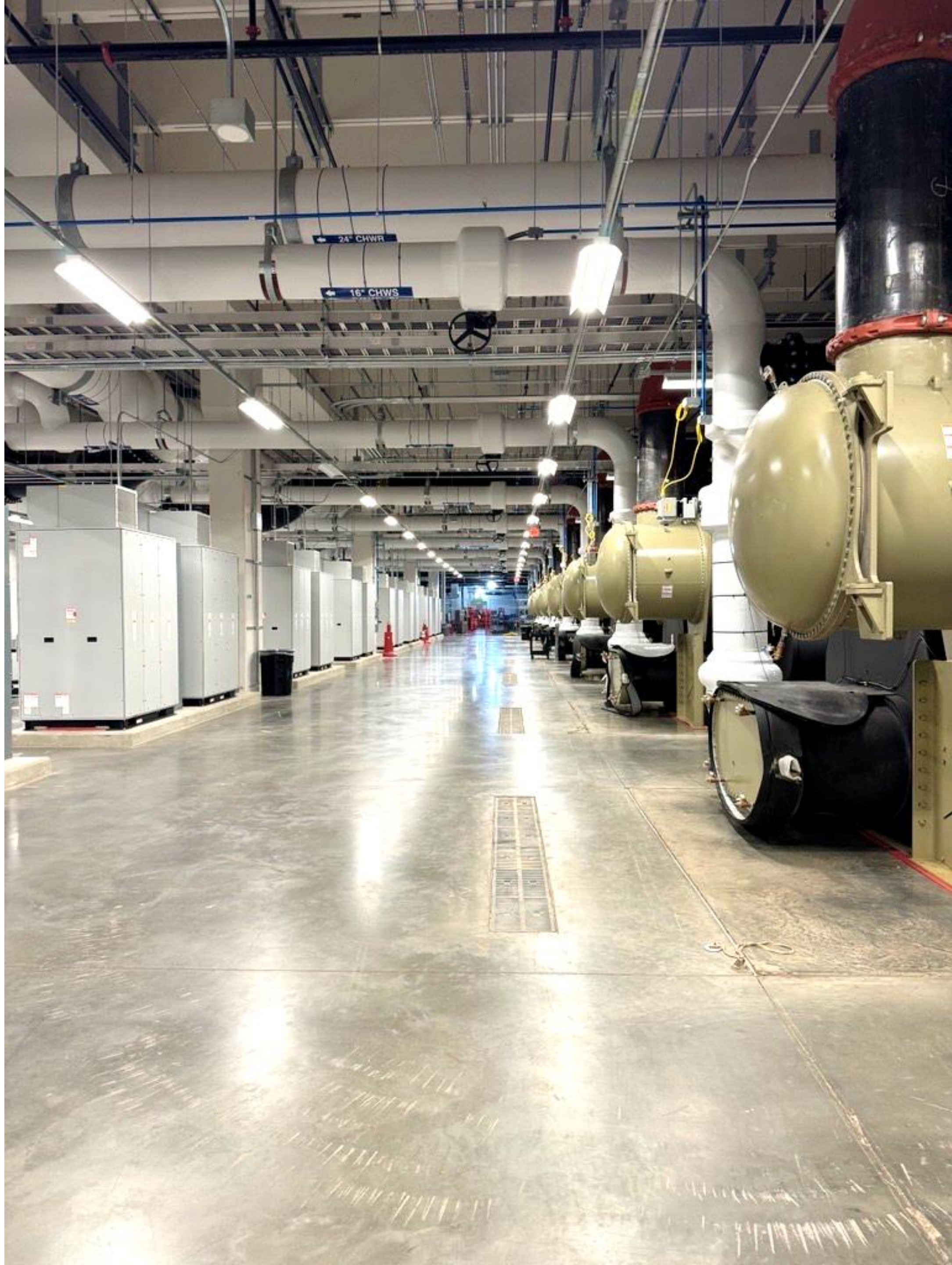
REFERENCE DESIGN #503

HIGH-EFFICIENCY COOLING FOR THE 250 MW AI FACTORY

Simplified System Design featuring CenTraVac® Duplex

An adaptable reference design engineered to navigate complexity and unlock greater efficiency.



INTRODUCTION

Artificial intelligence is driving massive growth in data center demand — and advanced cooling is critical to keep innovation running. Trane leads the way with proven thermal management solutions for AI factories and data centers of all sizes.

This reference design provides:

- ✓ A 250 MW cooling blueprint for AI factory applications
- ✓ Integrated air- and liquid-cooling configurations built to accommodate evolving server generations
- ✓ Guidance on CDUs, fan coil walls, chillers, dry coolers, pumps, and facility piping
- ✓ A foundation for mechanical design that complements electrical and controls systems
- ✓ An integral solution for heat recovery

DESIGN OVERVIEW

Temperature and Flow Rates

This table summarizes temperature and flow rate requirements for the water-cooled chillers in this reference design. These values represent an AI factory installed in Chicago, IL and can be adjusted for specific applications.

Technical Loop Supply Temperature: 41°C (105.8°F)

Technical Loop Return Temperature: 51°C (123.8°F)

Fan Coil Wall Supply Air Temperature: 27°C (80.6°F)

*Supports 45C cooling

Chicago, IL

- Max Ambient: 40°C (104°F)

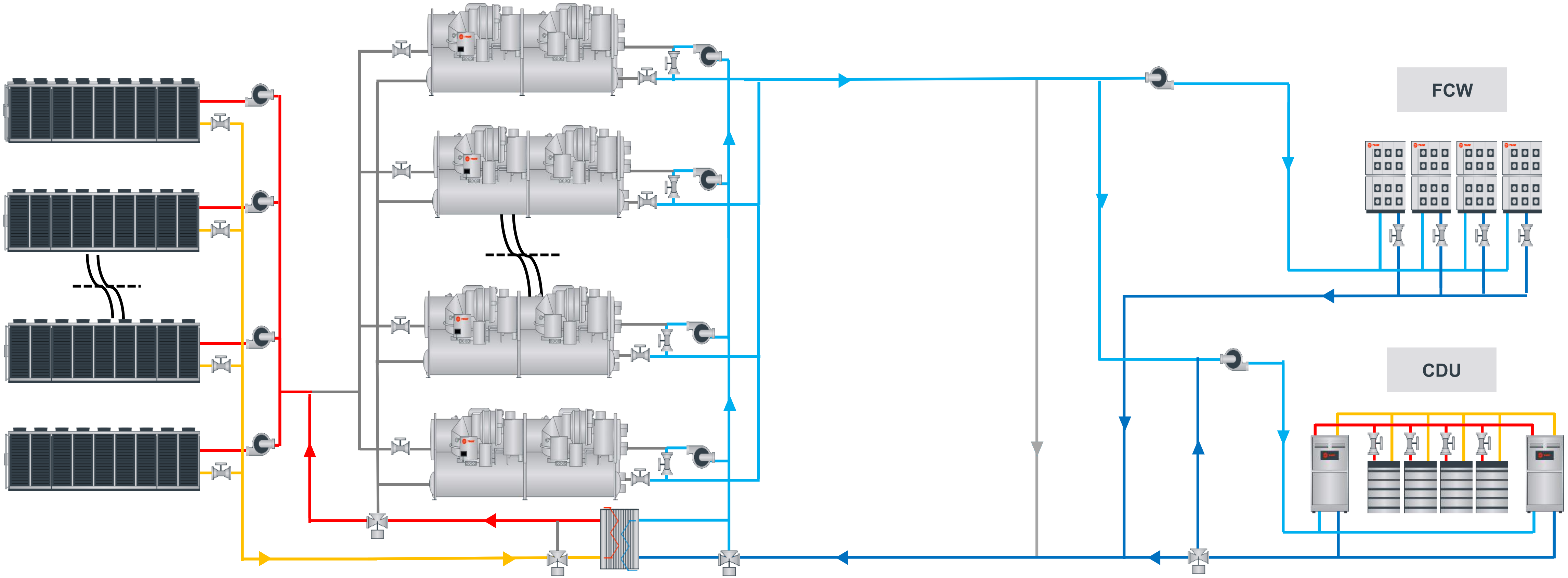
Liquid to Air Ratio	80 to 20	90 to 10	93 to 7	95 to 5
Total Block Load	250 MW (71,085 tons) or 17.86 MW (5078 tons) per Duplex chiller			
Facility Water to FCW	Entering: 22°C (71.6°F) / Leaving: 32°C (89.6°F)			
Facility Water to CDU	Entering: 37°C (98.6°F) / Leaving: 47°C (116.6°F)			
Mixed Return Water	41.4°C (106.4°F)	43.8°C (110.9°F)	44.7°C (112.4°F)	45.3°C (113.5°F)
Chiller Evaporator Water	Entering: 22°C (71.6°F) / Leaving: 41.4°C (106.6°F)			
Primary Flow	50178 GPM	48744 GPM		
Secondary Flow	49558 GPM	43905 GPM	42209 GPM	41079 GPM
Condenser Flow Rate	111,944 GPM			
Heat Rejection Loop Temperature	High: 58.9°C (138°F) / Low: 48.9°C (120°F)			
Heat Rejection Loop Fluid	Water*			

**Our recommendation is to utilize freeze protection.*

DESIGN OVERVIEW

Reference Diagram

- ✓ 250 MW mechanical cooling blueprint for AI factories
- ✓ Integrates air- and liquid-cooling systems
- ✓ Streamlined, low-complexity system - easy to commission
- ✓ Maximizes free cooling hours



DESIGN OVERVIEW

Customer Outcomes

Reduce power use

- Integrated heat recovery lowers system power use.
- Higher condenser temperatures reduce dry cooler fan power.
- Elevated liquid cooling temperatures maximize free cooling.
- Higher facility water delta T reduces pump power.
- Advanced controls optimize chiller lift and pump energy to maintain best-in-class PUE.

Reduced Time to Full Performance

- Fewer chillers allow for quicker installation and commissioning.
- A larger delta T allows for smaller hydronic infrastructure, reducing installation complexity.
- Future-ready with adaptable liquid-to-air cooling ratios using existing equipment.

Balanced total cost of ownership (TCO), redundancy and resiliency

- Lower-cost single-facility loop solution that incorporates: higher facility water delta T and elevated facility return water to maximize free cooling.
- Larger-capacity duplex chillers reduce overall footprint and enhance efficiency.
- High-efficiency water-cooled design with dry coolers keeps both energy and water costs low, improving ROI and sustainability metrics.

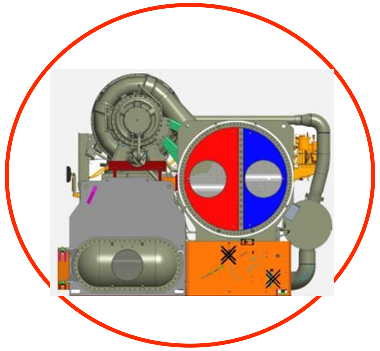
SYSTEM BENEFITS

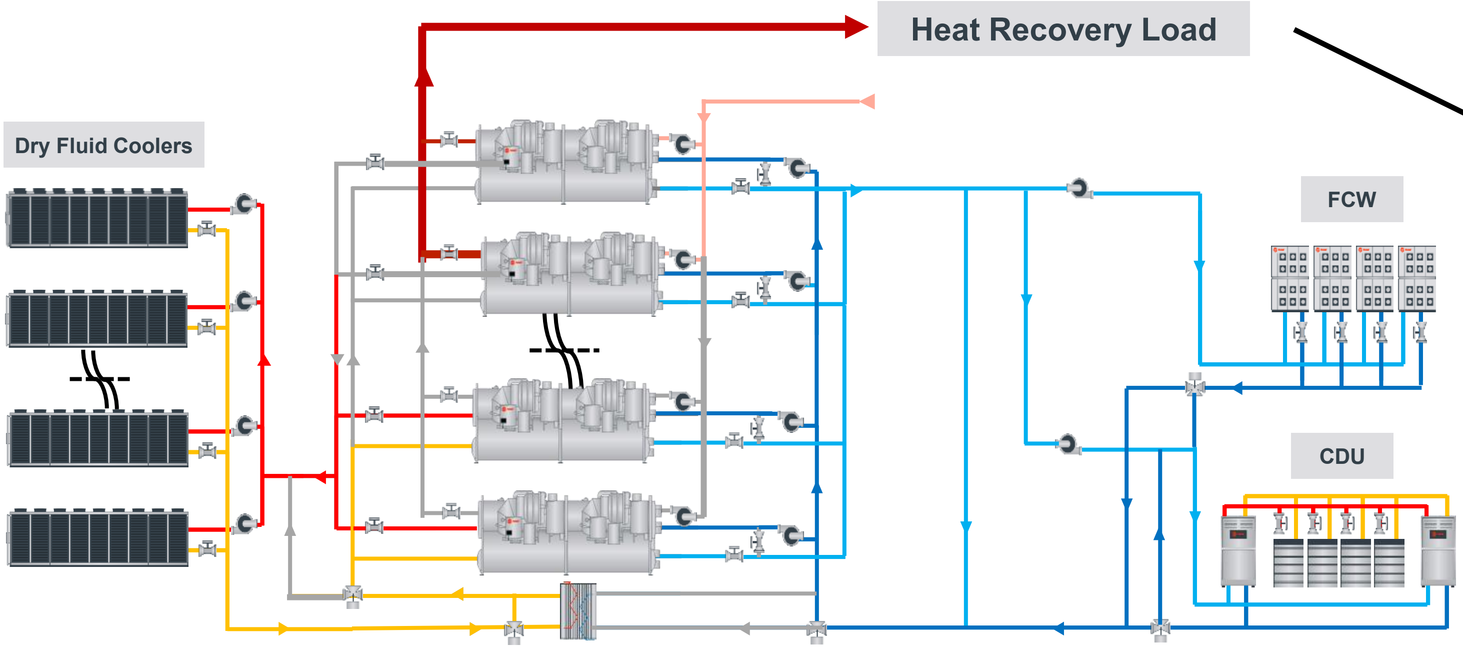
Water-cooled systems offer significant performance and sustainability advantages over air-cooled alternatives, delivering higher efficiency, lower water use and reduced environmental impact for large-scale AI data centers.

- Reduced chiller footprint with higher-capacity duplex chillers
- Simplified layout that maximizes free cooling for lower annualized Power Usage Effectiveness (PUE)
- Integrated heat recovery that unlocks enhanced efficiency
- Dry coolers eliminate water use — Water Usage Effectiveness (WUE) = 0
- R-1233zd refrigerant (GWP 1) significantly reduces carbon impact

Heat Recovery

- Duplex 6-pipe configuration allows simultaneous heat recovery and ambient heat rejection without the efficiency losses of an added isolation heat exchanger.
- More than doubles the efficiency of the chiller utilizing heat recovery while also eliminating the portion of fan power required by the heat-rejection dry coolers.
- Heat recovery can be applied to a portion of the chillers or to the entire cooling plant.
- Utilizing heat recovery reduces microclimate impact on ambient heat-rejection devices (dry fluid coolers).





10% Heat recovered utilized

14% Improvement in Thermal Management System efficiency

Increase Facility Water Delta T

Decrease Flow Requirement

- Maximizing delta T minimizes flow and pump power.
- Minimizing flow also reduces pipe size requirements, allowing more capacity through the same hydronic infrastructure (pipes, fittings, valves, insulation, space).

Maximize Chiller Delta T

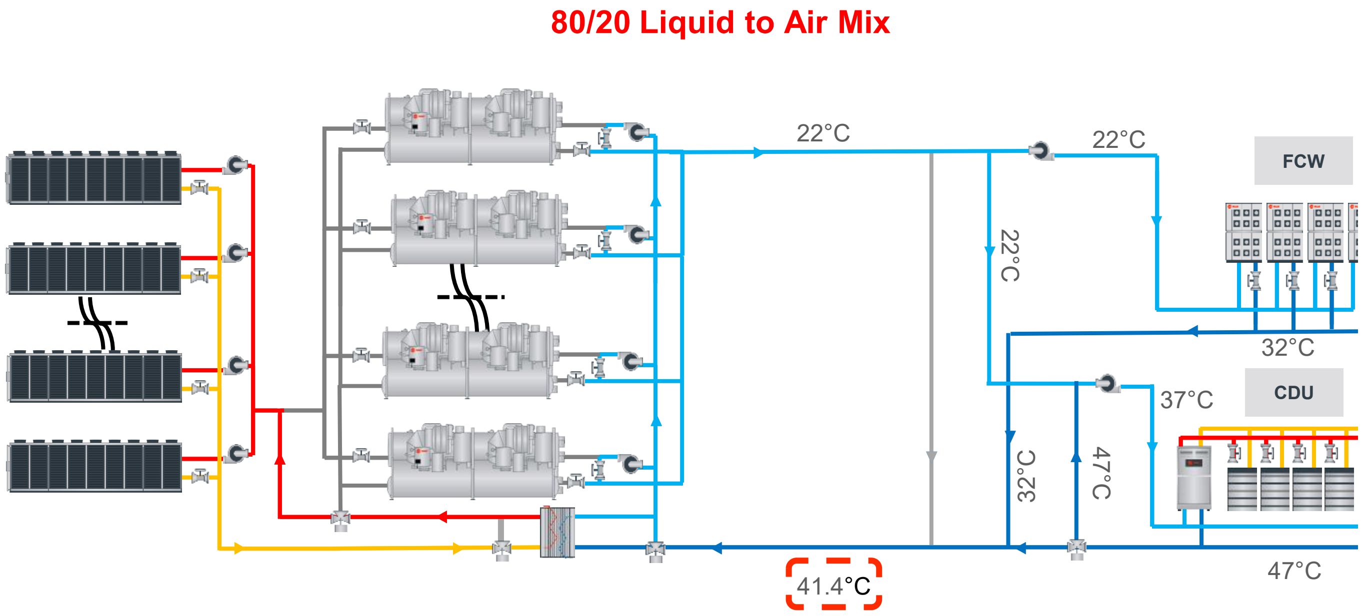
- As long as the minimum flow requirement for the equipment is met, maximizing delta T improves overall system efficiency.
- The cooling requirements differ: 72 to 90°F on FCW, and 98.6 to 116.6°F on the CDU. The chiller sees 72°F supply water blended with 116.6°F and 90°F return water, resulting in a higher delta T.

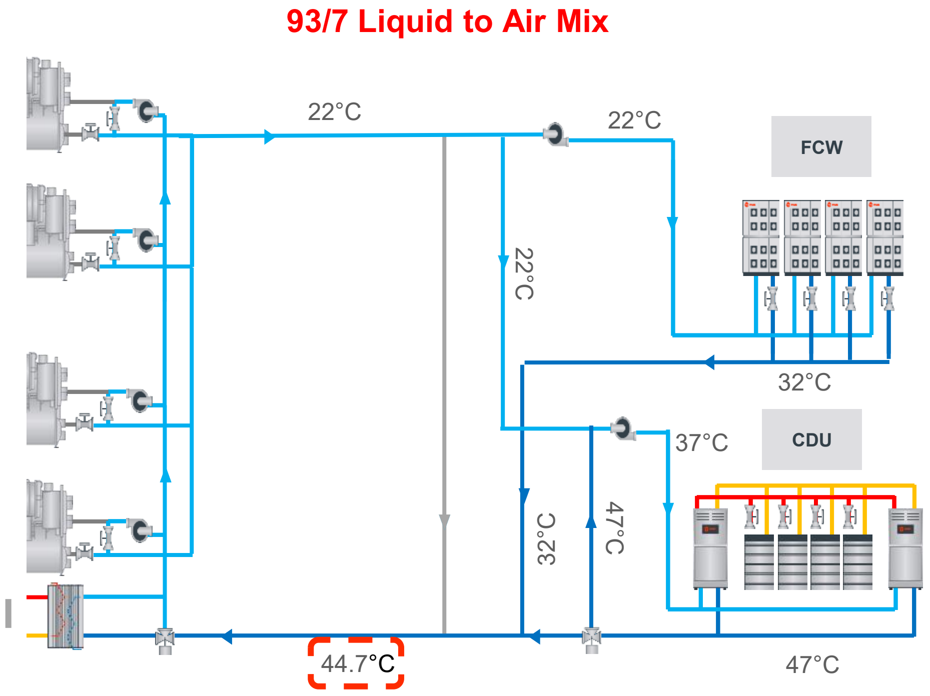
More Economizing Hours

- Supply water temperature is fixed based on airside cooling needs. The higher the return facility water temperature, the more capacity is available for free cooling.
- Any time the facility return water temperature (minus heat exchanger approach and dry cooler approach) is above ambient temperature, some degree of free cooling can be achieved.

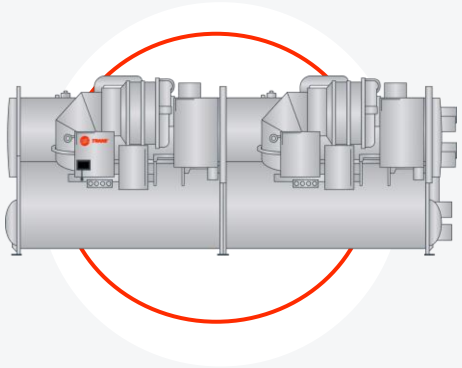
Future Ready Infrastructure That Adapts as You Evolve

Utilize the same infrastructure across multiple generations of IT equipment.
As IT equipment becomes more liquid-cooled, **take advantage of the increased opportunity for free cooling**.



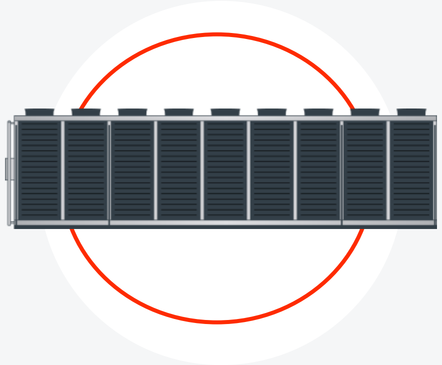


KEY SYSTEM COMPONENTS



Water-Cooled Chillers

Trane CenTraVac® chillers are engineered for data centers, operating efficiently at higher water temperatures to deliver reliable cooling and improved overall plant performance.



Dry Coolers

Dry coolers reject heat directly to ambient air using dry-bulb temperature, eliminating water use and achieving a WUE of zero. Trane works with leading manufacturers to assure each system is optimized for site conditions and climate.

Fan Coil Walls

Trane Fan Coil Walls provide higher capacity, efficient air cooling in the data hall, using medium chilled-water temperatures to deliver added capacity where air cooling is needed most.

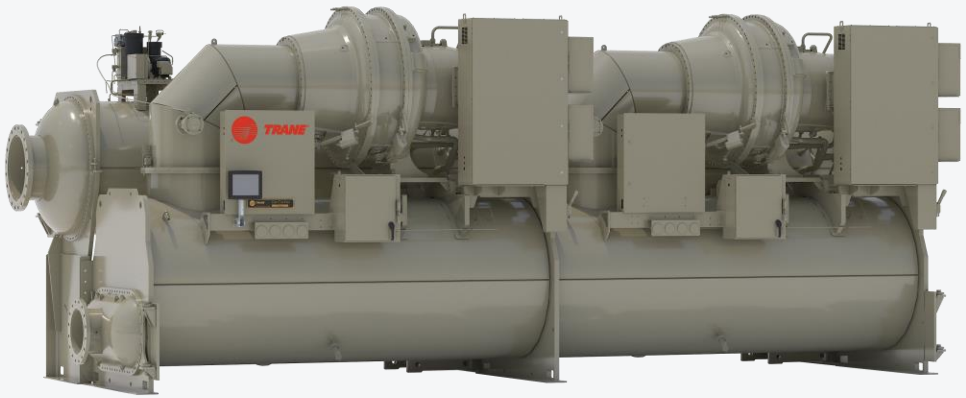
Coolant Distribution Units (CDUs)

Trane CDUs support the liquid-cooled portion of the data hall, separating facility and technical loops with a liquid-to-liquid heat exchanger for efficient, high-temperature cooling compatible with AI servers.

KEY SYSTEM COMPONENTS

CenTraVac® Water-Cooled Chillers Model CDHH

Design Characteristic	Requirements
Capacity Range	Up to 6,000 tons (21 MW)
Leaving Condenser Temp	Up to 68.3°C (155°F)
Facility Water Temperature Range	Up to 37.8°C (100°F)
Compressor	Two 2-stage Centrifugal Compressor
Heat Rejection Options	Dry Cooler/High Lift Application 6-pipe Heat Recovery Options
Refrigerant	Low GWP: R-1233zd
Restart After Power Loss	43-76 Seconds with UPS Depending Upon Starter/Drive
Power Feed Requirement	2300V to 12 kV Starter and Drive Options



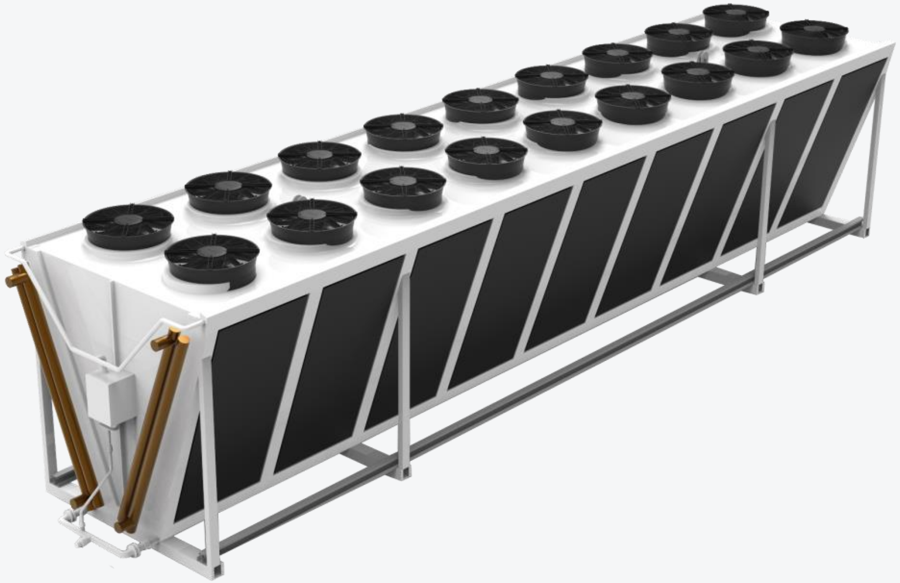
KEY SYSTEM COMPONENTS

Dry Cooler

Design Characteristic	Requirements
Capacity Range	1,500 tons (5 MW+)
Max Ambient Dry Bulb	62.8+°C (145+°F)
Fans	Variable Speed VFD or ECM Driven Fans
Power Feed Requirement	380-480, 3 ph, 50/60 Hz

Dry Cooler capacity and performance is dependent on local ambient extreme conditions.

* This is based on Albuquerque, New Mexico design conditions



There are many dry coolers solutions in the market. This design is based on a general dry cooler configuration. Specifications may change depending on the dry cooler used in application.

KEY SYSTEM COMPONENTS

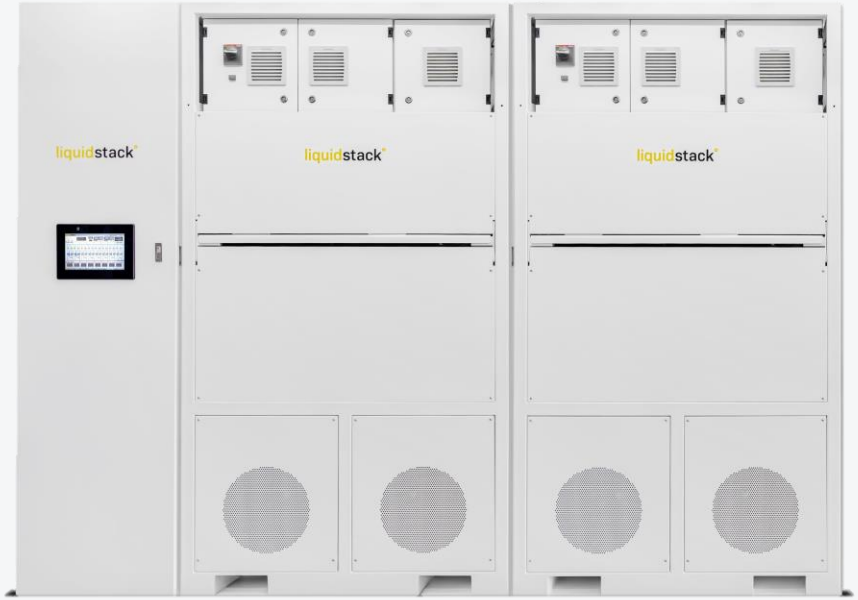
Fan Coil Wall

Design Characteristic	Requirements
Capacity Range	Up to 800 KW
Airflow Range	110K CFM+
Entering Air Temp	Up to 40°C (104°F)
Fan Type	ECM Direct Drive Fans
Additional Feature Options	Automatic Transfer Switch Controller Capacitor Backup Controls Teaming Application Backdraft Dampers
Filtration	2” or 4” Filters (MERV 8 or 11)
Harmonic Filtration	5% or Less of Total Demand Distortion
Power Draw	< 6% of Capacity Being Cooled in KW
Power Feed Requirement	415-480, 3 ph, 50/60 Hz

KEY SYSTEM COMPONENTS

Coolant Distribution Unit (CDU)

Design Characteristic	Requirements
Capacity Range	Up to 10 MW at 4°C (7.2°F) Approach
Effectiveness	>90% at 4°C (7.2°F) Approach
Minimum Pressure Head	40 PSID + dp Across CDU
Design Secondary (PG 25) Supply Temp	Up to 45°C (113°F)
Design Facility Water Temperature	Up to 41°C (105.8°F)
Max Ambient Temperature Operation	50°C (122°F)
Additional Feature Options	Scalable Solution Controls Teaming Application Pressure Independent Control Valve 316 Stainless Steel Plate Heat Exchanger Triple-Redundant Sensors in the Header
Secondary Side Filtration	25-Micron Filtration
Power Draw	< 1% of Capacity Being Cooled in KW
Power Feed Requirement	380-480, 3 ph, 50/60 Hz



KEY SYSTEM COMPONENTS

Computer Room Air Handler (CRAH)

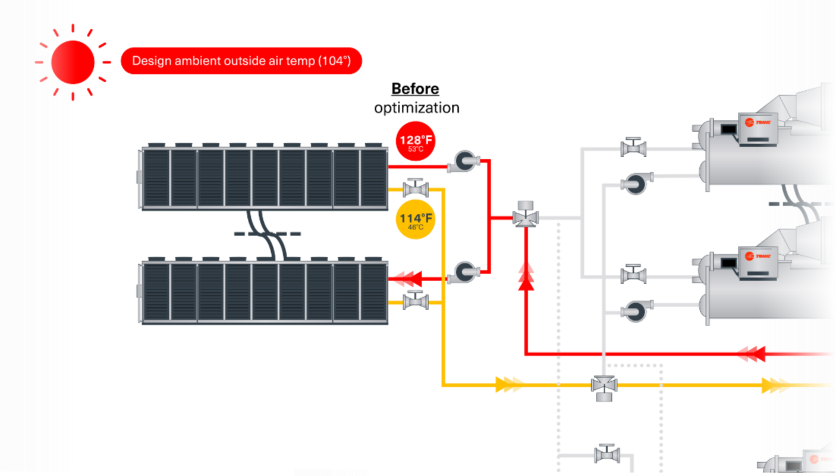
Design Characteristic	Requirements
Capacity Range	50kW to 360kW to support varied density zones
Airflow Range	5,000 - 50,000k CFM
Fan Type	ECM Direct Drive Fans
Entering Air Temp	Up to 43°C (110°F)
Additional Feature Options	Automatic Transfer Switch (ATS) Controller Capacitor Backup Condensate Pump Motorized return air damper
Filtration	2" (Merv 8 or 11) or 4" (Merv 8) Filters
Harmonic Filtration	5% or Less of Total Demand Distortion
Deployment Configuration	Downflow horizontal discharge for electrical room cooling Flexible for downflow white space use Optional upflow configuration
Power Feed Requirement	415-480, 3-phase, 60 Hz

OPTIMIZATION APPROACH

Elevating Condenser Loop Temperature and Increasing Condenser Loop delta T

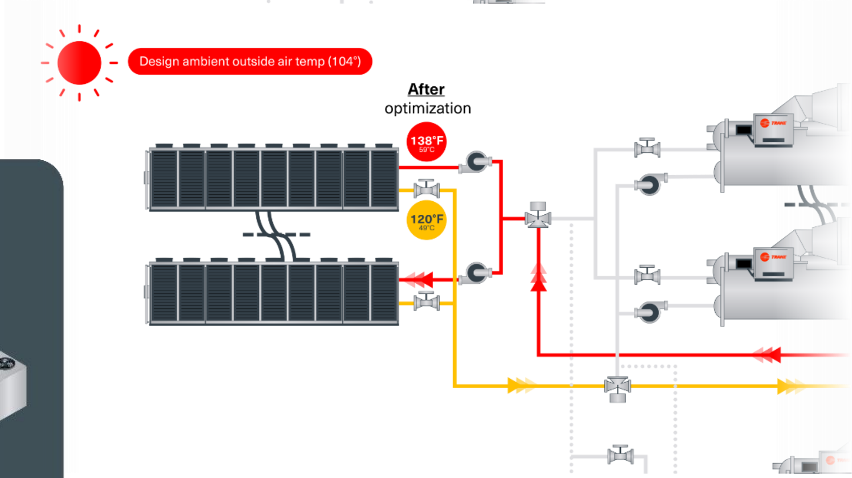
Impact to Chiller Plant

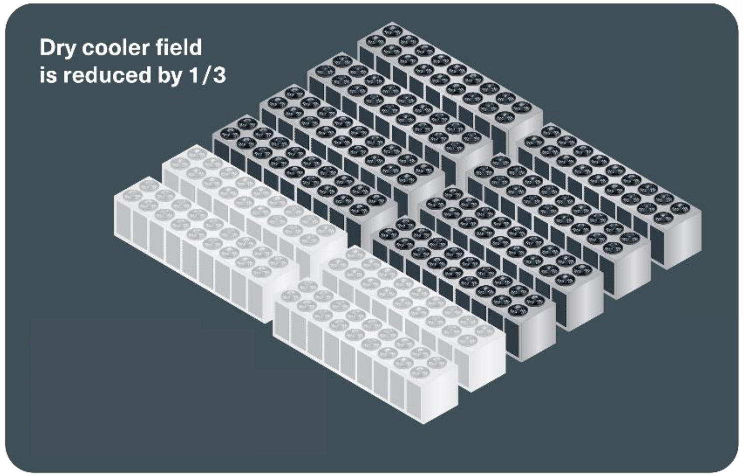
Raising the condensing temperature of the chiller increases the lift on the chiller's compressor. Lift can be approximated by the **Condensing Leaving Water Temperature – Evaporator Leaving Water Temperature**. Higher lift increases the amount of work the chiller's compressor is required to perform and decreases efficiency.



Impact to Dry Cooler/Pumps

Raising the condensing leaving water temperature increases the temperature difference to ambient air, allowing each dry cooler to deliver more capacity. This can reduce the number of dry coolers needed or improve their operating efficiency. A higher condenser water delta T lowers flow and pumping power, but the reduced flow may also limit capacity and require additional dry coolers.





BEST PRACTICES

Dry Coolers with Adiabatic Pre-Cooling*

How It Works

- Dry cooler performance depends on the temperature difference between process fluid and incoming dry-bulb air.
- Adiabatic cooling evaporates water into the inlet airstream, lowering effective dry-bulb temperature.
- Air temperature approaches wet-bulb, increasing heat-transfer capacity.
- Biggest gains occur in hot, dry climates with large DB–WB spreads.

Mechanical Cooling Benefits

- Boosts heat-rejection capacity during peak ambient temperatures.
- Reduces chiller lift and compressor power use.
- Allows smaller dry cooler selections or reduced loading on existing units.
- Cuts compressor and fan energy during high-temperature periods.

Free Cooling Benefits

- Dry coolers can support both mechanical and free cooling (with isolation HX).
- Adiabatic pre-cooling widens the ambient temperature range where free cooling is possible.
- Extends free-cooling hours and reduces chiller operation and energy use.

System Design Options

- Scenario 1: Reduced Number of Dry Coolers
  - Lower first cost
  - Smaller footprint
  - Lower mech-cooling cost
  - Maintained free cooling window
- Scenario 2: Same Number of Dry Coolers
  - Same first cost & footprint
  - Lower mech-cooling cost
  - Expanded free-cooling window

If water consumption is allowed

BEST PRACTICES

Freeze Protection

Outdoor equipment such as dry coolers and exposed piping is at risk of freezing when ambient temperatures drop below the fluid's freeze point. Protection can be achieved by selecting a suitable fluid or by adding heat to maintain temperature above freezing.

- Select a fluid with a freeze point below expected operating conditions
- Add heat to keep local temperatures above the fluid's freeze point

Glycol solutions (propylene or ethylene) have a freeze point, where crystals begin to form, and a burst point, where expansion can cause damage. Proper concentration ensures the fluid remains pumpable and prevents freezing under site conditions.

If water is used, heat must be added to maintain temperature above freezing — especially in heat-rejection devices like dry coolers. The required heat depends on ambient conditions, water volume, and insulation quality.

If glycol is undesirable in the full loop, install isolation heat exchangers and local pumps to confine glycol to small closed loops while maintaining protection for any connected water lines.

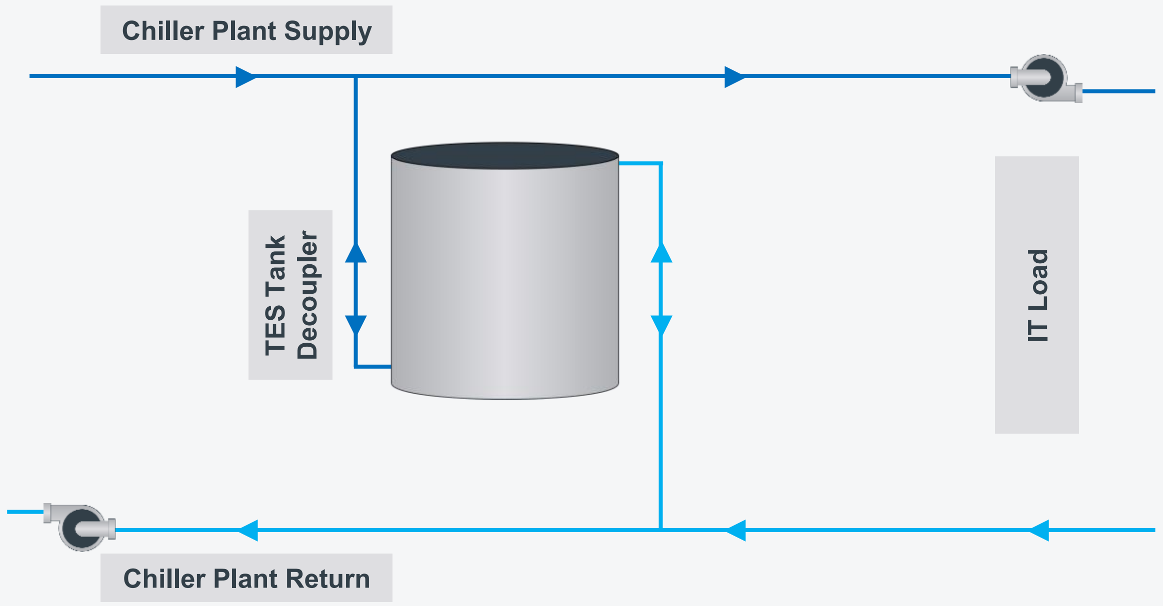
BEST PRACTICES

Thermal Energy Storage

Thermal storage can be integrated into the chiller plant in several ways, with tank location determined by system needs.

- **Tank in the decoupler line.** Locating the tank in the decoupler line includes all the benefits noted above. This location also allows it to act as a thermal battery — charging when production exceeds demand and discharging when demand is higher. This cycle can repeat throughout the day and be optimized by system controls.
- **Tank on return side**. When placed on the return side, the tank buffers large temperature swings in water returning to the chillers during rapid load changes. Maintaining stable return temperature helps chillers deliver consistent leaving-water temperature.

Thermal storage tank in the decoupler pipe



SYSTEM CONTROLS

Effective controls are critical to chiller plant performance and reliability. Trane's data center–specific control platform promotes efficiency, uptime and responsiveness by integrating all major components — chillers, dry coolers, pumps, valves, CDUs and fan coil walls — into one coordinated system.

SYSTEM CONTROLS

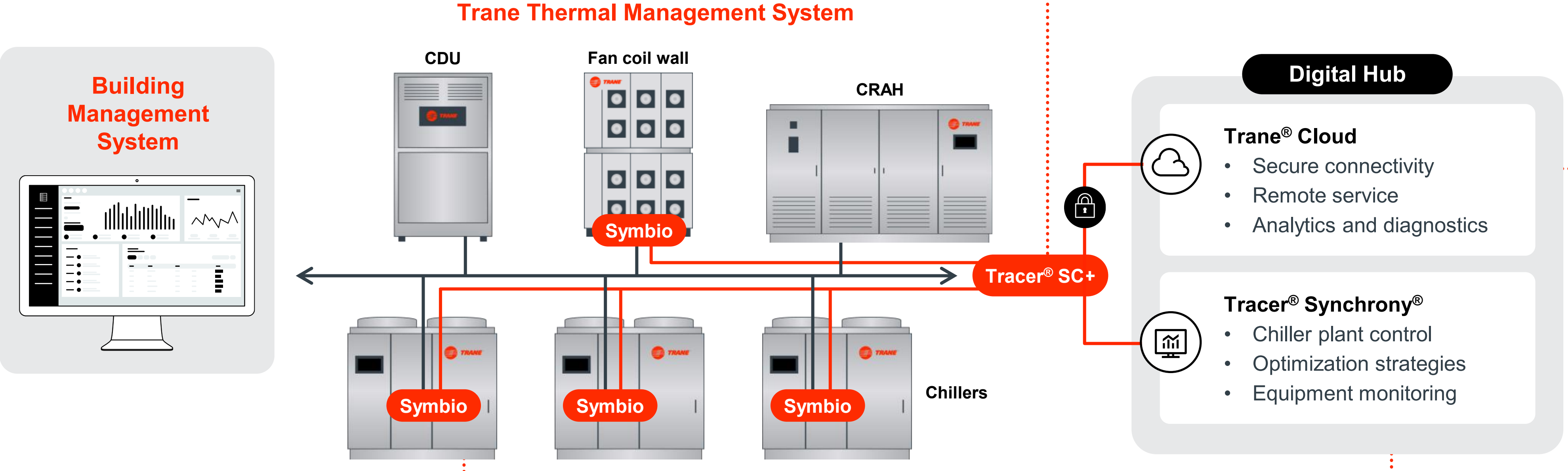
Reference Diagram

System Control

Tracer® is a unified thermal management system that simplifies operations by handling chiller rotation, staging, and sequencing with built-in tools that boost reliability and enable data-driven performance.

AI Enhancements

Take optimization further with our AI-driven efficiency engine. **Trane® AI Control** blends decades of expertise with real-time data to continuously improve your thermal management system and capture every possible watt of savings.



Insights + Optimization

When power is limited, your cooling system must run at peak efficiency—every kilowatt saved means more racks online. **Trane Intelligent Services** uses whole-system data to deliver actionable energy-saving strategies.

Equipment Connectivity

Symbio® controls collect and translate key equipment data into the **Tracer SC+,** enabling data-driven service and optimization.

Predictive Maintenance

With your permission, we can securely connect to your equipment or Tracer SC+ to enable **Connected Mechanical Service**. By monitoring trends and performance data, we help identify issues early so your team or our technicians can act before failures occur. And when on-site support is needed, **Trane Service Agreements** and **local technicians** are ready to respond.

TRANE SERVICE

As data centers expand in size and complexity, the need for dependable, efficient cooling grows with them. Trane's thermal management services are designed to meet these evolving demands — providing scalable, responsive support that adapts to changing loads, tighter schedules and zero-tolerance uptime requirements.

- Embedded expertise ensures reliable operation from design through expansion and refresh
- Proactive planning helps reduce risk and downtime
- Connected insights help optimize capacity and efficiency across the lifecycle

→ TRANE RENTAL SERVICES

Need unrivaled temporary thermal management and power solutions for your data center? Trust Trane Rental Services for:

- Level 2, 3, and 4 **commissioning services**, including line flushes and load bank testing
- **Expansion and retrofits** for new chip designs
- Planned **maintenance, emergency response, and redundancy** to protect SLAs
- Overcoming **new equipment lead times** to speed up new facility launches

As one of North America's largest OEM HVAC rental companies, Trane Rental Services leads the market. Our highly trained staff, rapid emergency response, and unmatched expertise are supported by 150 locations, 230 parts centers, and 2,600 technicians. Choose Trane Rental Services for reliable, expert solutions.

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DESIGN RESOURCES

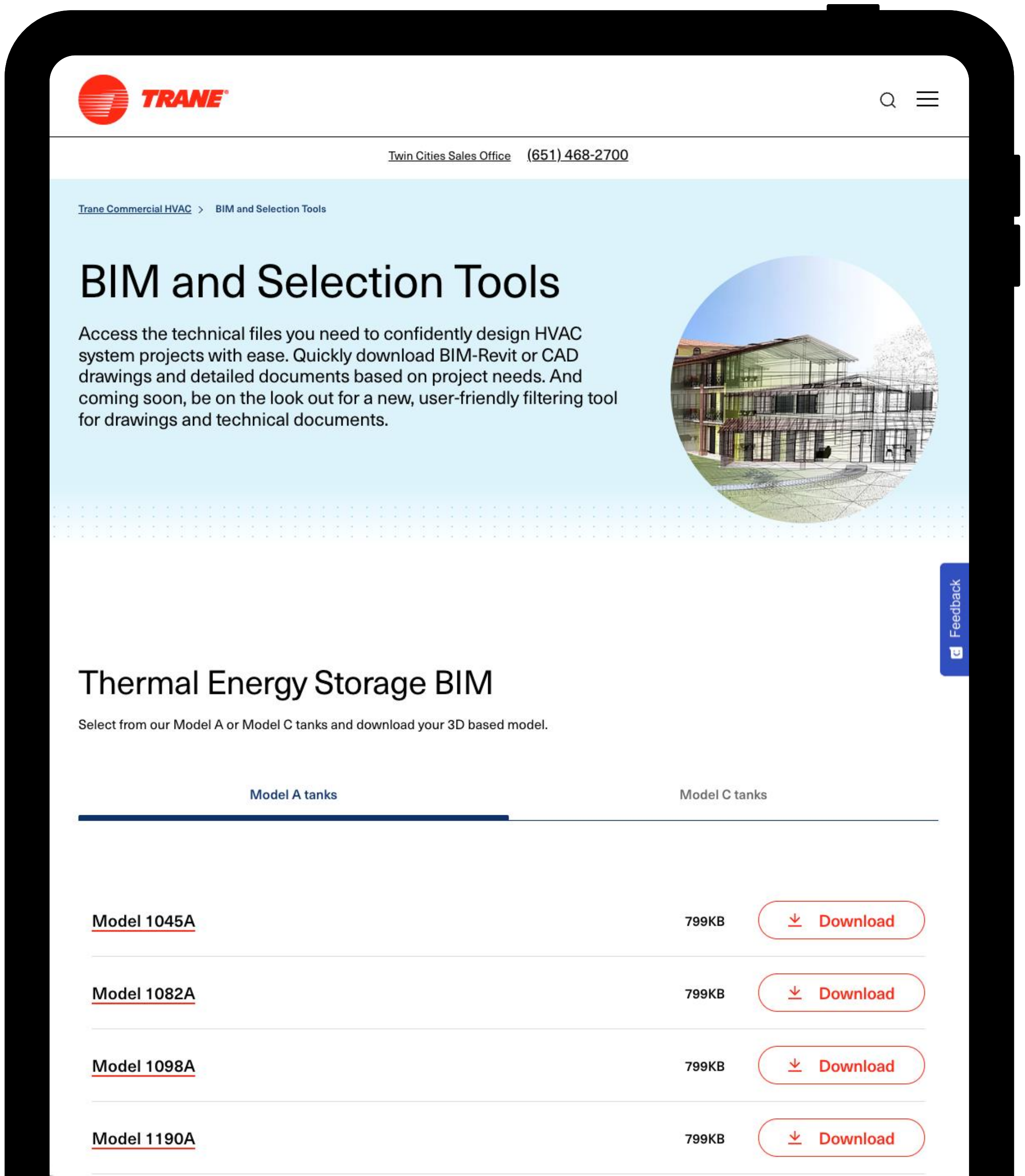
Trane provides a complete suite of resources to support the design of high-performance thermal management systems for data centers.

- All mechanical components are selected for site-specific conditions, with detailed submittal packages available
- System control sequences and operating modes can be customized for any chiller plant configuration
- TRACE™ modeling tools evaluate annual energy performance and efficiency
- Application guides and Trane experts are available to assist with design, optimization and implementation

Reach out to Trane today for more information.

HELPFUL LINKS

Trane BIM and Selection Tools →



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