Industrial Refrigeration: Opportunities for Energy Efficiency and Cost Savings

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Practical Items

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Please type any questions you have during the presentation into the Chat window located on the right-side of your computer screen.
Quiz

What do you already know about energy efficiency for industrial refrigeration?

1. Which of the following is true about industrial refrigeration?
2. Which of the following are parts of the refrigeration cycle?
3. What is the ActOnEnergy cash incentive amount for completing a qualifying industrial refrigeration project with a 1-10 year payback through the Custom Program?
What we’ll cover

- What is industrial refrigeration, and how is it different from conventional HVAC?
- The refrigeration cycle
- Major system components
- Typical energy efficiency measures (EEMs)
- Resources
About Me

Bryan Hackett, PE, Sr. Engineer II

- 17 years of experience

- Multiple papers published on energy savings in food processing and refrigeration facilities
  - 2 as lead author

- Industrial Services Team Leader at kW
  - Energy audits (led 150+)
  - Technical support and calc assistance
  - Retro-commissioning (RCx)
  - Implementation support
  - Remote energy management
  - Emerging technologies evaluation
What is Industrial Refrigeration?

- **Size:** 100 tons and larger
- **Refrigerant:** Ammonia (R717) in most cases, R22 in a few cases
- **System Types:** Centralized and built-up
- **Load Temps:** -60°F to 55°F

**Industries:**
- Refrigerated warehouses
- Fruit and vegetable processors
- Breweries, wineries, and carbonated beverages
- Dairy and ice cream processors
- Meat, poultry, and fish
- Chemical, petrochemical, and pharmaceutical
What industry do you work in?

- Refrigerated warehouse
- Fruit and vegetable processing
- Brewery or winery
- Carbonated beverages
- Dairy and ice cream processing
- Meat, poultry, and fish
- Chemical, petrochemical
- Pharmaceutical
How Does it Differ from Commercial Refrigeration or HVAC?

- Commercial refrigeration systems tend to be smaller, modular, and may use a different refrigerant for each evaporator temperature.
- Large HVAC systems are used to cool spaces at temperatures greater than 55°F.
- Industrial refrigeration mostly use flooded-type evaporator coils, while commercial refrigeration and HVAC almost always use DX-type evaporator coils.
Basic Refrigeration Cycle

- Evaporation
- Compression
- Condensation
- Expansion

![Diagram of Basic Refrigeration Cycle](image-url)
Evaporation

- Cold liquid refrigerant absorbs heat and boils
- Liquid → vapor
- Latent heat of vaporization
- Constant pressure and temperature
Compression

- Reduction in volume of vapor
- Increase in pressure and temperature
- Requires external work (power)
- Raises the boiling point of the refrigerant
- Power depends of Lift
Condensation

- Vapor condenses
- Vapor $\rightarrow$ liquid
- Latent heat + compressor power is rejected to atmosphere
- Constant temperature and pressure
Meters refrigerant
Separates high-pressure from low-pressure
Some liquid evaporates, which chills the remaining refrigerant
Supplies evaporators with chilled liquid refrigerant
Evaporators

All cooling happens at an evaporator.

Evaporators can be broken into two main types:

- Air-Coolers
- Liquid-chillers
Air-Coolers

- AKA Evaporator fan-coil
- Coils often have fins to increase heat transfer surface
- Fans move air over coil
- Refrigerated air is used to cool space or product
- Hot gas is commonly used to defrost evaporators
Air-Coolers (cont’d)

To maintain space temperature
- Freezers
- Coolers
- Industrial A/C

Process/Product cooling
- Spiral freezers
- Blast freezers
- Pressure coolers
The most common types of heat exchangers for liquid chilling are:

- Shell-and-tube
- Plate-and-frame (pictured)
- Falling-film
- Scraped-surface
What type of evaporator does your refrigeration system use: Air-Cooler or Liquid-chiller?
Compressors

**Purpose:** to increase the pressure and temperature of the refrigerant vapor so that heat can be rejected in the condenser.

The most common types of compressors used in industrial refrigeration are:

- Reciprocating
- Rotary Screw
- Rotary Vane
Reciprocating Compressors

Use:
- High and low-temperature applications

Configuration:
- Booster, high-stage, and single-stage

Compression ratios:
- Max. of 8:1 with ammonia

Maximum size:
- Approx. 300-hp

Capacity control:
- Typically cylinder unloading
  - Relatively good part-load performance
Rotary Screw Compressors

Use:
- High and low-temperature applications

Configuration:
- Booster, high-stage, and single-stage

Compression ratios:
- Max. of 20:1 with ammonia

Maximum size:
- >1000-hp

Capacity control:
- Typically slide valve.
- Part-load performance not as good as cylinder unloading.
- VFDs becoming more common on new compressors.
Oil Cooling

Screw compressors use oil for lubrication and cooling during compression, so the oil must be continuously cooled to maintain operating temperature.

There are two main types of oil cooling in use:

- Liquid injection
- External
Liquid Injection

- Liquid injection uses high-pressure liquid refrigerant to flash-cool when injected into the compressor body via a DX-valve.
- This method is simple and inexpensive to implement.
- However, it typically increases compressor power by 1-3%, but can be as high as 10% for low-temperature, single-stage operation.
There are two common types of external oil cooling:

- Thermosiphon (pictured)
- Recirculated Water or Glycol

Both types do not result in increased compressor power
What type of compressor does your refrigeration system use: Reciprocating, Rotary Screw, or Rotary Vane?
Condensers

- Reject heat from the system absorbed into the refrigerant.
- Evaporative condenser most common (pictured).
- Air-cooled or water-cooled condensers less common.
- Use fans to force or induce airflow to enhance heat rejection.
Evaporative Condensers

- Heat from refrigerant vapor is transferred to water.
- Some of the water evaporates into the air.
- Warm, moist air leaves through the top of the condenser.
- Heat rejection rate is a function of ambient wet-bulb temperature.
Two-Stage Compression

- Improved efficiency for low-temperatures systems (-25 °F and less).
- Intercooler to provide inter-stage desuperheating.
- Can efficiently support multiple evaporation (process) temperatures.
- Can implement subcooling or flash-cooling.
List of Typical EEMs and Definitions

Controls Measures:
- Floating head pressure control
- Compressor staging controls
- Active defrost management
- Adjust suction pressure setpoints

Equipment Retrofit Measures:
- VFDs on Evaporator Fans
- VFDs on Condenser Fans
- VFDs on Screw Compressors
- Condensate Subcooling
- Desuperheater
Floating Head Pressure Control

- Most systems have a fixed head pressure setpoint
- Reset head pressure setpoint based on wet-bulb temperature
- Reduction in compressor energy usage
- Increase in condenser fan energy usage

System energy savings 5 to 12%.

Savings depends on:
- Current setpoint pressure
- Existing condensing capacity
- Local weather data
Compressor Staging Controls

- Minimize screw compressors operating at part-load.
- Base load screw compressors at 100% load.
- Select most efficient part-load compressor for trim.

System energy savings 5 to 15%.

- Simple payback period from 1 to 3 years.
Active Defrost Management

- Controlling the initiation of a defrost cycle.
- Controlling the termination of a defrost cycle.
- Reducing unnecessary refrigeration load.

System energy savings up to 3%.

- Simple payback period from 2 to 4 years.
Adjust Suction Pressure Setpoints

- Raise suction pressure setpoints to highest level and still meet process and space temperatures and production rates.
- Reduces compressor temperature lift.
- Can be done based on production schedule.

System energy savings up to 10%.

- Simple payback period from 1 to 3 years.
VFDs on Evaporator Fans

- Reduces fan speed based on refrigeration load.
- Large reduction in fan power for a small reduction in speed.
- Helps reduce heat generated in cold storage spaces.

System energy savings up to 2%.

☐ Simple payback period from 1 to 3 years.
VFDs on Condenser Fans

- Reduces fan speed based on heat rejection load and wet-bulb temperature.
- Large reduction in fan power for a small reduction in speed.
- Helps maintain a steady head pressure.
- Benefits from floating head pressure control.

- System energy savings up to 3%.
- Simple payback period from 1 to 2 years.
VFDs on Screw Compressors

- Improves part-load performance of screw compressor.
- VFD reduces compressor speed down to 40 – 50%.
- Existing slide-valve is used below minimum speed.
- Not recommended as a retrofit solution for all screw compressors.

System energy savings 5 to 10%.

Simple payback period from 2 to 4 years.
Condensate Subcooling

- Increases low-temperature refrigeration capacity.
- Reduces low-stage (booster) compressor energy usage.
- Slightly increases high-stage compressor energy usage.

System energy savings up to 4%.

- Simple payback period from 1 to 5 years.
Desuperheater

- Reduces process heating loads, such as sanitation water heating.
- Can slightly increase the condensing capacity of the existing condenser.
- Slight reduction in condenser fan energy usage.
- Most beneficial to plants with steady hot water loads.

- System energy savings up to 2%.
- Simple payback period from 3 to 5 years.
Which EEM’s have you implemented?

Controls Measures:
- Floating head pressure control
- Compressor staging controls
- Active defrost management
- Adjust suction pressure setpoints

Equipment Retrofit Measures:
- VFDs on Evaporator Fans
- VFDs on Condenser Fans
- VFDs on Screw Compressors
- Condensate Subcooling
- Desuperheater
Resources

- “Industrial Refrigeration Best Practices Guide”
  - by the Industrial Efficiency Alliance
- “Industrial Refrigeration Handbook”
  - by W.F. Stoecker
- “Industrial Refrigeration Systems Energy Efficiency Guidebook”
  - by the Industrial Refrigeration Consortium (IRC)
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Survey Incentive: 50-80% of the survey cost
Implementation Incentive: $0.02/kWh saved
Pre-approval is required. Visit ActOnEnergy.com/Retro to learn more.
Real Example of Savings

- Food manufacturer
- Received over $6,600 to perform a survey
- Received nearly $12,000 in additional cash incentives to implement improvements
- Lowered their annual energy bills by over $83,000!
Find a Contractor

Click here to find a Contractor who is an ActOnEnergy Program Ally.
Resources

- Website: ActOnEnergy.com/Business
- Phone: 1.866.800.0747
- Fax: 1.309.677.7950
- Email: ActOnEnergyBusiness@Ameren.com
Quiz

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Questions?