Measurement & Verification of Energy Efficiency

Presented to APEM Energy Managers Forum
December 8th, 2007

By
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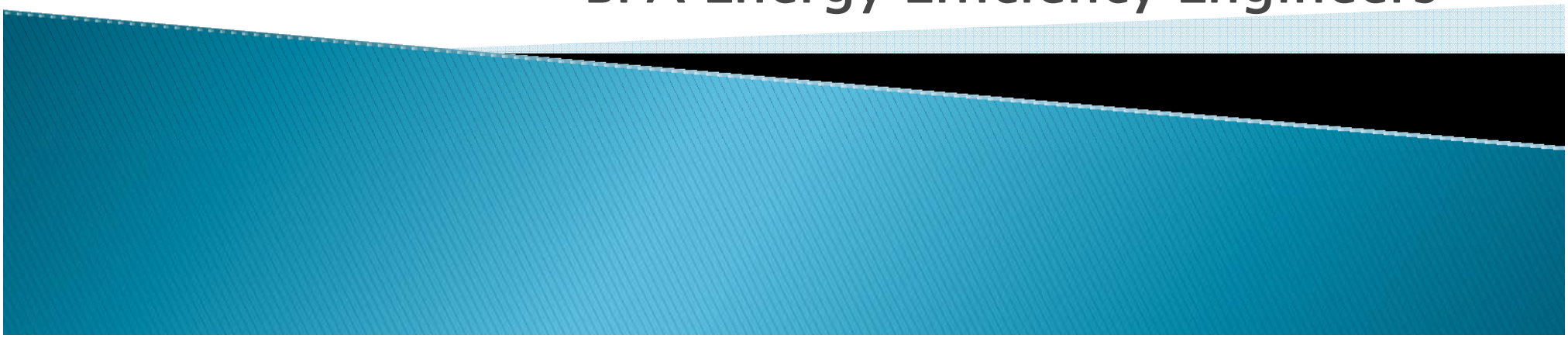
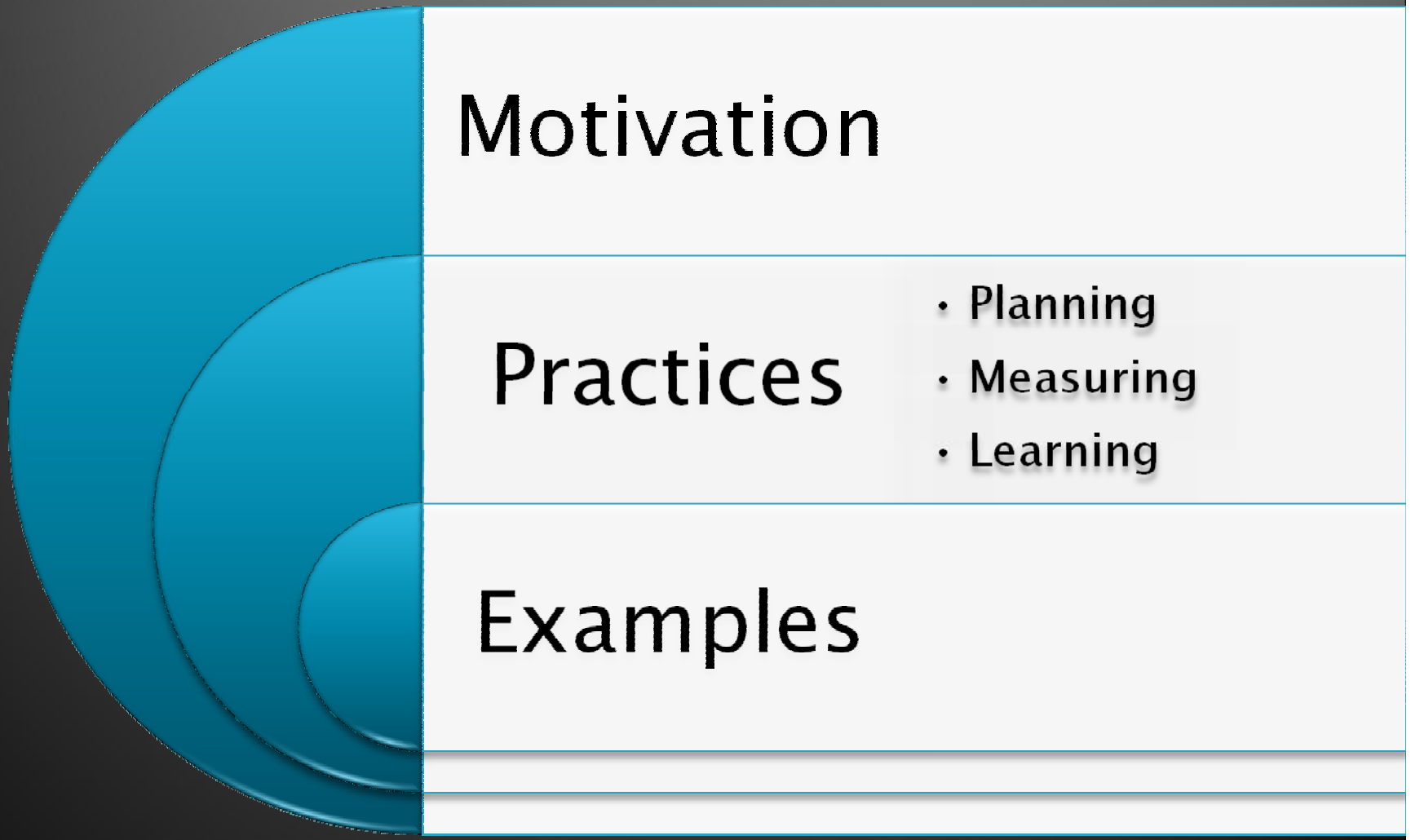
With Recognition to:
BPA Energy Efficiency Engineers



Dedicated To: BPA “Bubbas”

Overview of Presentation



Opportunity

- Consumers, business, and industry are all wanting to be "**Green**"; Sustainability is in!
- Bonneville and Pacific Northwest Utilities are investing in Energy Efficiency.

Energy Efficiency is in demand ! (again)

Challenge – *Our Credibility*

- Inflated energy savings performance claims.
- Failure to deliver claimed savings.
- Pressure to minimize effort required for quality M&V.

How do we, as Professional Energy Managers, deliver the goods?

– Quality M&V –

Where do we stand today on M&V?

1980's –

- Metering was mostly monthly kWh consumption.
- M&V was not a common concept.

1990's –

- Computers, networks, and electrical metering make big advances.
- M&V Concepts being developed and discussed.
- 1997 IPMVP published

2000's –

- M&V becoming a common concept.
- Metering technology – faster, better, cheaper
- Current challenge is wider use of M&V practices.

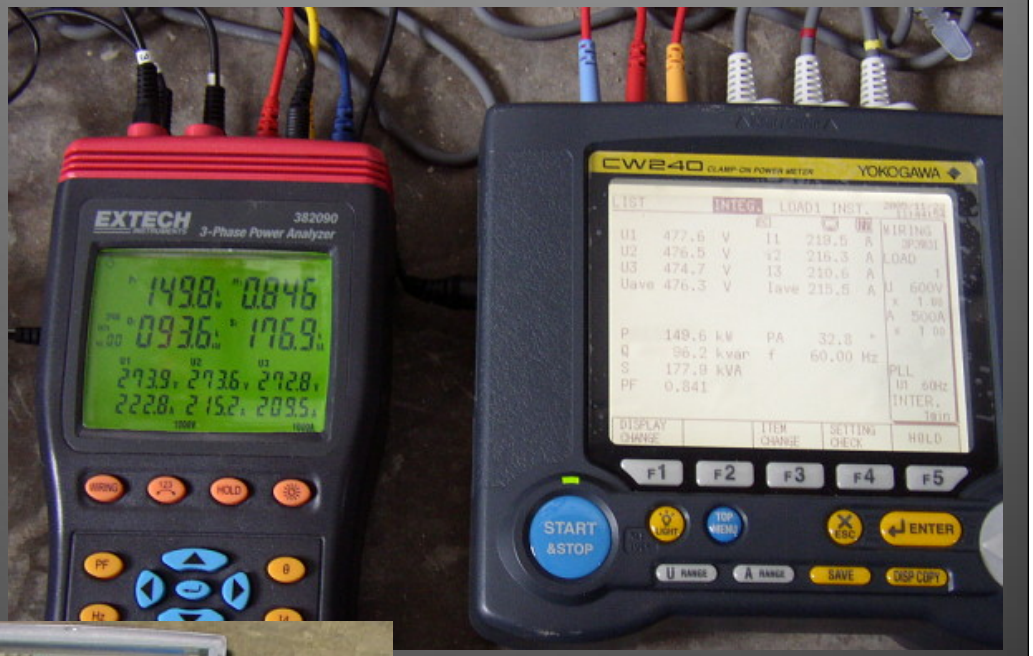
Measurement

- Just do it.

Measuring – it ain't always easy

It ain't always clean

And it definitely ain't cheap



"But it is almost always the smart thing to do
in serious industrial settings"

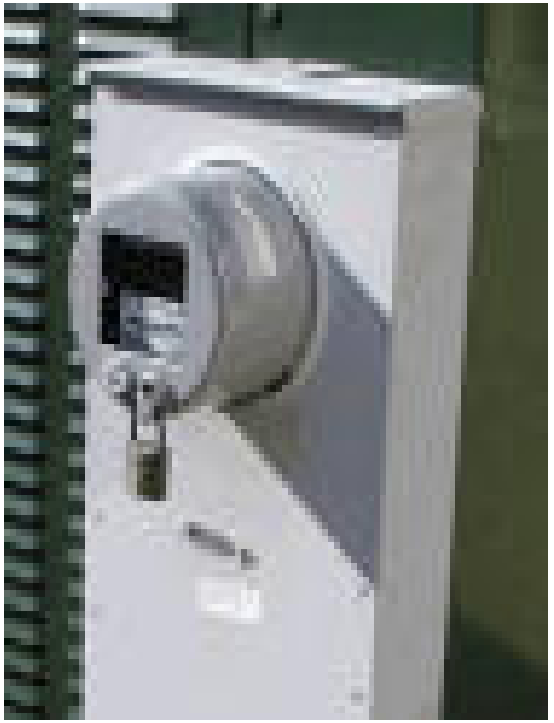
Don Casada

Measurement & Verification

- Lessons Learned from BPA Staff's Review of many Custom Project Proposals

Metered Power Sales
vs.
Calculated Energy Savings

(Or, why BPA needs quality M&V.)



Savings Calculation

Loads Affected	0.765	KW
Estimated compressor duty cycle during winter nights:	36%	
Estimated compressor duty cycle during non-winter nights:	36%	
Bin hours = potential off hours/night	8.0	
Cooler off hours per year. 365 x (line10)	2,920	
Annual Energy Savings (line 7) x [(line 8) x .25 + (line 9) x .75] x (line 11)	**804**	**KWH/yr**

Problem Proposals

- Didn't consider all the variables.
- Didn't think about boundaries.
- Complex calculations with un-stated assumptions
- **Absent and weak M&V Plans**

The M&V Plan

- The M&V Plan is a key element in any Project Proposal.
- During review, I focus on the M&V Plan much more than the estimated energy savings.

Favorite References

1. International Performance Measurement & Verification Protocols (IPMVP)

   http://www.evo-world.org/

2. Site Specific Verification Guidelines, BPA 1992

   http://www.bpa.gov/Energy/N/Projects/cr_discount/pdf/site_specific_verification.pdf

3. ASHRAE Guideline-14, Measurement of Energy and Demand Savings

PART 2

M&V Case Studies

- Walk-In Strip Curtains
- Dairy Vacuum Pump Measure
- Elevator Drive Retrofit
- Chiller Performance Measurement
- Paper Machine Pump VFD

Walk-in Cooler Strip Curtains Field Research Case Study

- Dangers of Verification without Measurement

  and

  Learning as We Go

  and

  Developing Cost Effective M&V

Background

- Large numbers of strip curtains have been installed and paid for based only on calculated savings!
- We have found **no** reliable published data on **as-installed** strip curtain **measured** energy savings.

Strip Curtain Energy Savings Equation

$$\Delta kWh = \sum^{evaptemp} \frac{\Delta \text{case load} \times A \times hr_{open}}{\overline{EER}_{base} \times 1000} \times 365$$

where:

Δcase load	= change in case load due to strip curtains
A	= Area of walk-in door (sf)
hr_{open}	= hours/day walk-in doors are open
[redacted]	= annual average compressor efficiency

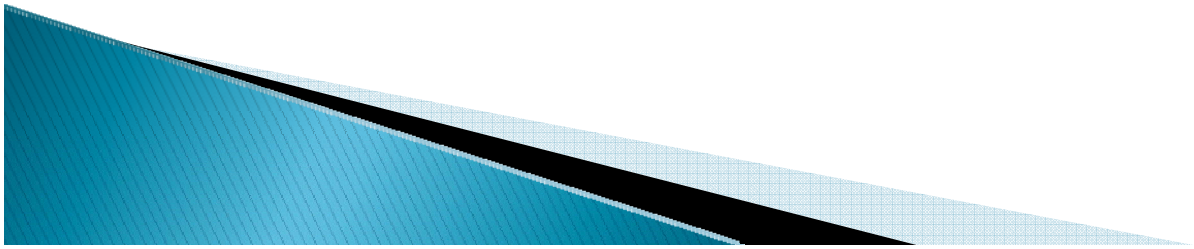
and where hr_{open} is based on a qualitative assessment of how much time the door is open:

Why field tests are sometimes necessary.

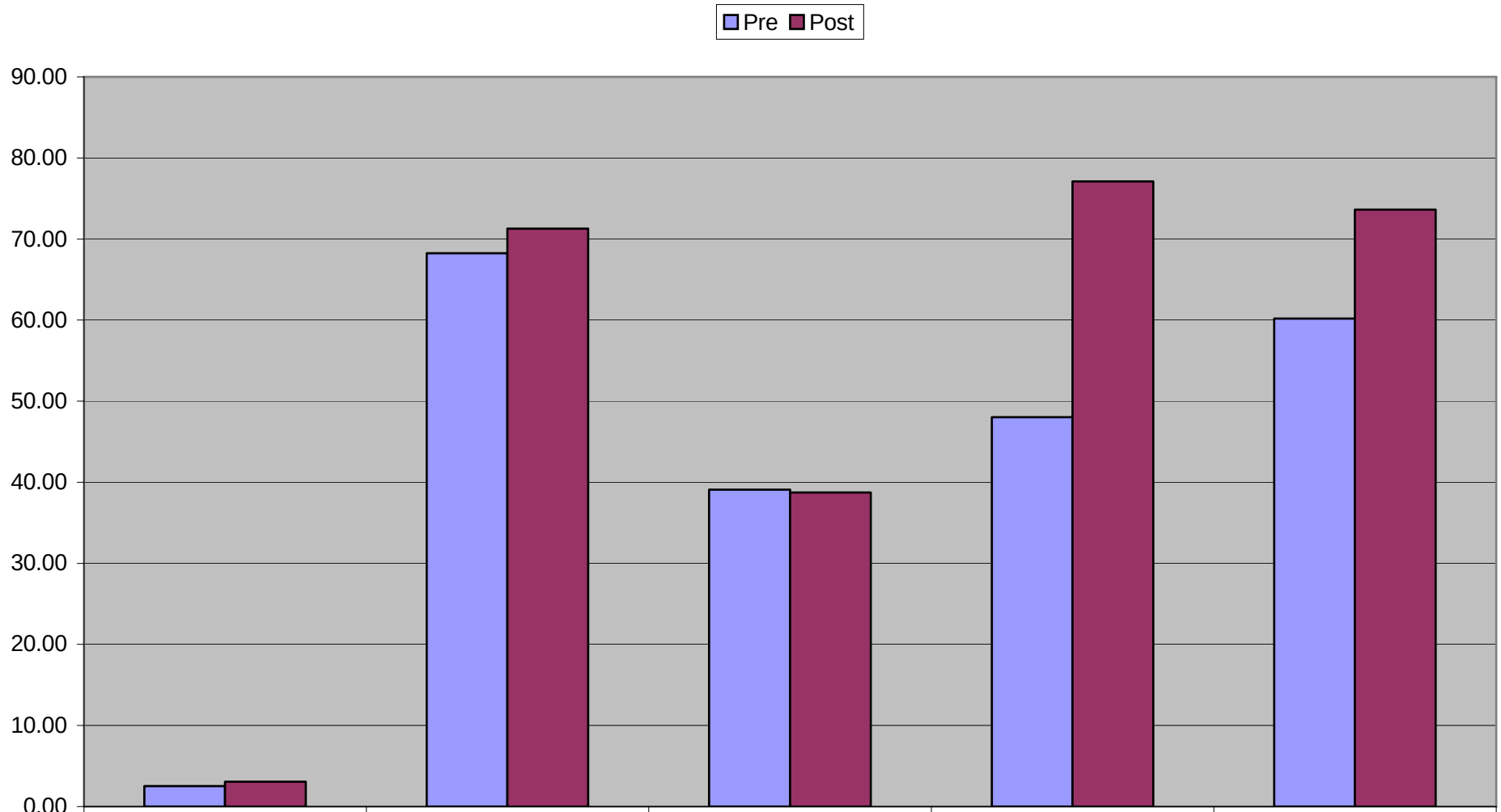
BPA Phase 1 Metering Plan

Pre and Post Installation – 2 week period, 15 minute recording interval.

- **Compressor** – Average and max kW.
- **Door** – Monitor % open in each 15 minute interval.
- **Temperatures** – Monitor walk-in temperature, temperature of room connected to walk-in door, and outside ambient temperature.



Fox Grocery - Walk-in Cooler Strip Curtain



	Average kW	Average Store Temperature	Average Cooler Temperature	Average Door Open Time (minutes per day)	Average kWh/Day
Pre	2.51	68.25	39.09	48.04	60.17
Post	3.07	71.27	38.73	77.09	73.61

BPA Phase 2 – Field Research

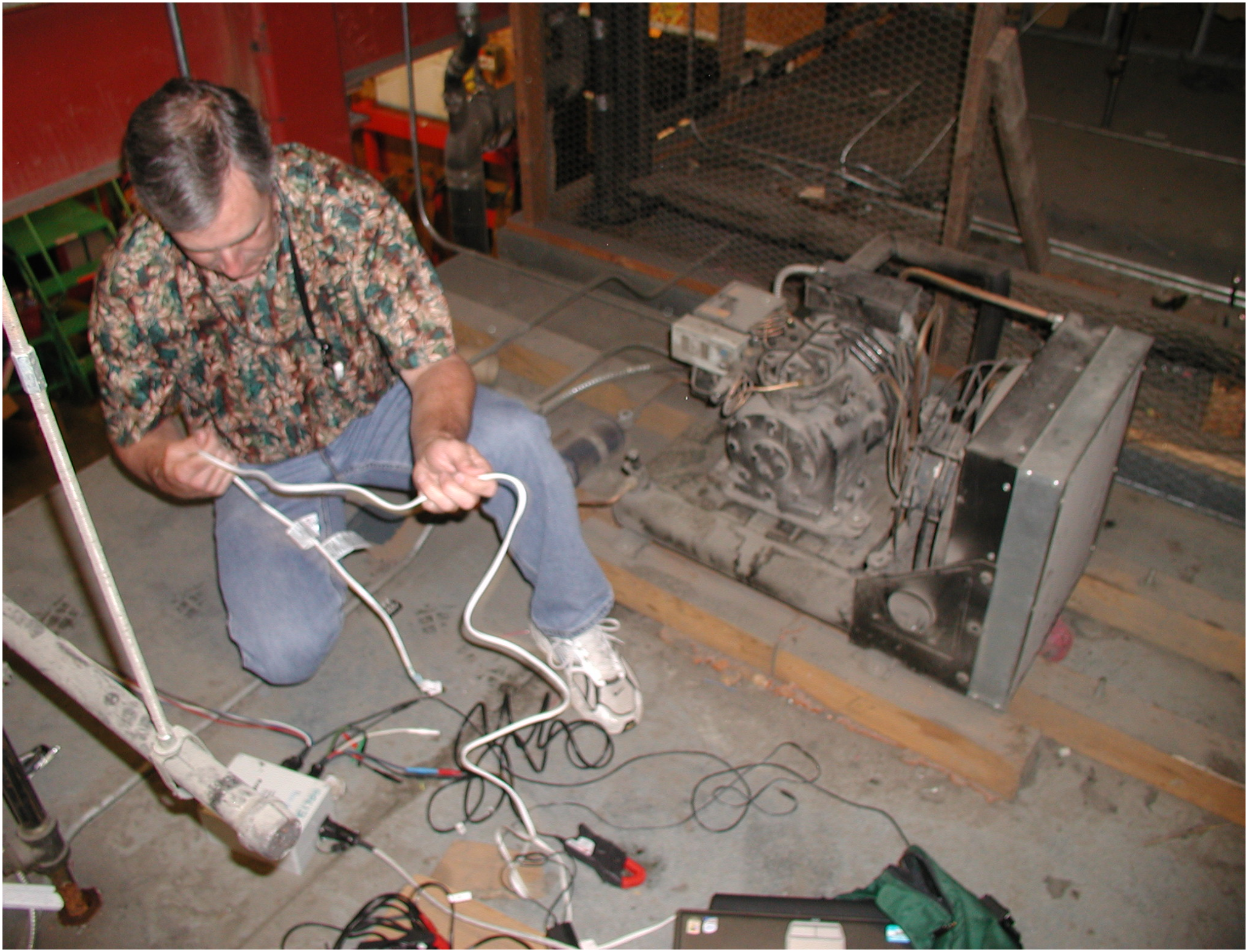
Part A

- **Measure** the energy savings from installing strip curtains on several more walk-in coolers and freezers.

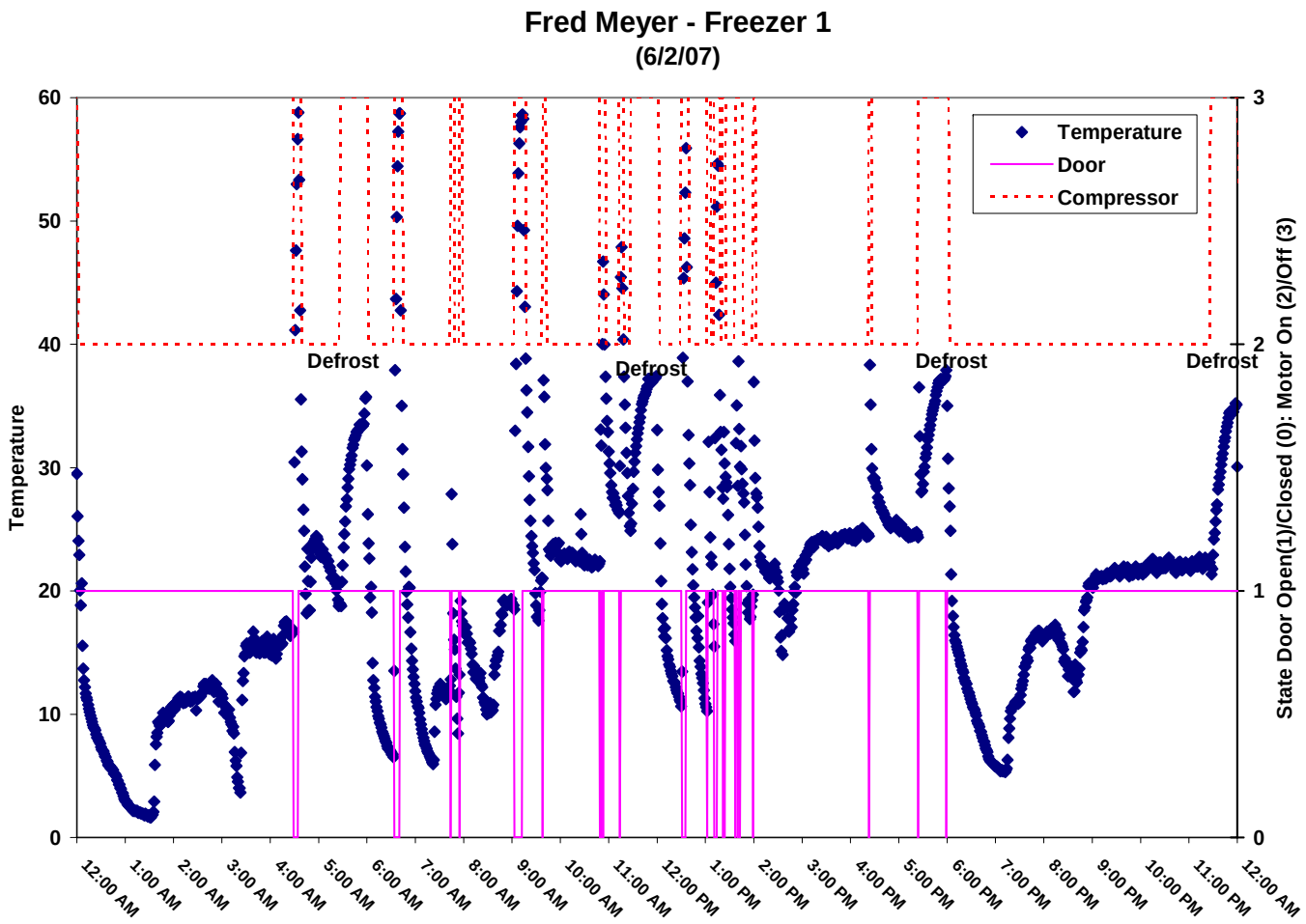
Part B

- **Evaluate** the efficacy of the draft M&V Protocol.
- **Recommend** enhancements/modifications, as appropriate.

NO STORAGE
Close Door After Use
CLOSE DOOR
COMMUNICATION BOARD
THINK SHRINK
12 36 COUNT BOXES
MILK CHOCOLATE
Reese's



Time-Series Graph



Measurement Results – *for 5 Sites*

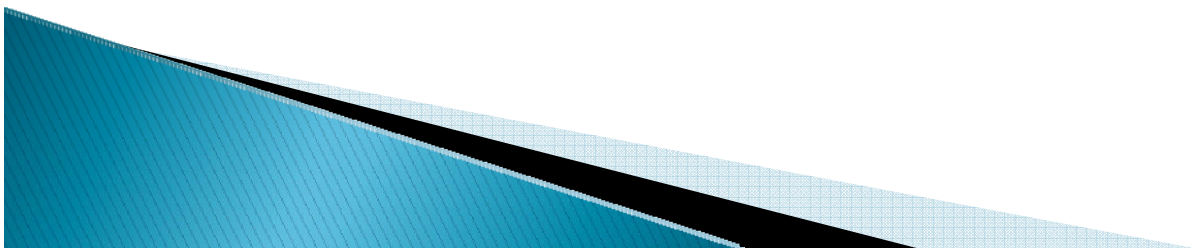
Location	Description	Product	Door Open %	Compressor Run %	Measured Energy Savings (kWh/yr)	Calculated Energy Savings (kWh/yr)
Ridgefield	Cooler	Dairy	-1.7	-0.2	-24.5	1,829
Ridgefield	Freezer	Frozen Foods	-0.5	0.0	0.0	6,442
Hockinson	Cooler	Beverages	-0.2	2.6	-431.9	1,348
Fred Meyer	Freezer 1	Dessert	0.2	-0.6	-90.9	3,190
Fred Meyer	Freezer 2	Ice Cream	1.0	0.9	476.2	4,702
Total			**-1.2**	**2.7**	**-71.1**	**17,512**

Measured Energy Savings: ***-71 kWh/yr***

Calculated Energy Savings: ***17,512 kWh/yr***

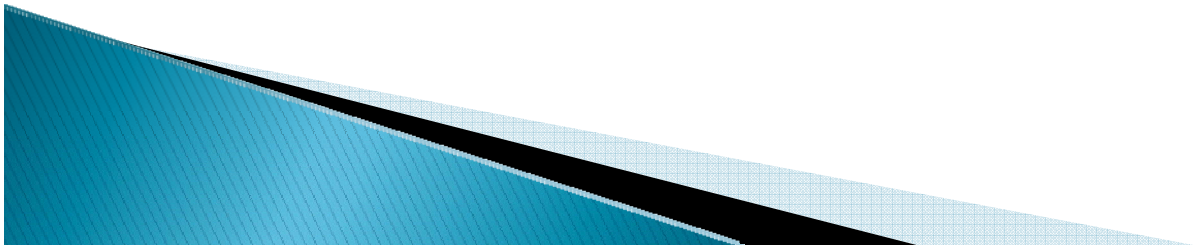
Findings – *from five installations*

1. Three of the five walk-ins were found to use more energy after installation of the strip curtains.
2. Overall, there was a small (< 1%) net energy increase after strip curtains were installed.
3. Three of the walk-ins were observed to have potentially malfunctioning defrost or temperature controls.
4. Run-time loggers vs. recording kWh meters: under-estimated compressor kWh by less than 5%, on average.



M&V Plan Enhancements for Phase 3 Field Tests

1. Specify the location of case temperature sensor
2. Install data-logging current transducers on electric defrost element(s).
3. Identify the temperature control set point and location of thermostat.
4. Use energy loggers rather than motor state loggers as much as possible.
5. Monitor operation at 1-minute intervals rather than 15-minute
6. Do not mount the store temperature sensors on the walk-in surface.



Dairy Vacuum Pump VFD Case Study

- Designing Cost Effective M&V

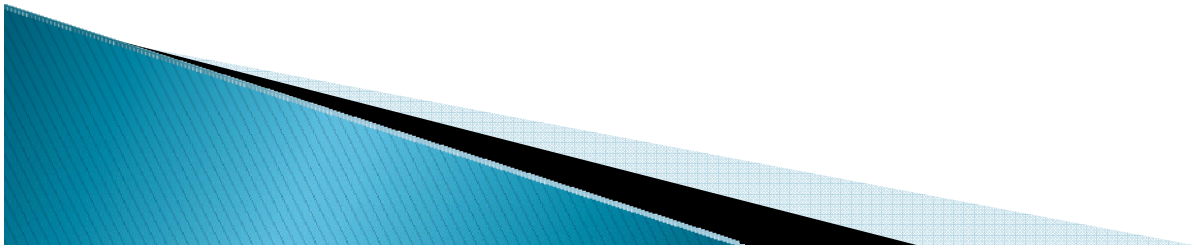
Dairy vacuum pump with VFD

Overview – *Vacuum Pump VFDs*

- Small savings per projects, dozens of projects, lots of drive time.
- Installed performance of VFDs relatively good (w/o extensive oversight).

Challenge:

Develop a cost effective M&V approach.



Lots of Good of Data

Vacuum Pump VFD's

Data Logged		Calculator	
Project	Annual kWh Savings	Project	Annual kWh Savings
Abbott Farms	16,348	Dave Hogan Dairy	45,949
Asay Dairy	11,235	Mike Grauwen	15,189
Dila Dairy	45,187	Dale Porter	9,190
Fairview Acres	53,542	Sunshine Acres	5,361
GEO Farms	13,505	Hales Dairy	7,148
Myers Dairy	20,904	Joe Findley	6,127
Adams Dairy	17,816	Classen Dairy	10,670
Joe Jenck	12,841	Silver Mist Dairy	9,956
Lourenzo Dairy	15,294	Wayne Christie	8,169
Menefee Dairy	23,944	Geinger Farms	24,506
Moss Creek Dairy	7,866	Woodstock Dairy	6,127
Nes-Til Farms	15,531	Ti-Su Dairy	18,380
Peterson Dairy	11,695	Sun Valley Jerseys	18,380
Ted Price Dairy	16,337	Andres Sanches	10,211
R&R Dairy	49,312	Chatelain's Farmasea	27,569
Rebob Dairy	14,104	Porter Jersey Farm	16,337
RSC Dairy	52,556	Louis Blaser Dairy	8,169
Spring Valley	10,903	Mistvale Farm	10,211
Tim Jenck	4,362	Shreves Dairy	8,169
Traskview Dairy	55,407	Marti Holsteins	18,380
Wilsona Dairy	16,856	Mountain Vista Dairy	44,928
AVERAGE	**19,397**		**15,673**

Options Considered

Identified Full Load Power and Operating hours as the key variables

Small (10 HP and under)

Large (over 10 HP)

A. Deemed Saving

B. Calculator

C. Snapshot of pre and post kW and post data logging of operating hours

D. Full 4-day pre and post 15-minute kW metering.

Current (FY 2008) Bonneville M&V Requirements for Dairy Vacuum Pump VFDs

- 10 hp or Less: (deemed), the customer must have an invoice showing horse power and an installation address.
- Greater than 10 HP: Submit a custom project proposal with an M&V Plan.

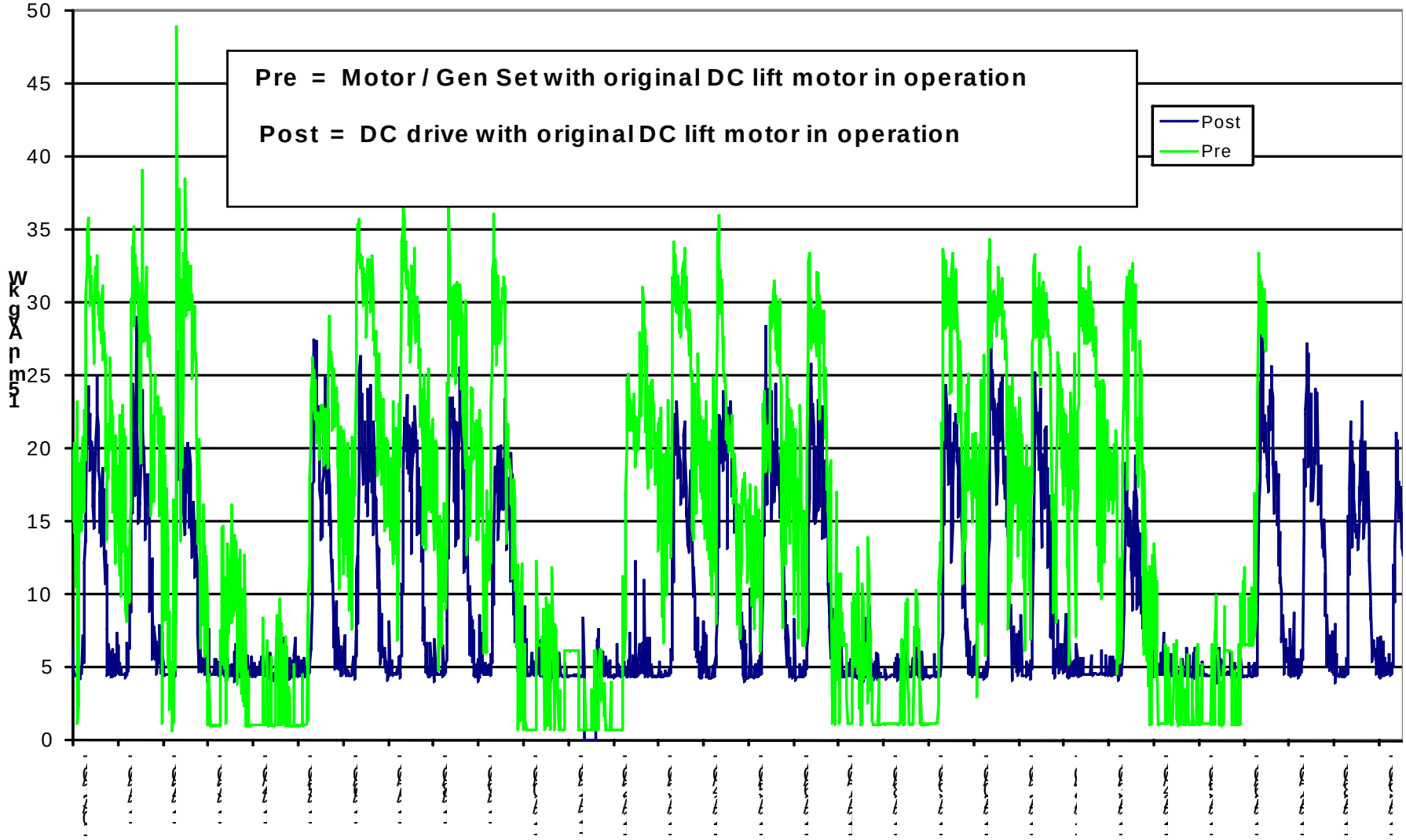
Elevator Retrofit Case Study

- Dangers of Deeming, or Stipulated vs. Metered

Overview

- Prior utility testing had established a "deemed" ***kWh savings per connected HP.***
- Facility owner asked BPA to meter the savings of this project (in a Federal Office Building) for their internal verification requirements.

Site Metered Data



Elevator *Metering vs. Deemed*

Pre and Post Metering Results

Motor-Gen	DC Drive	
Annual Energy Use	Annual Energy Use	
(kWh/Year)	(kWh/Year)	
865,900	492,373	

Overall Metered Project Energy Savings % ***43.1%***

Metered Savings	373,527	kWh / Year
Predicted Deemed Savings	828,500	kWh / Year

Or, Overall "Deemed" Project Energy Savings ***96%***

Chiller Performance Measurement Case Study

- Good M&V Helps Ensure Performance

  and,

  Efficiency Metric

  and,

  Good Use of Metering Resources

Overview

- Installed (2) new 500-ton centrifugal chillers with VFD's.

Are chillers operating at manufacturers published performance?

  - Measured performance as compared to ASHRAE/ANSI Std 550/590 Full Load and IPLV.

LIFTING CHILLER 1

YORK INTERNATIONAL

YORK INTERNATIONAL

Measurement Data

- Monitored Data:
  - Chiller kW
  - CHW Supply and Return Temperatures
  - CDW Supply and Return Temperatures
  - CHW Flow (GPM)
- One-Time Measurements:
  - CHW Flow (GPM)
  - Condenser Flow (GPM)
  - Chiller differential pressure at condenser and evaporator

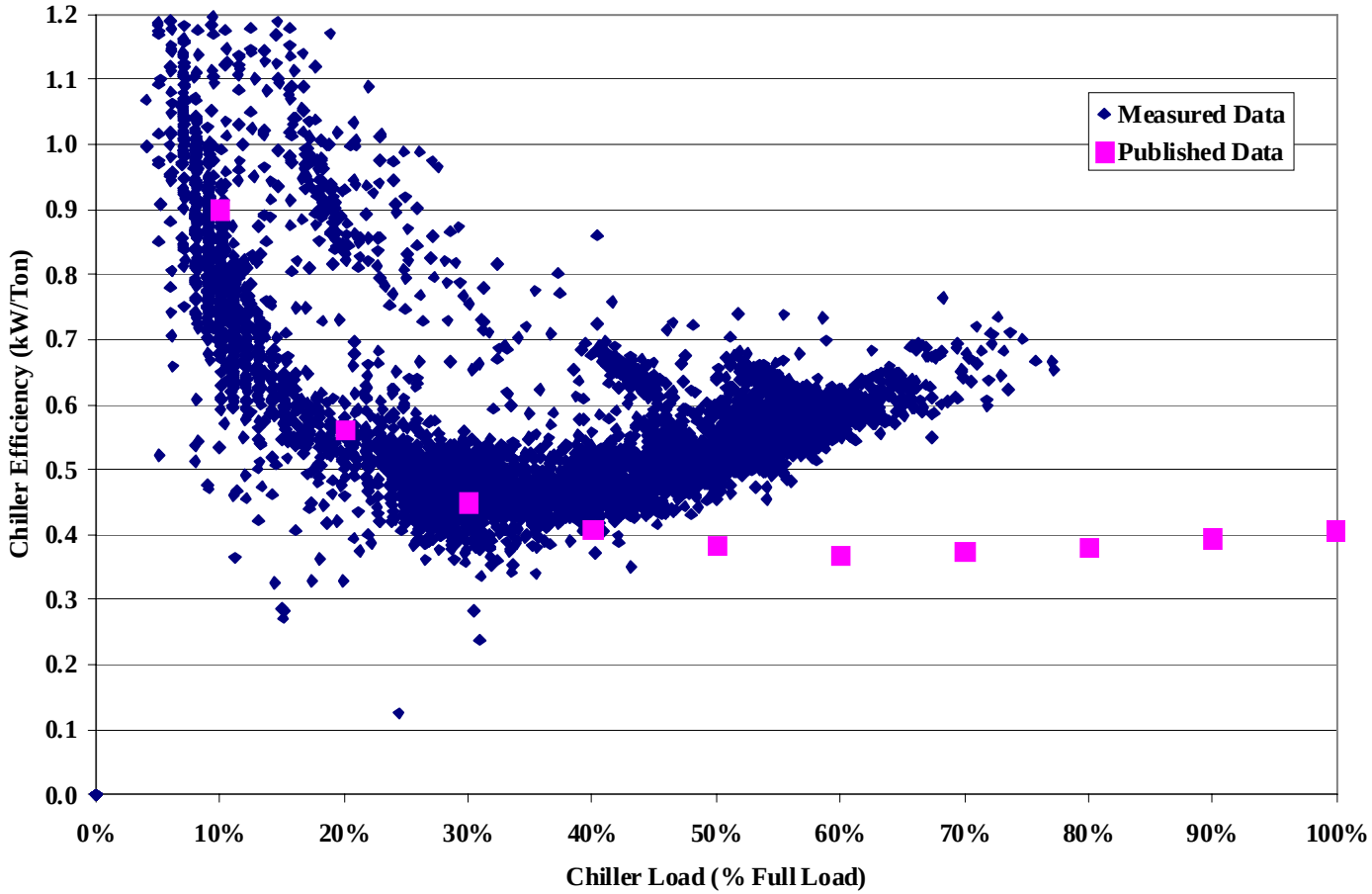
Efficiency Performance Metric:

- ***kW/Ton at defined load***

Data Collection

- The **building automation system** was used to trend-log temperature, CHW flow, and kW data, after **verification of sensor accuracy with hand-held devices.**

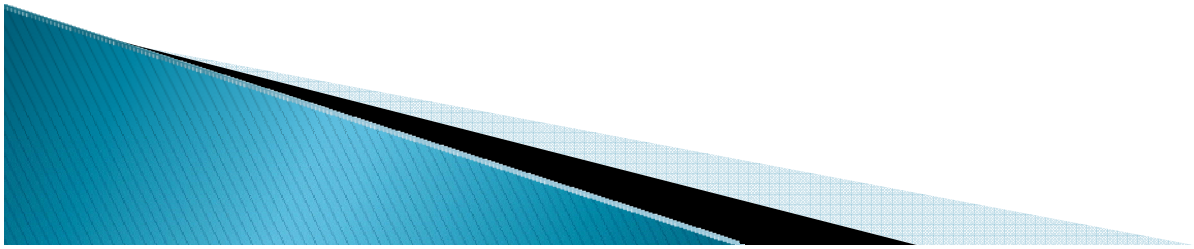
Chiller Performance – *As First Installed*



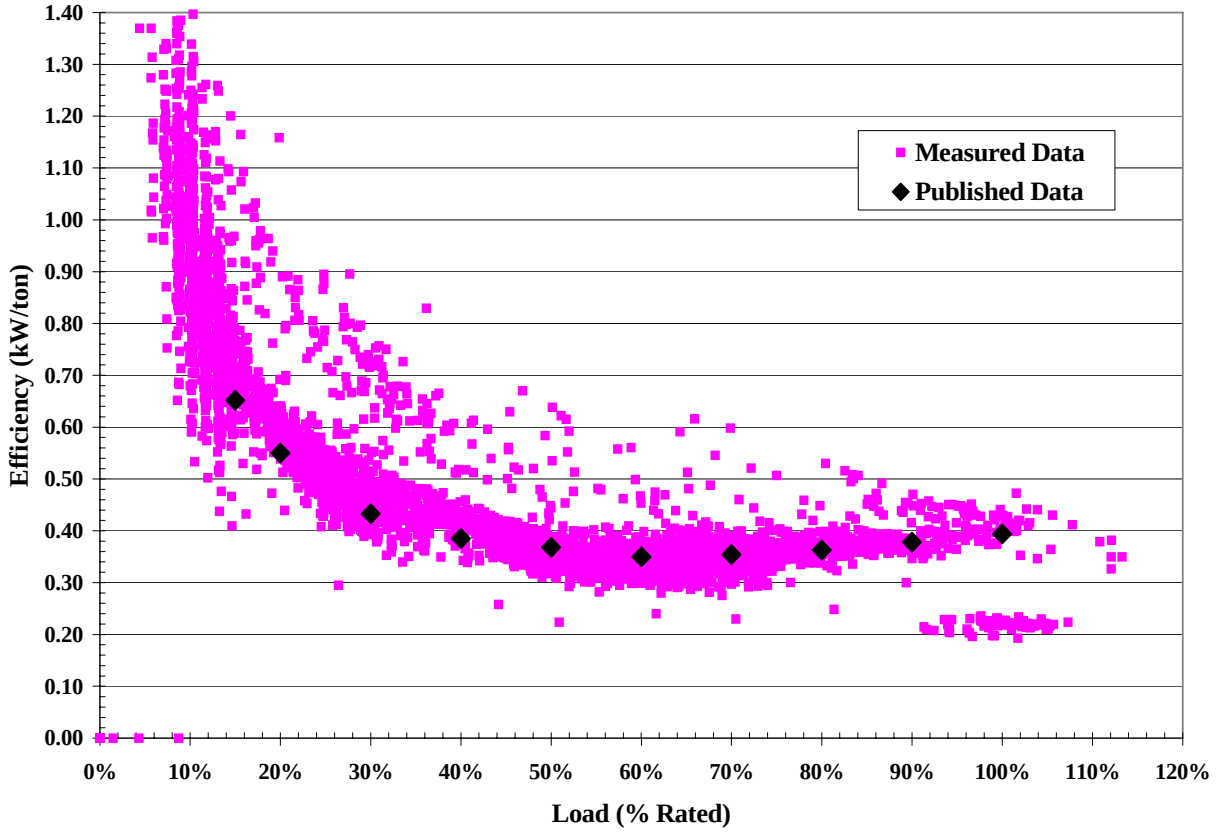
Feedback from Testing

M&V testing found problems with both CHW and condenser water flow.

	Design	Actual
CHW Flow Rate (GPM)	1200	1800
CW Flow Rate (GPM)	1130	1586



Chiller Performance – *After CHW and CDW Flow Corrections*



Problem Noted and Corrected!

After correcting the flow problems the two chillers were found to meet published performance data, at both full-load and part-load conditions

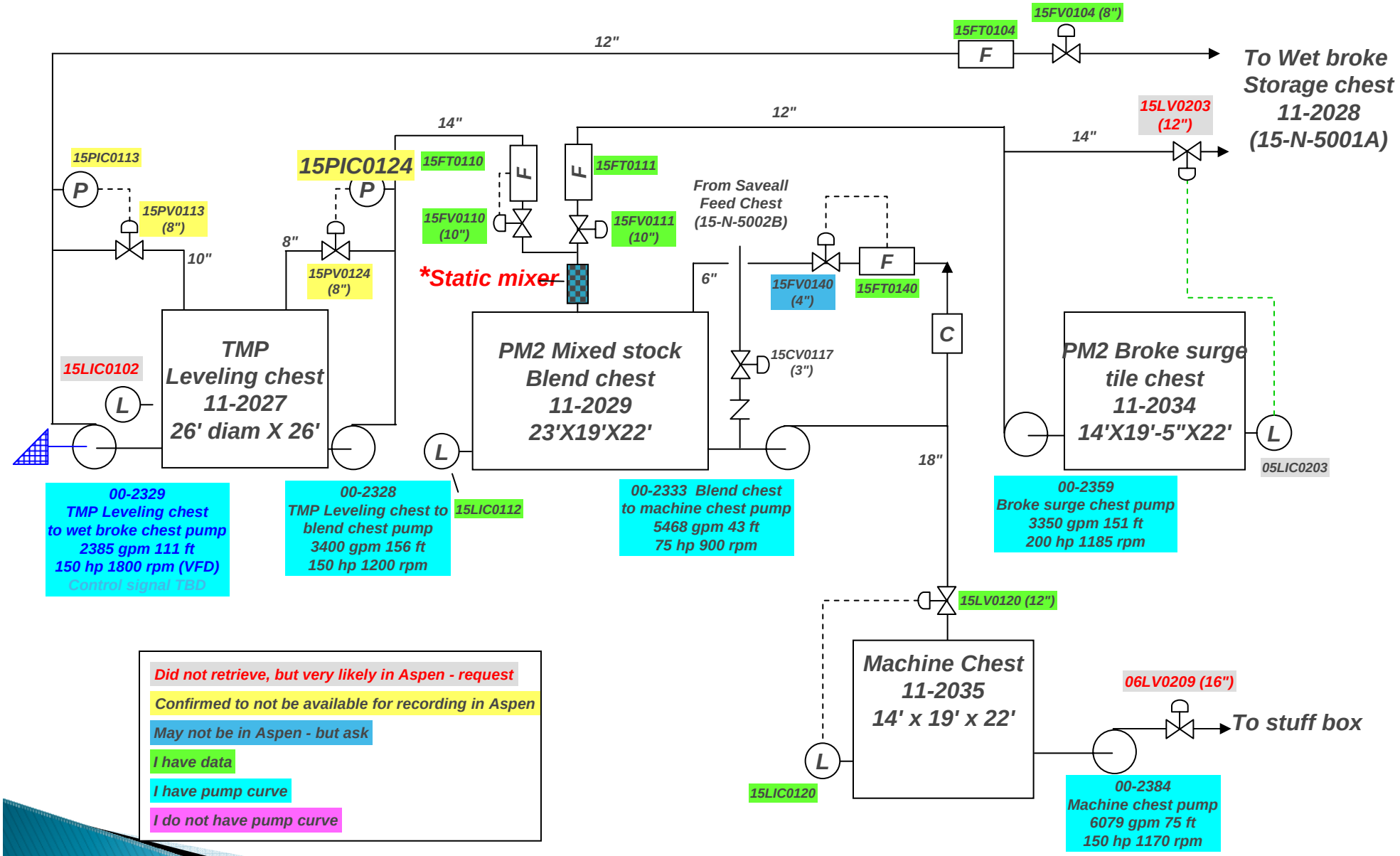
Final Test Results		
kW/Ton (Field)	0.395	kW/Ton
kW/Ton (Max Allowed)	0.41	kW/Ton
% Eff. Test Surpassed	**4.03**	**%**
Efficiency Pass/Fail?	**PASS**	
Full Load Capacity (Field)	483.2	Tons
Capacity (Min Allowed)	469.3	Tons
% Capacity Test Surpassed	2.97	**%**
Capacity Pass/Fail?	**PASS**	

Paper Machine Pumping – VFD replacing control valve and bypass

- M&V helps ensure energy savings.

PM2 Blend Chest Feeds, related flows

Drawings:15-N-5001A, -5001B, -5002B

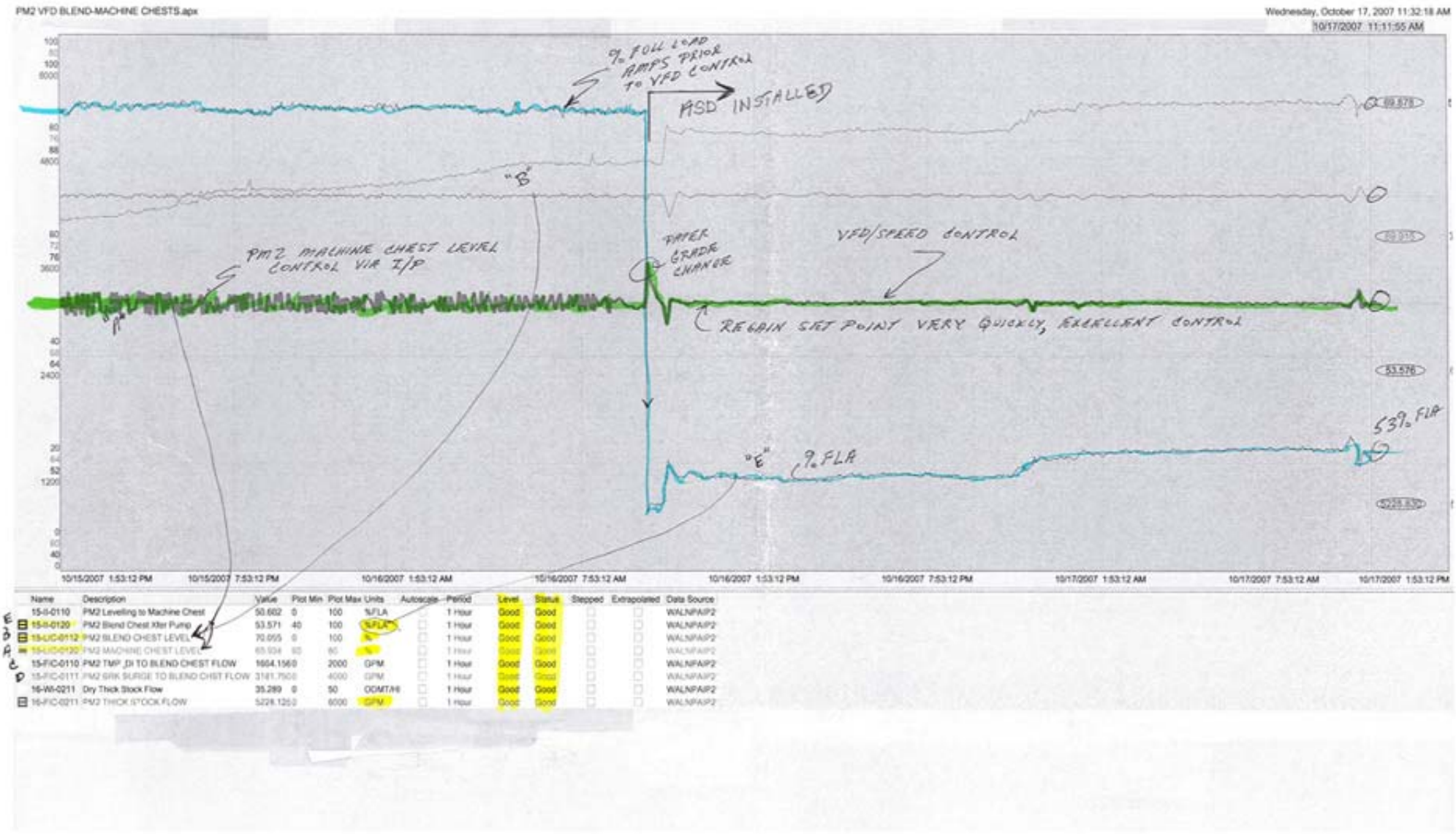


Throttling and bypassing in a single application: machine chest

Logging machine chest pump pressures

Logging power data, using BPA-supplied equipment

Snapshot from Plant Monitoring



Lessons Learned?

- Measurement is essential to verification.
- Proceeding without measurement is not recommended.
- Do up-front pilots and field tests of repeatable measures to simplify M&V for high volume measures.
- Utilizing existing information systems facilitates M&V.
- M&V has great value in ensuring that expected energy savings are realized.

The End