Engineering Workshop: Advanced Cooling
Solving the Energy Challenge through Innovations in Data Center Cooling

3m.com/immersion    Booth# B44

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Charles Benge, Director Mission Critical
Agenda

• Immersion Cooling Technology Introduction

• 3M Roadmap for Immersion Cooling at Open Compute

• Hyperscale Case Study Findings
Fluorochemical (FC) Fluids in Electronics Cooling:

- Non-flammable / Non-combustible
- Excellent Safety Profile
- Chemically Inert
- Electrically Non-Conductive
- Wide Range of Boiling Points

Immersion Cooling Approach

- Radar Klystrons and Military Test Methods Developed around FC Fluids.
- Cray Begins using FC Fluids for Immersion Cooling of Supercomputers.
- Allied Control Deploys 2-Phase Immersion with FC Fluids at 40MW Scale for Bitcoin Mining.

- IBM, 3M and Purdue Pioneer Use of 2-Phase Immersion with FC Fluids.
- Alibaba’s project Qilin paves the way for First Hyperscale X86 Deployment.
• Leverage OCP Data Center Project to help form immersion cooling ecosystem

• Seek collaborators to participate and contribute designs, best practices
  – IT hardware, mechanical systems, facility designs, power delivery

• **Today**: Hyperscale Case Study Findings

• **Near Future**: Immersion cooled power supply
Conventional air cooled commodity AC power supplies are not ideal for immersion and all power supplies are thermally limited. Expected modifications:

- **Firmware** – modify to operate without fan tach and at elevated temp
- **Density** – A typical PSU is about 80% air, adding fluid cost and weight
- **Organic Contaminants** – PSUs often contain solder flux, conformal coatings, silicone elastomers, hot melt adhesives, etc
- **Heat sinks** required for air cooling of MOSFETs are unnecessary
- **Electrical coatings**, potting and Isolation pads are unnecessary in filtered liquid dielectrics
- **Current capacity ratings** – The current capacity of circuit traces, FETs and resistors are driven by thermal considerations that shift in an immersion environment in ways that can reduce cost

**OCP Deliverable:** Immersion cooled AC power supply specification and concept
Future path to immersion cooled on-board power module

**Expected Benefits:** Lower cost/KW; Higher density; Reduced BOM
Case Study
Passive 2-Phase Immersion Cooling:

- Servers are placed side-by-side in a lidded bath of dielectric fluid.
- Devices cause fluid to boil.
- Rising vapor condenses transferring heat passively to facility water.
Project Requirements:

- 30 MW IT Load
- Hyper-scale deployment
- (4) 7.5 MW Data Halls
- Potential phased delivery
- Des Moines, IA
- 10 kW Avg. Air-cooled Rack
- 150 kW Avg. Tank
- Tier 3 Uptime Reliability

Comparison Criteria

Physical Metrics
- Acreage required for Site Development
- Gross Building Square Footage
- Data Hall Square Footage
- Watts per Square Foot

Construction Cost
- Total Cost built as single phase
- Cost per MW
- Cost per Square Foot
- Sub-system breakdown
- Focus on Mechanical and Electrical
- Labor rates for specialized systems

Construction Schedule
- Total Construction Time
- Equipment Procurement Time
- Labor Manpower

Mechanical and Electrical Systems
- Reliability
- Efficiency
- Practicality

Telecom / Compute
- GPU Server Architecture
- Density
- Server
- Cost per Compute - TBD

General
- Complexity/Simplicity
- Perception of Feasibility
- OpEx - TBD
- Sustainability
- Applicability
Immersion Cooling Module

- Tank Dimensions 7'-8" W x 2'-6" D x 5'-4" H
- Power, Process water and Telecom from above
- No raised floor needed, simplifying construction
- Much lower room height without any air plenum
- 150kW planned capacity per Tank
- Busbar system in bottom of Tank
- Ample white space around each tank, could be even higher density
Facility Comparison

**Air-cooled Hyper-scale**
- (4) 20,160 sf Data Halls
- Average 10 kW / cabinet
- 864 Cabinets / Hall
- 3,456 Cabinets Total
- Admin/Circulation: 32,779
- White Space: 80,640
- Direct Support: 106,894
- Total SF: 220,313
- WSF: 370

**Immersion Cooled**
- (4) 6,604 sf Data Halls
- Average 150 kW / Tank
- 54 Tanks / Hall
- 216 Tanks Total
- Admin/Circulation: 24,718
- White Space: 26,416
- Direct Support: 38,120
- Total SF: 89,254
- WSF: 1,100
Building Configuration

- Roof mounted Mechanical equipment
- No ceiling air plenum = reduced roof height
- Roof penetrations possible
- Simplified Electrical topology provides more reliability
- Tier 3 design
- 2.5 MW cell with single generator
- High density tanks require fewer electrical connections per kW
- Fluid is an insulator and reduces arc-flash risk
- 277V distribution provides reduction of electrical components such as PDU, RPP and busway
- 277V is a U.S. standard

<table>
<thead>
<tr>
<th></th>
<th>Air cooled</th>
<th>Immersion cooled</th>
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</thead>
<tbody>
<tr>
<td>IT Load</td>
<td>30 MW</td>
<td>30 MW</td>
</tr>
<tr>
<td>Phasing</td>
<td>(4) 7.5 MW Data Halls</td>
<td>(4) 7.5 MW Data Halls</td>
</tr>
<tr>
<td>Increment</td>
<td>(3) 2.5 MW cells / Hall</td>
<td>(3) 2.5 MW cells/per Hall</td>
</tr>
<tr>
<td>Backup</td>
<td>(2) Parallel 2250 Gensets</td>
<td>(1) 3250 Genset (w/ Catcher system)</td>
</tr>
<tr>
<td>Main Switchgear</td>
<td>5000A</td>
<td>4000A</td>
</tr>
<tr>
<td>UPS</td>
<td>(5) 500 kVA UPS Modules</td>
<td>(4) 700 kVA UPS Modules</td>
</tr>
<tr>
<td>UPS Distribution SWB</td>
<td>4000A SWB</td>
<td>4000A SWB</td>
</tr>
<tr>
<td>PDU</td>
<td>(4) 750 kVA PDU’s</td>
<td>N/A</td>
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<tr>
<td>Distribution</td>
<td>240V Distribution</td>
<td>277 U.S. Standard</td>
</tr>
<tr>
<td>Server Connection</td>
<td>Plugin Busway</td>
<td>Direct to server</td>
</tr>
<tr>
<td>Total Mechanical Load</td>
<td>11 MVA</td>
<td>3 MVA</td>
</tr>
<tr>
<td>Estimated Site Load</td>
<td>41 MVA</td>
<td>33 MVA</td>
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### Mechanical Topology

- Simplified Mechanical topology provides more reliability
- Tier 3 design
- No chillers with economizers and complex controls
- Removal of chillers eliminates need for major, time-consuming PMs and overhauls
- High density tanks are passive mechanical devices
- Water temperature in many climates allows for full capacity cooling without evaporation infrastructure
- Opportunity for heat recovery with Process Water

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<td>Phasing</td>
<td>(4) 7.5 MW Data Halls</td>
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</tr>
<tr>
<td>Data Hall Cooling</td>
<td>(22) 372 kW CRAHs / Hall</td>
<td>(54) Passive immersion tanks / Hall</td>
</tr>
<tr>
<td></td>
<td>Requires Containment</td>
<td></td>
</tr>
<tr>
<td>Cooling Plant</td>
<td>WC Chiller Plant / Hall</td>
<td>Dry Coolers / Hall</td>
</tr>
<tr>
<td>Chillers</td>
<td>(3) 1280 Ton WCC</td>
<td>None</td>
</tr>
<tr>
<td>Pumps</td>
<td>(9) CHWP, CWP, CWBP</td>
<td>(9) Process Pumps</td>
</tr>
<tr>
<td>Cooling Towers</td>
<td>(3) 1280 Ton Evaporative</td>
<td>(9) Dry coolers</td>
</tr>
<tr>
<td>Water Temp</td>
<td>CHW: 60 F / 76 F</td>
<td>Process: 112 F / 127 F</td>
</tr>
<tr>
<td>PUE</td>
<td>1.23</td>
<td>1.07</td>
</tr>
<tr>
<td>Estimated Annual</td>
<td>$19.4M</td>
<td>$16.9M</td>
</tr>
<tr>
<td>Electricity Cost</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Estimated Annual</td>
<td>299 Mgal (MU + WW)</td>
<td>0 Gal</td>
</tr>
<tr>
<td>Water Consumption</td>
<td>$21.05M</td>
<td>$16.9M</td>
</tr>
<tr>
<td>Estimated Energy Cost</td>
<td></td>
<td></td>
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## Telecom Comparison

<table>
<thead>
<tr>
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<th>Air cooled</th>
<th>Immersion cooled</th>
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</thead>
<tbody>
<tr>
<td><strong>Server Housings</strong></td>
<td>864 Cabinets per Data Hall</td>
<td>54 Tanks per Data Hall</td>
</tr>
<tr>
<td></td>
<td><strong>3,456 Cabinets</strong></td>
<td><strong>216 Tanks</strong></td>
</tr>
<tr>
<td><strong>Servers</strong></td>
<td>13 (2 GPU) per Cabinet</td>
<td>48 (8 GPU) per Tank</td>
</tr>
<tr>
<td></td>
<td>11,232 per Data Hall</td>
<td>2,592 per Data Hall</td>
</tr>
<tr>
<td></td>
<td><strong>44,928 Servers</strong></td>
<td><strong>10,368 Servers</strong></td>
</tr>
<tr>
<td><strong>Prod Switches (A+B)</strong></td>
<td>2 per 3 Cabinets</td>
<td>2 per Tank</td>
</tr>
<tr>
<td></td>
<td>576 per Data Hall</td>
<td>108 per Data Hall</td>
</tr>
<tr>
<td></td>
<td><strong>2,304 Switches</strong></td>
<td><strong>432 Switches</strong></td>
</tr>
<tr>
<td><strong>Connectivity</strong></td>
<td>1 Gb Cat6 (Servers to Switch)</td>
<td>10 Gb Cat6 (Servers to Switch)</td>
</tr>
<tr>
<td></td>
<td>10 Gb 6MMF MPO (Switch to Core)</td>
<td>100 Gb 24MMF MPO (Switch to Core)</td>
</tr>
<tr>
<td><strong>Telecom ROM</strong></td>
<td>$16.3M (hard cost)</td>
<td>$3.7M (hard cost)</td>
</tr>
</tbody>
</table>
$4.8M per MW less expensive than traditional Air-Cooled Server Data Center

- $195M Immersion v. $348M Air-cooled

- No need for PDUs, RPPs, Busway or CRAH/CRACs in Data Center Space

- Tanks eliminate traditional cabinets and reduce fiber & copper cabling needs

- Better Utilization & Efficiency of Electrical & Mechanical systems Reduce Equipment Counts without sacrificing Redundancy
30% Construction Schedule Reduction

- Reduced Site & Structural Construction Compared to Traditional Build of Equal Computing Power
- Less “Long Lead” Equipment
- Fewer Pieces of Critical Equipment in Data Hall Space