Chilled Water Piping Configurations

Roy Hubbard
Agenda

- Understanding the three basic piping systems
  - Design and Off-design operation
  - Advantages and Disadvantages
- Low DeltaT Syndrome – causes, effects, and solutions
- Design & Control Considerations (VPF)
  - Chillers
  - CHW Pumps
  - Bypass Valve
Chilled Water Piping System Types (typical)

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Load Valves</th>
<th>Installed Cost</th>
<th>Pumping Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant Primary Flow</td>
<td>3-way</td>
<td>Lowest</td>
<td>Highest</td>
</tr>
<tr>
<td>Primary / Secondary</td>
<td>2-way</td>
<td>Highest</td>
<td>Medium</td>
</tr>
<tr>
<td>Variable Primary Flow</td>
<td>2-way</td>
<td>Medium</td>
<td>Lowest</td>
</tr>
</tbody>
</table>
Load Equation

Load = Flow X DeltaT
Constant Primary Flow (CPF)
Constant Primary Flow (CPF)

Dedicated Pumping

Load = Flow X DeltaT

Constant Primary Flow at 100% System Load
Three-way valves control capacity by varying water temperature range in coil
Constant Primary Flow at **Design**

**Table:**

<table>
<thead>
<tr>
<th></th>
<th>Per Chiller</th>
<th>System</th>
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</thead>
<tbody>
<tr>
<td><strong>Load</strong></td>
<td>500 Tons (1760 kW)</td>
<td>1500 Tons (5280 kW)</td>
</tr>
<tr>
<td><strong>Primary</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Flow</strong></td>
<td>3000 gpm (189 l/s)</td>
<td></td>
</tr>
<tr>
<td><strong>Delta T</strong></td>
<td>12°F (6.7°C)</td>
<td></td>
</tr>
</tbody>
</table>
Constant Primary Flow at **75% Load**

<table>
<thead>
<tr>
<th>Primary</th>
<th>Per Chiller</th>
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<tbody>
<tr>
<td>Flow</td>
<td>3000gpm (189 l/s)</td>
<td>1125 Tons (3960kW)</td>
</tr>
<tr>
<td>Delta T</td>
<td>9°F (5.6°C)</td>
<td>9°F (5.6°C)</td>
</tr>
</tbody>
</table>

Load

<table>
<thead>
<tr>
<th>Load</th>
<th>Per Chiller</th>
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<tbody>
<tr>
<td>375 Tons (1320kW)</td>
<td>1125 Tons (3960kW)</td>
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</tbody>
</table>
**Constant Primary Flow at 50% Load**

<table>
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</thead>
<tbody>
<tr>
<td>Load</td>
<td></td>
</tr>
<tr>
<td>250 Tons (880kW)</td>
<td>750 Tons (2640kW)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Primary</th>
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<tbody>
<tr>
<td>Flow</td>
</tr>
<tr>
<td>Delta T</td>
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</table>
Constant Primary Flow at **25% Load**

<table>
<thead>
<tr>
<th>Per Chiller</th>
<th>System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load</td>
<td>125 Tons (440kW)</td>
</tr>
<tr>
<td>Primary</td>
<td></td>
</tr>
<tr>
<td>Flow</td>
<td>3000 gpm (189 l/s)</td>
</tr>
<tr>
<td>Delta T</td>
<td>3°F (1.7°C)</td>
</tr>
</tbody>
</table>
Constant Flow Primary

- **Advantages**
  - Lowest installed cost
  - Less plant space than P/S
  - Easy to Control & Operate
  - Easy to Commission

- **Disadvantages**
  - Highest Plant Energy Cost (must run all, even at low loads)
Primary (Constant) / Secondary (Variable)
Primary (Constant) / Secondary (Variable)

SLoad = Flow X DeltaT

PLoad = Flow X DeltaT
Primary (Constant) / Secondary (Variable)

Headered Pumping
Primary (Constant) / Secondary (Variable)

*Dedicated Pumping*
Primary (Constant) / Secondary (Variable)

**Rule of Flow**

Primary flow must always be equal to or greater than Secondary flow.
Primary/Secondary at Design

<table>
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<tbody>
<tr>
<td>Load</td>
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<tr>
<td>500 Tons (1760kW)</td>
<td>1500 Tons (5280kW)</td>
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<table>
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<tr>
<th></th>
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<th>Bypass</th>
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<tbody>
<tr>
<td>Flow</td>
<td>3000gpm (189 l/s)</td>
<td>3000gpm (189 l/s)</td>
<td>0gpm (0 l/s)</td>
</tr>
<tr>
<td>Delta T</td>
<td>12°F (6.7°C)</td>
<td>12°F (6.7°C)</td>
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100% Load = 100% Sec Flow

100 ft (303 kPa) Head

50 ft (152 kPa) Head
Primary/Secondary at 75% Load

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<tr>
<td>Flow</td>
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</tr>
<tr>
<td>3000gpm (189 l/s)</td>
<td>2250gpm (142 l/s)</td>
<td>750gpm (47 l/s)</td>
</tr>
<tr>
<td>Delta T</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9°F (5°C)</td>
<td>12°F (6.7°C)</td>
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</tbody>
</table>

75% Load = 75% Sec Flow

Primary Pumps
1000 GPM Each (63 l/s)
500 Ton (1760 kW) Chillers

Secondary Pumps
2250 GPM @ 44 °F
142 l/s @ 6.7 °C

Cooling Coils with Two-Way Valves

75% Load = 75% Sec Flow

56 °F (13.3 °C)
Primary/Secondary at 50% Load

Primary Pumps 1000 GPM Each (63 l/s)  
500 Ton (1760 kW) Chillers

2000 GPM @ 53 °F  
(126 l/s) @ 11.7 °C

53 °F  
(11.7 °C)

53 °F  
(11.7 °C)

Secondary Pumps  
1500 GPM @ 44 °F  
95 l/s @ 6.7 °C

Cooling Coils with Two-Way Valves

500 GPM @ 44 °F  
32 l/s @ 6.7 °C

50% Load = 50% Sec Flow

Per Chiller | System
---|---
Load | 375 Tons (1320kW) 750 Tons (2640kW)

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<tr>
<td>Flow</td>
<td>2000gpm (126 l/s)</td>
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<td>500gpm (32 l/s)</td>
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<td>Delta T</td>
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Primary/Secondary at 25% Load

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<tbody>
<tr>
<td>1000 gpm (126 l/s)</td>
<td>750 gpm (47 l/s)</td>
<td>250 gpm (16 l/s)</td>
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</table>

<table>
<thead>
<tr>
<th>Delta T</th>
<th>Primary</th>
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<td>9°F (5°C)</td>
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25% Load = 25% Sec Flow
What Controls the Flow of the Secondary Loop?

But what controls the VSD’s?
Valve Controls Leaving Air Temperature (LAT)
Valve Controls Leaving Air Temperature (LAT)
Set Point = 55° (12.8°) LAT

EAT = 80 (26.7)

LAT = 55 (12.8)
Valve Controls Leaving Air Temperature (LAT)  
Set Point = 55° (12.8°) LAT
Valve Controls Leaving Air Temperature (LAT)
Set Point = 55º (12.8º) LAT

AIR FLOW
EAT = 79 (26.1)

T
AIR FLOW
LAT = 54 (12.2)
As Valve Opens, Pressure in loop lowers
As Valve Closes, Pressure in loop rises
Pressure Differential Sensor Controls Secondary Pump Speed

Differential Pressure sensor on last coil

- controls speed
- to Set Point (coil WPD+Valve PD+Piping PD+Safety)
- located at end of Index Circuit for best efficiency

Set Point
P=25 ft (76 kPa)
Primary (Constant) / Secondary (Variable)

**Advantages**
- Easy to Control
- Easy to Commission
- Loop separation
  - Easier trouble-shooting
  - Separating isolated loads/buildings for lower total pump energy
  - Lower Plant Energy (can sequence chillers and ancillary equipment)
- Versatile – multi-circuit capability

**Disadvantages**
- Medium Pump Energy Cost
- Highest Installed Cost (Sec Pumps, Piping, etc.)
- Potential for higher plant energy loss because of Low Delta T syndrome
Variable Primary Flow
Variable Primary Flow

\[
\text{Load} = \text{Flow} \times \Delta T
\]

Variable Primary Flow at 100% System Load
Two-way valves control capacity
By varying flow of water in coils
Primary/Secondary System

Three Differences?

Variable Primary System
Variable Primary Flow at Design

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<td>Delta T</td>
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100% Load = 100% Flow
Variable Primary Flow at 75% Load

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<tr>
<td>Flow</td>
<td>2250 gpm (189 l/s)</td>
<td>0 gpm (0 l/s)</td>
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<tr>
<td>Delta T</td>
<td>12°F (6.7°C)</td>
<td>----</td>
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75% Load = 75% Flow
### Variable Primary Flow at 50% Load

**Diagram:**
- Primary Pumps: 750 GPM each (47 l/s)
- Flow Meter: 1500 GPM @ 56 ºF (95 l/s) @ 13.3 ºC
- Cooling Coils with Two-Way Valves
- Bypass Valve Closed
- Condenser
- Evaporator
- VSD

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<td>Flow</td>
<td>1500 gpm (95 l/s)</td>
</tr>
<tr>
<td>Delta T</td>
<td>12 ºF (6.7 ºC)</td>
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**Legend:**
- 50% Load = 50% Flow
**Variable Primary Flow at 25% Load**

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<tbody>
<tr>
<td><strong>Flow</strong></td>
<td>750 gpm (95 l/s)</td>
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<tr>
<td><strong>Delta T</strong></td>
<td>12°F (6.7°C)</td>
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</table>

**25% Load = 25% Flow**
Variable Primary Flow in Bypass Mode
System flow below chiller min flow (250 gpm)

<table>
<thead>
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<tbody>
<tr>
<td>Load</td>
<td>50 Tons (176 kW)</td>
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</tbody>
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<td>Flow</td>
<td>250 gpm (95 l/s)</td>
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Varying Flow Through Chillers - Issues

- **Issue During Normal Operation**
  - Chiller Type (centrifugal fast, absorbers slow)
  - Chiller Load (min load - no variance, full load - max variance)
  - System Water Volume (more water, more thermal capacitance, faster variance allowed)
  - Active Loads (near or far from plant)
  - Typical VSD pump ramp rate setting of 10%/minute (accel/decel rates set to 600 seconds)
Varying Flow Through Chillers - Issues

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  - Active Loads (near or far from plant)
  - Typical VSD pump ramp rate setting of 10%/minute (accel/decel rates set to 600 seconds)

- **Issue Adding Chillers**
  - Modulating isolation valves on chillers
Variable Primary System – Staging on chillers & changes in flow rate

Current Situation – 1 chiller running

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<tr>
<td>Load</td>
<td>500 Tons (1760kW)</td>
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</tbody>
</table>

1000 GPM @ 44 °F
63 l/s @ 6.7 °C

Primary Pumps
500 GPM each
(32 l/s)

1000 GPM @ 56 °F
(63 l/s) @ 13.3 °C
Variable Primary System – Staging on chillers & changes in flow rate

Current Situation – building load increases, valve opens, second chiller starts

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<tbody>
<tr>
<td>Load</td>
<td></td>
</tr>
<tr>
<td>275 Tons (967kW)</td>
<td>550 Tons (1934kW)</td>
</tr>
</tbody>
</table>

If valve opens too quick:
Chiller, shuts down on low chilled water temp cutout

Best practice!
Open valve over 1.5 to 2 minutes to allow for system stabilization

Primary Pumps
550 GPM each (35 l/s)

1100 GPM @ 45 °F
69 l/s @ 7.2 °C

Flow Meter
Bypass Valve Closed

1100 GPM @ 57 °F
(69 l/s) @ 13.9 °C

45.0 °F
(7.2 °C)
Variable Primary Flow (VPF) System Arrangement

- **Advantages**
  - Lower Installed Cost (approx. 5% compared P/S)
    - No secondary Pumps or piping, valves, electrical, installation, etc.
    - Offset somewhat by added 2W Bypass Valve and more complex controls
  - Less Plant Space Needed
  - Best Chilled Water Pump Energy Consumption *(most optimeady configuration)*
    - VSD energy savings
    - Lower Pump Design Head
Primary/Secondary

Primary Pumps
1000 GPM Each (63 l/s)

Condenser
56 °F (13.3 °C)
Evaporator

Condenser
56 °F (13.3 °C)
Evaporator

Condenser
56 °F (13.3 °C)
Evaporator

Secondary Pumps
3000 GPM @ 44 °F
189 l/s @ 6.7 °C

100 ft (303 kPa) Head

Cooling Coils with Two-Way Valves

0 GPM @ 44 °F
0 l/s @ 6.7 °C

50 ft (152 kPa) Head
Variable Primary Flow

- 140 ft (424 kPa) Head
Pump Energy

\[
BHP = \frac{GPM \times \text{Head}}{3960 \times \text{Pump}_{\text{Eff}}}
\]
Variable Primary Flow (VPF) System Arrangement

- **Advantages**
  - Lower Installed Cost (approx. 5% compared P/S)
    - No secondary Pumps or piping, valves, electrical, installation, etc.
    - Offset somewhat by added 2W Bypass Valve and more complex controls
  - Less Plant Space Needed
  - Best Chilled Water Pump Energy Consumption (most optimeady configuration)
    - VSD energy savings
    - Lower Pump Design Head
    - **Higher Pump Efficiency**
With VPF you will need larger pumps compared to P/S, but they will be operating at a more efficient point, yielding energy savings.
Pump Energy

$$\text{BHP} = \frac{\text{GPM} \times \text{Head}}{3960 \times \text{Pump}_{\text{Eff}}}$$
Variable Primary Flow (VPF) System Arrangement

- **Advantages**
  - Medium Installed Cost (approx. 5% compared P/S)
    - No secondary Pumps or piping, valves, electrical, installation, etc.
    - Offset somewhat by added 2W Bypass Valve and more complex controls
  - Less Plant Space Needed (vs P/S)
  - Best Chilled Water Pump Energy Consumption *(most optimally configuration)*
    - VSD energy savings
    - Lower Pump Design Head
    - Higher Pump Efficiency
  - Lower potential impact from Low Delta T (can over pump chillers if needed)
Variable Primary Flow (VPF) System Arrangement

- **Advantages**
  - Medium Installed Cost (approx. 5% compared P/S)
    - No secondary Pumps or piping, valves, electrical, installation, etc.
    - Offset somewhat by added 2W Bypass Valve and more complex controls
  - Less Plant Space Needed (vs P/S)
  - Best Chilled Water Pump Energy Consumption (most optimal design configuration)
    - VSD energy savings
    - Lower Pump Design Head
    - Higher Pump Efficiency
  - Lower potential impact from Low Delta T (can over pump chillers if needed)

- **Disadvantages**
  - Requires more robust (complex and properly calibrated) control system
  - Requires coordinated control of chillers, isolation valves, and pumps
  - Potentially longer commissioning times to tune the system
  - Need experienced facility manager to operate/maintain properly
Low Delta T Syndrome

Design Delta T = 12°F

Cooling Coils with Two-Way Valves

Primary Pumps

Condenser

Evaporator

Secondary Pumps

VSD

VSD

VSD

56°F

44°F
Major Causes of Low Delta T

- Dirty Coils
Chilled Water Coil
Chilled Water Coil

Load = Flow X Delta T

56 (13.3)

44 (6.7)
Chilled Water Coil

Load = Flow \times \Delta T
Major Causes of Low Delta T

- Dirty Coils
- Controls Calibration
- Leaky 2-Way Valves
- Coils Piped-Up Backwards
Chilled Water Coil

AIR FLOW

56 (13.3)

AIR FLOW

44 (6.7)
Major Causes of Low Delta T

- Dirty Coils
- Controls Calibration
- Leaky 2-Way Valves
- Coils Piped-Up Backwards
- Mixing 2-Way with 3-Way Valves in the same system
Low Delta T Syndrome
3 Way Valves Mixed with 2 Way
Primary/Secondary at Design

*Ideal Operation*

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**Chart:**

- **Primary Pumps:** 1000 GPM Each (63 l/s)
- **Secondary Pumps:** 3000 GPM @ 44 °F (189 l/s @ 6.7 °C)
- **Condensers**:
  - 56 °F (13.3 °C)
  - 56 °F (13.3 °C)
  - 56 °F (13.3 °C)
- **Evaporators**:
  - 12 °F (6.7 °C)
  - 12 °F (6.7 °C)
  - 12 °F (6.7 °C)

**Delta T**:

- Primary: 12 °F (6.7 °C)
- Secondary: 12 °F (6.7 °C)
- Bypass: ----

**Flow**:

- Primary: 3000gpm (189 l/s)
- Secondary: 3000gpm (189 l/s)
- Bypass: 0 gpm (0 l/s)

**Cooling Coils with Two-Way Valves**

---

**100% Load = 100% Sec Flow**
Primary/Secondary at 67% Load

*Ideal Operation*

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<tr>
<td>500 Tons</td>
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<tr>
<td>1760kW</td>
<td>3518kW</td>
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<td>(126 l/s)</td>
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</tr>
<tr>
<td>12°F (4.4°C)</td>
<td>12°F (6.7°C)</td>
<td>----</td>
</tr>
</tbody>
</table>

67% Load = 67% Sec Flow

Primary Pumps
1000 GPM Each
(63 l/s)

Secondary Pumps
2000 GPM @ 44°F
126 l/s @ 6.7°C

Cooling Coils with Two-Way Valves

44°F
(6.7°C)

12°F
(6.7°C)

0 GPM @ 44°F
0 l/s @ 6.7°C
Primary/Secondary at 67% Load

Low DeltaT

<table>
<thead>
<tr>
<th>Per Chiller</th>
<th>System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load</td>
<td></td>
</tr>
<tr>
<td>500 Tons</td>
<td>1000 Tons</td>
</tr>
<tr>
<td>(1760kW)</td>
<td>(3518kW)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Primary</th>
<th>Secondary</th>
<th>Bypass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow</td>
<td>2000gpm (126 l/s)</td>
<td>2280gpm (144 l/s)</td>
</tr>
<tr>
<td>Delta T</td>
<td>10°F (5.6°C)</td>
<td>10°F (5.6°C)</td>
</tr>
</tbody>
</table>

67% Load = 76% Sec Flow
Primary/Secondary at 67% Load

**Low DeltaT**

<table>
<thead>
<tr>
<th>Per Chiller</th>
<th>System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load</td>
<td>417 Tons (1467kW)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Primary</th>
<th>Secondary</th>
<th>Bypass</th>
</tr>
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<tbody>
<tr>
<td>Flow</td>
<td>2000gpm (126 l/s)</td>
<td>2280gpm (144 l/s)</td>
</tr>
<tr>
<td>Delta T</td>
<td>10°F (5.6°C)</td>
<td>10°F (5.6°C)</td>
</tr>
</tbody>
</table>

67% Load = 76% Sec Flow

- **Primary Pumps**
  - 1000 GPM Each (63 l/s)
  - 2000 GPM @ 54 °F (?) (126 l/s) @ 12.2 °C ?)

- **Secondary Pumps**
  - 2280 GPM @ 45.2 °F
  - 144 l/s @ 7.3 °C

- **Secondary Pumps**
  - 2280 GPM @ 45.2 °F
  - 144 l/s @ 7.3 °C

- **Cooling Coils with Two-Way Valves**
  - 280 GPM @ 54 °F ?
  - 17.7 ?+ l/s @ 12.2 °C ?

- **Bypass**
  - 54 °F ?
  - (12.2 °C ?)
Primary/Secondary at 67% Load

Low DeltaT

67% Load = 76% Sec Flow

<table>
<thead>
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<th>Per Chiller</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Load</td>
<td></td>
</tr>
<tr>
<td>333 Tons (1172kW)</td>
<td>1000 Tons (3518kW)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Primary</th>
<th>Secondary</th>
<th>Bypass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow</td>
<td>3000gpm (189 l/s)</td>
<td>2280gpm (144 l/s)</td>
<td>720 gpm (0 l/s)</td>
</tr>
<tr>
<td>Delta T</td>
<td>8°F (4.4°C)</td>
<td>10°F (5.6°C)</td>
<td>----</td>
</tr>
</tbody>
</table>

Primary Pumps
1000 GPM Each (63 l/s)

Secondary Pumps
2280 GPM @ 44 °F
144 l/s @ 6.7 °C

Cooling Coils with Two-Way Valves

44 °F (6.7 °C)

10°F (5.6°C)
Primary (Constant) / Secondary (Variable) Rule of Flow

Primary flow must always be equal to or greater than Secondary flow.
Negative Effects of Low Delta T in P/S Systems

Consequences:

- Higher secondary pump energy
  - pumps run faster

- Higher chilled water plant energy
  - Ancillary equipment

- Can’t load up chillers
  - more than ratio Act DT / Des DT
  - 10/12 = 83% or 417 tons
Variable Primary Flow at 67% Load

Ideal Operation

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>Load</td>
<td>500 Tons (1760kW)</td>
<td>1000 Tons (3518kW)</td>
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<th>Bypass</th>
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<tbody>
<tr>
<td>Flow</td>
<td>2000gpm (126l/s)</td>
<td>0gpm (0 l/s)</td>
</tr>
<tr>
<td>Delta T</td>
<td>12°F (6.7°C)</td>
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</table>

67% Load = 67% Sec Flow
Variable Primary Flow at 67% Load
Low DeltaT (can over-pump chillers)

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<td>Flow</td>
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</tr>
<tr>
<td>Delta T</td>
<td>Delta T</td>
</tr>
<tr>
<td>10°F (5.6°C)</td>
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67% Load = 76% Sec Flow
Negative Effects of Low Delta T in VPF Systems

**Consequences:**

- Higher secondary pump energy
- Pumps run faster
- Higher chilled water plant energy
- Ancillary equipment
- Can’t load up chillers
  - More than ratio Act DT / Des DT
  - $10/12 = 83\%$ or 417 tons
VPF Systems mitigate Low Delta T Impacts

But:

- No additional energy from running more chillers than required.
- Can fully load up chillers by over-pumping.
  - more than ratio Des DT / Act DT
  - 12/10 = 120% or 1200 gpm (1000 des)
  - 20% increase in flow is 44% increase in WPD, so 15 ft would rise to 22 ft.
  - Max WPD for YKs 2P is 45 ft, 3P is 67 ft
Solution to (or reduce effects of) Low Delta T

- Address the causes
  - Clean Coils
  - Calibrate controls periodically
  - Select proper 2W valves (dynamic/close-off ratings) and maintain them
  - No 3W valves in design
  - Find and correct piping installation errors
- Over deltaT chillers by resetting supply water down (P/S)
- Over pump chillers at ratio of Design Delta T / Actual Delta T (VPF)
- Use VSD Chillers & Energy-based sequencing (from 30 to 80% Load)

Solve at Load, Mitigate at Plant
VPF Systems Design/Control Considerations

- Chillers
  - Equal Sized Chillers preferred, but not required
  - Maintain Min flow rates with Bypass control (1.5 fps)
  - Maintain Max flow rates (11.0 to 12.0 fps) and max WPDs (45’ for 2P, 67’ for 3P)
  - Modulating Isolation Valves (or 2-position stroke-able) set to open in 1.5 to 2 min
  - Don’t vary flow too quickly through chillers (VSD pump Ramp rate – typical setting of 10%/min)

- Sequence
  - If CSD Chillers – run chillers to max load (Supply Temp rise). Do not run more chillers than needed (water-cooled, single compressor assumed)
  - If VSD Chillers – run chillers between 30% and 80% load (depending on ECWT and actual off-design performance curves). Run more chillers than load requires.
  - Add Chiller - CHW Supply Temp or Load (Flow X Delta T) or amps (if CSD)
  - Subtract Chiller - Load (Flow X Delta T) or Amps (if CSD)
VPF Systems Design/Control Considerations

- Pumps
  - Variable Speed Driven
  - Headered arrangement preferred
- Sequence
  - with chillers (run more pumps than chillers for over-pumping capability)
  - Flow-based sequencing
  - Energy-based sequencing (most efficient combination of pumps)
- Speed controlled by pressure sensors at **end** of index circuit (fast response important)
  - Direct wired
  - Piggyback control for large distances
  - **Optimized** - Reset pressure sensor by valve position of coils
VPF Systems Design/Control Considerations

- **Bypass Valve**
  - Maintain a minimum chilled water flow rate through the chillers
    - Differential pressure measurement across each chiller evaporator
    - Flow meter preferred
  - Modulates open to maintain the minimum flow through operating chiller(s).
  - Bypass valve is normally open, but closed unless Min flow breeched
  - Pipe and valve sized for Min flow of operating chillers
  - High Range-ability (100:1 or better preferred)
  - PSID Ratings for Static, Dynamic, And Close Off = Shut Off Head of Pumps
  - Linear Proportion (Flow to Valve Position) Characteristic preferred
  - Fast Acting Actuator
  - Locate in Plant around chillers/pumps (preferred)
    - Energy
    - Avoid Network traffic (response time is critical to protect chillers from potential freeze-up)
VPF Systems Design/Control Considerations

- Load Valves
  - High Range-ability (200:1 preferred)
  - PSID Ratings for Static, Dynamic, and Close Off = Shut-off Head of Pumps
  - Equal Percentage (Flow to Load) Characteristic
  - Slow Acting Actuator

- Staging Loads
  - Sequence AHUs On/Off in 10 to 15 min intervals
Summary on VPF Design (optimal design criteria)

**Chillers**
- Size equally with same WPDs (best)
- Respect Min/Max Flows (and max WPDs) through chillers
- Set Pump VSD Ramp function to about 10%/min (600 sec 0 to Max Speed)
- Use Modulating (preferred) or Stroke-able Valves (if linear flow to time) on chiller evapside, headered pumping
- Use 2 Position Valves on chiller evaps, dedicated pumping

**Pumps**
- VSD Controllers
- Headered Pumping Arrangement (preferred)
- Dedicated Pumping OK (over-size pumps)

**2 Way Valves**
- Select for Static, Dynamic, Close-off ratings (PSID) equal to pump SOH (plus fill pressure)
- Range-ability 100 to 200:1
- If Bypass – fast acting, linear proportion
- If Coils – slow acting, equal percentage, “On-Off” stagger air units (10-15 min intervals)

**Controls**
- Set-point far out in index circuit (lower the value, the better the pump energy)
- Set Ramp function in VSD Controller (10%/min average or decel rate of 600 sec from max speed to zero)
- Run 1 more pump than chillers (when headered)
- Chillers On by common Supply Temp, Load, Amps
- Chillers Off by Load, Amps
- Over-pump Chillers to combat Low Delta T and get Max Cap out of chillers
- Bypass controlled by flow meter (preferred) or evap WPD of largest chiller (best location in plant for best energy)
Chilled Water Piping Configurations

Questions?

Roy Hubbard