Industrial Refrigeration Systems: Floating Head Pressure Control For Peak Energy Performance

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Is it a new concept?

December, 1910

SAY, MR. REFRIGERATING ENGINEER

of what value is your costly refrigerating machinery if you do not have enough cold water to keep the head pressure down?

Ice plant efficiency must commence at the well. Unless your water supply system insures for you ample volume, economy of operation, and absolute reliability your refrigeration will cost too much.

Let our catalog on air lift pumping bring you the FACTS about real pumping satisfaction.

Put Your Pumping Problems Up to Pumping Experts!

INDIANA AIR PUMP CO., Indianapolis, Ind.

December, 1920

C. J. TAGLIABUE MFG. CO.
Single Stage Compression System

Evaporative Condenser

Evaporative Condenser

High Pressure Receiver

King valve (automatic)

Dry suction

Compressor(s)

Evaporative Condenser

Evaporative Condenser

High pressure gas

Head Pressure

DX evaporator

Flooded Evaporator

Suction Trap

Compressor(s)

Refrigerant Transfer System

To HPR

Suction

Trap

Compressor(s)

T

Equalizer line

High pressure liquid

Overfed evaporator(s)

Wet return

Pumped recirculator

Overfed evaporator(s)

T

1

2

3

4
Evaporative Condenser Operating Principles

(Induced draft, counter flow)
Moist, hot air out

Eliminators
Spray header

High pressure vapor refrigerant, in
High pressure liquid refrigerant, out

Ambient air

Remote sump
Makeup water

Local pump
Remote pump
Condenser water circuit
Head Pressure Control
Head Pressure Control (continued)

How is head pressure controlled in industrial refrigeration systems?
Head Pressure Control (continued)

• Heat rejection system controls head pressure

• Factors influencing condensing pressure:
  o Outside air wet bulb
  o Saturated condensing temperature
  o Air flow rate
  o Water flow (wet/dry operation)
Evaporative condenser performance depends on:

- **Outside air wet bulb temperature (OAWB)**
  - As outside air wet bulb temperature **increases**, evaporative condenser capacity **decreases**
  - Capacity decrease $\sim 2.5\%$ per °F in OAWB

- **Saturated condensing temperature (SCT)**
  - As saturated condensing temperature **increases**, evaporative condenser capacity **increases**
  - Capacity increase $\sim 6\%$ per °F SCT
Performance Characteristics (continued)

- **Wet/dry operation**
  - **Dry** operation significantly reduces capacity
  - Rule-of-thumb: 65% reduction in capacity in dry vs. wet

- **Air flow rate**
  - Increased air flow rate increases condenser capacity
  - Increased air flow rate greatly increases condenser fan HP
Performance Characteristics (continued)

Graph showing the relationship between Relative Condensing Capacity [%] and Outdoor Air Wet-bulb [F]. The graph includes three lines:
- Blue line labeled $T_{\text{condensing}} = 105 \, \text{F}$
- Red line labeled $T_{\text{condensing}} = 85 \, \text{F}$
- Black line labeled $T_{\text{condensing}} = 95 \, \text{F}$
# Floating Head Pressure Compressor Effects

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>95</td>
<td>181</td>
<td>229.2</td>
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<tr>
<td>65</td>
<td>103</td>
<td>249.9</td>
<td>200.2</td>
<td>0.8</td>
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</table>

30% efficiency improvement!
Condensing Pressure – Occurrence Hours

- 3,487 hour
- 547 hour
Design Condensing Pressure

• Most common design head pressures
  o 181 psig, 196 psia (95°F saturation temperature)

• Alternatives to consider
  o 166 psig, 181 psia (90°F saturation temperature)
    ▪ Good for WI climate, situations that allow floating head pressure most months of year
  o 152 psig 167 psia (85°F saturation temperature)
    ▪ Good for moderate to cold climates, system designs that allow floating head pressure most months of year
Condenser Fan Control Options

- Single speed fan with on/off control
  - Most common method of head pressure control
  - Need to set cut-in (e.g. 150 psig), cut-out pressures (e.g. 145 psig)
  - Simple control method but results in:
    - Highest energy consumption option
    - Higher maintenance (fan motors, belts)
    - Potential for liquid management problems in multiple condenser systems

- Two-speed fan control
Condenser Fan Control Options (continued)

- **Variable frequency drive**
  - Set a target head pressure, modulate fan speed to maintain
  - A very simple principle, method to implement
    - Slightly higher capital cost
    - Lowest energy consumption control alternative
    - For multiple condenser systems, modulate **ALL** condensers together
    - Smooth system operation with minimal transients
## Condenser Fan Control Map

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Mode 1</th>
<th>Mode 2</th>
<th>Mode 3</th>
<th>Mode 4</th>
<th>Mode 5</th>
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<tbody>
<tr>
<td>1</td>
<td>Small Motor</td>
<td>off</td>
<td>on</td>
<td>off</td>
<td>on</td>
</tr>
<tr>
<td></td>
<td>Large Motor</td>
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<td>off</td>
<td>on</td>
<td>on</td>
</tr>
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<td>on</td>
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<tr>
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<td>Large Motor</td>
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</tr>
<tr>
<td>3</td>
<td>Small Motor</td>
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<td>on</td>
<td>on</td>
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</tr>
<tr>
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<td>Large Motor</td>
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<td></td>
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<tr>
<td></td>
<td>Large Motor</td>
<td>off</td>
<td></td>
<td>variable speed</td>
<td></td>
</tr>
</tbody>
</table>
Condenser Fan Control Options

- Small Motor On/Off, Large Motor On/Off
- Small Motor On/Off, Large Motor On/Off
- Small Motor On/Off, Large Motor Half-Speed
- Small Motor Half-Speed, Large Motor Half-Speed
- Small Motor VFD, Large Motor VFD

Approximately 44% and 6% efficiency improvements are noted.
Floating Head Pressure Control

• An operating strategy that:
  o Allows head pressure to drop with decreasing outside air wet bulb temperature
  o Takes advantage of excess evaporative condenser capacity during cool outside air conditions
  o Head pressure allowed to drop to a pre-determined minimum (for example, $P_{cond,min} = 110$ psig)

• Consequences of lowering head pressure
  o Slight increase in evaporative condenser energy use
  o Significant decrease in compressor energy use
Floating Head Pressure Control (continued)

Benefits

• Improved system efficiency ~1.3% for each °F reduction in saturated condensing temperature

• Increased system capacity

• Prolonged compressor life (decreased compression ratio)

• Oil cooling loads decrease
Case Study: Madison Ice Arena

- New system (1996)
- City-owned, operated
- Rink operated year-round
- Capacity = 103 tons
- Six compressors, max power = 240 kW
- Refrigerants = R22 + ethylene glycol
- Evaporative condenser
- Annual electrical operating cost = $45,600
Case Study: Madison Ice Arena (continued)

• As-installed – head pressure controlled 220-235 psig
• Proposed – allow condenser pressure to ‘float’ with varying outdoor temperature
• Low pressure limit reset to 150 psig
  ○ Required change – fan controller setpoint
• Advantages
  ○ Quieter, lower maintenance
  ○ 21% operating cost savings = $9,600/year
Floating Head Pressure Control Constraints

Head pressure limits dictated by:

- *Hot gas defrost requirements*
  - Setting of defrost relief regulators
  - Sizing of hot gas main
  - Condensate management in hot gas main

- *DX evaporators*
  - Most TXVs need at least 75 psig differential pressure to function properly

- *Presence of liquid injection oil cooling*
  - Check manufacturer’s requirements for TXV pressure differential
Floating Head Pressure Control Constraints (continued)

- **Evaporative condenser selection**
  - Oversized evaporative condensers usually result in an optimum head pressure that depends on outdoor air temperature

- **Evaporative condenser fan controls**
  - VFD fans are best option

- **Compressor oil separator sizing**

- **Gas driven systems** (transfer systems and gas pumpers)
Floating Head Pressure Control Constraints (continued)

- *Hand expansion valve* settings
  - Significantly lowering head pressure will likely require seasonal HEV adjustments – can be overcome by using motorized valves or pulse width valves
- *Controlled-pressure receiver* set points
- *Heat recovery*
- *Engineering and operations* (knowledge, willingness)
Keys To Success

- Know your minimum head pressure

<table>
<thead>
<tr>
<th>Assessment</th>
<th>Head Pressure Min [psig]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good</td>
<td>125 psig</td>
</tr>
<tr>
<td>Better</td>
<td>115 psig</td>
</tr>
<tr>
<td>Best</td>
<td>100 psig</td>
</tr>
</tbody>
</table>

- Assess ability to lower minimum (constraints)
- Implement slowly, prove function
- Maintain - don’t let low hanging fruit grow back
Questions?

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Thank you!