Focus on Cold Storage Evaporator Fan VFDs Is a Market Transformation Success

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ABSTRACT

The "Evaporator Fan VFD Initiative" is a regional market transformation program focused on refrigeration fans in cold storage warehouses. The program is funded by the Northwest Energy Efficiency Alliance and is geared toward demonstrating the energy and non-energy benefits of variable frequency drives (VFDs) for evaporator fans in industrial refrigeration systems. This VFD application has significant energy savings potential, but had not been widely adopted until this market transformation initiative was put into place.

This paper presents background on the Initiative and its technical approach; discusses field trial results in apple and pear storage facilities and in refrigerated warehouses; describes a new market opportunity in potato storage facilities; assesses the extent of market transformation to date; and suggests future opportunities in industrial refrigeration efficiency.

Introduction

The Pacific Northwest has a large number of refrigerated warehouses related to the production, storage, and distribution of food products. One prominent sector of this market is the controlled atmosphere (CA) storage of apples and pears. This approach involves long-term storage of fresh fruit under controlled conditions. Other sectors of this market include food distribution warehouses, frozen food storage, and potato storage facilities.

In refrigerated warehouses, evaporator fans circulate room air across refrigerant coils. The fan motors are fairly small (⅓ hp to 20 hp), but quite numerous, and thus are usually the second largest energy user in most refrigeration systems, and are the largest user in CA storage. VFDs can slow the evaporator fans and reduce energy use up to 85 percent while maintaining the airflows necessary for temperature and product quality control.

Market Barriers

Although a number of facilities have employed VFD technology, several market barriers have prevented wider implementation. The primary barrier in fruit and potato storage facilities is perceived risk regarding the impact of reduced fan speed on product quality. A CA room can contain over one million pounds of fruit; therefore, fruit value dwarfs potential energy savings. Facility owners are conservative about making changes when current practices are acceptable.

Another barrier relates to the cost of energy in these locales (as low as $0.01 per kWh). In many cases energy savings alone cannot justify the capital investment in the variable frequency drives. Decision-makers need information on energy savings and non-

energy benefits in order to evaluate the return on investment from installation of evaporator fan VFDs.

For cold storage facilities, a barrier is uncertainty regarding adequate airflow distribution in large refrigerated rooms. For both CA storage and cold storage facilities, a technical barrier is concern that VFDs may cause fan motor failure.

Goal of the Initiative

The Initiative set out to overcome the market barriers and make evaporator fan VFDs an industry standard in refrigerated warehouses in the Pacific Northwest. In supporting the Initiative, the Northwest Energy Efficiency Alliance sought widespread acceptance of the technology among market actors by promotion of the energy and non-energy benefits. Market acceptance was predicated on reducing perceived risks associated with slower fan speeds. In particular, a goal was to determine whether use of VFDs could result in no adverse impact on, or even improvement in, fruit and potato quality. Many fruit growers, facility designers and refrigeration contractors believed that lowering air speed would have an adverse effect on fruit quality due to uneven temperature and air distribution in the storage environment. For cold storage warehouses, the project sought to better understand impacts of VFDs on room airflows and worker comfort.

The Alliance also hoped to see expansion of VFD installations within the Pacific Northwest region and the emergence of additional consultants and installation contractors in this market niche. The original period of the Initiative was from January 1998 through December 2000. The contract period was extended to June 2004 to allow the completion of full-scale installations in cold storage facilities; and to expand the scope of the project into potato storage facilities.

Technical Approach

Market Characteristics

Since the start of the Initiative in 1998, there has been limited growth (approximately 2 percent) in the Northwest refrigerated storage market. In the CA storage market, low prices for apples may have affected the industry's ability to fund new capital projects. Table 1 shows the approximate number of facilities in the Pacific Northwest (Idaho, Montana, Oregon and Washington) in 2001, annual MWh consumption, and savings potential.

Table 1. Refrigerated Warehouse Characteristics

Type of Facility	Number in Pacific Northwest	Annual Consumption (MWh/yr)	Cumulative Savings Potential (MWh/yr)
Controlled Atmosphere	236	181,000	108,000
Cold Storage	245	176,000	58,000
Potato Storage	220	193,000	39,000
Total	701	550,000	205,000

Sources: Evaporator Fan VFD Initiative: Baseline Market Evaluation Report, 1999; Evaporator Fan VFD Market Transformation Initiative: Market Progress Evaluation Report #3, 2002; Potato Fan VFDs: Phase 1 Alliance Report, 2002

The CA market is characterized primarily by storage of apples and pears. Storage facilities are concentrated in the Wenatchee and Yakima valleys in Washington State, with a few facilities in Idaho and Oregon. The secondary CA storage market in the Pacific Northwest is potatoes. Potato storage facilities are concentrated in southern Idaho and in eastern Oregon and Washington. Cold storage facilities consist of blast freezers for low-temperature storage of commodities such as processed potatoes and seafood; and distribution centers that store a variety of food products in different rooms at varying temperatures. These facilities are widely dispersed throughout the Pacific Northwest.

Application of VFDs in Industrial Refrigeration

The Initiative addresses three applications for evaporator fans: CA storage in apples and pears; ventilation fans in potato storage facilities; and other industrial refrigeration.

Controlled atmosphere storage. This application involves the careful control of temperature, oxygen, and carbon dioxide in a storage room to extend the keeping quality of apples and pears. Facilities typically consist of dozens of CA rooms, one or more common cold storage areas, and a cooled packing room. Typical storage temperature is around 33ºF. A typical CA room might hold 1,500 large field bins, with a total weight of over one million pounds of fruit.

The evaporators usually have between two and five fans. Despite using relatively small motors (most under 5 hp) and one evaporator coil per room, these fans are collectively the largest electrical load in a fruit storage facility.

Potato storage ventilation systems. These systems are designed to move air through stored potatoes in order to remove the heat of respiration and control product temperature and humidity. Potato storage buildings typically consist of a central plenum with lateral ducts that provide fan-powered ventilation at the bottom of a 20-foot high pile of potatoes. Air is returned from the top of the pile to the plenum to be recirculated. Typical storage temperature is 46ºF with a relative humidity of 95 percent.

A potato storage facility will have approximately 80 hp of fans for 20 million pounds of potatoes, using one or more evaporator coils per room. These fans are the largest electrical load in potato storage facilities.

Cold storage warehouses. These facilities are used for storage of a variety of food products and include food distribution centers, food processing facilities, and large freezers. These warehouses may have multiple rooms and may total as much as 500,000 square feet. Storage temperatures range from 35ºF to -5ºF.

Cold storage warehouses have similar evaporator coils to CA rooms, although in general they are larger because the spaces are larger and the loads due to colder temperatures are higher. Cold storage warehouses typically use more than one evaporator coil in each room. The evaporator fans are the second largest load in these facilities, after compressors.

Variable frequency drives. Variable frequency drives are electronic devices that can vary the line frequency of the current provided to a motor and thus control the speed of evaporator fans. At half speed, the fans will only consume about 15 percent of full-speed power while

providing 50 percent of the air movement and maintaining consistent and uniform temperatures throughout the refrigerated space. One VFD can control all the motors on an evaporator coil.

Other fan control. Other types of fan control are also used in these facilities. The two most common approaches are fan cycling and manual fan shedding. In fan cycling, all fans are turned off and on according to a set schedule or based upon measured temperatures. In split fan operation, half the fans may be manually turned off. The advantage of these approaches is that they cost very little to implement. On the other hand, they cannot achieve the energy reduction possible with VFDs; they cannot deliver the precise control that VFDs can provide; and they do not control space temperatures as well as VFDs can.

Demonstration Trials

The Alliance supported 26 demonstration field trials in order to quantify energy and non-energy benefits of evaporator fan VFDs. Seventeen of the trials were in CA fruit storage facilities in Washington State; one was a CA fruit storage trial in Idaho. Six trials were in cold storage warehouses in Idaho, Oregon and Washington. Two new trials are under way in potato storage facilities in Idaho.

In a typical CA field trial of fruit, one storage room in the facility would have a VFD installed. To evaluate mass loss in fruit, small mesh bags were filled with sample fruit that had been weighed prior to placement in the room. Test plans varied by site, but as many as 27 bags were loaded into each room, in a matrix of locations throughout the room. This process was repeated for a control room that did not have a VFD installed on its evaporator fans. The rooms would then be closed and remain sealed for approximately four to nine months. When the fruit was removed, the bags were retrieved and the fruit weighed and pressure tested (a test of fruit firmness). Mass loss comparisons were documented between sample fruit from the VFD room and fruit from the control room. Detailed findings were documented in case study reports.

A similar procedure is currently under way in two potato storage field trials. Case study reports will also be produced for results of these trials.

In a typical cold storage warehouse field trial, the VFD installation would comprise a larger percentage of facility square footage than was seen in CA storage, due largely to the space configuration of the facility. The emphasis in these trials was on documentation of VFD energy savings; reporting of non-energy benefits was expected to be more anecdotal, and focused on issues such as consistency of temperatures and worker comfort.

Demonstration Trial Results

The field trials in CA storage of fruit and in cold storage warehouses showed fan energy savings and non-energy benefits. Table 2 summarizes observed results.

Table 2. Demonstration Trial Results

Facility Type	Savings Range	Annual Savings (kWh/hp-yr)	Non-energy Benefits
CA VFDs	25-78%	2400	Reduced mass loss, improved firmness of fruit
Cold Storage VFDs	62-86%	3500	More even temperature distribution, improved worker comfort

Source: Evaporator Fan VFD Market Transformation Initiative: Market Progress Evaluation Report #3, 2002

Savings ranged between 25 percent and 86 percent, with most reductions between 60 percent and 70 percent. Annual kWh savings varied widely due to factors including room size and baseline fan control strategy. If a room had fans that were aggressively cycled before the VFD was installed, savings were much smaller than when fan cycling had not been used. A single-room test in a CA facility might save approximately 20,000 kWh per year, while a full-scale test installation in a cold storage facility might save more than 500,000 kWh per year. Based on varying electricity rates and the complexity of installation, simple paybacks ranged from 1.1 to 8 years.

In the CA storage facilities, all but one site produced significant mass loss reduction in stored fruit. Mass loss reduction ranged from 0.19 percent to 0.58 percent. Although these are small savings in mass loss, they add up to significant numbers when considered over millions of pounds of fruit. Normalized on the basis of installed horsepower, typical energy savings is valued at $72/hp-year and fruit quality improvement is valued at $43/hp-year. The major conclusion of importance to promoting the VFD technology in this application is that it does not have an adverse effect on fruit quality; in fact, improvements in quality were noted in the demonstration trials.

In the cold storage facilities, documentation showed that use of VFDs did not adversely affect temperature distribution in the storage rooms. Comments from facility personnel also suggested that lower airflows resulted in greater worker comfort and potential bottom-line benefits. For example, because product temperatures are more closely controlled when using VFDs, shipping delays may be avoided.

The demonstration trials in potato storage facilities have not yet been completed; however, preliminary evidence suggests that VFDs will produce significant energy savings while improving product quality.

Findings

The Alliance established market effect indicators to evaluate the success of the Initiative at addressing the market barriers. Table 3 lists the indicators and evaluation findings.

Table 3. Market Effect Indicators and Findings

Market Effect Indicator	Finding
• Make evaporator fan VFDs an industry standard in the Pacific Northwest.	• 23% of respondents feel evaporator fan VFDs are standard practice; 33% feel they are common practice. (Standard practice is the preferred and selected alternative; common practice means it is well known and often used.) • VFDs more widely accepted for cold storage than for CA storage.
• By the end of 2001, 5% more refrigerated warehouses would have installed evaporator fan VFDs than in the absence of the Initiative.	• Through 2001, about 15% more evaporator fan VFDs had been installed as compared to the baseline.
• Installations successfully achieved cost-effective savings while maintaining or improving product quality. • For fruit storage, the non-energy benefits were reducing mass loss and increasing firmness; for cold storage, they might include improved worker comfort and better temperature control.	• All project showed energy savings. • All fruit CA projects but one showed product quality improvements. • Anecdotal evidence that workers and managers value the non-energy benefits in cold storage facilities, although these benefits cannot be quantified. • Potato research findings are not yet available.
• Information on results is disseminated broadly throughout the industry and to consulting engineers.	• Case study reports were prepared; 50% of market actors and end users are aware of them. • Papers were presented at trade shows and technical conferences. • Project website (www.cascadeenergy.com) now includes comprehensive information on the Initiative. • A set of three different marketing brochures has been developed (CA storage, cold storage, and general approaches for evaporator fan VFD installations).
• Facilities other than those participating in the Initiative begin to use the technology.	• As of November 2000, there were no installations outside the project that could be attributable to Initiative influence. • By 2002, more than 30 sites that were not part of the field trials had used evaporator fan VFDs.
• Consulting engineers offer VFDs as an installation option, and original equipment manufacturers package VFDs with evaporator fan installations.	• A refrigeration equipment manufacturer has developed package equipment with integrated VFDs. • A VFD manufacturer is planning to develop a technical note for their use with evaporator fans. • While the project is broadly recognized and widely accepted by end users, one or two critical trade allies remain skeptical. Their concerns deal with installation complexity, possible impacts on some fruit varieties, and availability of alternative approaches for fan speed control. • Few consultants in the region offer comprehensive refrigeration system design services.

Source: Evaporator Fan VFD Market Transformation Initiative: Market Progress Evaluation Report #3, 2002

Conclusions

The demonstration trial results showed that VFDs on evaporator fans saved energy without adversely affecting fruit quality or damaging motors. The Initiative evaluation found that, as information from the demonstration trials was communicated to the marketplace, the technical approach became more widely accepted. From the demonstration trials and the evaluation reports, the Alliance has reached several conclusions about the Initiative.

- The Initiative has been successful in allaying the majority of concerns about the use of evaporator fan VFDs in the region.

- Current market penetration of VFDs in the Pacific Northwest is estimated at 18 percent for CA storage of fruit, 5 percent for potato storage and 43 percent for cold storage. Acceptance of VFDs appears to be occurring more rapidly in the Pacific Northwest than the Alliance originally estimated, due to success with key market actors, availability of electric utility incentives and reductions in the cost of VFDs. Compared to the high market penetration in cold storage, investment in VFDs has been lower in CA facilities due to generally poor market conditions for apples and pears over the last 5 years; and in potato storage due to lack of market awareness and diminished cost effectiveness in certain storage situations. On the other hand, the project contractor has recently reported new full-scale VFD installations in several large fruit storage facilities, as well as full-scale installations by five demonstration trial participants.
- The Initiative has achieved incremental market transformation. Equipment vendors and electrical contractors are well aware of VFD technology and its application to evaporator fans, and are strongly supportive of its use. There is some evidence that the industry has built infrastructure for general support of VFD applications. Furthermore, the project contractor is known by everyone in the region involved in industrial refrigeration and refrigerated warehouses, is widely recognized for its expertise on the subject, and is known for its efforts on behalf of the Alliance to promote the Initiative.
- There appears to be a decided improvement in the capabilities of electricians and vendors to properly install and support evaporator fan VFDs. The incidence of problems with motor burnout due to VFDs has decreased significantly. The main issues that remain are proper specification and technical support.
- A small impediment to long-term success of the Initiative appears to be a scarcity of expertise in the region. To date, the project contractor remains the major regional provider of design services for energy-efficient evaporator fan VFD applications, despite the attraction of utility incentive programs that should encourage other firms to begin providing design services.
- Evaporator fan VFD technology is likely to become ubiquitous over the next five to ten years, with or without utility incentive programs. This market trend is due in part to greater awareness of the benefits of the technology and the gradual reduction in cost of VFDs. Utility assistance and incentives could accelerate market penetration, especially in areas where low electricity rates marginalize this type of investment.
- Penetration potential appears to be limited to 80 percent for CA storage facilities, somewhat less for cold storage warehouses, and approximately 50 percent for potato storage facilities. Constraints include electrical limitations, inappropriate evaporator coil sizing, lack of compatible motors and fans, short storage period, and possible adverse impacts on certain fruit varieties.

Adaptive Management

Additional market transformation benefits can occur by identifying and following up on new opportunities that may arise during a project's implementation. In the case of the Evaporator Fan VFD Initiative, dissemination of results from the field demonstrations in CA storage led to a utility inquiry as to suitability of evaporator fan VFDs in potato storage.

With approval from the Alliance, the project contractor documented current use of VFDs in potato storage facilities, completed a market assessment, and collaborated with the University of Idaho on demonstration trials using similar protocols to those developed for the demonstration trials in apple and pear storage facilities. The project contractor will also assess the technical potential for VFD applications in onion storage.

When the demonstration trial work on VFDs in potato storage is completed and documented, the project contractor will complete case study reports and take the results to appropriate industry conferences and trade shows. The region will benefit from having information available on another application of evaporator fan VFD technology.

Additional Opportunities

The Evaporator Fan VFD Initiative is drawing to a close with successful attention to applications of the technology in specific markets. Now that more is known about the benefits of this technology, it may be appropriate to examine the feasibility of integrated optimization approaches for industrial refrigeration systems. There is recognition that in seeking to transform the market for a single technology, certain other opportunities may not receive the attention they deserve.

As the market for VFDs matures and becomes an industry standard, the Alliance may encourage the market actors to identify other cost-effective measures that could be undertaken as part of a longer-term strategy for serving industrial refrigeration users. There may be incremental benefits in providing a full measure of products and services to the client rather than offering design services limited to a single accepted technology.

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