Application*).

Chiller-Tower Optimization

The Tracer™ chiller-tower optimization extends Adaptive Control™ to the rest of the chiller plant. Chiller-tower optimization is a unique control algorithm for managing the chiller and cooling tower subsystem. It considers the chiller load and real-time ambient conditions, then optimizes the tower setpoint temperature to maximize the efficiency of the entire subsystem. This real-time optimization may vary tower temperatures between 10°C–32.2°C (50°F–90°F) depending upon current outdoor conditions, chiller loading, and ancillary efficiencies.

Tracer Building Controls

The Tracer AdaptiView™ chiller controller is designed to communicate with a wide range of building automation systems. To leverage all of your Series E™ CenTraVac™ chiller capabilities, integrate your chiller into a Tracer™ SC system controller or a comprehensive Tracer ES building management system.

The Tracer SC system controller can manage multiple systems within a building. It provides a flexible solution for managing your building's HVAC system, with an intuitive, web-based user interface and industry-leading 3D graphics and pre-programmed features such as:

- **Chiller plant management**—Allows you to manage multiple chillers of any size and coordinate with other equipment as part of your chiller plant operation for even greater energy efficiency and reduced operating costs.
- **EarthWise™ Systems**—Apply integrated pre-packaged design concepts that are optimized for energy and environmental performance; sustainable systems that deliver measurable, repeatable and superior performance with lower operating costs.

The Tracer ES building management software provides a web-based, scalable, integration platform for managing all of your facilities as a single enterprise. It allows you to view status and manage alarms and schedules from one system—from anywhere, and its reports enable enterprise-wide decision making for optimized performance. It also offers easy integration with other systems via BACnet® IP.

Standard Protections

The chiller controller uses proportional-integral-derivative (PID) control for all limits—there is no dead band. This removes oscillation above and below setpoints and extends the capabilities of the chiller.

Some of the standard protection features of the chiller controller are described in this section. There are additional protection features not listed here, please contact your local Trane account manager.

High Condenser-Pressure Protection

The chiller will protect itself from a starter failure that prevents disconnecting the compressor motor from the incoming line power.

The chiller controller's condenser limit keeps the condenser pressure under a specified maximum pressure. The chiller will run up to 100 percent of this setpoint before the Adaptive Control™ mode reduces capacity.

Starter-Contactor Failure Protection

The chiller will protect itself from a starter failure that prevents the compressor motor from disconnecting from the line to the limits of its capabilities.

The controller starts and stops the chiller through the starter. If the starter malfunctions and does not disconnect the compressor motor from the line when requested, the controller will recognize the fault and attempt to protect the chiller by operating the evaporator and condenser water pumps, oil/refrigerant pumps and attempting to unload the compressor.

Loss of Water-Flow Protection

Tracer AdaptiView™ control has an input that will accept a contact closure from a proof-of-flow device such as a flow switch or pressure switch. Customer wiring diagrams also suggest that the flow switch be wired in series with the cooling-water and condenser-water pump starter auxiliary contacts. When this input does not prove flow within a fixed time during the transition from Stop to Auto modes of the chiller, or if the flow is lost while the chiller is in the Auto mode of operation, the chiller will be inhibited from running by a diagnostic.

Evaporator Limit Protection

Evaporator Limit is a control algorithm that prevents the chiller from tripping on its low refrigerant-temperature cutout. The machine may run down to the limit but not trip. Under these conditions the intended chilled-water setpoint may not be met, but the chiller will do as much as it can. The chiller will deliver as much cold water as possible even under adverse conditions.

Low Evaporator-Water Temperature

Low evaporator-water temperature protection, also known as Freeze Stat protection, avoids water freezing in the evaporator by immediately shutting down the chiller and attempting to operate the chilled-water pump. This protection is somewhat redundant with the Evaporator Limit protection, and prevents freezing in the event of extreme errors in the evaporator-refrigerant temperature sensor.

The cutout setting should be based on the percentage of antifreeze used in the customer’s water loop. The chiller’s operation and maintenance documentation provides the necessary information for percent antifreeze and suggests leaving-water temperature-cutout settings for a given chilled-water temperature setpoint.

High Vacuum-Lockout Protection

The controller inhibits a compressor start with a latching diagnostic whenever the evaporator pressure is less than or equal to 31.1 kPaA (4.51 psia). This protects the motor by locking out chiller operation while the unit is in a high vacuum—preventing startup without a refrigerant change during commissioning.

Oil-Temperature Protection

Low oil-temperature trips when the oil pump and/or compressor are running may be an indication of refrigerant diluting the oil. If the oil temperature is at or below the low oil-temperature setpoint, the compressor is shut down on a latching diagnostic and cannot be started. The diagnostic is reported at the user interface. The oil heater is energized in an attempt to raise the oil temperature above the low oil-temperature setpoint.

High oil-temperature protection is used to avoid overheating the oil and the bearings.

Low Differential Oil-Pressure Protection

Oil pressure is indicative of oil flow and active oil-pump operation. A significant drop in oil pressure indicates a failure of the oil pump, oil leakage, or a blockage in the oil circuit.

During compressor prelube the differential pressure should not fall below 82.7 kPaD (12 psid). A shutdown diagnostic will occur within 2 seconds of the differential pressure falling below three-quarters of the low differential oil-pressure cutout.

When the compressor is running the shutdown diagnostic will occur when the differential pressure falls below the differential oil-pressure cutout for more than (cutout x 3) seconds. This allows for a relatively high cutout to be violated longer before triggering shutdown, as compared to a low cutout.

Excessive Purge Detection

Pump-out activity indicates the amount of air leaking into the chiller refrigerant system. The operator is informed when the air-leakage rate changes. The operator can specify an expected leakage rate, and can be notified though a diagnostic if the rate is higher than expected.

Occasionally, when a service technician performs a mechanical repair on the chiller, an unusually high pump-out rate is expected for a certain period of time following the procedure. The service excessive pump-out override allows the technician to specify a time period for the purge system to rid the chiller of air in the system. This temporarily suspends excessive purge detection.

Phase-Unbalance Protection

Phase-unbalance protection is based on an average of the three-phase current inputs. The ultimate phase-unbalance trip point is 30 percent. In addition, the RLA of the motor is derated by resetting the active current limit setpoint based on the current unbalance. The RLA derate protection can be disabled in the field-startup menu.

The following derates apply when the phase-unbalance limit is enabled:

Less than 20% unbalance = 100% RLA available
20% unbalance = 80% RLA available
25% unbalance = 86% RLA available
30% unbalance = Shutdown

Phase-Loss Protection

The controller will shut down the chiller if any of the three-phase currents feeding the motor drop below 10 percent RLA. The shutdown will result in a latching phase-loss diagnostic. The time to trip is 1 second at minimum, 3 seconds maximum.

Phase Reversal/Rotation Protection

The controller detects reverse-phase rotation and provides a latching diagnostic when it is detected. The time to trip is 0.7 seconds.

Momentary Power Loss and Distribution Fault Protection

Three-phase momentary power loss (MPL) detection gives the chiller improved performance through many different power anomalies. MPLs of 2.5 cycles or longer will be detected and cause the unit to shut down. The unit will be disconnected from the line within 6 line cycles of detection. If enabled, MPL protection will be active any time the compressor is running. MPL is not active on reduced-voltage starters during startup to avoid nuisance trips. The MPL diagnostic is an automatic reset diagnostic.

An MPL has occurred when the motor no longer consumes power. An MPL may be caused by any drop or sag in the voltage that results in a change in the direction of power flow. Different operating conditions, motor loads, motor size, inlet guide vane position, etc., may result in different levels at which this may occur. It is difficult to define an exact voltage sag or voltage level at which a particular motor will no longer consume power, but we are able to make some general statements concerning MPL protection:

The chiller will remain running under the following conditions:

- Second-order or lower harmonic content on the line
- Control-voltage sags of any magnitude less than 3 line cycles
- Control-voltage sags of 40 percent or less for any amount of time
- Line-voltage sag of 1.5 line cycles or less for any voltage magnitude sag

The chiller may shut down under the following conditions:

- Line-voltage sags of 1.5 or more line cycles for voltage dips of 30 percent or more
- Third-order or higher harmonic content on the line
- Control-voltage sags of three or more line cycles for voltage dips of 40 percent or more

Current-Overload Protection

The control panel will monitor the current drawn by each line of the motor and shut the chiller off when the highest of the three line currents exceeds the trip curve. A manual reset diagnostic describing the failure will be displayed. The current overload protection does not prohibit the chiller from reaching its full-load amperage. The chiller protects itself from damage due to current overload during starting and running modes, but is allowed to reach full-load amps.

High Motor-Winding Temperature Protection

This function monitors the motor temperature and terminates chiller operation when the temperature is excessive. The controller monitors each of the three winding-temperature sensors any time the controller is powered up, and displays each temperature at the service menu. The controller will generate a latching diagnostic if the winding temperature exceeds 129.4°C (265°F) for 0.5–2 seconds.

Surge Detection Protection

Surge detection is based on current fluctuations in one of three phases. The default detection criterion is two occurrences of root-mean square (RMS) current change of 30 percent within 0.8 seconds in 60 ±10 percent seconds. The detection criterion is adjustable with the Tracer™ chiller controller.

Overvoltage and Undervoltage Protection

While some components of the chiller are impervious to dramatically different voltages, the compressor-motor is not. The control panel monitors all three line-to-line voltages for the chiller, and bases the over and undervoltage diagnostics on the average of the three voltages. The default protection resets the unit if the line voltage is below or above ±10 percent of nominal for 60 seconds.

Power Factor and kW Measurement

Three-phase measurement of kW and unadjusted power factor yields higher accuracy during power imbalance conditions.

Short-Cycling Protection

This function mimics heat dissipation from a motor start using two setpoints: Restart Inhibit Free Starts and Restart Inhibit Start-to-Start Timer. This allows the Series E™ CenTraVac™ chiller to inhibit too many starts in a defined amount of time while still allowing for fast restarts. The default for Series E CenTraVac chillers is three Free Starts and a 20 minute Start-to-Start Timer. The control panel generates a warning when the chiller is inhibited from starting by this protection.

Restart Inhibit Free Starts: This setting will allow a maximum number of rapid restarts equal to its value. If the number of free starts is set to 1, this will allow only one start within the time period set by the Start-to-Start Time setting. The next start will be allowed only after the start-to-start timer has expired. If the number of free starts is programmed to 3, the control will allow three starts in rapid succession, but thereafter, it would hold off on a compressor start until the Start-to-Start timer expired.

Restart Inhibit Start-to-Start Time Setting: This setting defines the shortest chiller cycle period possible after the free starts have been used. If the number of free starts is programmed to 1, and the Start-to-Start Time setting is programmed to 10 minutes, the compressor will be allowed one start every 10 minutes. The start-to-start time is the time from when the motor was directed to energize to when the next prestart is issued.

Enhanced Protection Option

This optional package includes sensors and transducers that enable the following protection features:

Enhanced Condenser-Limit Control

Includes factory-installed condenser-pressure transducer and all necessary interconnecting piping and wiring. Enhanced condenser-limit control provides high-pressure cutout avoidance by energizing a relay to initiate head relief.

Note: *This option is in addition to the standard high refrigerant-pressure safety contact.*

Compressor-Discharge Refrigerant-Temperature Protection (optional)

Includes a factory-installed sensor and safety cutout on high compressor discharge temperature. Allows the chiller controller to monitor compressor discharge temperature, which is displayed at Tracer AdaptiView™ control and operator interface, Tracer™ TU and Tracer building controls.

Note: *When the chiller is selected with hot gas bypass, this sensor and its associated protections are included as standard.*

Sensing of Leaving Oil Set Temperature For Each Bearing

The compressor thrust bearing has three resistance temperature detectors (RTDs) that measure the bearing pad temperature during operation. The high bearing-temperature cutout is fixed at 82.2°C (180°F). If either bearing temperature violates the cutout, a latching diagnostic will be generated.

Weights

Important: *The unit weight information provided in Table 7, p. 54 through Table 10, p. 56 should be used for general information purposes only. Trane does not recommend using this weight information for considerations relative to chiller handling. The large number of variances between chiller selections drives variances in chiller weights that are not recognized in this table. For specific weights for your chiller, refer to your submittal package.*

The values in Table 7, p. 54 through Table 10, p. 56 are representative chiller weights based on the following:

- TECU tubes, 0.71 mm (0.028 in.) tube wall thickness.
- 1034.2 kPaG (150 psig) non-marine waterboxes.
- Operating weights are based on the largest possible refrigerant charge.
- Heaviest possible bundle and motor combination.

The values in Table 7, p. 54 through Table 10, p. 56 do NOT include the starter, or the following options:

- INDP (Industrial Control Panel) option—add 23 kg (50 lb)
- CPTR (Control Panel Transformer) option—add 127 kg (280 lb)
- SMP (Supplemental Motor Protection) option—add 230 kg (500 lb)

Table 7. Weights, 50 Hz chillers (kg)[a]

				Weight without Starters	
MODEL	**NTON**	**EVSZ**	**CDSZ**	**Operating**	**Shipping**
CVHH	950–1050	100M	100M	21322	18835
		100L	100L	22141	19425
		100M	10HM	25879	22594
		130M	130M	23728	20638
		130M	13HM	29317	25280
		160M	200M	27065	23163
		160M	20HM	33384	28458
		200L	220L	29810	25273
		220L	220L	31858	26780
	1550	200L	200L	28957	24792
		200L	20HL	35898	30599
		220L	220L	32359	27281
		220L	22HL	41153	34627
CDHH	1750–2250	400M	440M	51416	44210
	3050	440M	440M	56416	47857
		440X	440X	59233	49597

(a) To calculate the maximum chiller weight with starter/drive, add the starter/AFD weight from Table 11, p. 56 to the chiller maximum weight from Table 7. Note that Duplex™ chiller models CDHH will have two starters, one for each compressor.

Table 8. Weights, 50 Hz chillers (lb)[a]

				Weight without Starters	
MODEL	**NTON**	**EVSZ**	**CDSZ**	**Operating**	**Shipping**
CVHH	950–1050	100M	100M	47006	41524
		100L	100L	48813	42825
		100M	10HM	57053	49812
		130M	130M	52312	45499
		130M	13HM	64632	55732
		160M	200M	59669	51065
		160M	20HM	73599	62740
		200L	220L	65719	55718
		220L	220L	70235	59039
	1550	200L	200L	63839	54657
		200L	20HL	79141	67459
		220L	220L	71340	60144
		220L	22HL	90727	76339
CDHH	1750–2250	400M	440M	113353	97467
	3050	440M	440M	124375	105507
		440X	440X	130587	109343

(a) To calculate the maximum chiller weight with starter/drive, add the starter/AFD weight from Table 11, p. 56 to the chiller maximum weight from Table 8. Note that Duplex™ chiller models CDHH will have two starters, one for each compressor.

Table 9. Weights, 60 Hz chillers (kg)[a]

				Weight without Starters	
MODEL	**NTON**	**EVSZ**	**CDSZ**	**Operating**	**Shipping**
CVHH	900–1200	100M	100M	20384	17897
		100L	100L	21203	18487
		100M	10HM	24941	21656
		130M	130M	22790	19700
		130M	13HM	28379	24342
		160M	200M	26127	22225
		160M	20HM	32446	27520
		200L	220L	28872	24335
		220L	220L	30920	25842
	1500–1700	200L	200L	27932	23767
		200L	20HL	34873	29574
		220L	220L	31334	26256
		220L	22HL	40128	33602
CDHH	2000–2600	400M	440M	49094	41888
	2800–3300	440M	440M	54045	45486
		440X	440X	57386	47750

(a) To calculate the maximum chiller weight with starter/drive, add the starter/AFD weight from Table 11, p. 56 to the chiller maximum weight from Table 9. Note that Duplex™ chiller models CDHH will have two starters, one for each compressor.

Table 10. Weights, 60 Hz chillers (lb)[a]

				Weight without Starters	
MODEL	**NTON**	**EVSZ**	**CDSZ**	**Operating**	**Shipping**
CVHH	900–1200	100M	100M	44938	39456
		100L	100L	46745	40757
		100M	10HM	54985	47744
		130M	130M	50244	43431
		130M	13HM	62564	53664
		160M	200M	57601	48997
		160M	20HM	71531	60672
		200L	220L	63651	53650
		220L	220L	68167	56971
	1500–1700	200L	200L	61579	52397
		200L	20HL	76881	65199
		220L	220L	69080	57884
		220L	22HL	88467	74079
CDHH	2000–2600	400M	440M	108234	92348
	2800–3300	440M	440M	119148	100280
		440X	440X	126515	105271

[a] To calculate the maximum chiller weight with starter/drive, add the starter/AFD weight from Table 11, p. 56 to the chiller maximum weight from Table 10. Note that Duplex™ chiller models CDHH will have two starters, one for each compressor.

Table 11. Unit-mounted starters/Adaptive Frequency drives[a] maximum weights

Low Voltage (less than 600 volts)		**kg**	**lb**
	Wye-delta	253	557
	Solid State	253	557
Adaptive Frequency Drive (less than 600 volts)		**kg**	**lb**
	900 amp	1361	3000
	1210 amp	1361	3000
Medium Voltage (2300–6600 volts)		**kg**	**lb**
	Across-the-line	296	652
	Primary Reactor	727	1602
	Autotransformer	772	1702

[a] All weights are nominal and ±10%.

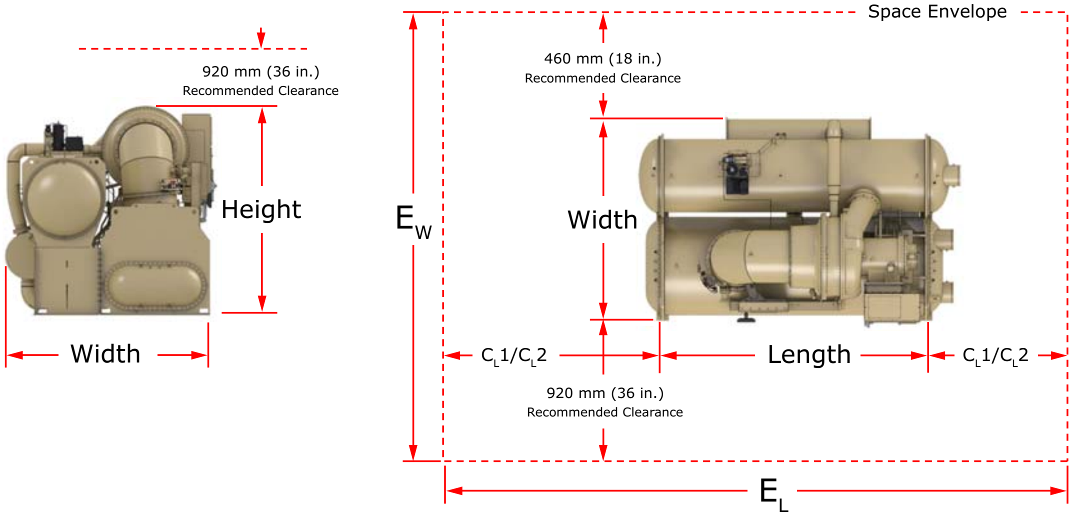
Physical Dimensions

Single Compressor Series E™ CenTraVac Chillers

Table 12. Water connection pipe sizes

	Shell Size						
Water Passes	**100**	**130**	**160**	**200**	**220**	**400**	**440**
Evaporator	**Metric Pipe Size (mm)**						
1 Pass	DN300	DN300	DN350	DN400	DN500	DN400	DN500
2 Pass	DN250	DN250	DN300	DN350	DN350	—	—
3 Pass	DN200	DN200	DN250	DN300	DN300	—	—
Condenser							
1 Pass	DN300	DN350	—	DN400	DN600	—	DN600
2 Pass	DN250	DN300	—	DN350	DN350	—	—
Evaporator	**Nominal Pipe Size (in.)**						
1 Pass	12	12	14	16	20	16	20
2 Pass	10	10	12	14	14	—	—
3 Pass	8	8	10	12	12	—	—
Condenser							
1 Pass	12	14	—	16	24	—	24
2 Pass	10	12	—	14	14	—	—

Figure 23. Space envelope for 50 and 60 Hz single compressor chillers[a]



(a) Without unit-mounted starters. Refer to Table 13, p. 58 and Table 14, p. 59 for data for single compressor Series E CenTraVac chillers.

Table 13. For Figure 23, p. 57: Physical dimensions for 50 and 60 Hz single compressor chillers (mm)[a]

			Space Envelope		Clearance		Base Unit Dimensions		
					Tube Pull				
Units	**Comp Size**	**Shell Configuration EVAP/COND**	**Length (E_L)**	**Terminal Box Only (E_W)**	**C_L1**	**C_L2**	**Length**	**Height**	**Width**
CVHH Chiller (50 Hz)	950 1050	100M/100M	9474	4470	4216	1194	4064	3078	3099
		100L/100L	10503	4470	4731	1194	4578	3078	3099
		130M/130M	9474	4524	4216	1194	4064	3248	3152
		160M/200M	9474	4575	4216	1194	4064	3439	3203
		200L/220L	10503	4704	4731	1194	4578	3498	3332
		220L/220L	10503	4878	4731	1194	4578	3597	3507
	1550	200L/200L	10503	4600	4731	1194	4578	3498	3228
		220L/220L	10503	4878	4731	1194	4578	3597	3507
CVHH Heat Recovery Chiller (50 Hz)	950 1050	100M/10HM	9474	4872	4216	1194	4064	3078	3500
		130M/13HM	9474	4928	4216	1194	4064	3248	3556
		160M/20HM	9474	5097	4216	1194	4064	3439	3725
	1550	200L/20HL	10503	5177	4731	1194	4578	3498	3805
		220L/22HL	10503	5728	4731	1194	4578	3597	4356
CVHH Chiller (60 Hz)	900 1000 1200	100M/100M	9474	4470	4216	1194	4064	3078	3099
		100L/100L	10503	4470	4731	1194	4578	3078	3099
		130M/130M	9474	4521	4216	1194	4064	3248	3150
		160M/200M	9474	4575	4216	1194	4064	3439	3203
		200L/220L	10503	4704	4731	1194	4578	3498	3332
		220L/220L	10503	4878	4731	1194	4578	3597	3507
	1500 1700	200L/200L	10503	4600	4731	1194	4578	3498	3228
		220L/220L	10503	4878	4731	1194	4578	3597	3507
CVHH Heat Recovery Chiller (60 Hz)	900 1000 1200	100M/10HM	9474	4872	4216	1194	4064	3078	3500
		130M/13HM	9474	4928	4216	1194	4064	3248	3556
		160M/20HM	9474	5097	4216	1194	4064	3439	3725
	1500 1700	200L/20HL	10503	5177	4731	1194	4578	3498	3805
		220L/22HL	10503	5639	4731	1194	4578	3597	4267

Notes:

1. Dimensions do not include waterboxes, hinges, starters, or other unit-mounted options that may affect unit size. Contact your Trane representative for more information.
2. C_L1 can be at either end of the machine and is required for tube pull clearance.
3. C_L2 is always at the opposite end of the machine from C_L1 and is required for service clearance.

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[a] Without unit-mounted starters. Refer to Figure 23, p. 57 for the space envelope for 50 and 60 Hz single compressor chillers.

Table 14. For Figure 23, p. 57: Physical dimensions for 50 and 60 Hz single compressor chillers (in.)[a]

			Space Envelope		Clearance		Base Unit Dimensions		
					Tube Pull				
Units	Comp Size	Shell Configuration EVAP/COND	Length (EL)	Terminal Box Only (EW)	CL1	CL2	Length	Height	Width
CVHH Chiller (50 Hz)	950 1050	100M/100M	373.0	176.0	166.0	47.0	160.0	121.2	122.0
		100L/100L	413.5	176.0	186.0	47.0	180.3	121.2	122.0
		130M/130M	373.0	178.1	166.0	47.0	160.0	127.9	124.1
		160M/200M	373.0	180.1	166.0	47.0	160.0	135.4	126.1
		200L/220L	413.5	185.2	186.0	47.0	180.3	137.7	131.2
		220L/220L	413.5	192.1	186.0	47.0	180.3	141.6	138.1
	1550	200L/200L	413.5	181.1	186.0	47.0	180.3	137.7	127.1
		220L/220L	413.5	192.1	186.0	47.0	180.3	141.6	138.1
CVHH Heat Recovery Chiller (50 Hz)	950 1050	100M/10HM	373.0	191.8	166.0	47.0	160.0	121.2	137.8
		130M/13HM	373.0	194.0	166.0	47.0	160.0	127.9	140.0
		160M/20HM	373.0	200.7	166.0	47.0	160.0	135.4	146.7
	1550	200L/20HL	413.5	203.8	186.0	47.0	180.3	137.7	149.8
		220L/22HL	413.5	225.5	186.0	47.0	180.3	141.6	171.5
CVHH Chiller (60 Hz)	900 1000 1200	100M/100M	373.0	176.0	166.0	47.0	160.0	121.2	122.0
		100L/100L	413.5	176.0	186.0	47.0	180.3	121.2	122.0
		130M/130M	373.0	178.0	166.0	47.0	160.0	127.9	124.0
		160M/200M	373.0	180.1	166.0	47.0	160.0	135.4	126.1
		200L/220L	413.5	185.2	186.0	47.0	180.3	137.7	131.2
		220L/220L	413.5	192.1	186.0	47.0	180.3	141.6	138.1
	1500 1700	200L/200L	413.5	181.1	186.0	47.0	180.3	137.7	127.1
		220L/220L	413.5	192.1	186.0	47.0	180.3	141.6	138.1
CVHH Heat Recovery Chiller (60 Hz)	900 1000 1200	100M/10HM	373.0	191.8	166.0	47.0	160.0	121.2	137.8
		130M/13HM	373.0	194.0	166.0	47.0	160.0	127.9	140.0
		160M/20HM	373.0	200.7	166.0	47.0	160.0	135.4	146.7
	1500 1700	200L/20HL	413.5	203.8	186.0	47.0	180.3	137.7	149.8
		220L/22HL	413.5	222.0	186.0	47.0	180.3	141.6	168.0

Notes:

1. Dimensions do not include waterboxes, hinges, starters, or other unit-mounted options that may affect unit size. Contact your Trane representative for more information.
2. CL1 can be at either end of the machine and is required for tube pull clearance.
3. CL2 is always at the opposite end of the machine from CL1 and is required for service clearance.

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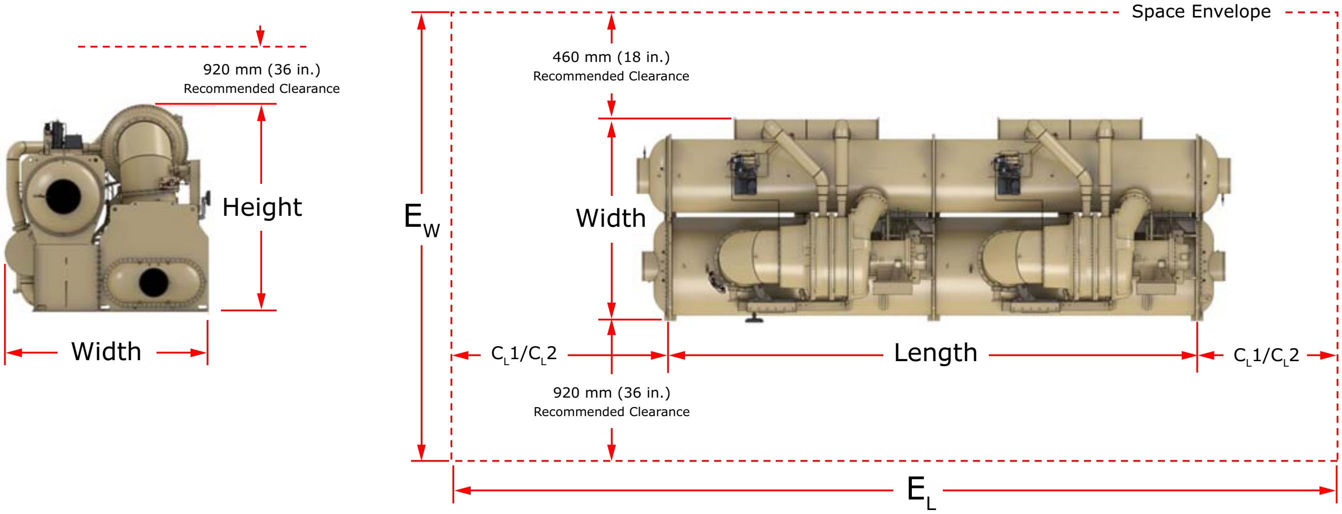
[a] Without unit-mounted starters. Refer to Figure 23, p. 57 for the space envelope for 50 and 60 Hz single compressor chillers.

Dual Compressor Series E™ CenTraVac Chillers

Table 15. Water connection pipe sizes

	Shell Size						
Water Passes	**100**	**130**	**160**	**200**	**220**	**400**	**440**
Evaporator	**Metric Pipe Size (mm)**						
1 Pass	DN300	DN300	DN350	DN400	DN500	DN400	DN500
2 Pass	DN250	DN250	DN300	DN350	DN350	—	—
3 Pass	DN200	DN200	DN250	DN300	DN300	—	—
Condenser							
1 Pass	DN300	DN350	—	DN400	DN600	—	DN600
2 Pass	DN250	DN300	—	DN350	DN350	—	—
Evaporator	**Nominal Pipe Size (in.)**						
1 Pass	12	12	14	16	20	16	20
2 Pass	10	10	12	14	14	—	—
3 Pass	8	8	10	12	12	—	—
Condenser							
1 Pass	12	14	—	16	24	—	24
2 Pass	10	12	—	14	14	—	—

Figure 24. Space envelope for 50 and 60 Hz dual compressor chillers[a]



(a) Without unit-mounted starters. Refer to Table 16, p. 61 and Table 17, p. 61 for data for dual compressor Series E CenTraVac chillers.

Table 16. For Figure 24, p. 60: Physical dimensions for 50 and 60 Hz dual compressor chillers (mm)[a]

			Space Envelope		Clearance		Base Unit Dimensions		
					Tube Pull				
Units	**Comp Size**	**Shell Configuration EVAP/COND**	**Length (E_L)**	**Terminal Box Only (E_W)**	**C_L1**	**C_L2**	**Length**	**Height**	**Width**
CDHH Chiller (50 Hz)	1750 2250	400M/440M	17729	4704	8077	1727	7925	3498	3332
	3050	440M/440M	17932	4878	8077	1930	7925	3597	3507
		440X/440X	20371	4878	9296	1930	9144	3597	3507
CDHH Chiller (60 Hz)	2000 2600	400M/440M	17729	4704	8077	1727	7925	3498	3332
	2800 3300	440M/440M	17932	4878	8077	1930	7925	3597	3507
		440X/440X	20371	4878	9296	1930	9144	3597	3507

Notes:

1. Dimensions do not include waterboxes, hinges, starters, or other unit-mounted options that may affect unit size. Contact your Trane representative for more information.
2. C_L1 can be at either end of the machine and is required for tube pull clearance.
3. C_L2 is always at the opposite end of the machine from C_L1 and is required for service clearance.

(a) Without unit-mounted starters. Refer to Figure 24, p. 60 for the space envelope for 50 and 60 Hz single compressor chillers.

Table 17. For Figure 24, p. 60: Physical dimensions for 50 and 60 Hz dual compressor chillers (in.)[a]

			Space Envelope		Clearance		Base Unit Dimensions		
					Tube Pull				
Units	**Comp Size**	**Shell Configuration EVAP/COND**	**Length (E_L)**	**Terminal Box Only (E_W)**	**C_L1**	**C_L2**	**Length**	**Height**	**Width**
CDHH Chiller (50 Hz)	1750 2250	400M/440M	698.0	185.2	318.0	68.0	312.0	137.7	131.2
	3050	440M/440M	706.0	192.1	318.0	76.0	312.0	141.6	138.1
		440X/440X	802.0	192.1	366.0	76.0	360.0	141.6	138.1
CDHH Chiller (60 Hz)	2000 2600	400M/440M	698.0	185.2	318.0	68.0	312.0	137.7	131.2
	2800 3300	440M/440M	706.0	192.1	318.0	76.0	312.0	141.6	138.1
		440X/440X	802.0	192.1	366.0	76.0	360.0	141.6	138.1

Notes:

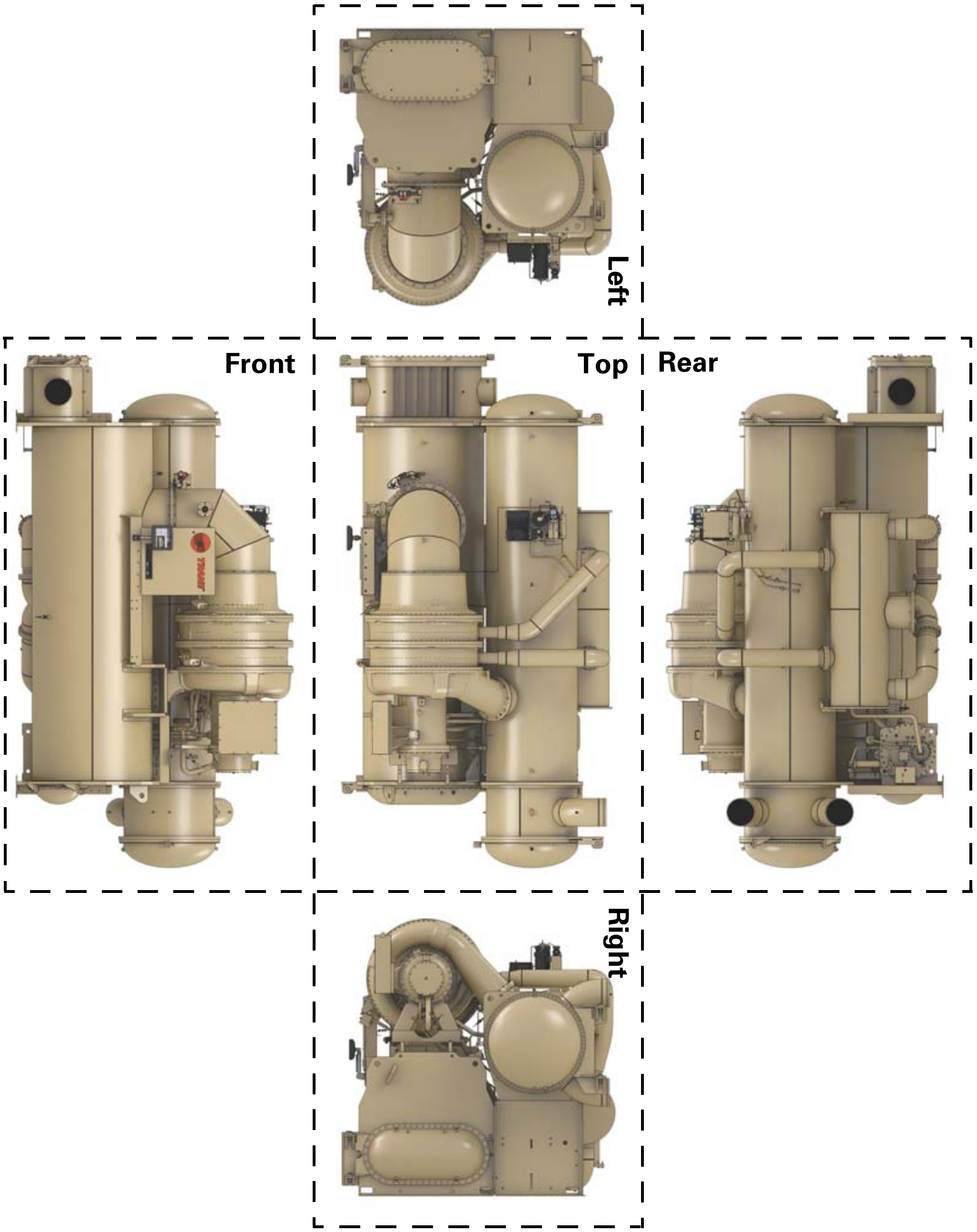
1. Dimensions do not include waterboxes, hinges, starters, or other unit-mounted options that may affect unit size. Contact your Trane representative for more information.
2. C_L1 can be at either end of the machine and is required for tube pull clearance.
3. C_L2 is always at the opposite end of the machine from C_L1 and is required for service clearance.

(a) Without unit-mounted starters. Refer to Figure 24, p. 60 for the space envelope for 50 and 60 Hz single compressor chillers.

Chiller Views

Note: *Figure 25 shows five different views of the Series E™ CenTraVac™ chiller: front, left, right, top, and rear view. These views are intended to help you visualize the possible connections and combinations that may be available for your unit. You must contact your local Trane account manager to configure your selection for an as-built drawing to confirm it is available and to provide appropriate dimensions.*

Figure 25. Front, left, right, top, and rear views—Series E™ CenTraVac™ chillers (CVHH shown; CDHH is similar)



Waterbox Lengths

Table 18. Waterbox lengths, 1034.2 kPaG (150 psig), mm

			Evaporator			Condenser					
		Shell	Passes	Supply Length	Return Length	Supply Length	Return Length	Passes	Shell		
1034.2 kPaG (150 psig)	Non-Marine	100M/L	1	515	515	470	470	1	100M/L	Non-Marine	1034.2 kPaG (150 psig)
			2	555	350	518	302	2			
			3	490	490	—	—	3			
		130M	1	544	544	545	545	1	130M		
			2	588	376	543	341	2			
			3	518	518	—	—	3			
		160M	1	592	592	—	—	1	160M		
			2	592	389	—	—	2			
			3	573	573	—	—	3			
		200M/L	1	440	440	536	536	1	200M/L		
			2	430	243	537	359	2			
			3	413	413	—	—	3			
		220L	1	466	466	559	559	1	220L		
			2	447	264	563	384	2			
			3	444	444	—	—	3			
		400M	1	440	592	536	536	1	400M		
		440M/X	1	466	466	559	559	1	440M/X		
		10HM	1	—	—	433	433	1	10HM		
			2	—	—	520	220	2			
		13HM	1	—	—	433	433	1	13HM		
			2	—	—	551	220	2			
		20HM/L	1	—	—	512	512	1	20HM/L		
			2	—	—	519	220	2			
		22HM/L	1	—	—	513	513	1	22HM/L		
			2	—	—	519	220	2			
	Marine	100M/L	1	1018	1018	949	949	1	100M/L	Marine	
			2	1018	351	949	302	2			
			3	1018	1018	—	—	3			
		130M	1	1043	1043	987	987	1	130M		
			2	1043	376	987	341	2			
			3	1043	1043	—	—	3			
		160M	1	1207	1207	—	—	1	160M		
			2	1176	389	—	—	2			
			3	1176	1176	—	—	3			
		200M/L	1	885	885	1111	1111	1	200M/L		
			2	834	243	1047	359	2			
			3	802	802	—	—	3			
		220L	1	993	993	1322	1322	1	220L		
			2	840	264	1054	384	2			
			3	—	—	—	—	3			
		400M	1	885	885	—	—	1	400M		
		440M/X	1	993	993	1322	1322	1	440M/X		

Table 19. Waterbox lengths, 1034.2 kPaG (150 psig), in.

			Evaporator			Condenser					
		Shell	Passes	Supply Length	Return Length	Supply Length	Return Length	Passes	Shell		
1034.2 kPaG (150 psig)	Non-Marine	100M/L	1	20.3	20.3	18.5	18.5	1	100M/L	Non-Marine	1034.2 kPaG (150 psig)
			2	21.9	13.8	20.4	11.9	2			
			3	19.3	19.3	—	—	3			
		130M	1	21.4	21.4	21.5	21.5	1	130M		
			2	23.1	14.8	21.4	13.4	2			
			3	20.4	20.4	—	—	3			
		160M	1	23.3	23.3	—	—	1	160M		
			2	23.3	15.3	—	—	2			
			3	22.6	22.6	—	—	3			
		200M/L	1	17.3	17.3	21.1	21.1	1	200M/L		
			2	16.9	9.6	21.2	14.1	2			
			3	16.3	16.3	—	—	3			
		220L	1	18.3	18.3	22.0	22.0	1	220L		
			2	17.6	10.4	22.2	15.1	2			
			3	17.5	17.5	—	—	3			
		400M	1	17.3	23.3	21.1	21.1	1	400M		
		440M/X	1	18.3	18.3	22.0	22.0	1	440M/X		
		10HM	1	—	—	17.1	17.1	1	10HM		
			2	—	—	20.5	8.7	2			
		13HM	1	—	—	17.1	17.1	1	13HM		
			2	—	—	21.7	8.7	2			
		20HM/L	1	—	—	20.1	20.1	1	20HM/L		
			2	—	—	20.4	8.7	2			
		22HM/L	1	—	—	20.2	20.2	1	22HM/L		
			2	—	—	20.4	8.7	2			
	Marine	100M/L	1	40.1	40.1	37.3	37.3	1	100M/L	Marine	
			2	40.1	13.8	37.3	11.9	2			
			3	40.1	40.1	—	—	3			
		130M	1	41.1	41.1	38.8	38.8	1	130M		
			2	41.1	14.8	38.8	13.4	2			
			3	41.1	41.1	—	—	3			
		160M	1	47.5	47.5	—	—	1	160M		
			2	46.3	15.3	—	—	2			
			3	46.3	46.3	—	—	3			
		200M/L	1	34.8	34.8	43.7	43.7	1	200M/L		
			2	32.8	9.6	41.2	14.1	2			
			3	31.6	31.6	—	—	3			
		220L	1	39.1	39.1	52.0	52.0	1	220L		
			2	33.1	10.4	41.5	15.1	2			
			3	—	—	—	—	3			
		400M	1	34.8	34.8	—	—	1	400M		
		440M/X	1	39.1	39.1	52.0	52.0	1	440M/X		

Table 20. Waterbox lengths, 2068.4 kPaG (300 psig), mm

			Evaporator			Condenser					
		Shell	Passes	Supply Length	Return Length	Supply Length	Return Length	Passes	Shell		
2068.4 kPaG (300 psig)	Non-Marine	100M/L	1	399	399	507	507	1	100M/L	Non-Marine	2068.4 kPaG (300 psig)
			2	366	211	518	315	2			
			3	373	373	—	—	3			
		130M	1	399	399	557	557	1	130M		
			2	401	211	568	356	2			
			3	373	373	—	—	3			
		160M	1	413	413	—	—	1	160M		
			2	406	214	—	—	2			
			3	368	368	—	—	3			
		200M/L	1	503	503	565	565	1	200M/L		
			2	492	250	565	318	2			
			3	466	466	—	—	3			
		220L	1	614	614	633	633	1	220L		
			2	578	337	599	373	2			
			3	552	552	—	—	3			
		400M	1	503	503	565	565	1	400M		
		440M/X	1	614	614	633	633	1	440M/X		
	Marine	100M/L	1	712	712	963	963	1	100M/L	Marine	
			2	979	211	912	315	2			
			3	607	607	—	—	3			
		130M	1	712	712	1034	1034	1	130M		
			2	662	211	989	356	2			
			3	607	607	—	—	3			
		160M	1	742	742	—	—	1	160M		
			2	712	214	—	—	2			
			3	662	662	—	—	3			
		200M/L	1	984	984	992	992	1	200M/L		
			2	933	250	924	318	2			
			3	901	901	—	—	3			
		220L	1	1152	1152	1381	1381	1	220L		
			2	1000	337	1113	373	2			
			3	—	—	—	—	3			
		400M	1	984	984	—	—	1	400M		
		440M/X	1	1152	1152	1381	1381	1	440M/X		

Physical Dimensions

Table 21. Waterbox lengths, 2068.4 kPaG (300 psig), in.

			Evaporator			Condenser					
		Shell	Passes	Supply Length	Return Length	Supply Length	Return Length	Passes	Shell		
2068.4 kPaG (300 psig)	Non-Marine	100M/L	1	15.7	15.7	20.0	20.0	1	100M/L	Non-Marine	2068.4 kPaG (300 psig)
			2	14.4	8.3	20.4	12.4	2			
			3	14.7	14.7	—	—	3			
		130M	1	15.7	15.7	21.9	21.9	1	130M		
			2	15.8	8.3	22.4	14.0	2			
			3	14.7	14.7	—	—	3			
		160M	1	16.3	16.3	—	—	1	160M		
			2	16.0	8.4	—	—	2			
			3	14.5	14.5	—	—	3			
		200M/L	1	19.8	19.8	22.2	22.2	1	200M/L		
			2	19.4	9.8	22.2	12.5	2			
			3	18.3	18.3	—	—	3			
		220L	1	24.2	24.2	24.9	24.9	1	220L		
			2	22.8	13.3	23.6	14.7	2			
			3	21.7	21.7	—	—	3			
		400M	1	19.8	19.8	22.2	22.2	1	400M		
		440M/X	1	24.2	24.2	24.9	24.9	1	440M/X		
	Marine	100M/L	1	28.0	28.0	37.9	37.9	1	100M/L	Marine	
			2	38.5	8.3	35.9	12.4	2			
			3	23.9	23.9	—	—	3			
		130M	1	28.0	28.0	40.7	40.7	1	130M		
			2	26.1	8.3	39.0	14.0	2			
			3	23.9	23.9	—	—	3			
		160M	1	29.2	29.2	—	—	1	160M		
			2	28.0	8.4	—	—	2			
			3	26.1	26.1	—	—	3			
		200M/L	1	38.7	38.7	39.1	39.1	1	200M/L		
			2	36.7	9.8	36.4	12.5	2			
			3	35.5	35.5	—	—	3			
		220L	1	45.3	45.3	54.4	54.4	1	220L		
			2	39.4	13.3	43.8	14.7	2			
			3	—	—	—	—	3			
		400M	1	38.7	38.7	—	—	1	400M		
		440M/X	1	45.3	45.3	54.4	54.4	1	440M/X		

Mechanical Specifications

Compressor

Guide Vanes

Fully modulating variable inlet guide vanes provide capacity control. The guide vanes are controlled by an externally-mounted electric vane operator in response to refrigeration load on the evaporator.

Impellers

Fully shrouded impellers made of high strength aluminum alloy are directly connected to the motor rotor shaft operating at 3000 rpm (50 Hz) or 3600 rpm (60 Hz). The impellers are dynamically balanced and over-speed tested at 3750 rpm (50 Hz) and 4500 rpm (60 Hz). The motor-compressor assembly is balanced to a maximum vibration of 3.8 mm/s (0.15 in./s) at 3000 rpm (50 Hz) or 3600 rpm (60 Hz) as measured on the motor housing.

Compressor Casing

Separate volute casings of refrigerant-tight, close-grained cast iron are used on the centrifugal compressor; each incorporating a parallel wall diffuser surrounded by a collection scroll. The diffuser passages are machined to ensure high efficiency. All casings are proof- and leak-tested.

Motor

Compressor motors are hermetically sealed two-pole, squirrel cage induction-type. They are built in accordance with Trane specifications and guaranteed by the manufacturer for continuous operation at the nameplate rating. A load-limit system provides protection against operation in excess of this rating. The rotor shaft is heat-treated carbon steel and designed such that the critical speed is well above the operating speed. The control circuit prevents motor energization unless positive oil pressure is established. Impellers are keyed directly to the motor shaft and locked in position. Nonferrous, labyrinth-type seals minimize recirculation and gas leakage between the stages of the compressor.

380–600V, 3-phase 60 Hz and 380–415V, 3-phase 50 Hz motors are supplied with six terminal posts for reduced-voltage wye-delta starting. For low-voltage, solid-state starters and AFDs, connecting links are furnished to convert the motor to a 3-lead motor.

3300–13800V, 3-phase 60 Hz and 3300–11000V, 3-phase 50 Hz motors are supplied with three terminal posts for full-voltage (across-the-line) or reduced-voltage (primary reactor or autotransformer) starting. Motor terminal pads are supplied. A removable sheet metal terminal box encloses the terminal board area.

Motor Cooling

Motor cooling is accomplished by a patented refrigerant pump that supplies liquid refrigerant to the motor. The refrigerant circulates uniformly over the stator windings and between the rotor and stator. All motor windings are specifically insulated for operation within a refrigerant atmosphere.

Lubrication

The oil pump for low voltage Series E chillers is driven by a 380–600V, 50/60 Hz, 3-phase, 2 hp motor, while the oil pump for medium voltage models is driven by a 200–240V, 50/60 Hz, 1-phase, 2 hp motor. The motor and pump assembly are submerged in the oil sump to ensure a positive oil supply to the compressor bearings at all times. Two low watt density heaters maintain the oil temperature to minimize its affinity for refrigerant.

The oil tank is constructed in accordance with ASME Section VIII, Division I. It is designed with an open internal volume to accommodate the separation of refrigerant vapor from oil during operation. An electrically actuated ball valve prevents foaming and oil loss during a chiller start.

It utilizes two heater elements and a cooling sub-system that consists of a small brazed plate heat exchanger working in combination with a solenoid valve.

Evaporator

Shell and Waterboxes

The evaporator shell is constructed of carbon steel plate and incorporates a steel rupture disc in accordance with the ASME Section VIII, Division I. A refrigerant temperature coupling is provided for a low limit controller or customer use.

Multiple pass arrangements are available at 1034.2 kPaG (150 psig) or 2068.4 kPaG (300 psig) water side working pressures, with grooved connections. Flanged connections and/or marine-type waterboxes are also available.

Tube Sheets

A thick carbon steel tube sheet is welded to each end of the shell and then drilled and reamed to accommodate the tubes. Three annular grooves are machined into each tube hole to provide a positive liquid and vapor seal between the refrigerant and water side of the shell after tube rolling. Intermediate tube support sheets are positioned along the length of the shell to avoid contact and relative motion between adjacent tubes.

Tubes

Individually replaceable, seamless tubing available in a variety of materials, depending on the customer’s needs, is used as the evaporator heat transfer surface; tubing is available in either 25 mm (1 inch) or 19 mm (0.75 inch) outside diameter. Tubes are externally and internally enhanced, and mechanically expanded into the tube sheets (and are secured to the intermediate supports with tube clips) to provide a leak-free seal and eliminate tube contact and abrasion due to relative motion.

Eliminators

Multiple layers of metal mesh screen form the eliminators and are installed over the tube bundle along the entire length of the evaporator. The eliminators prevent liquid refrigerant carryover into the compressor.

Refrigerant Distribution

A refrigerant distributor on the base of the evaporator assures uniform wetting of the heat transfer surface over the entire length of the shell and under varying loads. High velocity, refrigerant-spray impingement on the tubes is prevented through this design.

Refrigerant Flow Control

A multiple orifice flow-control system maintains the correct pressure differential between the condenser, economizer, and evaporator over the entire range of loading. This patented system contains no moving parts.

Shell Tests

The refrigerant side of the evaporator shell, complete with tubes but without waterbox covers, is proof-tested at 448.2 kPaG (65 psig) for ASME and 493.0 kPaG (71.5 psig) for PED (European Code), vacuum leak-tested, and finally pressure leak-tested with a helium mass spectrometer. The water side of the evaporator shell, with waterboxes in place, is hydrostatically tested at 1.3 times the design working pressure, but not less than 1344.5 kPaG (195 psig) for 1034.2 kPaG (150 psig) waterboxes or 2689.0 kPaG (390 psig) for 2068.4 kPaG (300 psiG) waterboxes.

Note: *These tests are not to be repeated at installation.*

Condenser/Heat Recovery Condenser

Shell and Waterboxes

The condenser shell is constructed of carbon steel plate designed and constructed in accordance with ASME Section VIII, Division I.

Multiple pass arrangements are available at 1034.2 kPaG (150 psig) or 2068.4 kPaG (300 psig) water side working pressures, with grooved connections. Flanged connections and/or marine-type waterboxes are also available.

Tube Sheets

A thick carbon steel tube sheet is welded to each end of the shell and is drilled and reamed to accommodate the tubes. Three annular grooves are machined into each tube hole to provide a positive liquid and vapor seal between the refrigerant and water sides of the shell after tube rolling. Intermediate tube support sheets are positioned along the length of the shell to avoid contact and relative motion between adjacent tubes.

Tubes

Individually replaceable, seamless copper tubing available in either 25 mm (1 in.) or 19 mm (0.75 in.) outside diameter is used as the evaporator heat transfer surface. Tubes are externally and internally enhanced, and mechanically expanded into the tube sheets (and are secured to the intermediate supports with tube clips) to provide a leak-free seal and eliminate tube contact and abrasion due to relative motion.

Refrigerant Gas Distribution

A baffle plate between the tube bundle and the condenser shell distributes the hot compressor-discharge gas longitudinally throughout the condenser and downward over the tube bundle. The baffle plate prevents direct impingement of high velocity compressor-discharge gas upon the tubes.

Shell Tests

The refrigerant side of the condenser shell, complete with tubes, but without waterbox covers, is proof-tested at 448.2 kPaG (65 psig), vacuum leak-tested, and finally pressure leak-tested with a helium mass spectrometer. The water side of the condenser shell, with waterboxes in place, is hydrostatically tested at 1.3 times the design working pressure, but not less than 1344.5 kPaG (195 psig).

Note: *These tests are not to be repeated at installation.*

Economizer

The 2-stage (60 Hz) Series E™ chiller utilizes a single stage economizer, and the 3-stage (50 Hz) models utilize a 2-stage economizer. The economizer is constructed in accordance with ASME Section VIII, Division I and consists of either one or two interstage pressure chambers which utilize a multiple orifice system to maintain the correct pressure differential between the condenser, economizer, and evaporator over the entire range of loading. This patented system contains no moving parts. 50 Hz Duplex™ (dual compressor, CDHH) models use a two-stage economizer per circuit. 60 Hz Duplex (dual compressor, CDHH) models use a single-stage economizer per circuit.

Purge System

Standard Features

- 115 Vac, 50/60 Hz, 1-Phase.
- 175 watt carbon tank heater.
- 12.3 minimum circuit ampacity.
- 2309.7 kPaG (335 psig) design pressure high side.
- 1206.6 kPaG (175 psig) design pressure low side.
- The purge is 654 mm (25.75 in.) high, 699 mm (27.5 in.) wide, and 552 mm (21.75 in.) deep.
- The purge uses an R-404A refrigeration circuit with a 1/4 hp condensing unit/10.3 total unit amps (fan, compressor, expansion valve), and a compressor suction temperature sensor.

The purge tank has a fusible plug, evaporator coil, normally-closed float switch, and the following connections:

- 6 mm (1/4 in.) liquid return with filter-drier and moisture indicator
- 16 mm (5/8 in.) vapor line

The expansion valve automatically controls the purge suction pressure to 234.4 kPaA (34 psia).

The pump-out system consists of a pump-out compressor, pump-out solenoid valve, and an exhaust solenoid valve.

The carbon bed tank incorporates a temperature sensor and a regenerative cycle, a 175-watt resistive heater, 1034.2 kPaG (150 psig) pressure relief valve, and a temperature sensor. The carbon bed tank automatically collects and scrubs refrigerant molecules from the noncondensable gas and drives any collected refrigerant vapor back into the chiller. This design keeps the purge efficiency at peak levels throughout its life without the maintenance required on other purges.

The purge controller interfaces with the following intelligent devices on an IPC3 communications link: liquid-level switch, dual relay output, quad relay output, dual triac output, suction temperature sensor, and carbon temperature sensor. Fifty hertz applications have a separate voltage correction transformer.

The purge controller communicates with the Tracer AdaptiView™ controller and display, which is mounted on the front of the chiller control panel. Descriptive text indicates purge operating mode, status, set points, purge operating data reports, diagnostics, and alarms. Operating modes Stop, On, Auto, and Adaptive operate the purge refrigeration circuit and accumulate noncondensables with or without the chiller running.

Chiller Controller

The microcomputer control panel is factory installed and tested on the CenTraVac™ chiller. All controls necessary for the safe and reliable operation of the chiller are provided including oil management (when required), purge operation, and interface to the starter or AFD. The control system is powered by a control power transformer included in the starter panel. The microcomputer control system processes the leaving evaporator fluid temperature sensor signal to satisfy the system requirements across the entire load range.

The microprocessor controller is compatible with reduced-voltage or full-voltage electromechanical starters, variable-speed drives, or solid-state starters. Depending on the applicability, the drives may be factory mounted or remote mounted.

The controller will load and unload the chiller via control of the stepper motor/actuator which drives the inlet guide vanes open or closed. The load range can be limited either by a current limiter or by an inlet guide vane limit (whichever controls the lower limit). It will also control the evaporator and condenser pumps to insure proper chiller operation.

Approximately 200 diagnostic checks are made and displayed when a fault is detected. The display indicates the fault, the type of reset required, the time and date the diagnostic occurred, the mode in which the machine was operating at the time of the diagnostic, and a help message. A diagnostic history displays the last 10 diagnostics with the time and date of their occurrence.

The panel features machine protection shutdown requiring *manual* reset for:

- Low oil temperature
- Actuator drive circuit fault
- Low differential oil pressure
- Extended compressor surge
- Excessive loss of communication
- High condenser refrigerant pressure
- Critical sensor or detection circuit faults
- Low evaporator refrigerant temperature

The display also provides reports that are organized into six groupings: Evaporator, Condenser, Compressor, Motor, Purge, and the ASHRAE Chiller Log. Each report contains data that is accessed by scrolling through the menu items. Each grouping will have a heading which describes the type of data in that grouping. This data includes:

- Phase currents
- Last 10 diagnostics
- Phase voltages
- Current limit setpoint
- Water flows (optional)
- Purge suction temperature
- Oil temperature and pressures
- Motor winding temperatures
- Current chiller operating mode
- Water pressure drops (optional)
- Watts and power factor (optional)
- Bearing temperatures (optional)
- Outdoor air temperature (optional)
- All water temperatures and setpoints
- Condenser liquid refrigerant temperature
- Compressor starts and hours running
- Saturated refrigerant temperatures and pressures
- Refrigerant detection external to chiller in ppm (optional)
- Control source (i.e., local panel, external source, remote BAS)

The controller is capable of receiving signals from a variety of control sources (which are not mutually exclusive—i.e., multiple control sources can coexist simultaneously) and of being programmed at the keypad as to which control source has priority. Control sources can be:

- Tracer™ building controls (interface optional)
- The local operator interface (standard)
- A 4–20 mA or 2–10 Vdc signal from an external source (interface optional, control source not supplied by chiller manufacturer)
- Process computer (interface optional, control source not supplied by chiller manufacturer)
- Generic BAS (interface optional, control source not supplied by chiller manufacturer)

The control source with priority will then determine the active setpoints via the signal that is sent to the control panel.

Isolation Pads

Isolation pads are supplied with each CenTraVac™ chiller for placement under all support points. They are constructed of molded neoprene.

Refrigerant and Oil Charge

A full charge of refrigerant and oil is supplied with each unit. The oil ships in the unit's oil sump and the refrigerant ships directly to the job site.

Thermometer Wells and Sight Glasses

In addition to the thermometer wells provided for use with the standard unit safety controls, a well is provided for measurement of the liquid refrigerant condensing temperature and a coupling for the evaporating temperatures. Sight glasses are provided for monitoring oil charge level, oil flow, compressor rotation, and purge condenser drum.

Insulation

Factory applied insulation is available as an option on all units. All low temperature surfaces are covered with 19 mm (3/4 in.) Armaflex® II or equal, with a thermal conductivity = 0.79 W/m^2 (0.28 Btu/h·ft^2), including the evaporator, waterboxes, suction elbow, economizer, and motor cooling lines.

Refrigerant Pumpout/Reclaim Connections

Connections are factory-provided as standard to facilitate refrigerant reclaim/removal required during maintenance or overhaul in accordance with ANSI/ASHRAE 15.

Painting

All painted Series E™ CenTraVac™ chiller surfaces are coated with two coats of air-dry beige (primer and finish top coat) solvent-based enamel paint prior to shipment.

Unit-Mounted Starter Options

Low voltage unit-mounted starters can be wye delta or solid state (380–600V), or an Adaptive Frequency™ drive in a IP 20 enclosure (380–480V).

Medium-voltage starters (3300–6600V) are available to unit-mount on most sizes in across-the-line (full voltage), primary reactor, or autotransformer.

Unit-Mounted, Refrigerant Cooled Adaptive Frequency Drive (AFD)

The Trane AFD is a closed loop, liquid cooled, microprocessor-based PWM design. The AFD is both voltage- and current-regulated. The output power devices are insulated gate bipolar transistors (IGBTs).

The AFD is factory mounted on the chiller and ships completely assembled, wired, and tested. Patented Trane AFD control logic is specifically designed to interface with the CenTraVac™ chiller controls. AFD control adapts to the operating ranges and specific characteristics of the chiller, and chiller efficiency is optimized by coordinating compressor motor speed and compressor inlet guide vane position. The chilled-water control and AFD control work together to maintain the chilled-water setpoint, improve efficiency and avoid surge. If surge is detected, AFD surge avoidance logic makes adjustments to move away from and avoid surge at similar conditions in the future.

Standard Conversion Table

To Convert From:	To:	Multiply By:
Length		
Feet (ft)	meters (m)	0.30481
Inches (in.)	millimeters (mm)	25.4
Area		
Square feet (ft^2)	square meters (m^2)	0.093
Square inches ($in.^2$)	square millimeters (mm^2)	645.2
Volume		
Cubic feet (ft^3)	cubic meters (m^3)	0.0283
Cubic inches ($in.^3$)	cubic mm (mm^3)	16387
Gallons (gal)	liters (L)	3.785
Gallons (gal)	cubic meters (m^3)	0.003785
Flow		
Cubic feet/min (cfm)	cubic meters/second (m^3/s)	0.000472
Cubic feet/min (cfm)	cubic meters/hr (m^3/h)	1.69884
Gallons/minute (gpm)	cubic meters/hr (m^3/h)	0.2271
Gallons/minute (gpm)	liters/second (L/s)	0.06308
Velocity		
Feet per minute (fpm)	meters per second (m/s)	0.00508
Feet per second (fps)	meters per second (m/s)	0.3048
Energy, Power, and Capacity		
British thermal units per hour (Btu/h)	kilowatt (kW)	0.000293
British thermal units per hour (Btu)	kilocalorie (kcal)	0.252
Tons (refrig. effect)	kilowatt (refrig. effect)	3.516
Tons (refrig. effect)	kilocalories per hour (kcal/hr)	3024
Horsepower	kilowatt (kW)	0.7457
Pressure		
Feet of water (ft H_20)	pascals (Pa)	2990
Inches of water (in. H_20)	pascals (Pa)	249
Pounds per square inch (psi)	pascals (Pa)	6895
Pounds per square inch (psi)	bar or kg/cm^2	6.895×10^{-2}
Weight		
Ounces	kilograms (kg)	0.02835
Pounds (lb)	kilograms (kg)	0.4536
Fouling factors for heat exchangers		
0.00085 ft^2·°F·h/Btu	= 0.132 m^2·°K/kW	
0.00025 ft^2·°F·h/Btu	= 0.044 m^2·°K/kW	

Temperature Conversions

		Temperature			Temperature Interval	
Scale		**°C**	**°F**		**°C**	**°F**
Celsius	x°C =	x	1.8x + 32	1°C =	1	9/5 = 1.8
Fahrenheit	x°F =	(x-32) / 1.8	x	1°F =	5/9	1

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