Technical Development Program

COMMERICAL HVAC
CHILLER EQUIPMENT

Air-Cooled Chillers

PRESENTED BY:

Omar Rojas
Sales Engineer
BRACE YOURSELF

3 HOURS OF CHILLER TRAINING ARE COMING
AIR-COOLED CHILLERS

Introduction
Objectives

• List the various types and tonnages of air-cooled chillers and their operational characteristics

• Describe the correct applications for air-cooled chillers

• Identify the available options and accessories
Air-Cooled Chiller Package

Air-Cooled Condenser

Compressor(s)

Evaporator (cooler) Barrel

Expansion Device

Packaged Unit
Air-Cooled Condensing Temperature

- Design Air Inlet Temperature: 95° F
- Air Rise: 15° F
- Leaving Difference*: 15° F
- Refrigerant Condensing Temperature: 125° F

* Difference between condensing temperature and leaving air

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Section 1 – Introduction
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Air-Cooled vs. Water-Cooled Chillers

Air-Cooled Chiller Advantages
- Lower installed cost
- Quicker availability
- No cooling tower or condenser pumps required
- Less maintenance
- No mechanical room required

Water-Cooled Chiller Advantages
- Higher efficiency
- Custom selections in larger sizes
- Large tonnage capabilities
- Indoor chiller location
- Longer life
Water-Cooled Chiller System Requirements

Section 1 – Introduction
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Air-Cooled Chiller System Requirements

Air-Cooled Chiller

Section 1 – Introduction
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SECTION 2

AIR-COOLED CHILLERS

Basic Refrigeration Cycle
Air-Cooled Refrigeration Cycle

*Flooded cooler, which has water in the tubes, is also used.
Air-Cooled Chiller Components
Air-Cooled Chiller Components

- **Cooler / Evaporator**
  - Refrigerant to water
  - Removes heat from chilled water loop

- **Condenser**
  - Refrigerant to air
  - Rejects heat to atmosphere

- **Compressor**
  - Transfers heat to condenser
  - Reciprocating, scroll, screw and centrifugal types

- **Expansion Device**
  - Maintains high-to-low side pressure differential
  - Provides proper superheat of the gas to the compressor
Three Types of Evaporators

- DX Shell-and-Tube
- Flooded Shell-and-Tube
- Brazed-Plate
Brazed-Plate Evaporator

Note: Brazed-Plate Heat Exchangers are also used as condensers.
Direct Expansion Shell-and-Tube Evaporator

- Water is in the shell
- Refrigerant flows through the tubes
- Internal baffling distributes water over the tubes

Water Connection Flange
Refrigerant floods the tubes

Refrigerant in the shell

Water in tubes

Suction to compressor inlet

Refrigerant vapor

44° F
Chilled water out

54° F
Return water in
Flooded Shell-and-Tube Pass Arrangements

One-Pass

\[
\text{AREA} = A
\]

Low Pressure Drop, Low Rise

Two-Pass

\[
\text{AREA} = A/2
\]

Medium Pressure Drop, Medium Rise

Three-Pass

\[
\text{AREA} = A/3
\]

High Pressure Drop, High Rise
Condenser

Vertical Discharge Propeller Fans

Aerodynamically designed condenser fan deck

Air-Cooled Chiller
Compressor Types

Four types of compressors used in air-cooled chillers:
- Reciprocating (obsolete)
- Scroll
- Screw
- Centrifugal
Horizontally Mounted TXV

Mixed Phase to Evaporator

Superheat Sensing Bulb

Liquid Line
EXV Expansion Device

Stepper Motor

Mixed Phase to Evaporator

Liquid Lines
SECTION 4

AIR-COOLED CHILLERS

Chiller Controls
Chiller Controls and Starters

Starter Types

- Across-the-Line (full voltage)
- Part-Winding (soft start)
- Wye-Delta (soft start)
- VFD (soft start)

Capacity Control

Energy Management

- Chilled-Water Reset
- Demand Limit
Control Panel

Equipment-mounted

Hand-held

Section 4 – Chiller Controls
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### Starter Summary Information

<table>
<thead>
<tr>
<th>Starting Method</th>
<th>Motor Starting Current as a % of Locked Rotor Current</th>
<th>Full Load Current</th>
</tr>
</thead>
<tbody>
<tr>
<td>Across-the-Line</td>
<td>100</td>
<td>600</td>
</tr>
<tr>
<td>Part Wind</td>
<td>65</td>
<td>390</td>
</tr>
<tr>
<td>Wye-Delta</td>
<td>33</td>
<td>200</td>
</tr>
</tbody>
</table>
Capacity Control-Cycling Compressors

Multiple Scroll Chiller Design
Capacity Control Hot Gas Bypass

- Protects system in low-load conditions
- Active at minimum step of cooling only

Air-Cooled Condenser

Compressor

Evaporator (cooler) Barrel

Hot Gas Solenoid Valve

Discharge Bypass Valve

Section 4 – Chiller Controls
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Capacity Control Slide-Valve and VFD's
SECTION 5

AIR-COOLED CHILLERS

Air-Cooled Chiller Configurations
Packaged Single Piece Configuration

Ground or Roof-Mounted Chiller

Air Inlet to Condenser Coil

Electrical and Controls

Evaporator

Condenser Fans

Multiple Scroll Compressors

Section 5 – Air-Cooled Chiller Configurations
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Remote Cooler Barrel

Consult manufacturer’s recommendations for maximum separation distance.

Outdoor packaged air-cooled chiller with cooler removed

Field-installed refrigerant piping

Suction Line

Liquid Line

DX Evaporator

Water Outlet

Water Inlet

Outdoors

Indoors

Section 5 – Air-Cooled Chiller Configurations
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Condenserless Split-System Chiller

Outdoor Air-Cooled Condensers
(1) Per Compressor Circuit

Indoors Hot Gas
Liquid

Outdoors

Hot Gas
Liquid

Indoor Condenserless Chiller

Section 5 – Air-Cooled Chiller Configurations
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Benefits of Condenserless Chiller Configurations

- Roof does not need to support the compressor(s)
- Lower electrical costs because the compressor is closer to the indoor electrical panel
- More options for noise control
- Reduced freeze-up potential
Indoor Chiller & Indoor Air-Cooled Condenser

Indoor Condenserless Chiller

Indoor Centrifugal Fan Air-Cooled Condenser

Ducted inlet

Ducted Outlet

Hot Gas

Liquid
Indoor Chiller - Evaporative Condenser

Indoor Condenserless Chiller

- Hot Gas
- Liquid
- Coils
- Air In
- Air Inlet Louvers
- Spray Pump
- Wet Deck Surface
- Cold Water Basin
- Warm Air Out

Section 5 – Air-Cooled Chiller Configurations
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AIR-COOLED CHILLERS

Work Session

1. What are the four major components to the air-cooled chiller refrigeration cycle?
   _______________________________________
   _______________________________________
   _______________________________________
   _______________________________________  

2. List the three types of compressors used in air-cooled chillers.
   _______________________________________
   _______________________________________  
   _______________________________________  

3. List the three types of coolers or evaporators used in air-cooled chillers.
SO, YOU GOT ALL THE WORKSESSION QUESTIONS RIGHT...

TELL ME HOW YOU CAN NOW TEACH THE REST OF THE CLASS
AIR-COOLED CHILLERS

Application Topics
Application Topics

- Typical operating limits
- Effects of ambient air temperature
- Effects of leaving chilled-water temperature
- Variable flow minimum and maximum flow rates
- Freeze protection methods
- Refrigerants used in air-cooled chillers
- Chiller sizing
- Minimum chilled-water system volume
- Parallel and series chillers
- Clearances and installation
Typical Operating Limits

Check with manufacturer for unit specifics

- Minimum Outdoor Temperature -20° F
  (Standard unit 0° to 32° F)
- Maximum Outdoor Temperature 125° F
- Minimum Leaving Fluid Temperature 15° F
  (Standard unit 40° F)
- Maximum Leaving Fluid Temperature 60° to 70° F
- Maximum Return Water Temperature 85° F
# Effects of Ambient Air Temperature

## Typical Air-Cooled Chiller Full Load

<table>
<thead>
<tr>
<th>Entering Air °F</th>
<th>Tons</th>
<th>kW/Ton</th>
<th>% Change Capacity</th>
<th>% Change Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>75° F</td>
<td>112.1</td>
<td>0.952</td>
<td>+15</td>
<td>+20</td>
</tr>
<tr>
<td>85° F</td>
<td>105.5</td>
<td>1.069</td>
<td>+8</td>
<td>+11</td>
</tr>
<tr>
<td>95° F</td>
<td>97.5</td>
<td>1.208</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>105° F</td>
<td>89.5</td>
<td>1.384</td>
<td>-8</td>
<td>-15</td>
</tr>
<tr>
<td>115° F</td>
<td>81.2</td>
<td>1.621</td>
<td>-17</td>
<td>-35</td>
</tr>
<tr>
<td>125° F</td>
<td>73.1</td>
<td>1.923</td>
<td>-25</td>
<td>-60</td>
</tr>
</tbody>
</table>
### Effects of Leaving Chilled Water Temperature

#### Typical Air-Cooled Chiller at 95° F Ambient

<table>
<thead>
<tr>
<th>Leaving Chilled Water Temperature °F</th>
<th>kW / Ton</th>
<th>% Change Efficiency per °F</th>
<th>% Change Efficiency From 44° F</th>
</tr>
</thead>
<tbody>
<tr>
<td>44</td>
<td>1.237</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>43</td>
<td>1.253</td>
<td>-1.1</td>
<td>-1.1</td>
</tr>
<tr>
<td>42</td>
<td>1.266</td>
<td>-1.0</td>
<td>-2.2</td>
</tr>
<tr>
<td>41</td>
<td>1.280</td>
<td>-1.1</td>
<td>-3.5</td>
</tr>
<tr>
<td>40</td>
<td>1.295</td>
<td>-1.2</td>
<td>-4.6</td>
</tr>
</tbody>
</table>
Variable Flow Minimum and Maximum Flow Rates

For variable flow, the maximum rate of change per minute is 10% of the design flow rate.

- **Flooded Cooler**
  - Minimum flow is the gpm that corresponds to 3.0 fps water velocity in the tubes
  - Maximum flow results in an approximate 5° F $\Delta T$ in cooler
  - Maximum flow is approximately 5 gpm/ton

- **DX Cooler**
  - Minimum flow is the gpm that corresponds to 1.0 fps water velocity in the shell
  - Maximum flow results in an approximate 5° F $\Delta T$ in cooler
  - Maximum flow is approximately 5 gpm/ton
Freeze Protection Methods

- Drain the chiller loop
- Use cooler heater
- Circulate the water continuously
- Use antifreeze solution
- Combinations of the above
Freeze Damage

Burst Coil

Cracked Housing
Evaporator Barrel Heater

- Refrigerant in tubes
- Water (glycol) in shell
- Heater cable wrapped around the shell
- Factory or field-installed
## Freeze vs. Burst Protection

### Propylene Glycol

<table>
<thead>
<tr>
<th>Protection Temperature (°F)</th>
<th>For FREEZE protection ** % by weight</th>
<th>For BURST protection ** % by weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>+20</td>
<td>18</td>
<td>12</td>
</tr>
<tr>
<td>+10</td>
<td>29</td>
<td>20</td>
</tr>
<tr>
<td>0</td>
<td>35</td>
<td>25</td>
</tr>
<tr>
<td>-10</td>
<td>41</td>
<td>29</td>
</tr>
<tr>
<td>-20</td>
<td>45</td>
<td>30</td>
</tr>
<tr>
<td>-30</td>
<td>48</td>
<td>32</td>
</tr>
<tr>
<td>-40</td>
<td>52</td>
<td>34</td>
</tr>
</tbody>
</table>

**Confirm with the local glycol supplier**
New refrigerants not scheduled for phase-out:

- **R - 134a**
- **R – 410A Puron™**
- **R – 407C**

**R-22 phase-out:**
- 2010 new equipment
- 2020 service
Chiller Sizing

- Do not oversize beyond 15%
- If future expansion, add a second chiller in parallel
- Use two small chillers versus one large chiller whenever possible
Minimum Chilled-Water System Volume

Volume tank may be necessary

- 3 gallons per ton of chiller for normal air-conditioning duty
- 6 to 10 gallons per ton of chiller for process duty or low ambient unit operation
- Mount tank on return line to chiller
Parallel and Series Chillers

Parallel – (Typically 18° F drop or less)

Series – (Typically greater than 18° F drop)
Clearances

Consult manufacturer’s literature for exact requirements

Unobstructed height is required for air discharge above fan deck

Approximately 6 ft air inlet space

Approximately 5 ft minimum normal service clearance, far side also

Approximately 6 ft minimum space required for air inlet

Require access to electrical panel door swing
Multiple Unit Separation

Consult manufacturer’s literature for exact requirements

10 ft Minimum

6 ft Minimum
SECTION 7

AIR-COOLED CHILLERS

Options and Accessories
Options and Accessories

- Low ambient operation
- Low chilled-water temperature
- Condenser coil corrosion protection
- Hydronics package
Low Ambient Operation

Control Section of Multi-Fan Air-Cooled Chiller

Fan speed control required for operation to -20° F ambient

Fan Speed Controllers
Low Chilled Water Temperature

Brine Duty

- From 40° F to 34° F leaving brine requires field reset of chiller controls
- From 34° F to 15° F leaving brine requires factory modification to chiller
Chiller Coil Corrosion Protection

Standard Coil
(majority of applications)

Plate fin coil options:
- Pre-Coated Aluminum Fins
  (moderate coastal protection)
- All Copper Coils
  (best coastal protection)
- Electro-Coated Aluminum Fins
  (best coastal and industrial protection)
Copper-Fin Coils

Copper tube/copper fin coils are used for corrosion resistance in coastal areas.
Pump in Hydronics Package

Pump assembly factory-supplied for an air-cooled chiller
The change in water system volume is about 1% for chilled-water systems.
SECTION 8

AIR-COOLED CHILLERS

Codes and Standards
Codes and Standards

- **ARI**
  Air Conditioning and Refrigeration Institute
  - Chiller performance certification
  - Random testing of manufactured units for verification
  - ARI 550/590-98
    - Latest standard for electric chillers

- **ASHRAE**
  American Society of Heating, Refrigerating and Air-Conditioning Engineers
  - ASHRAE 90.1
    - Chiller minimum efficiency requirements
  - ASHRAE 15
    - Safety of installations using refrigerants

- **ASME**
  American Society of Mechanical Engineers
  - Pressure vessel specifications
ARI Terms

• Definitions
  – **EER**: Measurement of a chiller’s efficiency at full load capacity
  – **IPLV**: Calculation of a chiller’s efficiency in addition to full load using weighted averages at various part load points

• ARI Conditions for Air-Cooled Chillers
  – Leaving chilled-water = 44° F
  – Chilled-water flow rate = 2.4 gpm/ton
  – Cooler fouling factor = 0.0001 hr °F ft²/Btu
  – Entering air temperature = 95° F
Locate relief outlets for safe venting
Locate inlet vents away from exhaust outlets per code
Restrict mechanical room access
Minimize low areas where refrigerant might collect
Size pressure relief lines per ASHRAE
Secure chiller drain valves
Install tight fitting mechanical room door
Run floor drains per local code
## Current Title 24 Minimum Efficiencies

### Air-Cooled Chillers

<table>
<thead>
<tr>
<th>Equipment Type</th>
<th>Size Category</th>
<th>Minimum Efficiency kW/Ton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air-cooled with condenser</td>
<td>&lt; 150 tons</td>
<td>9.562 EER / 12.5 IPLV</td>
</tr>
<tr>
<td></td>
<td>≥ 150 tons</td>
<td>9.562 EER / 12.75 IPLV</td>
</tr>
<tr>
<td>Air-cooled without condenser</td>
<td>All</td>
<td>Must be rated with matching condensers and comply with same efficiency requirements.</td>
</tr>
</tbody>
</table>

All must be rated with matching condensers and comply with same efficiency requirements.
New central cooling plants and cooling plant expansions will be limited on the use of air-cooled chillers. For both the limit is 300 tons per plant.
Exceptions:

1. Where the *water quality* at the building site fails to meet manufacturer’s specifications for the use of water-cooled chillers.

2. Chillers that are used to charge *thermal energy storage (TES)* system with a design temperature of less than 40°F.

3. Air cooled chillers with *minimum efficiencies* approved by the Energy Commission pursuant to §10-109(d).
SECTION 9

AIR-COOLED CHILLERS

Selection Criteria
SECTION 9

AIR-COOLED CHILLERS

Summary
Summary

- Listed the various types and tonnages of air-cooled chillers and their operational characteristics
- Described the correct applications for air-cooled chillers
- Identified the available options and accessories
WANTS A LOW FIRST AND MAINTAINANCE COST CHILLED WATER SYSTEM

GETS AN AIR-COOLED CHILLER
AIR-COOLED CHILLERS

Work Session

1. What are the four major components to the air-cooled chiller refrigeration cycle?
   __________________________________________
   __________________________________________
   __________________________________________
   __________________________________________

2. List the three types of compressors used in air-cooled chillers.
   __________________________________________
   __________________________________________
   __________________________________________

3. List the three types of coolers or evaporators used in air-cooled chillers.
Thank You

This completes the presentation.

TDP-622 Air-Cooled Chillers

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