March 5th, 2024

Direct Liquid Cooling

Cascade + McKinstry

CASCADE MISSION CRITICAL, LLC
Data Center Consulting

Expected Growth in Industry

While the adoption of **artificial intelligence** (AI) by business and the public is partially responsible for sector growth, a

tsunami of data

is also flooding into data centers from numerous sources, including **5G**, the **internet of things** (IoT), e-commerce, streaming services, cloud computing and **virtual reality** (VR).

And coming soon — the **autonomous vehicle**, which likely will generate literally terabytes of data daily through high-resolution cameras, radar, **lidar (light detection and ranging)**, GPS and automotive networks.

With or without AI, the level of data creation is almost unfathomable,

Every minute (globally)...

200 million emails sent

350,000 posts to X

100,000 hours spent on Zoom calls

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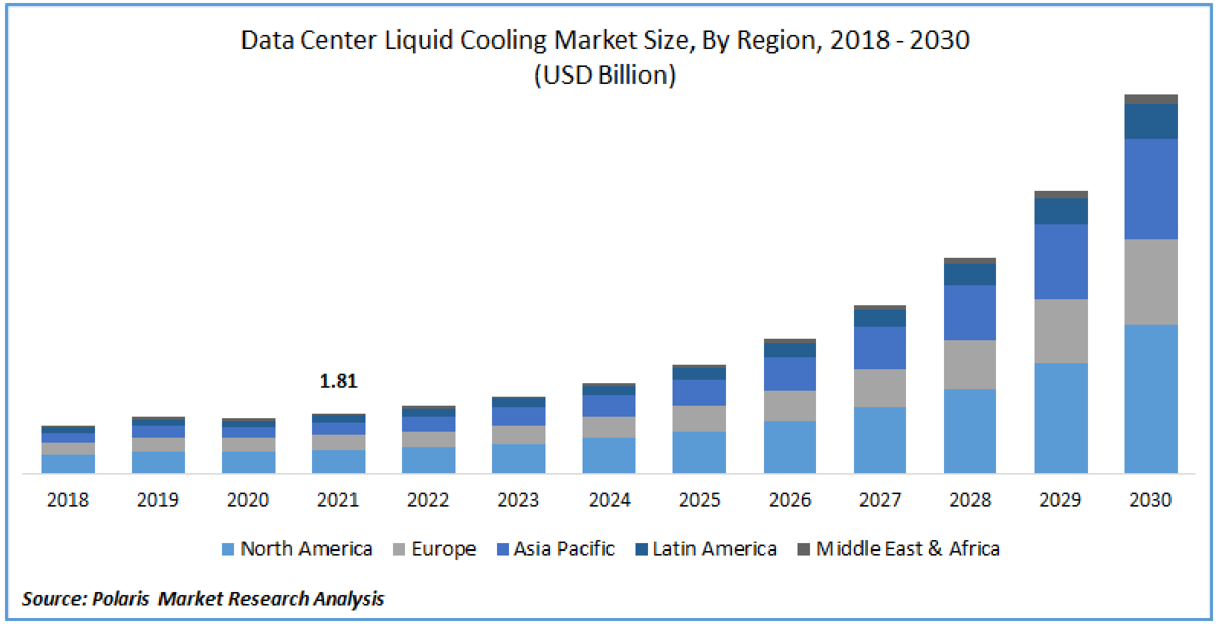
Industry Growth Trends

Industry Expansion

The global data center liquid cooling market was valued at USD 1.81 billion in 2021 and is expected to **grow to $11.33 billion** (CAGR of 24.0%) through 2030.



Trends Driving Greater Use of Liquid Cooling:

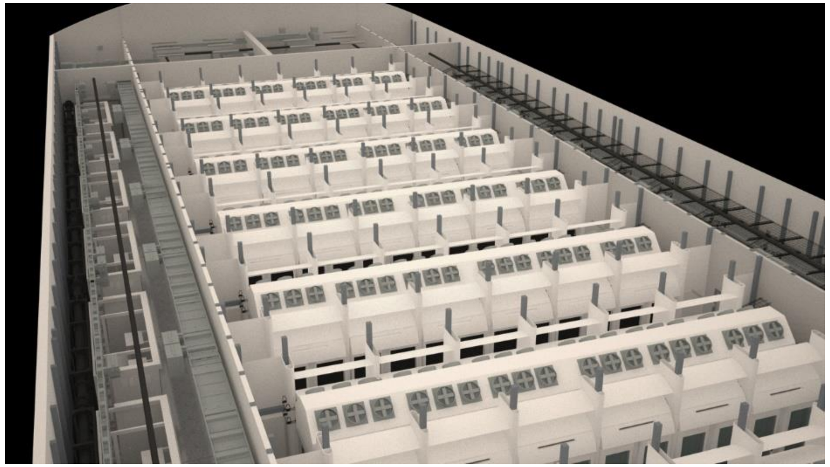
- Increased demand for compute-intensive workloads due to virtualization, increased security, and containerization
- Density and space constraints in data centers
- The rise of edge computing (cloud-based services)

Design and Planning Considerations

Everything Old is New Again....

A Personal History of Liquid Cooling

- IBM Mainframes: Separate Power and Cooling Distribution Systems to support chilled water cooled processors, mid-late 1980's.
- Direct to Chip and Direct Spray Systems using refrigerant liquid, 2005.
- Two phase flow rack based coil systems using refrigerant liquids, coupled with water cooled heat exchangers and exterior fluid coolers, 2010's.
- Today: Chilled water self contained cabinets, direct to chip cooling, immersion systems.



Courtesy of DDC Cabinet Technology

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Design and Planning Considerations

Rack Density: Pick Your Numbers

DDC S-Series Design Roadmap

DDC S-Series Cabinet Technology employs a variety of patented and patent pending technologies to deliver cooling and efficiency capabilities unavailable anywhere else.

Design Generation:	Gen 1	Gen 2	Gen 3	Gen 4
Release Date:	November 2011	November 2017	November 2020	November 2021 (Target Release Date)
Thermal Management:	Patented Dynamic Density Control™			
Cooling Design:	Water Flow Control	**Dynamic** Water Flow Control	Dynamic Water Flow Control + **Adaptive Demand Response**	Dynamic Water Flow Control + Adaptive Demand Response + **Liquid-to-Chip/Chassis Direct Cooling (LTC)**
Air Flow Design:	Dynamic Airflow Control (Supply)	Dynamic Airflow Control (Supply)	**Dynamic Supply & Return Airflow Control + Volumetric Pressure Mgmt.**	Dynamic Supply & Return Airflow Control + Volumetric Pressure Mgmt.
Density Design:	34kW	**52kW**	**85kW**	85kw – **170+kW (w/LTC Integration)**
Water Temperature Range:	40° - 65°F	40° - 65°F	40° - **80°F***	40° - 80°F*
CFM:	2500	**3500**	**7500**	7500
Rack Units:	45U	**40U**, 45U	40U, 45U, **60U**	40U, 45U, 60U **+ Support for OCP**
Power Operating Range:	< 3500w @ 30kW	**< 1600w @ 45kW**	**< 800w @ 45kW**	Pending Final Design
DDC-DCIM:	Temperature Set Point Control & Basic Monitoring	Temperature Set Point Control & **Advanced Monitoring**	Temperature, **Airflow, Water Volume Set Point Control + Advanced Energy Management + Predictive Analytics + Single Pane of Glass Management (SPG)**	Temperature, Airflow, Water Volume Set Point Control + Advanced Energy Management + Predictive Analytics + Single Pane of Glass Management (SPG)

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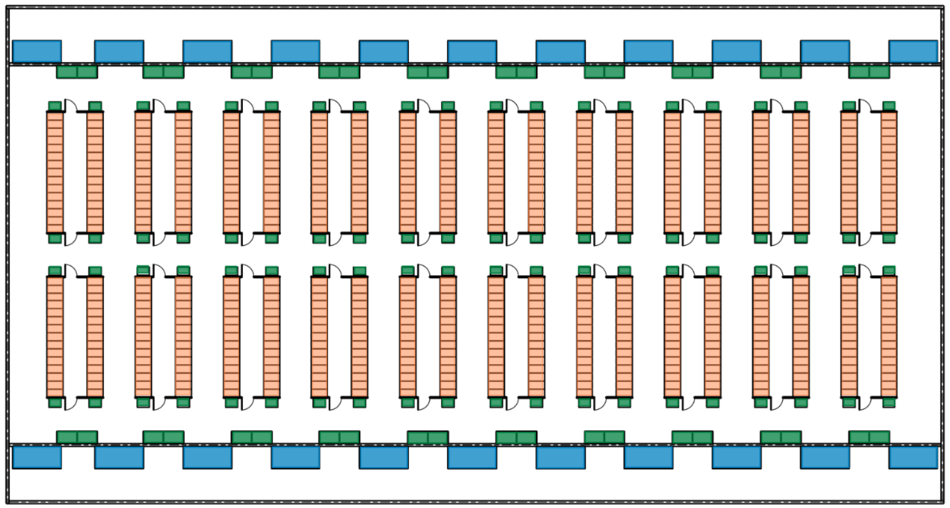
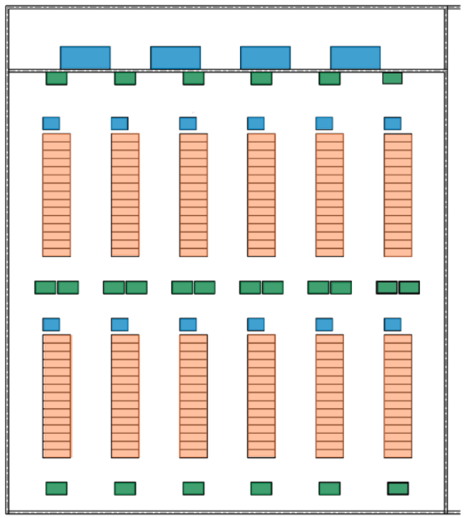
Courtesy of DDC Cabinet Technology

Design and Planning Considerations

Rack Density: Space Planning





Traditional Air Cooled Data Hall

- 6 MW of Critical Load
- 600 Racks @ 10 kW per Rack
- 29,000 sf of Space, including AHU Galleries

Liquid Cooled Rack Data Hall

- 6 MW of Critical Load
- 180 Racks @ 33.3 kW per Rack
- 13,345 sf of Space, including AHU Galleries

Remember that all of the Electrical Support Space will be the same for both approaches!

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Design and Planning Considerations

Rack Density: Facility Impacts

Split Cooling Requirements

- Different Temperatures for Racks versus space for people
- Do we need to provide separate loops?

Data Hall Physical Environment

- Going back to Raised Floor Systems?
- Provides separation of liquid and power systems
- Build in under-floor drainage systems. May be difficult in existing buildings or in multi-story buildings.
- Floor level changes and movement of materials a consideration if necessary to have base slab and raised floor conditions.

Structural Loading

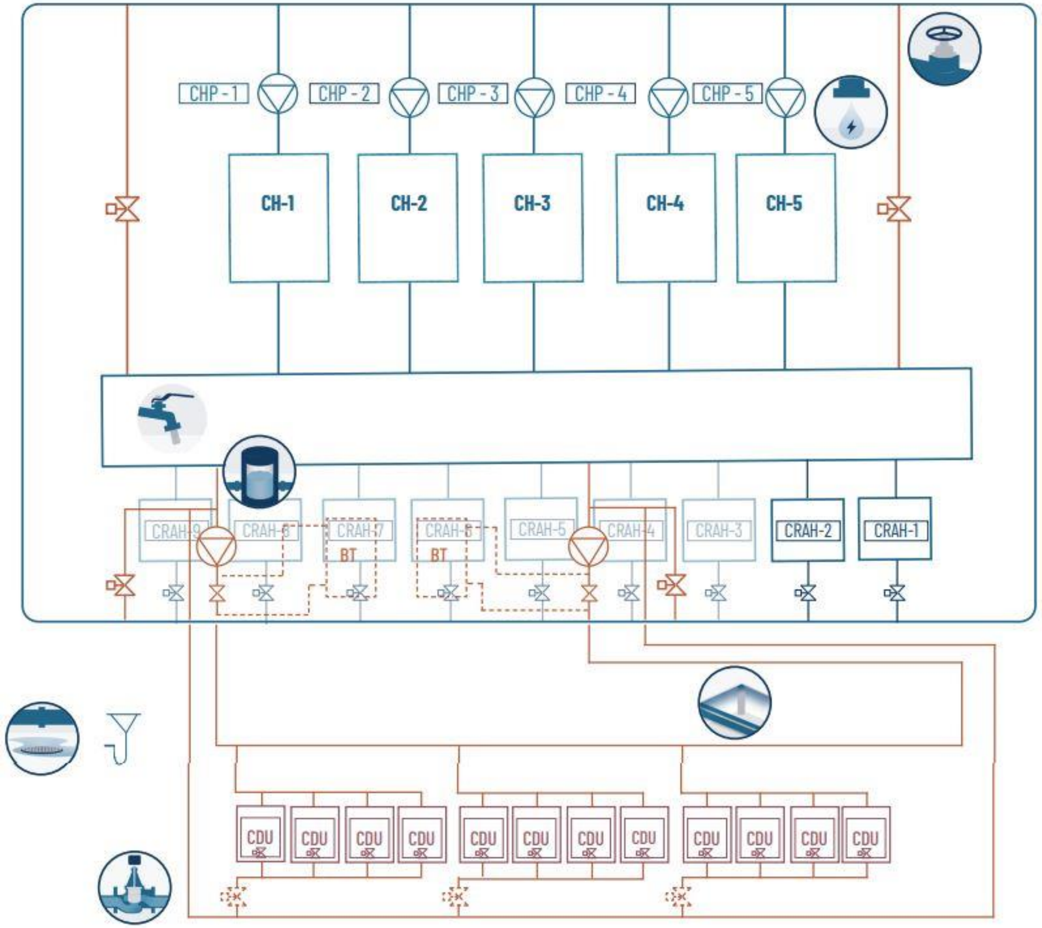
- Increased vertical load on floor systems.
- For elevated floors, structural deflection can become an issue.
- For seismic areas, lateral loads can have a severe impact on a building structure, especially in an existing building.

Heat Rejection Systems

- Water consumption is becoming the next limiting factor in site selection.
- Placement of air-cooled chillers, fluid coolers or cooling towers can be a significant user of site or roof area.
- Roof mounted equipment can impart very high axial and lateral loads.
- Roof mounted equipment may also be limited by local zoning codes.

Implementing Liquid Cooling Solutions

Straightforward– but details matter.

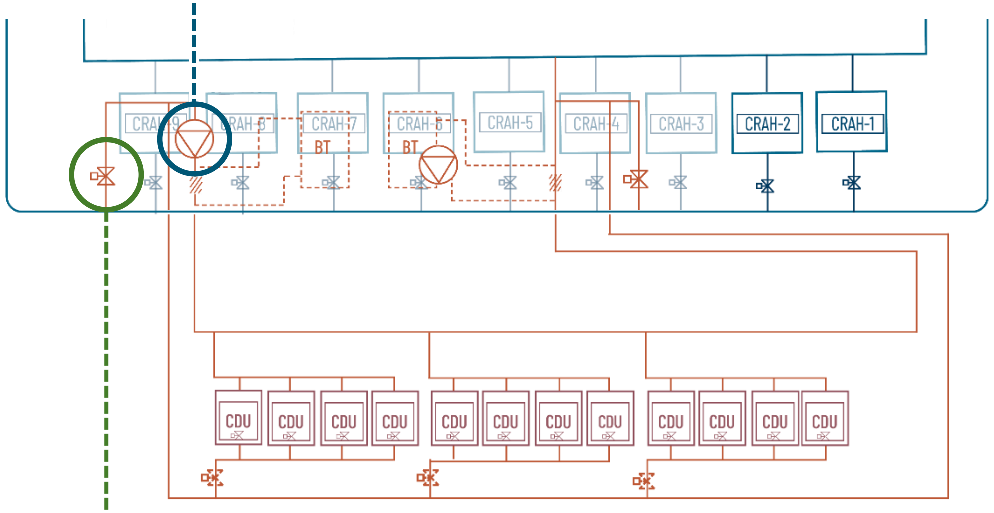


- Operating Pressures
- Water Chemistry
- Data Hall Drain(s) / Leak Detection
- Decoupled Direct Cooling Loops
- Bypass Value to Maintain Chiller EWT
- Direct Liquid Cooling Buffer Tanks
- Direct Liquid Cooling Loop Distribution
- System Performance
- Energy Expectations

Decoupling Direct Liquid Cooling Loop

CDU temperature and pressure requirements can drive the need for a decoupled direct liquid cooling loop

Dedicated pumps can be sized specifically for CDU needs



Dedicated control valve that allow direct liquid cooling loop to operate at different temperature from facility chilled water system

CDU High Differential Pressures (Upwards of 22psi compared to 10psi of a CRAH unit)

Different CDU Design Supply Water Temperatures (80F-100F compared to 65F in an air-cooled system)

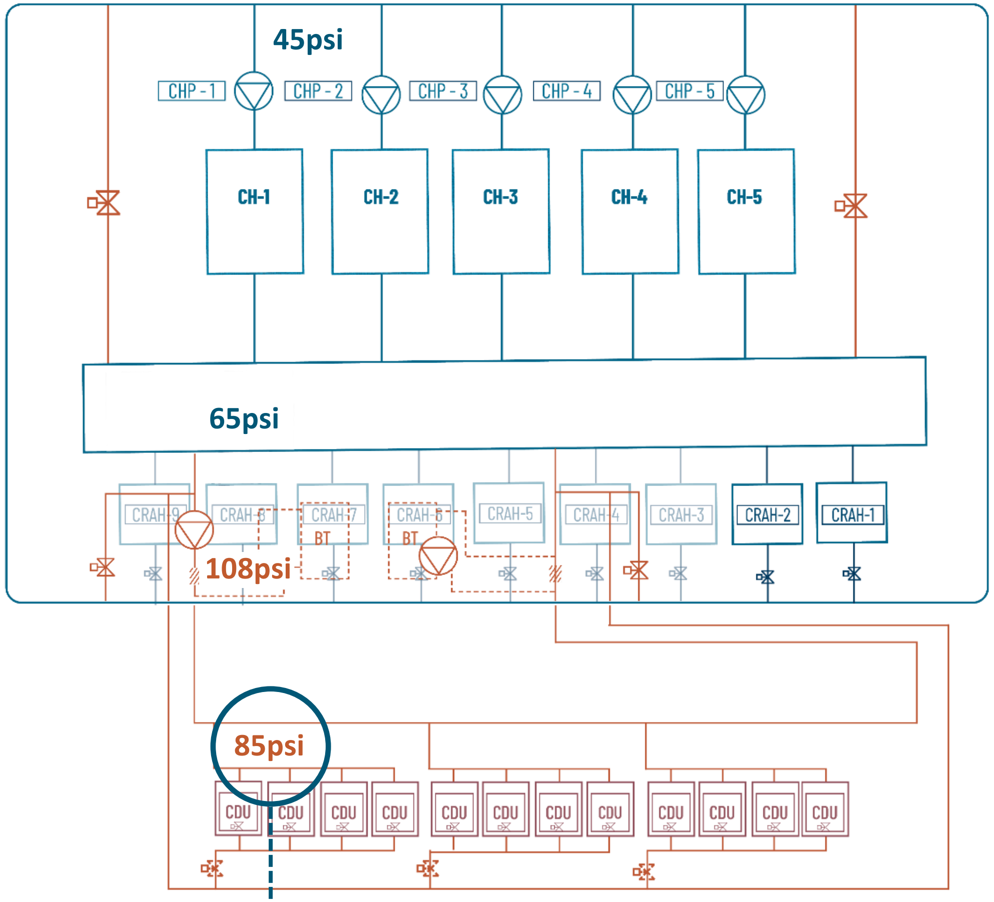
Operating Pressures

Operating pressures can vary between manufacturers and models

145psi

50psi to 90psi

Some lower max operating pressure may not work with facility chilled water systems without modifications



Above maximum operating pressure of some CDU models

Leak Mitigation

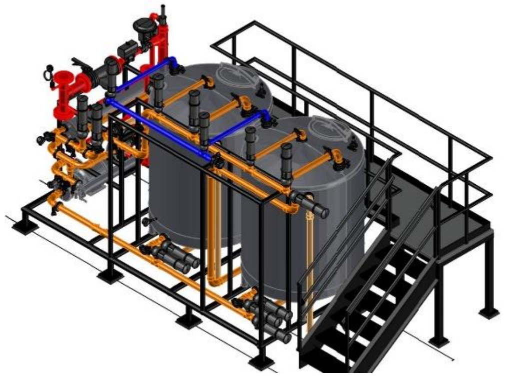
Several measures can be applied to help mitigate leaks

FLOOR MOUNTED PIPING

WATER CONTAINMENT

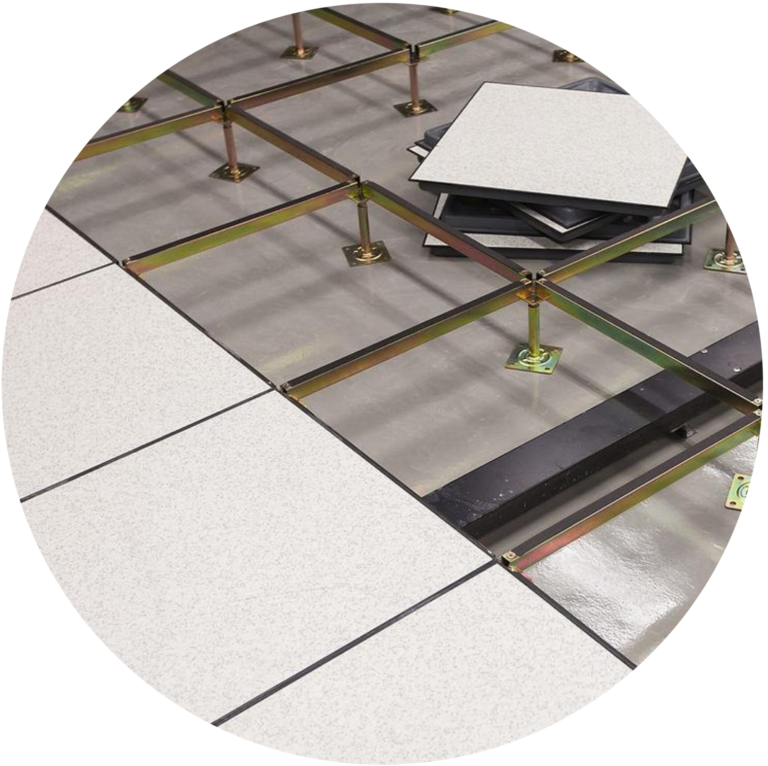
LEAK DETECTION

FLOOR DRAIN IN WHITE SPACE

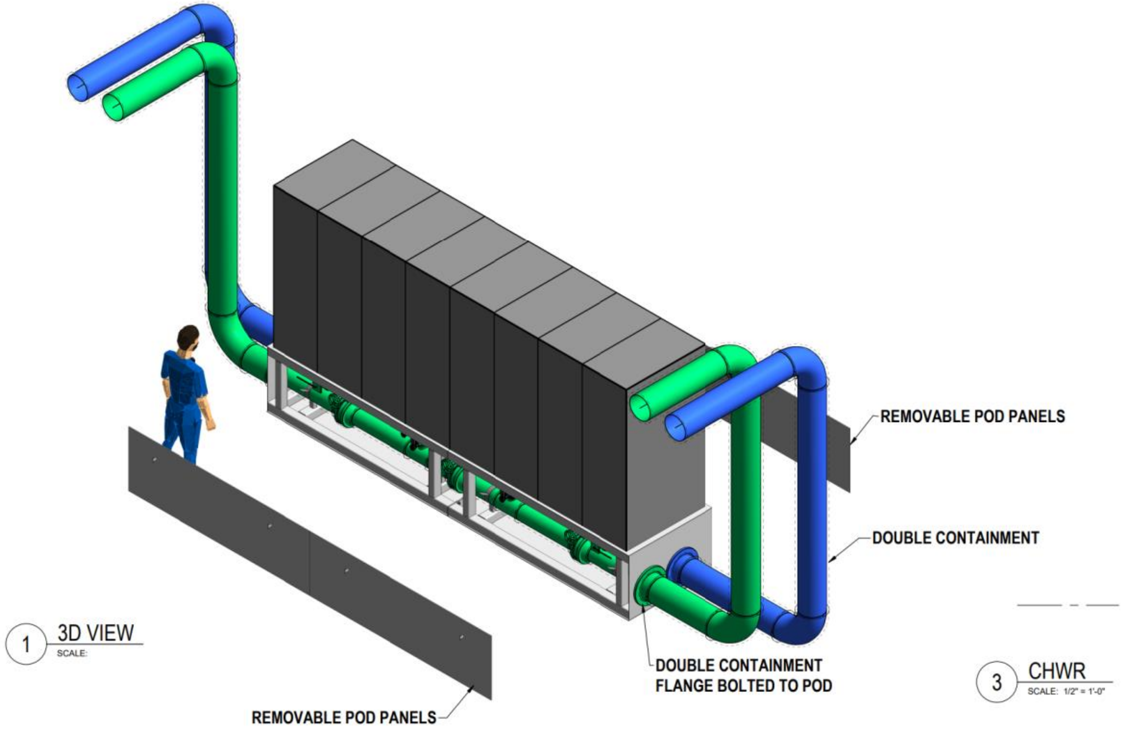


PRE-FABRICATED PIPING SKIDS

Liquid Cooling Loop Distribution



Could drive installing a raised floor in data hall not originally intended for raised floor



or get creative and provide a pre-manufacturer skid that could also support CDUs / Servers

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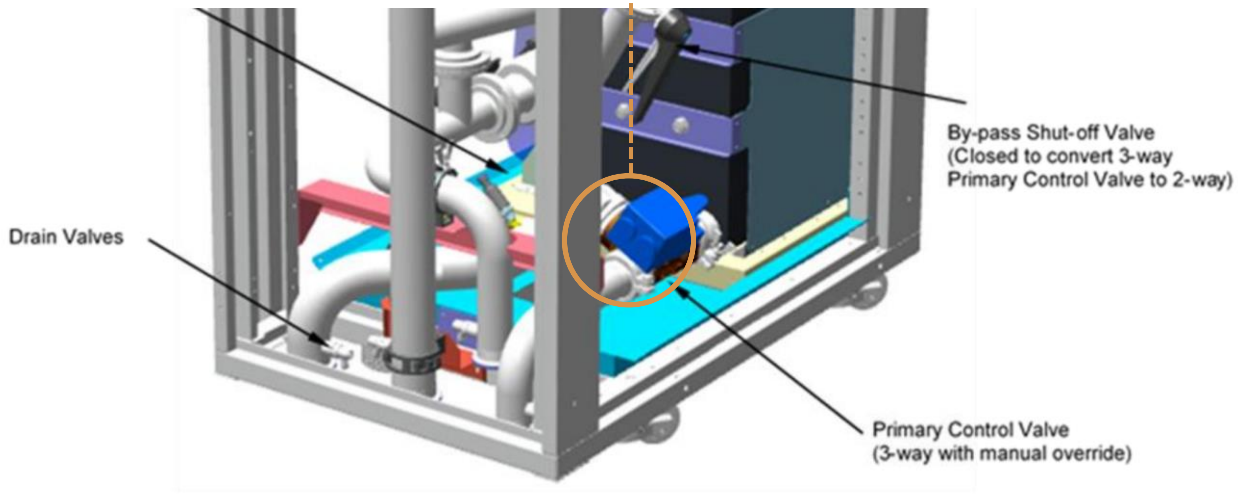
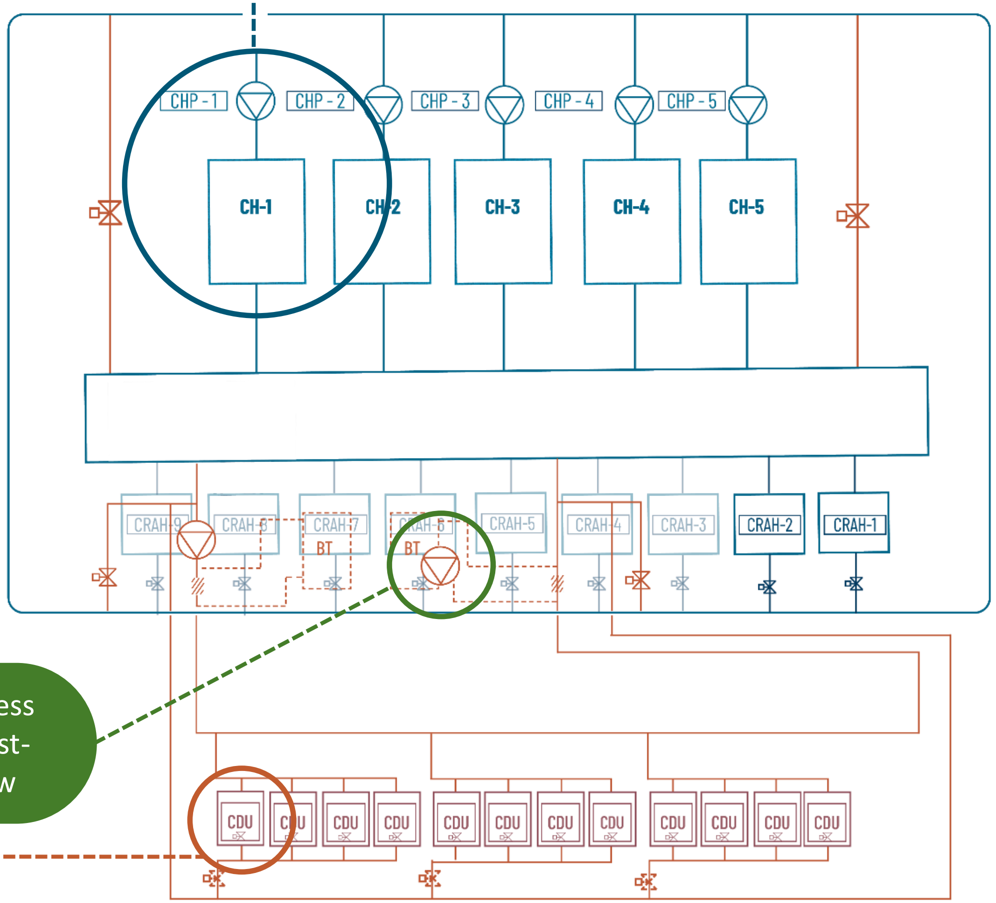
System Performance

Low delta T syndrome can drive excess flow needs in the direct cooling loop could drive the need to turn on chillers based on flow needs in lieu of load needs. This adversely effects building PUE

Typical CDUs are furnished with control valves. Many have an option for a 3-way valve.





Low delta T syndrome can drive excess flow needs at the pump or as a worst-case pumps that are starved of flow

3-way valves or poor performing 2-way valves can case low delta T syndrome in the facility chilled water system

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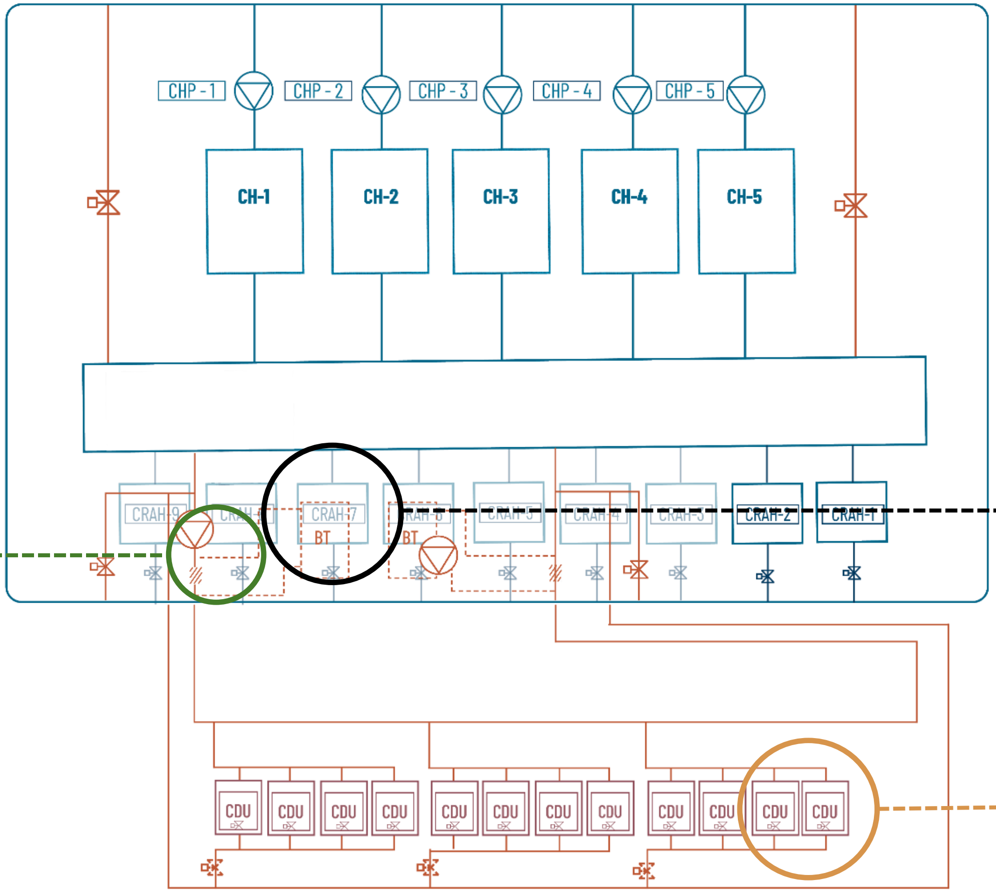
Power Failure Considerations



Providing UPS backed power to the pump and a buffer tank can mitigate liquid cooling temperature rise during a power failure

High CDU heat loads can cause loop temperatures to rise quickly during a power failure

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Water Chemistry

Water quality requirements can vary between CDU manufacturers:

Filtration	50 microns – this must be accomplished outside of the unit

Filtration Requirements	500 microns

Recommended Base Water Quality		
Item	**City Water**	**Purified Water**
Metals	~	< 0.1 ppm
Calcium	< 5 ppm	< 1 ppm
Magnesium	< 10 ppm	< 1 ppm
Manganese	< 1 ppm	< 1 ppm
Phosphorus	~	< 0.5 ppm
Silica	< 1 ppm	< 1 ppm
Sodium	< 2 ppm	< 1 ppm
Bromide	< 1 ppm	< 1 ppm
Nitrite	< 0.5 ppm	< 0.5 ppm
Chloride	< 1 ppm	< 0.5 ppm
Nitrate	< 0.5 ppm	< 0.5 ppm
Sulfate	< 40 ppm	< 0.5 ppm
Conductivity @20°C	~	< 10 µS/cm
pH	6.5 - 8.5	6.5 - 8
Turbidity (NTU)	< 1	< 1
Bacteria	< 100 cfu/mL	< 100 cfu/mL

Parameter	Recommended Limits
pH	7 to 9
Corrosion inhibitor	Required
Sulfides	<10 ppm
Sulfate	<100 ppm
Chloride	<50 ppm
Bacteria	< 1000 CFUs/mL
Total hardness (as $CaCO_3$)	<200 ppm
Residue after evaporation	<500 ppm
Turbidity	<20 NTU (Nephelometric)

Some requirements for very stringent and could drive the need for significant facility chilled water system measures

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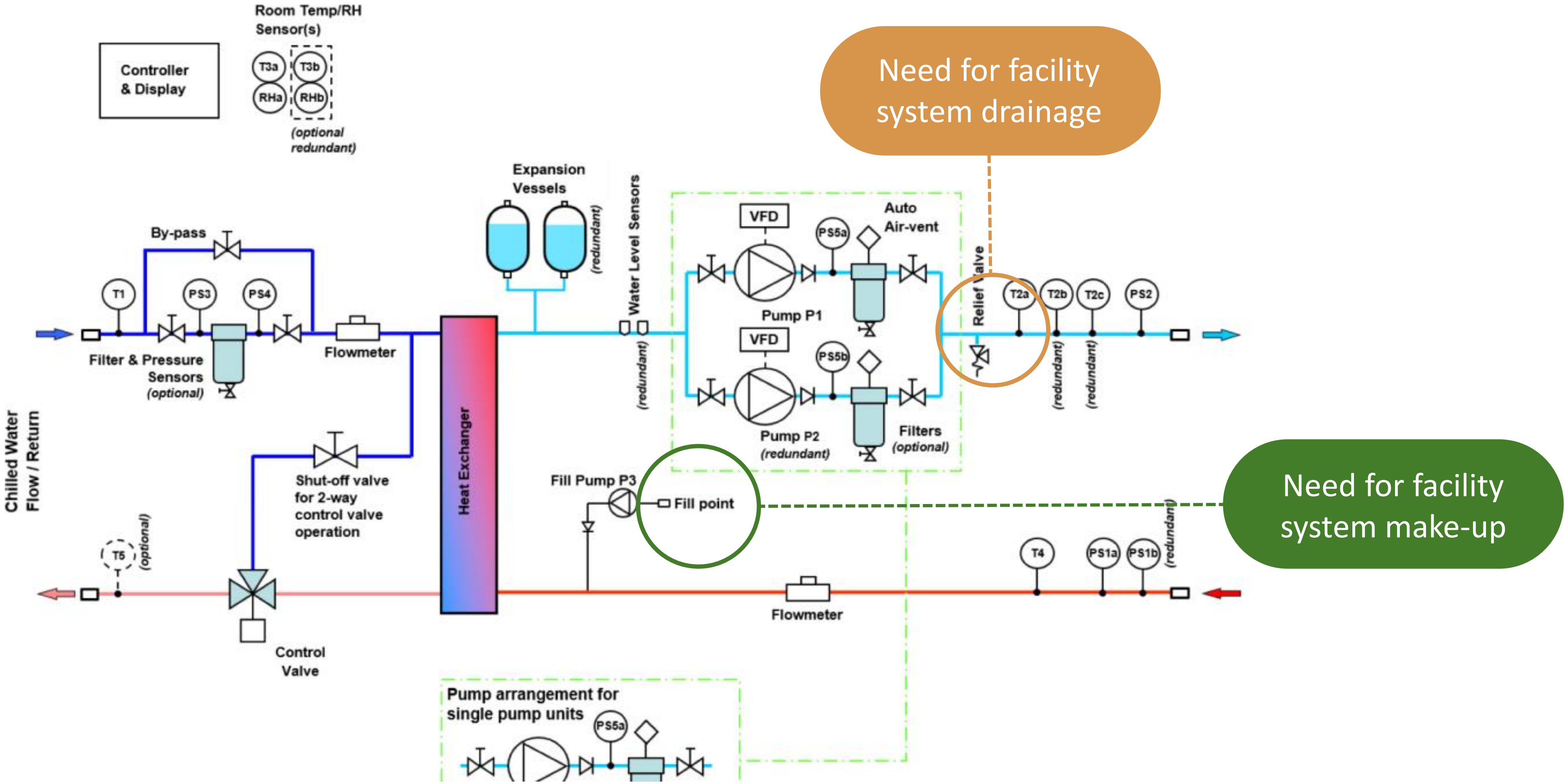
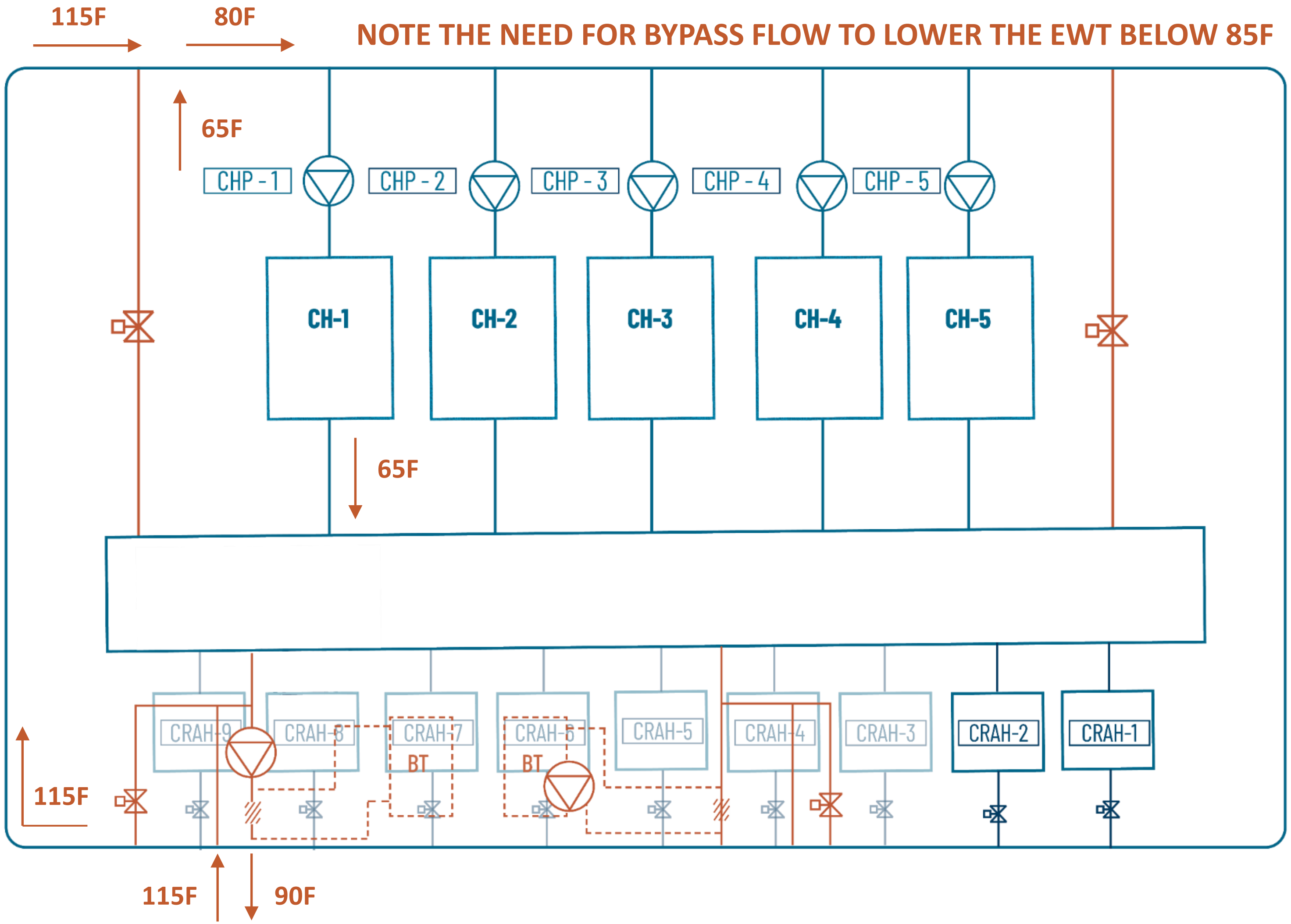
Technology Loop Considerations



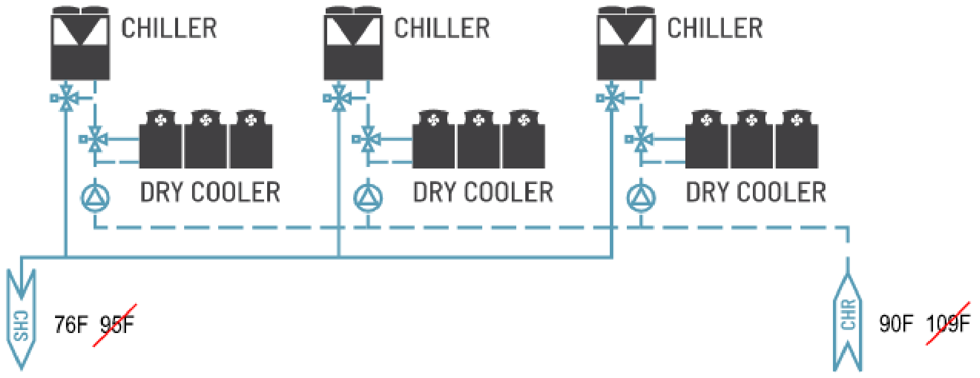
Chiller Max EWT

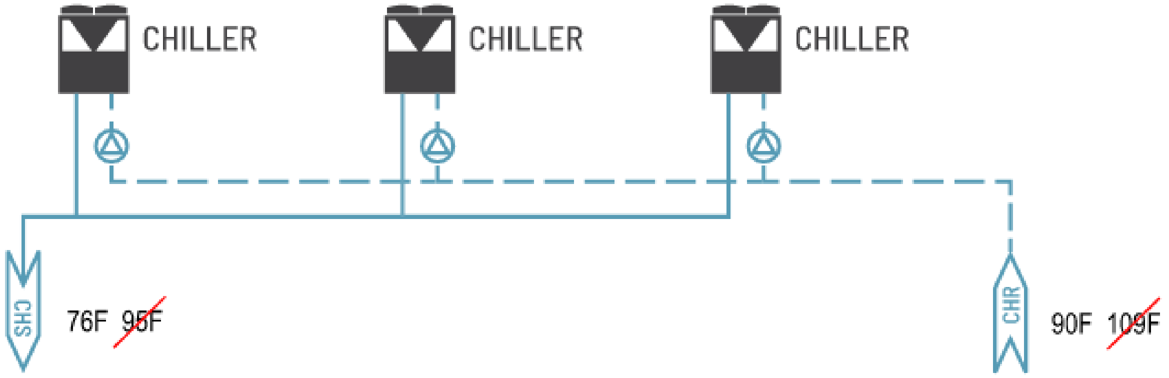
Chiller typically have a max EWT of 85-90F. This can be an issue if the liquid cooling loop is driving high return temperatures



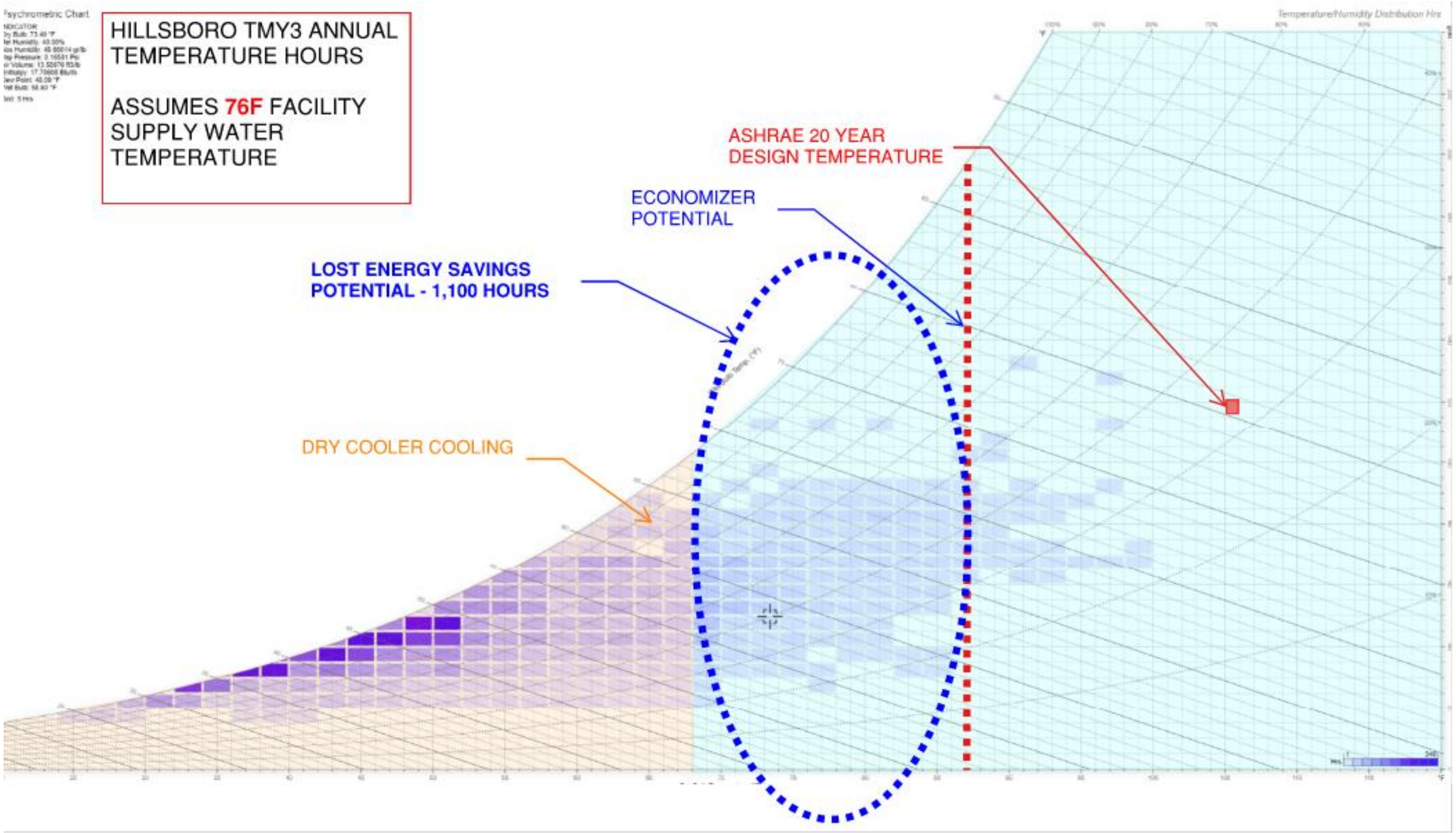
Typical Chilled Water System

Important Design Consideration - Chiller Maximum Entering Water Temperature = 85 – 90F

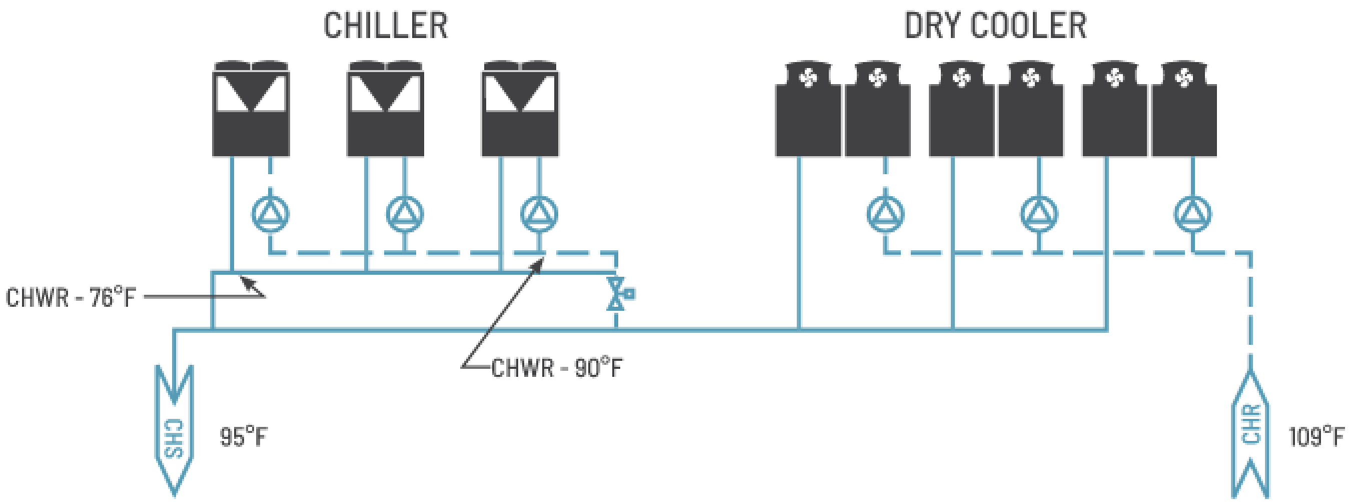




Hillsboro, OR – 95->76F Facility Water Supply



Separate Chiller Loop, Maximize Economizer



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Summary

- LImplementing liquid cooled solutions can be straightforward but there are important things to consider
- Detailed coordination is required with the IT technology equipment as it could drive facility solutions
- Think holistically!