Magi Evaporator Fan VFD Case Study

1.0 Executive Summary

As an energy efficiency measure, a variable frequency drive (VFD) was installed to allow reduced fan speed operation in Room 17 at Magi Plant #4. This room is a large room, approximately 100' feet in length with a capacity of 3,000 bins. The energy and fruit quality performance of Room 17 was compared with the adjacent Room 16 over a full CA season. During the 1999 test year, both rooms contained golden delicious apples. Tables 1 through 6 summarize the test results, potential cost savings, and project costs.

Our conclusions are:

- Evaporator fan VFDs offers significant energy savings relative to the fan cycling baseline.
- Fruit quality was improved both in terms of fruit mass loss and fruit firmness. The reduced mass loss translates into additional fruit boxes.
- The return on investment for a large scale installation should be attractive particularly if energy rates rise as predicted and/or Okanogan PUD offers energy efficiency incentives.
- VFD equipment and installation costs are likely to be lower on large-scale installations.
- Energy savings per room could be increased by 15,000 to 20,000 kWh relative to the savings achieved through several strategies. This would increase the energy savings by about 50% relative to those achieved. These strategies would be:
  - Decreasing VFD speed 14 days after room sealing versus a 28 day delay in the test.
  - Dropping to 40% minimum speed.
  - Setting the VFD at minimum speed during the 7 days of room pre-cooling prior to loading.
  - Avoiding full speed operation at mid-season and when the room is unloaded.

Table 1 - Energy Savings from Monitoring

Monitoring Start Date and Time	28-Sep-99	
Room 17 shutdown	25-Apr-00	
Room 16 shutdown	20-May-00	
Average season length	222	days
Average amperage in control room over the season	25.6	amps
Control Room kW/amp multiplier	0.46	kW/amp
Average kW in control room over season (includes fan cycling)	11.8	kW
Monitored average kW in VFD room over season (includes full speed operation)	5.5	kW
Season long evaporator fan energy savings	33,560	kWh
Compressor efficiency (Sullair compressor, 30 psi suction, 125 psi discharge)	1.0	BHP/TR
Compressor motor efficiency	93%	
Screw compressor power requirements when unloaded	40%	
Additional compressor energy savings	4,592	kWh
Total energy savings	**38,152**	**kWh/yr**

Table 2 - Energy and Demand Cost Savings

	Existing	30% Increase	75% Increase
Marginal Energy Cost (Okanogan PUD Service Schedule 3)	$0.0271 per kWh	$0.0352 per kWh	$0.0474 per kWh
Peak Demand Rate (assume no change in peak demand rate)	$2.00 per kW	$2.00 per kW	$2.00 per kW
Annual Energy Cost Savings ($)	$1,034	$1,344	$1,809
Annual Peak Demand Cost Savings ($)	$85	$85	$85
Total Energy and Demand Cost Savings ($)	$1,119	$1,429	**$1,894**

Two increases in energy rates are projected, but not confirmed, based upon discussions with Magi and Okanogan PUD.

Table 3 - Fruit Mass Loss Improvement for VFD Room 17

Mass Loss Savings (including correction for length of season)	0.19%	
Number of Bins per Room	3,000	
Fruit Weight per bin	900	lbs
Room Packout	80%	
Total Weight Savings of Packed Fruit	4,037	lbs
Fruit weight per box	42	lbs
Number of additional packed boxes per room	96	boxes
Fruit value per box	$13.00	per box
Packing Cost per box	$7.00	per box
Fruit mass savings per room	**$577**	per year

Table 4 - Fruit Firmness Comparison

	Room 17 VFD	Room 16 Control
Average Firmness (all samples, 3 readings per fruit)	15.1	14.6
Average for Least Firm Apple	12.8	11.8
Average for Firmest Apple	17.8	18.5

Table 5 - Total Savings

Combined Fruit Mass, Energy, and Demand Cost Savings	**$2,471**	per year

Table 6 – Project Costs

Square D VFD (ATV56D23N4U)	CED	$2,649
Input Reactor and Output Filter	CED	$1,166
Installation Labor and Miscellaneous Materials	Ideal Electric	$526
Main Tarp	RD Bussard & Son	650
Side Tarps	RD Bussard & Son	110
Miscellaneous Tarping Materials	-	100
Tarp Installation Labor not accounted		
Total		$5,201

2.0 Installation and Operation Description

2.1 Room 17 VFD Installation Description

A single 25 hp variable torque VFD was installed to drive the six 3 hp evaporator fans in Room 17. An input reactor was installed to minimize the harmonics produced by the drive. An output filter was installed to eliminate voltage spikes that can cause motor insulation failure. All components were sized for the measured motor current in Room 17.

The VFD was not integrated into the control system. Instead, speeds were set manually by the refrigeration operator.

2.2 Room 17 Tarping and Stacking Pattern

Given the large capacity and length of Room 17, the majority of the room was tight stacked and tarps were employed to cut off air recirculation paths at the top and sides of the room and force air through the stack.

2.3 Room 17 VFD Operation

Room 17 was loaded between September 24 and 28. The fans were operated at full speed for approximately 28 days following room closure. The fan speed was reduced to 50% on October 25. In general, fan speed remained at 50% for the duration of the season with the exception that the fans were increased to full speed for a 4 day period in January and during the last 18 days of operation in April. This 18 day period encompassed a period of fruit conditioning (i.e. additional defrosts and lower suction pressures to toughen the fruit for handling) as well as room unloading.

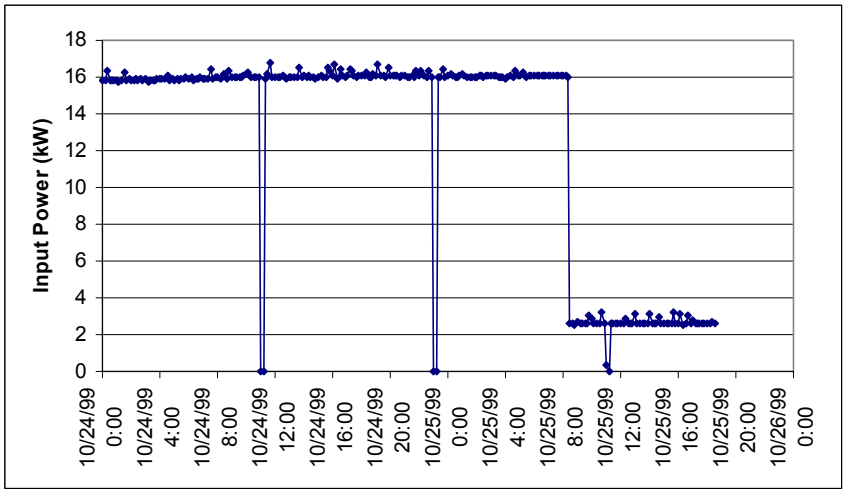

Figure 1 – Measured Input Power to VFD as speed is reduced to 50%

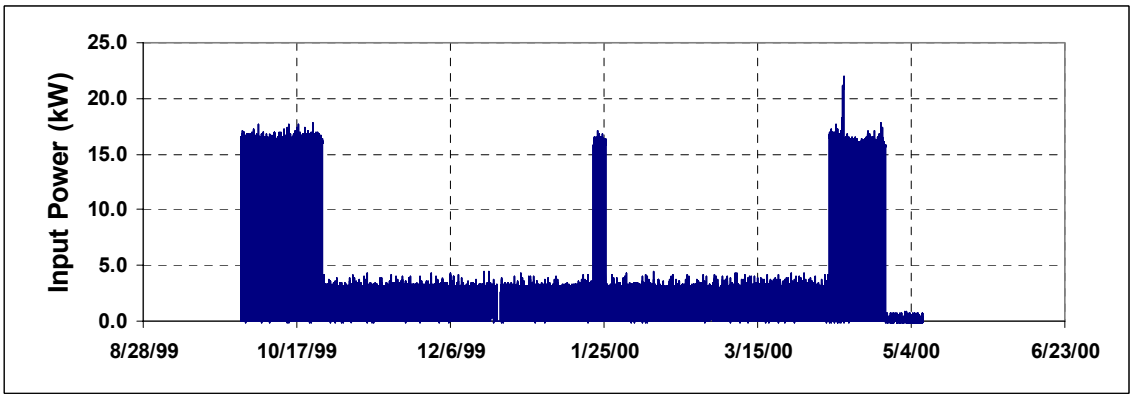

Figure 2 - Room 17 VFD Input Power for full season

2.4 Room 16 (Control Room) Operation

Room 16 was loaded between September 20 and 27. Room 16 was stacked conventionally (i.e. rows were spaced uniformly with gaps between each row). No tarps were employed.

The refrigeration operator employed limited fan cycling in Room 16. Fan cycling was first initiated on December 6. Fan cycling was typically a regime of 1 hour on, 2 hours off. Fan cycling was only intermittently implemented. The fans were cycled for a week or two followed by a similar period of continuous fan operation.

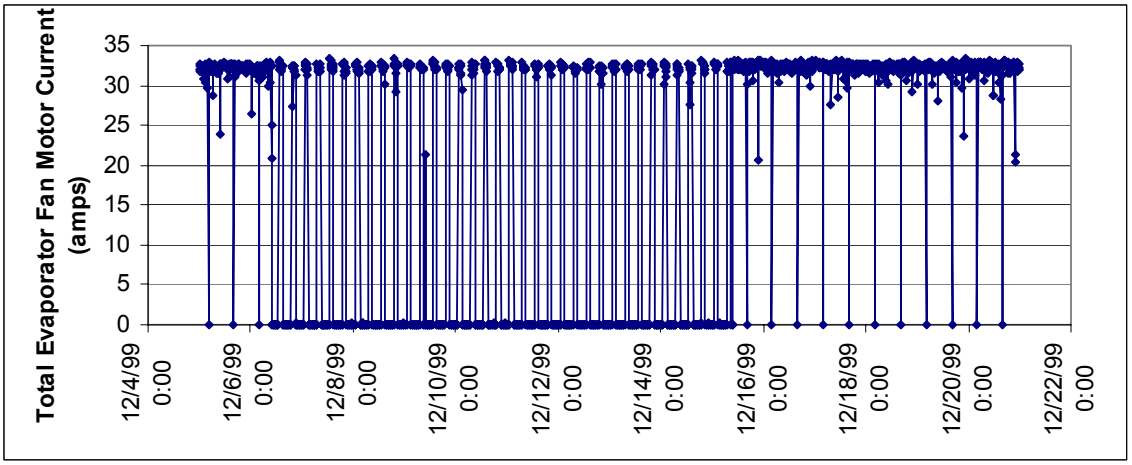

Figure 3 - Typical Evaporator Fan Cycling in the Room 16 (control room)

3.0 Fruit Quality Comparison

To evaluate fruit quality, a total of 160 apples were sampled from a single bin from a large grower (Grower #516 – NW Fruit #2). These apples were marked and individually weighed on September 21. The apples were sorted in terms of size such that each location in each room would have a gradation of apple sizes from smallest to largest. The weighed samples were loaded into mesh bags of 8 fruit and buried in selected bins for retrieval at the end of the CA season. A total of 10 bags were placed in each room. Half the samples were placed near the back of the room (3 stacks from the back wall). The fruit was placed in the 1st, 3rd, 5th, 7th, and 10th bin in the stack. The other half were placed in the cross-stacked bins near the door. Again, five samples were placed in the same stack in the same bin numbers.

Samples were retrieved and re-weighed at the end of the season to evaluate mass loss. After weighing the fruit was pressure tested.

Mass loss figures were adjusted for control Room 16 due to the longer holding period for this room. Essentially, mass loss figures were scaled back based upon the number of days in storage. This correction factor is likely to be very conservative in that most fruit mass loss is typically lost during the pull-down and then again during the "fruit toughening" at the end of the storage period.

Table 6 - Mass Loss Summary for Fruit Samples

	Room 16	Corrected Room 16	Room 17	Difference between Room 16 Corrected & 17	Difference between Room 16 & Room 17
Mass Loss (Avg all Samples)	3.53%	3.04%	2.86%	0.19%	0.67%
Mass Loss (Evaporator End)	3.56%	3.07%	2.94%	0.13%	0.62%
Mass Loss (Opposite Evaporator)	3.50%	3.02%	2.77%	0.25%	0.73%
Mass Loss (Avg Location 1 & 6)	4.16%	3.58%	3.36%	0.22%	0.79%
Mass Loss (Avg Location 2 & 7)	3.40%	2.93%	3.02%	-0.09%	0.38%
Mass Loss (Avg Location 3 & 8)	3.45%	2.98%	2.76%	0.21%	0.69%
Mass Loss (Avg Location 4 & 9)	3.26%	2.81%	2.64%	0.17%	0.62%
Mass Loss (Avg Location 5 & 10)	3.39%	2.92%	2.50%	0.42%	0.89%

In addition to the mass loss improvements, pressure readings averaged about 0.5 psi higher for the VFD room than for the control room. Due to the longer storage period for the control room, the true pressure difference between the rooms would have been lower.