Evaporator Fan VFD Effects on Energy and Fruit Quality

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Overview

Our firm is at the 18 month point of a two year research project to investigate the energy and fruit quality benefits of evaporator fan variable frequency drives in controlled atmosphere rooms. During the 1998-1999 holding season, we conducted ten comparative tests of evaporator fan VFDs in commercial CA rooms in Washington. In each test, a bin fruit room with an evaporator fan VFD was compared to second room that used an alternate fan control strategy. Depending on the site, the alternate fan control strategy was continuous fan operation, alternating fan operation, or fan cycling. The field trials consistently showed excellent energy savings. Also, the tests showed reduced mass loss in every case.

The first page of this document provides:

- A brief background on evaporator fan VFDs.
- A summary of our test methodology.
- A list of assumptions regarding economic return on this technology based upon our test findings.

The remainder of the document consists of answers to frequently asked questions.

Basics of Evaporator Fan VFDs

VFDs are electronic motor controllers that can be used to reduce fan speed after field fruit has been pulled down to storage temperatures. Collectively, the evaporator fans are usually the single largest electrical load in a CA facility during the long holding season. The VFDs offer very attractive energy savings. At half fan speed, (which is typical during the holding season), the fans will consume only about 15% of full speed power.

Test Description

One major element of the testing involved placement of fruit samples at 15 locations within each CA room as the rooms were filled during harvest. In order to minimize differences in our test fruit, our general procedure was to take all fruit from a single bin from a single grower. Each fruit was weighed, numbered, and placed in a mesh bag (6 or 8 fruit to a bag depending on the site). The sample bags were buried under one or two layers of fruit in the CA bins as the rooms were loaded. The bags were retrieved when the rooms opened the following spring or summer. The fruit was re-weighed and then sent to the laboratory for testing. At some sites, this process was repeated for multiple growers.

Most room to room comparisons involved similar length holding seasons. Room loading and unloading were not identical in every case.

The ten sites included red delicious apples (8 lots), golden delicious apples (9 lots), and D'Anjou pears (1 lot).

In addition to fruit quality testing, two sites included detailed monitoring of temperatures (17 locations per room), dew point measurement (one location per room), and real time mass loss data from a load cell. A third site included measurement of carbon dioxide and oxygen concentrations at high and low air movement locations within the room. These measurements were intended to provide insight regarding conditions within the room and their ultimate effect on fruit quality.

Economic Assumptions

To put the results in context, we estimated energy and fruit savings for each field trial and return on investment.

Fruit savings were based upon:

- The total fruit weight in the room.
- The difference in percentage mass loss between the VFD room and the control room.
- An assumed 80% packout rate and $12/box fruit value.

The VFD costs were estimates for large scale installations.

The Economics of Variable Frequency Drives (VFDs) For Control Atmosphere Storage

What kind of simple payback should I expect?

Simple paybacks for the field trials ranged from 1.1 to 2.9 years when energy savings and mass loss improvements were considered.

Simple paybacks ranged from 1.6 to 21.6 years when only energy savings were considered.

Why is there a large range of simple paybacks?

Simple paybacks were influence by storage duration, baseline fan operations (full speed, alternating or cycling), mass loss, and utility rates.

When would I expect the fastest payback?

Fast paybacks are characterized by having a full speed fan baseline, long storage duration and high cost electricity (Test sites 3,4 and 9).

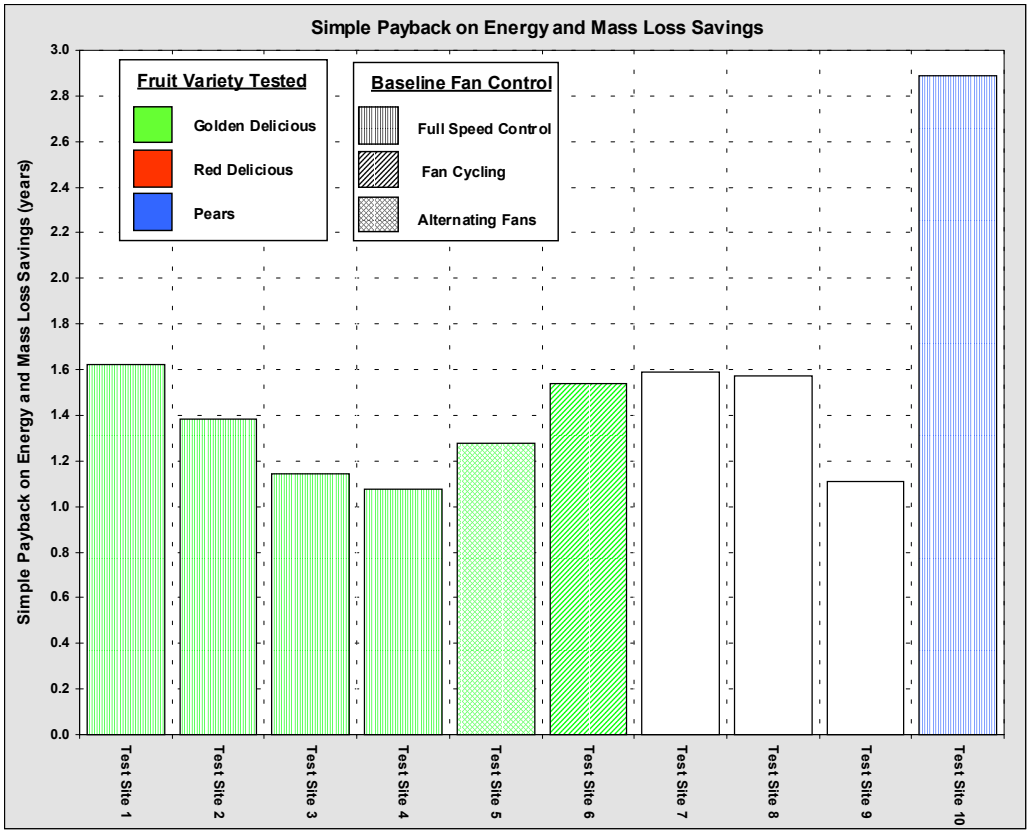
When is a mass loss improvement with VFD operation important to project economics?

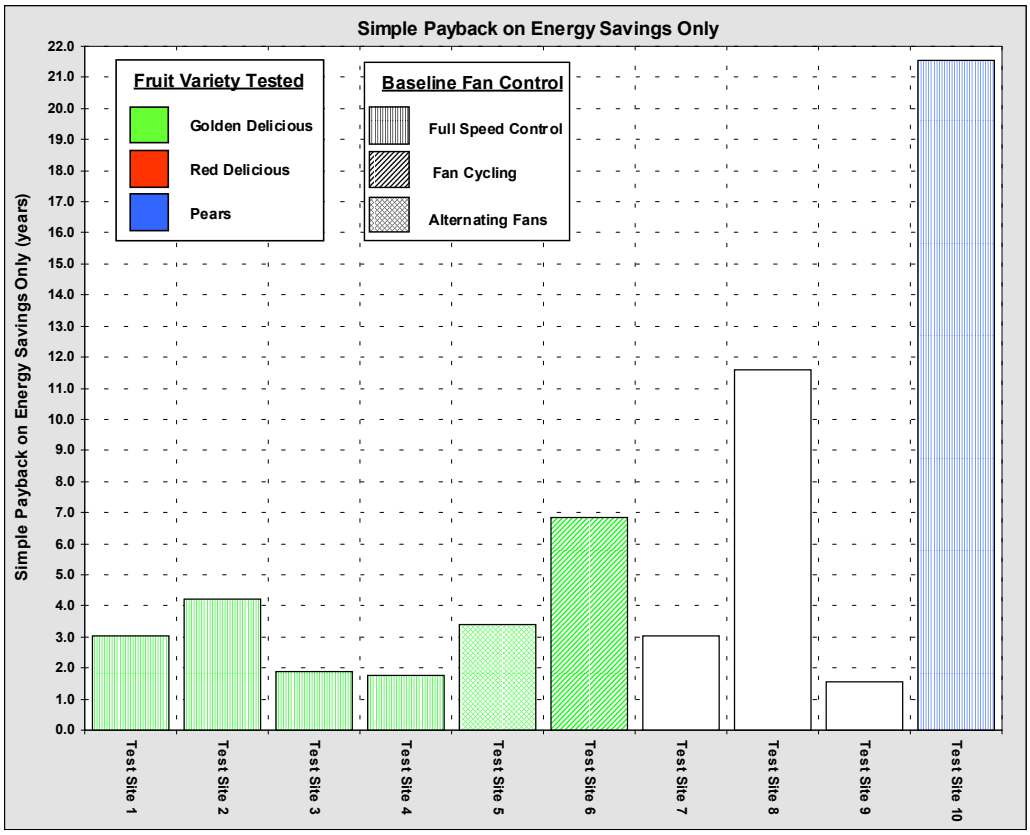
When facilities have:

- Low baseline fan energy use (fan cycling or alternating fans) such as test sites 5, 6 and 8.
- A short storage duration - test site 10.
- Low cost electricity - test sites 1, 2, 6, 7 and 10.

What rules of thumb would indicate if a CA room is a good candidate for VFD control?

- Any new construction.
- Long storage duration.
- Baseline of full speed fan operation.
- Located in an area with high cost electricity.





The Impact of VFDs on Bin Stored Control Atmosphere Fruit

Will using a VFD reduce product mass loss?

YES! VFD operation produced lower average mass loss in all 18 tests involving 10 separate VFD installations.

How much mass loss improvement was seen?

Mass loss savings ranged from 0.06% to 0.58%.

What fruits and varieties were tested?

Golden Delicious Apples - 9 Tests
Red Delicious Apples - 8 Tests
Anjou Pears - 1 Test

Where were the biggest mass loss improvements found?

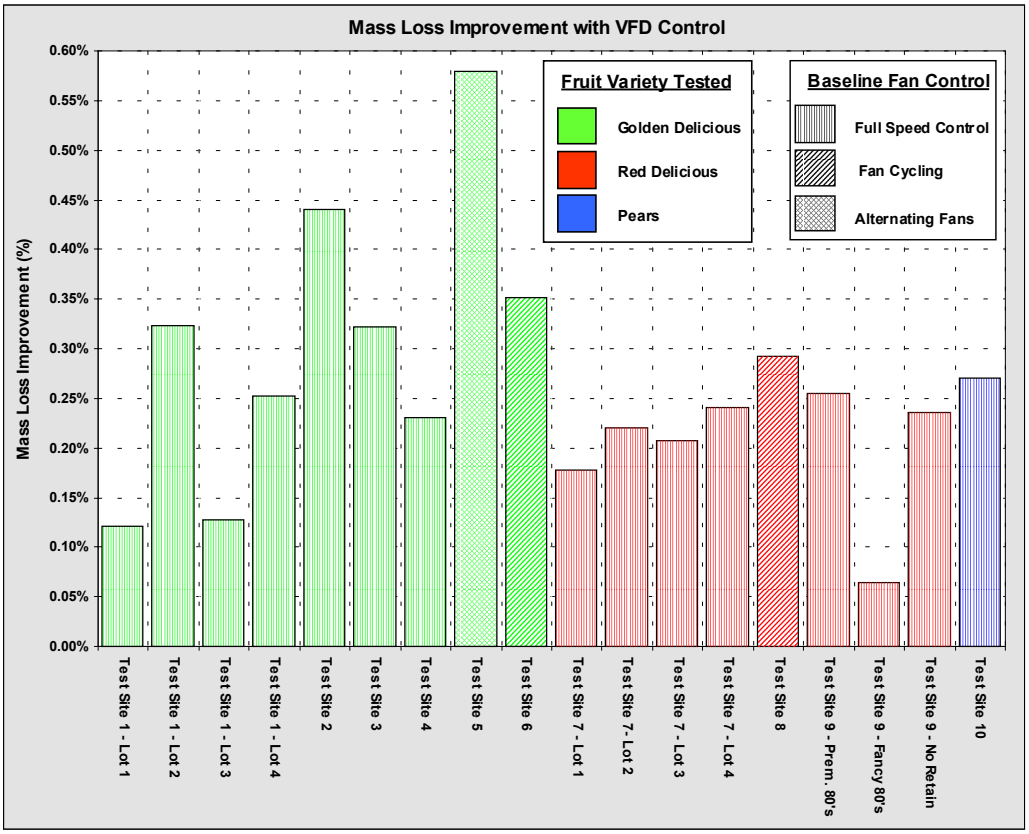
- The biggest overall improvements were found in golden delicious apples.
- An improvement of 0.27% was realized in the Anjou pear test during only ~50 days of reduced speed operation with the VFD.
- Tests with long holding periods.
- Tests where the baseline fan control was fan cycling or alternating fans.

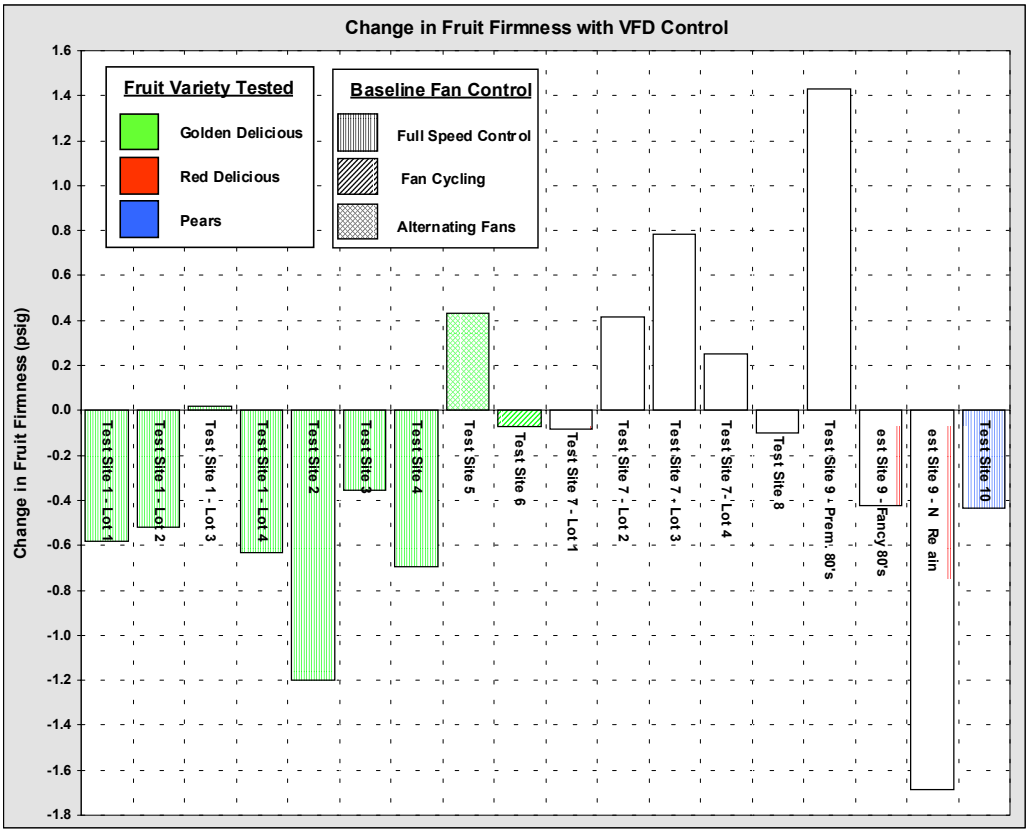
What impact does VFD operation have on fruit firmness?

- Average fruit firmness decreased in 7 out 9 of the VFD tests on golden delicious.
- Average fruit firmness decreased in 4 out 8 of the VFD tests on red delicious.
- Average fruit firmness decreased in the one pear test.

Under what circumstances were the largest decreases in fruit firmness observed?

- At test site 9, in the two tests where the firmness decreased with the VFD, the sample fruit was tested prior to storage and deemed unsuitable for long term CA storage.
- At test site 4, it was necessary extrapolate the change in firmness (the control opened 100 days after the VFD room). There is considerable room for error in the extrapolation.





Reliable and Energy Efficient VFD Operation

How much energy saving can be expected with VFD operation?

In the field trials, energy savings varied from 24% to 78%.

When were the largest energy savings achieved?

At facilities that used full speed fans and had long storage periods.

When were the smallest energy savings achieved?

At facilities that fan cycled or shed fans after the fruit pulldown (test sites 5, 6 and 8).

Can peak demand charges be reduced by using VFDs?

With careful management, VFD's can significantly reduce peak demand charges.

Do VFDs impact fruit pulldown?

The VFD has no impact as fan speed is not reduced during the fruit pulldown period.

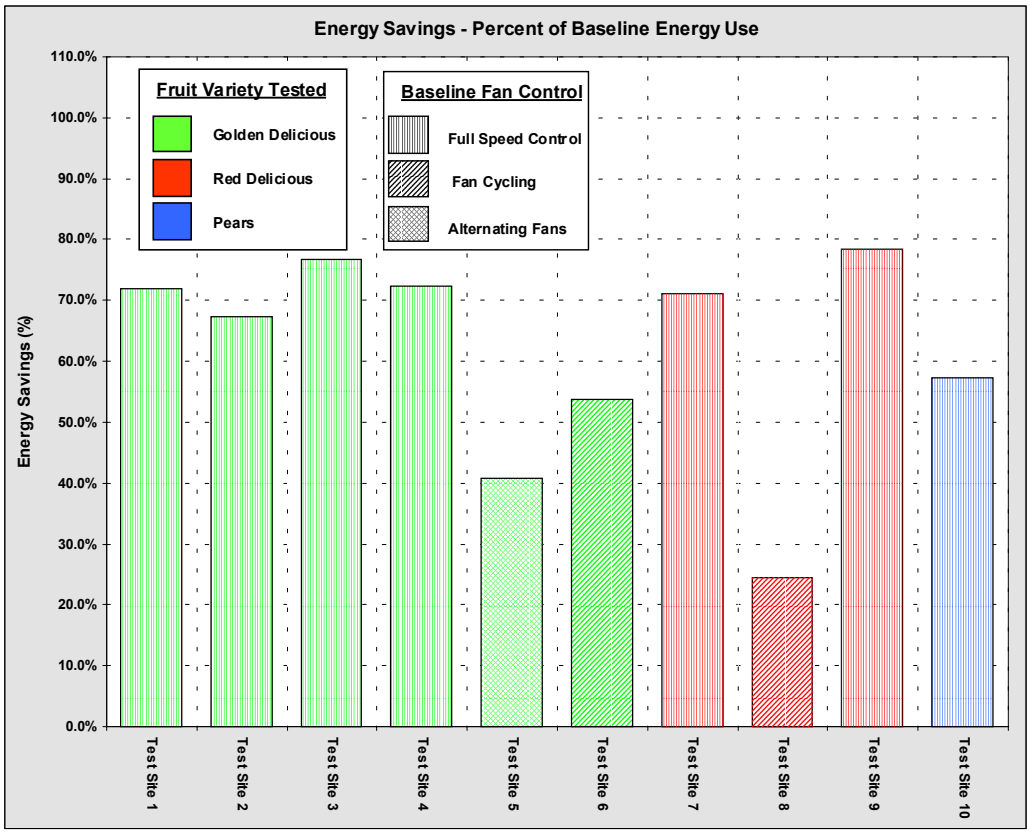
When should fan speed be reduced with the VFD?

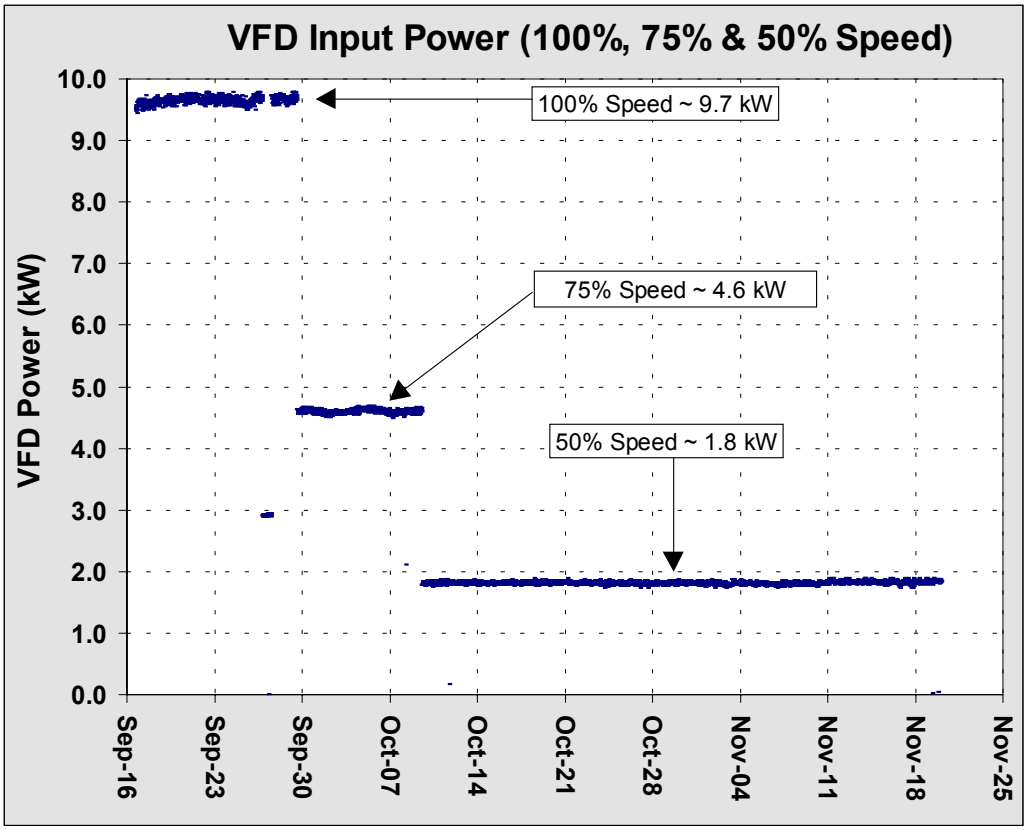
After the fruit has been brought to room temperature.

In the field trials, fan speed was reduced 3 to 4 weeks after the rooms sealed.

How far should fan speed be reduced?

In the field trials, the minimum fan speed was limited to 40% to 50% speed. Further reduction in speed provides little additional savings.





The Impact of VFD Operations on Room Conditions

Will reducing fan speed produce warm spots in the room?

No. Extensive temperature monitoring at two facilities showed no warm spots. Temperatures were monitored inside 15 bins distributed evenly in each test room

The warmest probe in the VFD rooms were only 0.03°F and 0.16°F warmer than the respective warmest control room probe.

Will reducing fan speed produce cold spots in the room?

At reduced speed, air comes off the coil colder than in a full speed room. As a result, colder temperatures were seen towards the top of the VFD rooms.

The coldest probe in the VFD rooms were only 0.23°F and 0.16°F colder than the respective coldest control room probe.

How would you summarize the difference in temperture control between VFD and full speed operation?

VFD operation resulted in a slightly higher variation in temperatures thoughout the room.

When comparing the VFD vs. the control room, the total average temperature variation for all 15 probes were 0.89°F vs. 0.63°and 0.59°F vs 0.27°F for the two tests.

Was there any evidence of CO2 buildup or any adverse impact on gas concentrations at reduced speed?

No. At one facility, gas samples were obtained in the VFD room in a high air flow location (near the evaportor)and a low air flow location (within a bin in the back lower corner of the room).

Gas concentrations in these two locations were practically identical, indicating that the air in the room was adequately mixed at reduced speed.

Did reducing speed increase the relative humidity or Dew Point temperature in the VFD room?

Yes. The relative humidity was slightly higher in the VFD room at both test sites.