ARE YOU READY?

Commissioning Liquid Cooled Data Centers

CAI Mission Critical

CAIReady.com

AGENDA

- Technology Overview
- Data Center Liquid Cooling Design Components
- T&C Methodology
- Project References
- Q&A

Technology Overview

BASIC CONCEPT

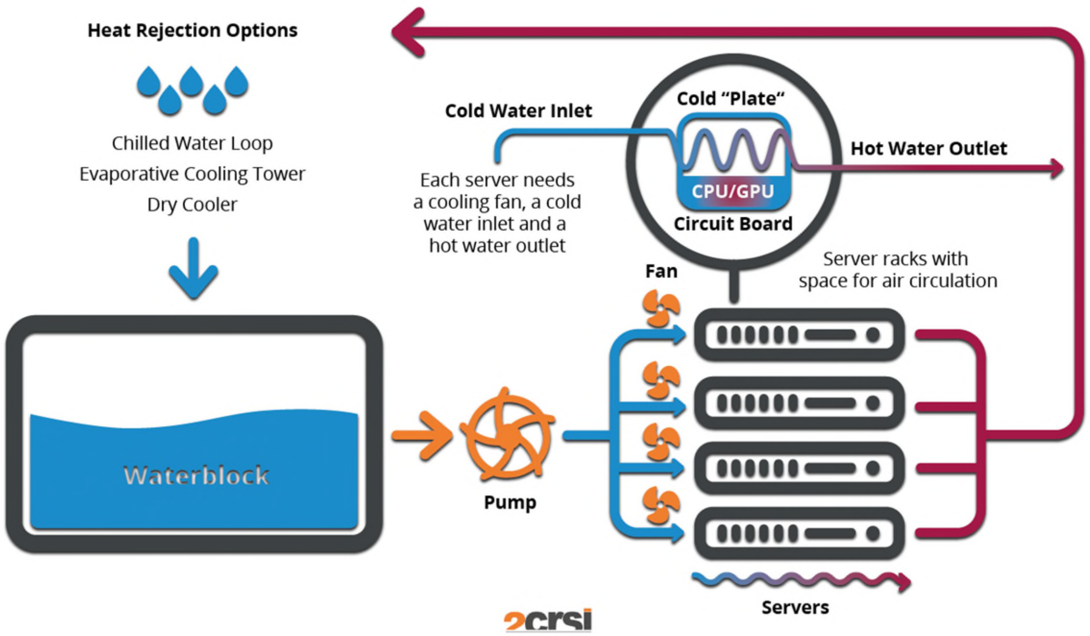
Liquid cooling technology operates by taking heat directly from the servers or chips using liquid as the heat transfer medium, instead of traditionally using air.

Types of liquid cooling:

1. Liquid Cooling Direct-to-Chip
   Use liquid to siphon off heat from processor components directly
2. Immersion cooling
   Servers are submerged in a dielectric fluid
   - Open Tub – Single Phase
   - Seal Tub – Two Phases

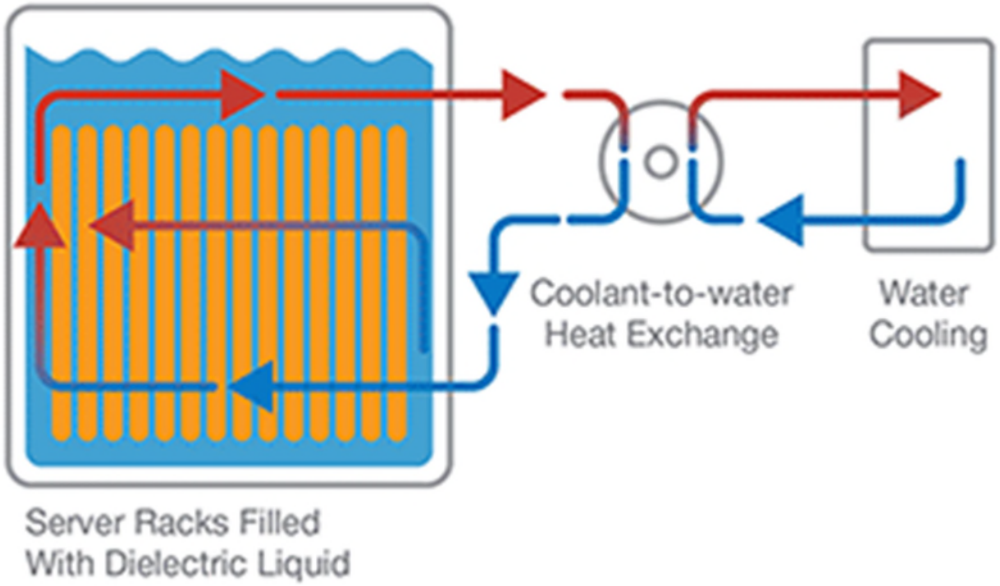
LIQUID COOLING DIRECT-TO-CHIP

- Liquid coolant is in contact with the hot components of a server - CPU or GPU - with a cold plate placed directly on the chip. The electric components are never in direct contact with the coolant.
- Fans are still required to provide airflow through the server to remove the residual heat. While the air-cooling infrastructure is greatly reduced.
- Coolants can be either water or dielectric fluids.



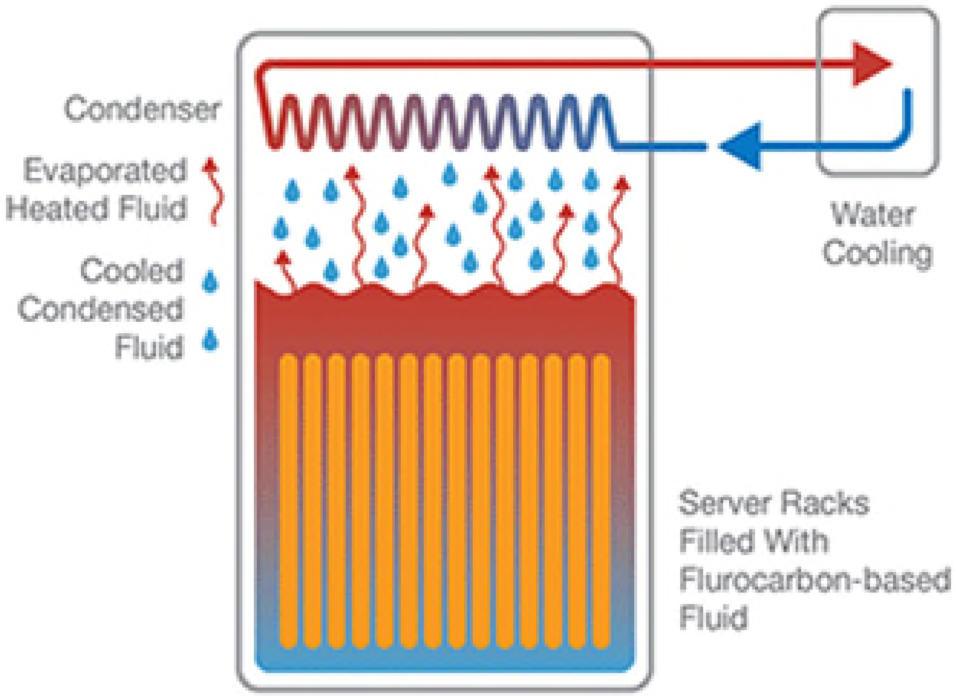
SINGLE PHASE IMMERSION COOLING

- Hardware is submerged in a dielectric fluid transferring heat away as the fluid flows through a heat rejection mechanism, such as a heat exchanger, which is typically operated with facility water.
- Organic or halogenated fluids may both be used in this application, although the latter are typically associated with higher cost and maintain a less favorable environmental sustainability profile.



TWO PHASE IMMERSION COOLING

- A fluorocarbon-based fluid readily boils when in contact with equipment hot spots, transitioning the fluid from a liquid to a vapor that can be condensed in a heat exchanger and recirculated into the cooling tank.
- This phase change of liquid to gas allows the fluid to draw large amounts of heat from the equipment but also requires integration of system design elements to facilitate the transition, and a sealed system to prevent costly fluid loss from evaporation.



ADVANTAGES

- More efficient than traditional air conditioning
- Compute-intensive workloads (AI / GPU)
- Density and space constraints
- Adapted for new applications (virtualization / security / AI)
- Targeted cooling where heat is directly removed from the hottest components
- Reduced need for air conditioning
- Recommended for rack >30kW / Required for rack >100kW
- Lower service and repair costs
- Removes the need for strict humidity control within space

CHALLENGES

Fluid Toxicity
- Toxic nature of chemicals used in fluid for immersion cooling

Corrosion
- Fluids utilized are potentially corrosive

Bacteria
- Although issues potentially arise with dielectric fluids, biocides can be introduced in small doses to eliminate bacteria

Material & Tubing
- Plastic material can introduce pollutants

Leakage
- Could have detrimental effects on facility equipment; insurance firms and equipment manufacturers may be hesitant to award policies or honor warranties on systems damaged due to immersion fluid leakage

Design & Implementation Competencies
- As liquid cooling designs increasingly emerge, expertise in facility delivery may come at a higher cost due to need for industry expertise

Data Center Liquid Cooling Design components

LIQUID-TO-CHIP SYSTEM BREAKDOWN

Primary

- Primary loop
- Cooing towers / Dry coolers
- Chillers (optional)
- Primary pumps
- Additional terminal units (FWU, CRAH, CRAC)
- Make-up water
- Accessories

Secondary

- Cooling Distribution Unit (CDU)
- Fluid/Fluid heat exchanger
- Secondary pump
- Controls and accessories
- Secondary loop
- Rack Manifolds
- Sensors and controls

Chiller

Dry Cooler

Cooling Tower

CRAH

CDU external view

CDU internal components

Liquid cooled Rack

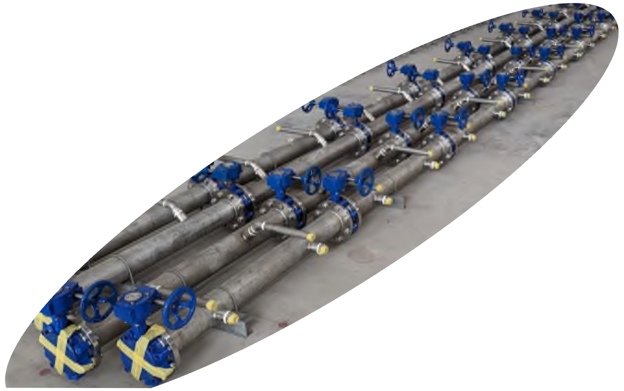
Direct-to-Chip

T&C Methodology

T&C METHODOLOGY – SECONDARY LOOP

Considerations:

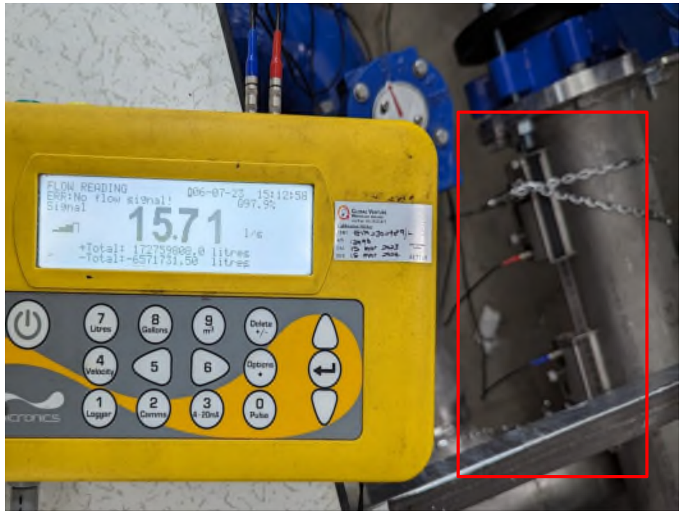
- CDU redundancy verification
- Specific SLAs to demonstrate
- Type of fluid and quality verification
- Fluid production and fill-up
- TAB, pressure drop and pressure setpoint
- Materials compatibility
- Flushing
- Pipes temperature and heat radiation in the white space/raised floor
- Access and maintainability (raise floor, et cetera)
- Couplings and quick connections
- Leakage risk mitigations, leak detection
- Prefab and QA/QC checks, welding, etc.



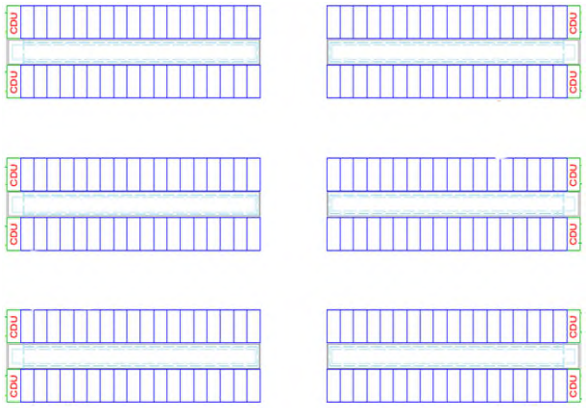
SECONDARY LOOP FLUSHING & TAB

Considerations:

- Type of fluid and quality verification
- Flushing velocity verification
- Fluid production and fill-up/top-up
- Flushing pump setup (skid?)
- Flushing pump connection
- Flushing bypass
- CDU flushing
- Manifolds flushing
- Dead legs
- Load bank flushing and connection sequence
- Drain points
- Venting points
- Flushing water availability and quality
- Potential fluid pollutions



Flow sensor



Data Hall Topology with 2N CDUs.

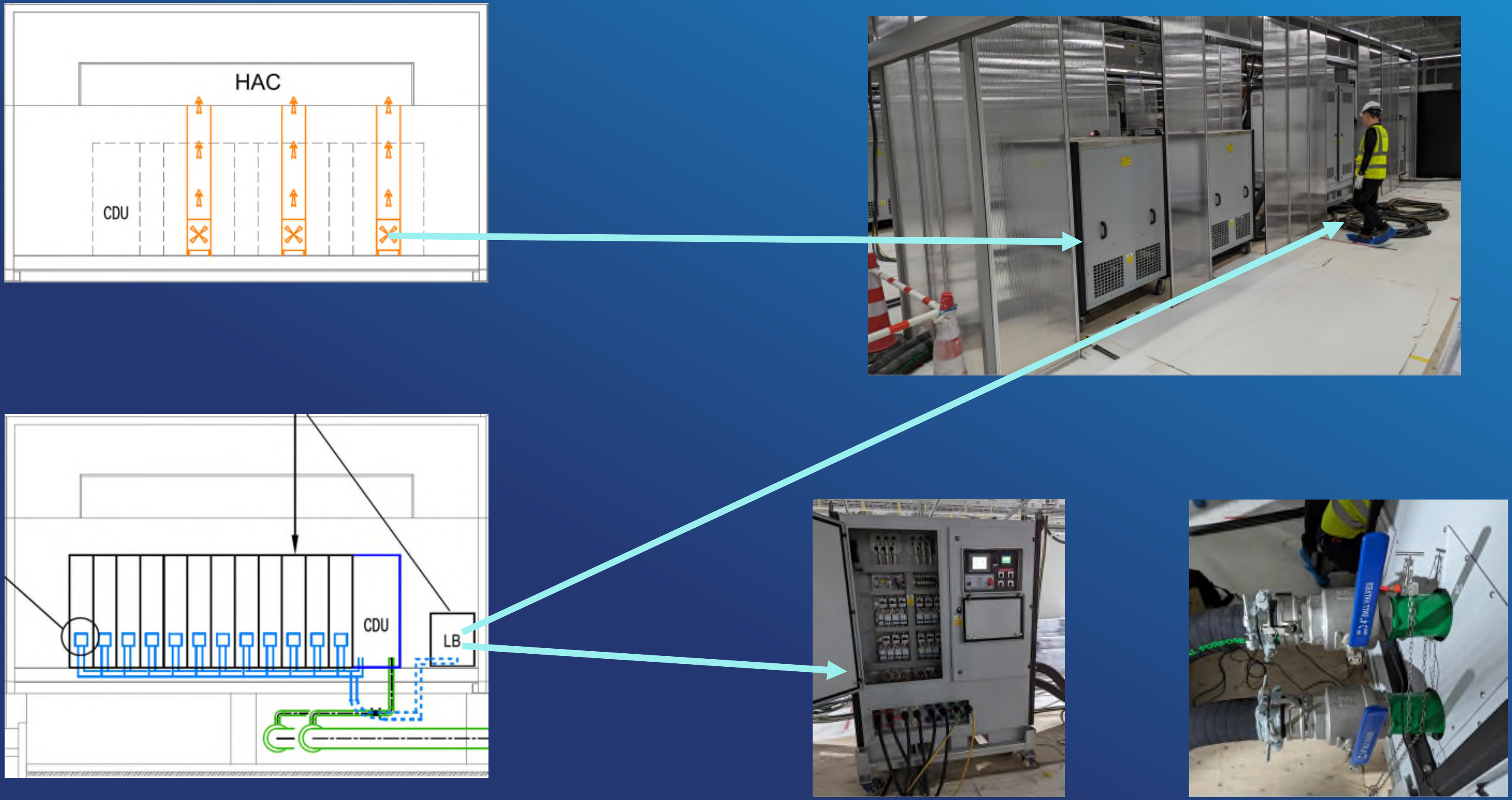
Testing Equipment

T&C METHODOLOGY – CX LEVEL 2

1. Safety Checks
2. Documentation
3. Installation Verifications – Mechanical
4. Installation Verifications - Electrical
5. Flushing is Crucial, Primary and Secondary
6. Loops System Walks

CDU Installation Checks
Check the cabinet done leveling and position bracket screw and nut tightened
Check external coolant and facility side pipe cutoff valve, pressure and temperature gauge installed for each CDU
Check incoming power supply for the unit including rating, torque marked, labelled and is isolated.
Check all control cables are terminated and labelled
Check earthing cable is connected firmly to earthing point
Check faclity water side piping connected, flushing and airtight passed. Report to be attached (by GC)
Check coolant side piping connected, flushing and airtight passed. Report to be attached (By GC)
Check 80L DI water prepare already for each unit filling
Check leak wire installed under raised floor and fix on concrete floor
Check installation position for Unit to match approved drawing
Check availability of primary condnesor water supply for unit
Check the supporting frame of unit
Check pipe size
Check pipe thermal insulation inside the unit
Check pipe IN/OUT connections to ensure that there is no leakage
Check the unit is clear of debris.
Check the drain pipe connection & installation (if applicable)
Check the unit isolator installation & condition (if applicable)
Check the condition of the plate heat exchanger
Check there is no damage to the external casing and internal components.
Check the installation of pumps and motors to ensure that all fixing bolts, wedges, and obstacles are already removed.
Check valves installation.
Check unit temperature and pressure sensor installation
Check wall mounted panels is installed in correct location (if applicable)
Conduct Insulation resistance on each conductor L-1-2, L2-3, L1-3, L-N, L-E
Check that the communication cables have been installed.
Check ATS has power connections terminated on both sources
Check batteries present and secure.
Check manual valves for condition and operation
Check secondary piping connection
Check the primary and secondary water systems have been flushed and cleaned by contractor in accordance with the relevant specification and method statement. Report to be provide prior inspection.
Correct labels applied
Correct external warning signs applied
Confirm with mechanical contractor pipework has been pressure and leak tested.
Check cable termination are properly torqued and marked.
Check all acessories (Expansion Tank, Heat Exchanger, filter, CDU pump, fill pump,control valve, touch panel, filling point, etc.) present, labels applied and no sign of damage.
Check interfaces with DCS
Confirm vendor spares available, appropriate and close to site

LOAD TESTS EQUIPMENT



CX LEVEL 3

1. Component Tests
2. Alarm & Communication Tests
3. Failure Tests
4. Basic Functional Tests
5. Load Tests
6. Redundancy Tests

Main tests overview:

1. Preliminary Checks/Visual Checks
2. CDU Energization
3. Controller setpoints and alarm checks
4. List of Event and Alarm Test on HMI
5. BMS communication, alarms and point to graphics checks
6. Individual Units Functional checks
    1. Automatic Operation Mode
    2. Standby Operation Mode
    3. Manual Mode test
    4. Auto Mode Test
7. Single CDU Load tests, Full and partial Load (100%/50%)
    1. Primary Side (Flow, dP, S&R Temp, dT, Capacity)
    2. Secondary Side (Flow, dP, S&R Temp, dT, Capacity)
    3. Power verifications (Voltage, Current, Hz, Power Factor, consumption, Apparent power)
8. Coolant Supply Temperature Sensor Failure Mode (In pressure and flow control mode)
9. Coolant Supply/Return Pressure Sensor Failure Mode (In pressure and flow control modes)
10. Coolant Flow Sensor Failure Mode (In flow control mode)
11. Pump Failure Test (In pressure and flow control modes)
12. Control Board Failure Test (In pressure and flow control modes)
13. Control Board Failure Test During Minimum Flow (In flow control mode)
14. Filing Pump Operation and Failure Test
15. ATS Operational Test
16. Battery Backup Time Test
17. Leakage Sensor Test
18. CDU Failure in Group Control test (for all control mode)
    1. Pump Failure
    2. EPICV Failure
    3. Control Board Failure
    4. Flow Sensor Failure
    5. ATS Operational Test
19. CDU Internal Communication Loss
20. As Left Test Conditions

CX LEVEL 4

1. Advanced Functional Tests
2. Group Failure Scenarios

Level 4 Functional Performance Test Procedure - CDU

A. Manual Mode - HAND / OFF / AUTO Modes and Switch Functionality

B. Manual Mode - Manual Mode Local Control

C. Manual Mode - HAND Mode Pump Speed Control

D. DCS Remote Enable / Disable Operation

E. Coolant temperature Control - Automatic

F. Pump Flow Control - Automatic

G. Fill Mode - Automatic

H. Failure Scenarios

- Loss of Primary Power Source A/B
- CDU Leak alarm
- CDU Pump Failure
- ePICV Failure
- Control Board Failure
- Flow Sensor Failure
- Supply Temperature Sensor Failure
- Return Temperature Sensor Failure
- Coolant Supply Pressure Sensor Failure
- Coolant Return Pressure Sensor Failure
- DCS HLI Communication Loss

I. Alarm Verifications

K. Post CxL4 Documentation & Closeout

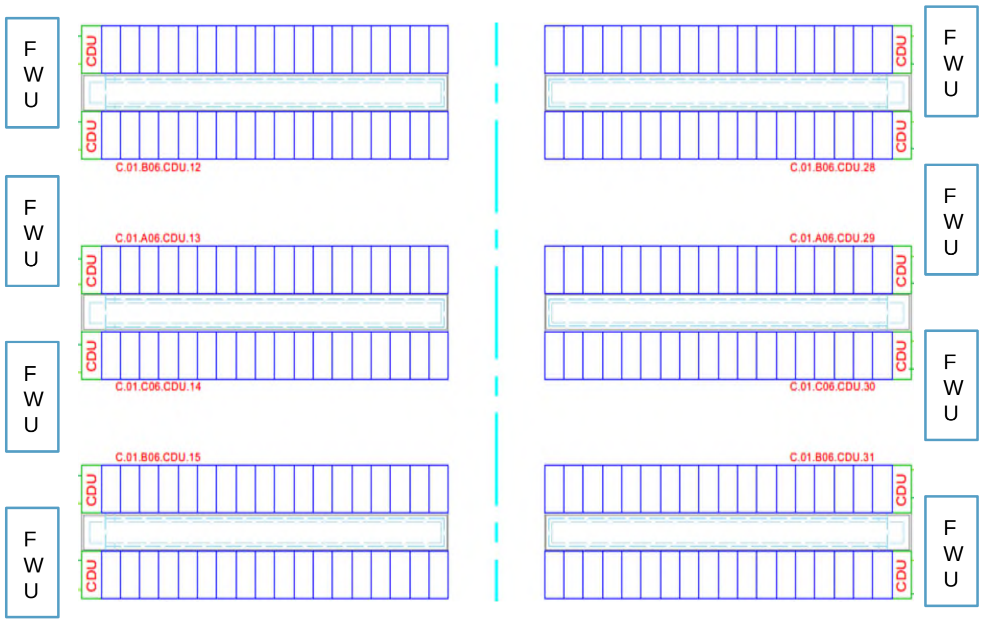
CX LEVEL 5 - IST

Electrical IST

- Additional consideration for the CDU power availability and busway loads

Mechanical IST

- Heat Load test (33%, 50%, 66%, 75%, 100%)
- Chilled/Cooled water plant tests
- Primary loop redundancy Test
- Secondary Loop redundancy Test (if necessary)
- Terminal unit redundancy tests (FWU/CRAH/IEC)
- CDU Redundancy Tests



Data Hall Topology

LOAD TESTS - SAFETY

Project References

CAI EXPERIENCE WITH LIQUID COOLING

Facility: 3x 25 MW Colocation Data Center
Location: Johor, Malaysia
Client: Confidential
System: Liquid to Chip Technology
Status: Commissioned in 2023 & 2024

Facility: 100+ MW Colocation Data Center
Location: Middle East
Client: Confidential
System: 2 Phase Immersion Cooling Technology
Status: In Progress

Facility: Large Scale Colocation Data Center
Location: Texas, USA
Client: Confidential
System: 2 Phase Immersion Cooling Technology
Status: In Progress

Q&A

Any questions?