Industrial Refrigeration
Best Practices Guide

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CHAPTER 1

Introduction

Background

This Guide identifies and discusses best practices for making industrial refrigeration systems both energy-efficient and productive. The highest levels of efficiency in these systems are achieved through a combination of design, construction, commissioning, operation, and maintenance. This Guide provides insights into approaches to industrial refrigeration systems that cost less to operate, are reliable, can maintain accurate and consistent temperatures in refrigerated spaces, help ensure that processing equipment operates consistently, and can meet varying production needs.

This Guide was developed with the support of the Northwest Energy Efficiency Alliance. The Alliance is a non-profit corporation supported by electric utilities, public benefits administrators, state governments, public interest groups and energy efficiency industry representatives. These entities work together to make affordable, energy-efficient products and services available in the marketplace.

The Alliance is committed to programs that will cause market transformation, wherein energy users are influenced by example, education, and experience to increasingly consider and make choices in favor of energy-efficient products and services.

Goals

Ultimately, market transformation for energy efficiency in industrial refrigeration is achieved by changing the business practices of food processing companies, cold-storage and refrigerated warehouses, and the trade allies that support and serve them. Design standards and operation-and-maintenance practices that increase and maintain energy efficiency can also be adopted by users of industrial refrigeration and their engineering consultants and contractors.

In this context, the goals of this Best Practices Guide are:

- **To identify opportunities to increase electrical energy efficiency in industrial refrigeration systems** The Guide specifically focuses on energy savings measured in kilowatt-hours (kWh).
It is written primarily for audiences in the Pacific Northwest region of the United States, where energy costs are the largest portion (usually over 80%) of typical electric bills. The Guide does not specifically address reducing peak monthly power demand, measured in kilowatts (kW). However, in most cases, a system that saves energy will also reduce peak demand. This Guide also does not address load-shifting strategies, where refrigeration load is shifted from a high-cost time period to a low-cost time period, nor does it address reactive power (power factor, or kVAR) or power-quality issues such as harmonics.

- **To better understand industrial refrigeration as a system**  
  Energy efficiency in industrial refrigeration includes both selecting efficient components and integrating those components into an efficient system. The goal is to minimize the energy consumption of the entire system. Frequently, one or more small constraints in a system can limit the efficiency of the overall system. In other instances, reducing the energy use of one type of component may increase the energy use of another. Understanding the way the system behaves as a whole lets us avoid building in “weak links” and allows us to strike an efficient balance between components.

- **To motivate system designers, contractors, plant engineers, and owners to consider life-cycle costs when installing or upgrading industrial refrigeration systems**  
  The equipment-supply and design-build businesses are very cost-competitive, and facility owners have limited capital budgets. Therefore, system design often emphasizes low initial cost rather than low life-cycle cost. Energy costs are the most significant ongoing life-cycle cost, and are a major component of the total present-value cost of a refrigeration system.

- **To highlight non-energy benefits of energy-efficient practices**  
  In most situations, investments in energy efficiency can also reduce labor costs, increase productivity, increase product quality, and increase system reliability.

- **To emphasize that best practices include more than just system design**  
  Commissioning and well considered operation-and-maintenance practices contribute importantly to the long-term energy performance of the system.

**Focus on Industrial Refrigeration**

This Guide focuses solely on industrial refrigeration systems, which we define in the following broad terms.

**Table 1: Qualifying attributes of industrial refrigeration systems**

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Criteria</th>
</tr>
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<tbody>
<tr>
<td>Size:</td>
<td>100 tons or larger</td>
</tr>
<tr>
<td>Refrigerant:</td>
<td>Ammonia (R-717) in the vast majority of cases, with some R-22 applications</td>
</tr>
<tr>
<td>System Type:</td>
<td>Centralized and built-up, as opposed to commercial refrigeration equipment which is simpler, more modular, and distributed</td>
</tr>
<tr>
<td>Load Temperatures:</td>
<td>-60°F to 55°F with normally at least one load below 40°F</td>
</tr>
<tr>
<td>Function:</td>
<td>Primarily storage and processing of food products</td>
</tr>
<tr>
<td>Industries:</td>
<td>Refrigerated warehouses, including controlled atmosphere</td>
</tr>
<tr>
<td></td>
<td>Fruit and vegetable processors ranging from fresh product storage to highly processed pre-prepared meals</td>
</tr>
<tr>
<td></td>
<td>Breweries and wineries</td>
</tr>
<tr>
<td></td>
<td>Dairy and ice cream processors</td>
</tr>
<tr>
<td></td>
<td>Meat, poultry, and fish processors</td>
</tr>
</tbody>
</table>
Industrial refrigeration systems are distinct from two related system types, which are not covered in this Guide:

- Commercial refrigeration systems (such as those in grocery stores) which tend to be smaller, simpler, and more modular.
- Large HVAC systems that cool spaces occupied by people and equipment, and that maintain space temperatures higher than 55°F.

**Road Map to this Best Practices Guide**

This Best Practices Guide is written for a wide audience. Readers (and users, for it is intended that this document be used) will certainly include:

- Owners, officers, and regional managers of food-processing companies
- Plant managers, production and operation managers, and maintenance managers
- Corporate engineering staff at food-processing companies
- Operators of refrigeration systems
- Personnel in utility efficiency programs
- Design engineers and energy analysts
- Contractors and vendors who serve the industrial refrigeration market

Although most of this Best Practices Guide will be of interest to all readers, some sections will be of particular interest to specific audiences. The chapters of the Guide and how each audience may find them valuable are outlined below and illustrated in Figure 1. We hope that you will find useful information on best practices for your refrigeration system for energy efficiency, to control operating costs, and to realize productivity benefits—fundamentally, to improve your bottom line.

*Chapter 2: Best Practices Overview*, beginning on page 5, includes an overview of design, operation, and maintenance best practices, an outline of the major categories of improvement, and a guide on how to obtain best practices in industrial refrigeration systems.

*Chapter 3: Refrigeration System Basics*, beginning on page 10, reviews refrigeration basics and, if needed, will help familiarize you with industrial refrigeration concepts and equipment. If you are already familiar with refrigeration systems and related components you may want to skip this section, but it may be useful for reference. You may also want to skip this chapter if you are looking for a higher level view of best practices. You can refer to this chapter as needed.

*Chapter 4: Best Practices for Equipment, Systems, and Controls*, beginning on page 46, describes energy-efficient concepts, equipment, controls, and system types. This chapter features recommended best practices. If you are an owner, plant engineer, or operator, we recommend that you understand these best practices and consider them, if feasible, for your facility. This chapter also highlights the benefits beyond energy cost savings that are often associated with increased...
energy efficiency. This chapter is not an engineering manual and should be accessible to all potential
readers described above.

Chapter 5: Best Practices for O&M and Commissioning, beginning on page 84, addresses how
operation, maintenance, and commissioning affect the energy performance of the system. This
chapter is not a training manual for operation and maintenance, but addresses these points on a
higher level that is suitable for most readers.

Chapter 6: Tools for Implementing Best Practices, beginning on page 90, provides tools and
concepts to help you address your system and work toward best practices. This chapter is geared
more toward management personnel (owners, corporate engineers, and operators) at food-
processing plants. It includes a self-assessment survey that covers many of the concepts featured in
this Guide. This chapter also includes other energy-management tools, concepts, and engineering
references.

Chapter 7: Case Studies, beginning on page 111, includes three short case studies that were selected
to show how some of these best practices have been implemented in the Pacific Northwest.

You will find another useful resource at the end of Chapter 4. Beginning on page 80, under
Efficiency Checklist, are three tables—one each for compressors, evaporators, and condensers—that
summarize the key best practices from Chapter 4 and Chapter 5.
Chapters 2–6 are omitted in this excerpt.
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This section contains short case studies that were selected to show how some of these Best Practices have been implemented in the Pacific Northwest.

- Henningsen Cold Storage
- Oregon Freeze Dry
- WestFarm Foods
The Project

The Henningsen family has been in the cold-storage business since 1923. When you have been in the business for more than eighty years, you take the long view, and one way to do that is to look at life-cycle costs.

Headquartered in Hillsboro, Oregon, Henningsen Cold Storage Co. is a full-service, public, refrigerated warehousing company that offers over 36 million cubic feet of frozen and refrigerated warehousing space and has locations in Idaho, North Dakota, Oklahoma, Oregon, Pennsylvania, and Washington.

In 1996, Henningsen built a state-of-the-art cold-storage warehouse in Gresham Oregon. After nearly a decade of operation, it is still an outstanding example of Best Practices in energy-efficient industrial refrigeration.
The Gresham Warehouse Story

During the summer of 1995, planning was nearing completion on the new Henningsen Cold Storage facility in Gresham, Oregon. The 50,000-square-foot facility would provide food-storage and blast-freezing services to their customers. According to Paul Henningsen, great-grandson of the company’s founder and director of corporate development, the goal for the facility was to provide high-quality services at a fraction of typical operating cost. Cascade Energy Engineering, Inc. was brought in to recommend cost-effective energy-efficiency measures.

Because this was a new construction project, a “baseline” design was developed that included standard facility design, equipment, and controls. This was compared to a system design that included state-of-the-art equipment and controls, along with extra insulation and efficient lighting. The new facility opened in June of 1996 and was built with all recommended efficiency improvements.

After a rigorous commissioning and verification process, annual energy savings of 1,140,000 kWh, worth $51,000, were documented—a 42% reduction compared to the baseline design.

The incremental cost of the upgrades in design, equipment, and controls was $410,000. These additional costs were partially offset by efficiency incentives from the serving utility, Portland General Electric and by state tax credits offered by the Oregon Department of Energy. These incentives brought the effective payback down to about four years (at 1996 energy rates).

At the time, Paul Henningsen said “This project reduces our power bill and improves our bottom line, and since we know more about what’s going on in our facility, we make better decisions. My advice is that since power rates never seem to get cheaper, installing efficient equipment will help you offset likely increases.”

These words proved to be prophetic. The four-year payback may have been a bit of a stretch at the time, but the Henningsen team’s foresight was rewarded when energy rates surged upward in 2000.

Energy Efficiency

Energy-efficiency improvements include:
- 6 inches extruded polystyrene wall insulation
- 6 inches extruded polystyrene floor insulation
- 15 inches extruded polystyrene ceiling insulation
- Three fast-acting warehouse doors serving dock
- 400W Bi-level HPS lighting fixtures
- Oversized condenser at 85°F design
- Axial condenser fans
- VFD condenser and evaporator fan control
- Evaporators sized for 10°F temperature difference
- Three diversely sized screw compressors
- Thermosiphon compressor cooling
- Premium-efficiency motors
- Computer control system
- Automatic non-condensable gas purger
- Coordinated VFD and slide-valve control on trim compressor

Continued Success

The energy-efficient system design proved its worth to the company’s bottom line, so when Henningsen more than doubled the size of the facility in 1998, efficient design, equipment, and controls were again specified. This brought an additional 660,000 kWh per year in energy savings and reduced operating costs by $30,000 annually.
**The Project**

Oregon’s Willamette Valley with its mild climate, 40 inches of annual rainfall and fertile soil is one of the largest food production centers in the nation. It was the perfect home in 1963 for a small firm that processed dried fruit for breakfast cereals. Over the years, the firm developed military rations and private-label food brands. It also perfected the freeze-drying process that combines the freshness, color, and aroma of frozen foods with the shelf stability and convenience of canned and dehydrated foods. Today, Oregon Freeze Dry, Inc. in Albany is the largest custom processor of freeze-dried products in the world and a technological leader in the freeze-drying process.

Oregon Freeze Dry has three manufacturing plants on its 35-acre site. Its manufacturing process is energy-intensive, especially the two-stage ammonia-based industrial refrigeration system that serves 14 freeze-dry chambers and several cold rooms.

The company’s engineering staff initiated a study, with help from Pacific Power and an energy-engineering firm. The study revealed several energy-saving opportunities that the company implemented.

In March 2003, Oregon Freeze Dry completed installation of variable-frequency drives (VFDs) on each of four screw compressors of its refrigeration system. These allow the compressor motors to vary speed to match refrigeration loads. The company also replaced an undersized 8-inch suction line with a 12-inch line. The energy savings of the VFD and suction line were substantial—nearly 2 million kilowatt-hours annually or 34% of the refrigeration system’s base energy use. In addition, the VFDs require minimal employee training and reduce motor and compressor wear.
**Background**

The engineering staff at Oregon Freeze Dry believes plant energy use is their responsibility. In 2002, they decided to look at the ammonia-based refrigeration system, one of their most energy-intensive systems. They invited Al Leake of Pacific Power to discuss energy-efficiency projects and available incentives.

Pacific Power arranged for Cascade Energy Engineering to perform an energy study to find specific ways to improve the efficiency of the refrigeration system. Their report suggested three efficiency measures: 1) installing variable-frequency drives (VFDs) on four of the eight compressors; 2) adding a new suction line between two plants, and 3) expanding computer controls to manage the VFDs.

The existing compressors inefficiently varied capacity with slide valves. The VFDs would instead allow the compressor motors to vary speed to match refrigeration loads. The existing undersized suction line created a large pressure drop which required a lower (and less efficient) system suction pressure.

Oregon Freeze Dry management reviewed the report, found the financial payback and incentives attractive, and approved the installation.

**Features**

- ABB variable frequency drives were installed on four screw compressors (two high stage and two booster compressors). The remaining four compressors are now used for base loading and back-up.
- A Techni-Systems computer-control system manages which compressors run and at what speeds to meet the refrigeration load with maximum efficiency.
- A 12-inch-diameter suction line supplements the old 8-inch line.

**Replication**

- In industrial refrigeration systems, VFDs are often cost effective for screw compressors, evaporator fans, and condenser fans. Generally, VFDs are useful where equipment operates for long hours in systems with variable loads or light loads.
- If a compressor operates at or near full speed most of the time, adding an adjustable speed drive will not be cost effective.
- A VFD may not always be the best way to control capacity. Sequencing of multiple compressors or the use of a reciprocating compressor for trim are other possibilities.
- The use of VFDs is only one way to save energy in industrial refrigeration systems. Other ways include refrigeration computer control, thermosiphon oil cooling, high-speed energy efficiency doors, and bi-level lighting.

**Benefits**

- VFDs and control system efficiently vary the capacity of the refrigeration system with speed control rather than with the less efficient slide valves.
- Energy savings of 1,939,000 kilowatt hours/year (34 percent of base energy use) with no reductions in production.
- Energy cost savings of $77,700/year.
- Reduced wear on motors and compressors due to soft starts and fewer operating hours.
- The VFDs and control system require minimal employee training.
WestFarm Foods is one of the largest dairy manufacturers in the nation, with 1,200 employees at 11 processing plants in Washington, Oregon, Idaho and California. In early 1996, WestFarm Foods began planning for an expansion and modernization of their Portland, Oregon creamery.

WestFarm engineers were designing a new Extended Shelf Life (ESL) processing line and the associated cooler space. Increased loads from the ESL process and cooler would require adding a 350-hp compressor to supplement the existing 350-hp and 600-hp screw compressors. This in turn would require another condenser.

WestFarm and their Portland General Electric account representative arranged for Cascade Energy Engineering to perform a detailed energy study, starting with data logging of the existing refrigeration system. The data collected included suction pressure, condensing pressure, and compressor slide valve position. Hour meters recorded run time for the liquid solenoid valves and power measurements were made on the primary refrigeration compressor.

Data logging revealed three major issues with the existing systems. First, compressors operated unloaded much of the time because they were sequenced manually, not by computer control, to meet the wide range of plant loads. Second, the high minimum condensing pressure of 140 psig, which was required to ensure proper liquid ammonia flow throughout the sprawling plant, resulted in increased compressor power, particularly during the winter. Third, the evaporator coil liquid solenoids in the milk cooler were off much of the time, resulting in excessive fan power.
Efficiency Opportunities

A review of the baseline refrigeration bid specification revealed several opportunities to increase energy efficiency. First, the baseline design condensing temperature of 90°F would unnecessarily increase summer compressor energy use. Second, the heat rejection rate of the baseline condenser was a relatively inefficient 225 MBH/hp. Efficiencies of 300 MBH/hp or higher are possible. Third, the baseline design included neither computer control nor variable-frequency drives (VFDs).

Features

A computer control system was installed to provide improved compressor sequencing, tighter control of condenser fan set points, and more importantly, a “backbone” for VFD control.

A 350-hp VFD was installed on the new compressor, working in conjunction with its slide valve to provide load trim. The other compressors are now either off or at 100% capacity.

VFDs were used on the evaporator fans in the milk cooler and the new ESL cooler. The computer reduces fan speed whenever space temperature is satisfied.

A new high-pressure ammonia receiver with a booster pump was installed to ensure adequate liquid pressure to sensitive loads. This allowed the minimum condensing pressure to be reduced from 140 psig to 90 psig.

A larger, more efficient condenser was specified, and all condenser fans were equipped with VFD control to manage condenser capacity with speed rather than cycling.

Efficiency Measures

Implemented energy-efficiency measures include:

- Refrigeration computer control system
- Screw compressor VFD control
- Evaporator fan VFD control in ESL cooler
- Evaporator fan VFD control in milk cooler
- 90 psig condensing pressure
- Oversized/efficient evaporative condenser
- Condenser fan VFD control

Results

Implemented measures reduced annual energy consumption at the WestFarm facility by more than 2,000,000 kWh—nearly 40% of the total refrigeration energy use. Annual operating costs were reduced by about $75,000.

The entire package of improvements cost $310,000. Although this represented an attractive 4.2-year payback, incentives from Portland General Electric and a 35% tax credit from the Oregon Department of Energy reduced the final customer payback to one year.