Chiller Plant Design

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What is a Chiller Plant?

• **Major components:**
  • Building or Process cooling load
  • Water cooled chiller- (this can be air-cooled)
  • Cooling Tower
  • Pumps and piping
  • Controls
Why use chilled water?

• Chilled Water Is A Great Way To Move Energy Around A Building
• A 2” Pipe Moves As Much Energy As A 42” Duct
• A Chilled Water Coil W/ Valve Can Offer Excellent Control
• Dehumidification
• Chiller Plants Can Be Very Efficient
• Locate Equipment Away From Occupants
• Service
• Sound
• Safety
Energy Usage

Energy Use by Sector

- Industry: 30%
- Residential: 22%
- Transportation: 29%
- Commercial: 19%
- Other: 28%

Electricity Use by Sector

- Buildings: 72%
- Other: 28%

Source: Energy Information Administration 2009
Talking about Green? Sustainability? and High Performance!

**Green:**
More efficient equipment

**Sustainable:**
Design considers the big picture, how is equipment made, where it is installed, how long it lasts....

**High Performance:**
High Efficient equipment, sized, installed and maintained correctly for maximum impact
Full load on “Design Day”

Design Performance
- Chiller: 58%
- Tower: 5%
- Fans: 24%
- Pumps: 13%
Question: What is a cooling “Design Day”

a. The day the building load calculation was begun?

b. The first day the HVAC System is turned on?

c. The hottest day of the year?

d. The coldest day of the year?
Question: What is a cooling “Design Day”

a. The day the building load calculation was begun?

b. The first day the HVAC System is turned on?

c. The hottest day of the year?

d. The coldest day of the year?

ANSWER: c
Basic system

• Chiller
• Cooling Tower
• Building Cooling Load
• Pumps and Piping
Annual Energy Usage

- Fans: 43%
- Pumps: 22%
- Tower: 2%
- Chiller: 33%
Chiller Basics

- Air, Water Or Evaporatively Cooled
- Reciprocating, Scroll, Screw Or Centrifugal Compressors
- DX or Flooded Evaporators
Single Chiller

Cooling Tower

Water-Cooled Chiller

Condenser Water Pump

Chilled Water Pump

Air Handling Unit
Typical Air-Cooled Chiller Piping Detail

Air-Cooled Chiller

- Pressure Gauge (Typical)
- Return
- Supply
- Drain Valve
- Shutoff Valve (Typical)
- Thermometer (Typical)
Typical Water-Cooled Chiller Piping Detail

- **Supply**
- **Return**

**Shutoff Valves**

**Drain Valve**

**Thermometer (Typical)**

**Condenser Water**

**Drain Valve**

**Flange (Typical)**

**Pressure Gauge (Typical)**

**Strainer (if pump is on return side of chiller)**

**Chilled Water**

**Water-Cooled Chiller**

Section 6 – Typical Piping Details at Equipment

Supply | Return

---

Return | Supply
Typical Cooling Towers

Cooling towers are heat rejecters. They do not condense refrigerant so they are not considered condensers.
Basic Cooling Tower Operating Characteristics

- Approximately 90°F Saturated Air
- 95°F db
- 78°F wb

From Water-Cooled Condenser

85°F

Back to Condenser
Closed-Loop System

Includes:

- A chiller and/or a boiler
- Coils that produce cooling or heating
- Two or three-way valves to control the coils
- Piping and pump to circulate water
- An expansion tank (insignificant water contact with air)
Open-Loop System

- The water-cooled condenser is typically part of a water-cooled chiller or water-cooled package unit.
- A cooling tower rejects the condenser heat to the atmosphere.
- Flow rates and temperatures are industry standards for North America.
- Piping and pumps circulate water.
- Water is reused and exposed to the ambient conditions in the cooling tower.
Once-Thru Water System

- Much less common due to environmental concerns
- Water is sent to waste or returned back to source
- Large consumption of water
- Source example: river, lake, well
Question: What is a Closed Loop?

a. The pipe is capped

b. It is not open to the atmosphere

c. The chilled water piping is a closed loop
Question: What is a Closed Loop

a. The pipe is capped

b. It is not open to the atmosphere

c. The chilled water piping is a closed loop

ANSWER: b and c
Closed loop and Open loop- Recap!

• **Closed Loop**
  • The chilled water piping is usually a closed loop
  • A closed loop is not open to the atmosphere
  • The pump needs only to overcome the friction loss in the piping and the components
  • The pump does not need to lift” the water to the top of the loop

• **Open Loop**
  • When open cooling towers are used in the condenser piping
  • The condenser pump must overcome the friction of the system and “lift” the water from the sump to the top of the tower
Flow and Capacity

\[ Q = W \times C_p \times \Delta T \]

Where

- \( Q \) = Quantity Of Heat Exchanged (Btu/hr)
- \( W \) = Flow Rate Of Fluid (US gpm)
- \( C_p \) = Specific Heat Of Fluid
- \( \Delta T \) = Temperature Change Of Fluid (°F)

For Water

- \( Q \) (Tons) = US gpm x (°Fin - °Fout) x 500
- \( Q \) (Btu/hr) = US gpm x (°Fin - °Fout)/24
Load Basics

• Chilled Water Coils
  Transfer Heat From
  Building Air To Chilled
  Water

• Process Loads
  • Cooling Jackets
1-Pipe Distribution System

- Typical Heating Terminal
- Monoflow® Fitting
- Main Piping Loop
  Supply and Return (1 size throughout)
- Boiler
- System Pump

Typical Heating-Only System
2-Pipe Distribution System

Summer Mode

- Supply Piping
- Typical Heating and Cooling Terminal
- Boiler
- Chiller
- System Pump
- Return Piping

Typical Heating and Cooling Terminal
3-Pipe Distribution System

Distributes hot and cold water simultaneously

Typical Heating and Cooling Terminal

Chilled Water Supply

Boiler

Hot Water Supply

Chiller

System Pumps

Common Return Piping with Mixed Hot and Cold Water

Special 3-pipe Water Control
4-Pipe Distribution System

Distributes hot and cold water simultaneously

4-Pipe Heating and Cooling Terminal
Chilled Water Supply
Boiler
Chiller
System Pumps
Hot Water Supply

Section 3 – Water Distribution Systems
Direct and Reverse Return Systems
Return header flow is same direction as supply flow

Water leaves Unit-1 and goes all the way around in returning to source

The first unit supplied is the last returned

Circuit pressure drop through Unit-1 = Unit-2 = Unit-3 = Unit-4 = Unit-5

Balancing valves may be eliminated
• Water enters Unit-1 from supply
• Water leaves Unit-1 and returns directly to source
• The first unit supplied is the first returned
• Unequal circuit pressure drops result
• Circuit pressure drop through
  Unit-1 < Unit-2 < Unit-3 < Unit-4 < Unit-5
• Balancing valves are a necessity
Piping Materials

Typical Materials:

≥ 2 1/2-in. Schedule 40 black steel
≤ 2-in. Schedule 40 black steel or Type L copper
Control Valves

- 3-Way Diverting
  - 2 outlets 1 inlet

- 3-Way Mixing
  - 2 inlets 1 outlet

- 2-Way Modulating
Expansion Tanks

**Open Tank**
- Open to air
- Air-water interface

**Closed Tank**
- Very popular
- Captured air space
- Air-water interface

**Closed Diaphragm Tank**
- Flexible membrane
- No air-water interface
- Very popular
Piping Example

Figure 3-13. Pipe Loop Sizing Example
Piping Example

Given The Following Pressure Drops in Feet

- **Coil**  3.0 ft
- **Pipe**
  - Try To Be Around 4ft P.D. Per 100 Ft Piping
  - 2” Pipe= 3.1ft/100ft
  - 10.7 ft
- **Gate Valve**  0.04 ft
- **Balancing Valve**  2.0 ft
- **4 Elbows**  0.91 ft
- **2 Tees**  0.64 ft
- **Control Valve**  8.2 ft

• Total  25.35 ft
Air Vents

Locate at high points

Typical Locations:
• Risers
• Coils
• Terminals

Manual or Automatic Air Vent

Service Valve

From Terminal Coil

To Return Main

4 Pipe Diameters
Thermometers, Gauges and Pete’s Plug

Locate thermometers and gauges at inlets and outlets of equipment

Pete’s Plugs:
Temperature and Pressure Ports
How many pipe hangers are needed and what is their support distance?

- Distance between hangers is 14 ft
- Number of hangers = \( \frac{100}{14} = 7 \)
Check for Volume Tank Requirements

Rule of thumb for chilled-water systems:

- 3 gallons per nominal ton of chiller for **normal** air-conditioning duty
- 6 to 10 gallons per nominal ton of chiller for process duty or low ambient unit operation
In-Line Pump

Small capacity design

Motor

Pump Assembly
Close-Coupled Pump

Internal Self-Flushing Seal
Base-Mounted End Suction Pump

- **Coupling Guard**
- **Motor**
- **Short Shaft**
- **Discharge**
- **Suction**
- **Welded Steel Frame** provides support and installation ease
Double-Suction Vertical Split Case Pump

Vertical Suction and Discharge

Large-capacity designs for chillers and cooling towers
Double-Suction Horizontal Split Case Pump

Large-capacity design for chillers and cooling towers
### Pump Type Comparison

<table>
<thead>
<tr>
<th>Pump Type</th>
<th>Cost</th>
<th>Flow &amp; Head Capability</th>
<th>Space Required</th>
<th>Ease of Service</th>
</tr>
</thead>
<tbody>
<tr>
<td>In Line</td>
<td>Least 1</td>
<td>200 gpm @ 55 ft</td>
<td>Least 1</td>
<td>Poor 5</td>
</tr>
<tr>
<td>Close-Coupled</td>
<td>2</td>
<td>2,300 gpm @ 400 ft</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>End Suction</td>
<td>3</td>
<td>4,000 gpm @ 500 ft</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Vertical Split Case</td>
<td>4</td>
<td>9,000 gpm @ 400 ft</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Horizontal Split Case</td>
<td>Highest 5</td>
<td>40,000 gpm @ 600 ft</td>
<td>Most 5</td>
<td>Good 3</td>
</tr>
</tbody>
</table>
Single Chiller

REMEMBER THIS? ARE YOU READY TO PLAY IN THE WATER?
Parallel Flow Systems

Production Loop (primary)

Building System Loop (secondary)

Hydraulic Decoupler (Bridge)

Alternate Bypass Line minimum chiller flow

233 Ton

400 gpm

400 gpm
Building Load 100% (700 Tons)

3 x 267 Ton, Primary/Secondary

Production Loop (primary)

Building System Loop (secondary)

Hydraulic Decoupler (Bridge)

Alternate Bypass Line

minimum chiller flow

700 tons / 3 chillers = 233 tons per chiller

When building 100% loaded, entering condenser water = 85°F
Variable Primary

Automatic Isolation Valves

Variable Speed Primary Pumps

Control Valve, sized for minimum chiller flow

Bypass

Flow Meter

350 Ton 350 Ton

1050 gpm
Both chillers designed to operate at 42F/83F.

Downstream screw chiller cools from 50F – 42F

Upstream centrifugal chiller cools from 58F – 50F.

Reduced Lift = Reduced Speed = Reduced KW
Variable Flow vs. Constant Flow

Pump Work Cut In Half
Summary

• Lift = SCT – SST

• CS vs VS Centrifugal Chillers

• VFDs take advantage of Part Lift & Part Load with Speed Control

• Variable Speed Screw Technology

• Series Counter Flow Systems Reduce Lift & Lower KW

• Chiller Plant Analysis
Integration of Systems

HVAC & Electronic Security
- Electronic locks, and energy management systems
- Access control, intrusion monitoring and video surveillance
- Air handling, fan coils and refrigeration
- Service, maintenance and inspection

Fire Safety
- Fire detection and alarm systems
- Fire fighting and suppression systems

Building Systems
- Building Automation System
- Chillers and controls