Keeping Customers Competitive & Productive with Energy Efficiency & Power Quality Solutions

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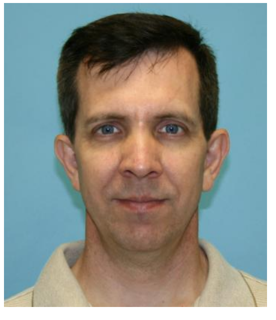
Technologist



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Project Engineer

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Randy Horton
Ron Domitrovic
Baskar Vairamohan

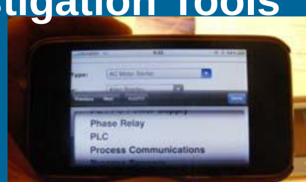
Industrial Power Quality

Base Research: PQ Compatibility (PS1C)

PQ Standards

PQ Device Sensitivity, PQ Contribution, & Mitigation

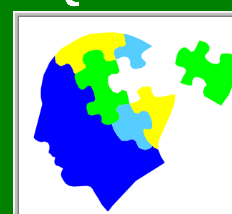
PQ Investigation Tools



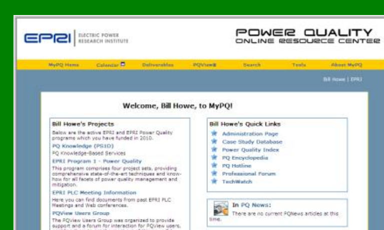
Base Research: PQ Knowledge (PS1D)

PQ Resources

PQ Hotline

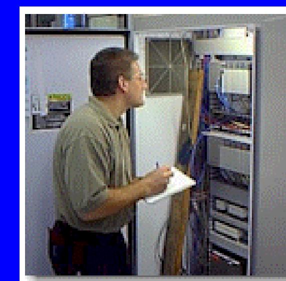


MyPQ website



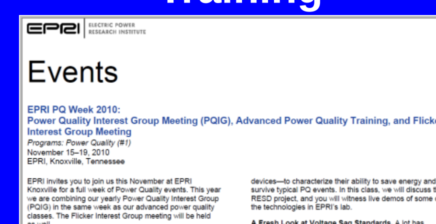
Supplemental Research

Site Investigations



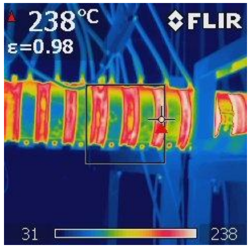
RESD Testing

Training



EPRI's Industrial Energy Efficiency and Power Quality Work

- Headed up primarily from Knoxville, we specialize in solving EE & PQ Problems In all Manufacturing Sectors
- Our Primary mission is to Focus on Reducing End Use Customer Losses by improving process energy efficiency and PQ through:
  - Testing (lab and field)
  - EE & PQ Audits
  - Consulting with OEMs
  - Training
  - Portable Test Hardware



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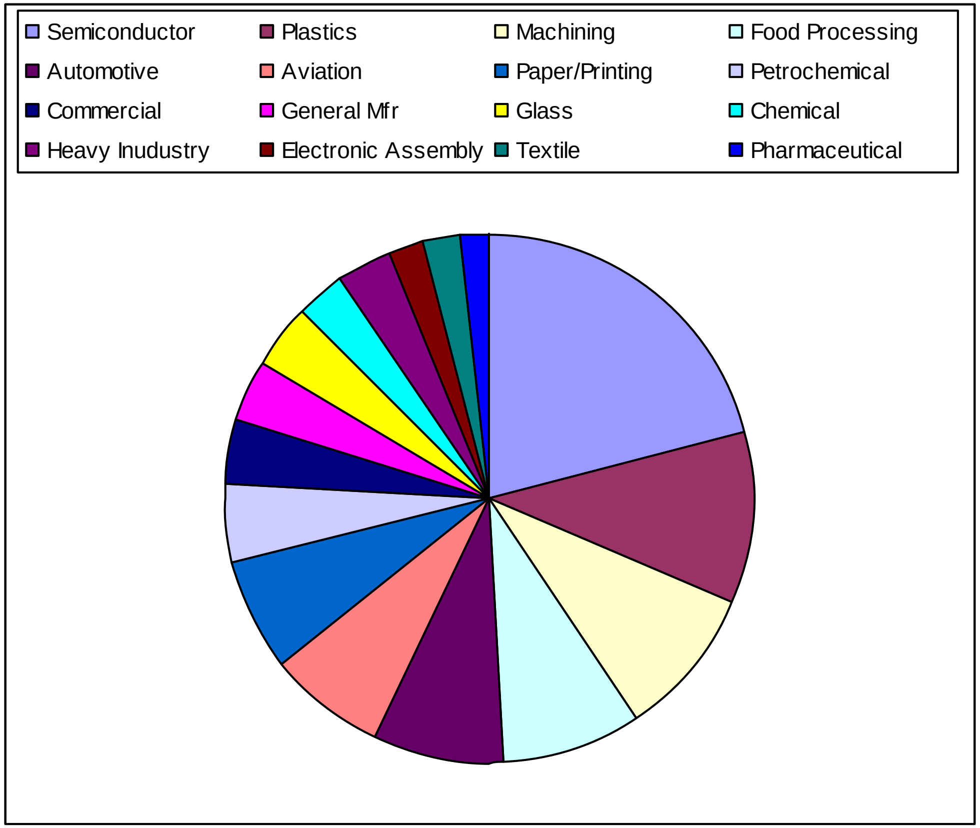
EPRI Industrial Site Investigations1996-2008

Industry	Sites	Percentage
Semiconductor	27	21%
Plastics	13	10%
Machining	12	9%
Food Processing	11	9%
Automotive	10	8%
Aviation	9	7%
Paper/Printing	9	7%
Petrochemical	6	5%
Commercial	5	4%
General Mfr	5	4%
Glass	5	4%
Chemical	4	3%
Heavy Inudustry	4	3%
Electronic Assembly	3	2%
Textile	3	2%
Pharmaceutical	2	2%
Total Voltage Sag PQ Investigations 1996-2008	128	
Average Per Year	10	



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Presentation Outline

- **9 AM - Power Quality:**
  - The Electrical Environment: Common Levels of Power Quality
  - Voltage Sags and Solutions (use the PQ Investigator)
  - Power Factor Correction
  - Harmonics Concerns and Solutions
  - Case Studies
- **Break 2:50 (15 Minutes)**
- **10:30 PM - Energy Efficiency:**
  - Reduction of Thermal Losses/Waste Heat Recovery
  - Upgrading of Lighting Technology and Controls
  - Use of Premium Efficiency Motors
  - Efficient Application of Adjustable Speed Drives
  - Compressed Air Best Practices
  - Chilled Water Systems
  - Advanced Technologies
  - Case Studies
  - ISO 50001/Superior Energy Performance
  - FYI – Use of DOE Industrial Technologies Program (ITP) Tools
- **12:00 PM - Conclusion**

PQ Session

- The Electrical Environment: Common Levels of Power Quality
- Voltage Sags and Solutions (use the PQ Investigator)
- Power Factor Correction
- Harmonics Concerns and Solutions
- Case Studies

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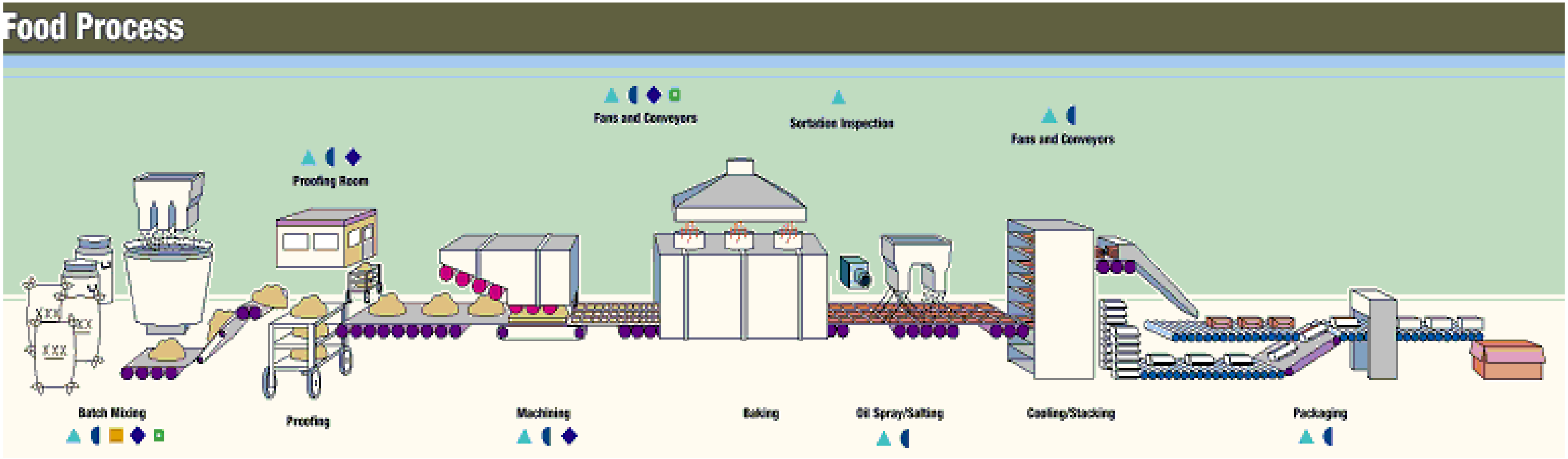
The Electrical Environment: Common Levels of Power Quality

IEEE-1159

Categories			Typical Duration	Typical Spectral Content	Typical Voltage Magnitude	Method of Characterizing	Typical Causes	Example of Power Conditioning Solutions
Transients	Impulsive	Nanosecond	> 50 nanoseconds	5 ns rise		Peak Magnitude, Rise Time, Duration	Lightning, Electro-Static Discharge, Load Switching, Capacitor Switching	Surge Arresters, Filters, Isolation Transformers
		Microsecond	50 nanoseconds to 1 millisecond	1 μ rise				
		Millisecond	> 1 millisecond	0.1 ms rise				
	Oscillatory	Low Frequency	0.3 milliseconds to 50 milliseconds	< 5 kHz	0 to 4 pu	Waveforms, Peak Magnitude Frequency Components	Line/Cable Switching, Capacitor Switching, Load Switching	Surge Arresters, Filters, Isolation Transformers
		Medium Frequency	20 microseconds	5 to 500 kHz	0 to 8 pu			
		High Frequency	5 microseconds	0.5 to 5 MHz	0 to 4 pu			
Short Duration Variations	Instantaneous 0.5 cycles to 30 cycles	Sag			0.1 to 0.9 pu	RMS vs. Time, Magnitude, Duration	Remote System Faults	Ferroresonant Transformers, Energy Storage Technologies, UPS
	Momentary 30 cycles to 3 seconds	Swell			1.1 to 1.8 pu			
	Temporary 3 seconds to 1 minute	Interruption			< 0.1 pu	Duration	System Protection (Breakers, Fuses), Maintenance	Energy Storage Technologies, UPS, Backup Generators
Long Duration Variations	Undervoltages		> 1 minute		.08 to 0.9 pu	RMS vs. Time, Statistics	Motor Starting, Load Variations, Load Dropping	Voltage Regulators, Ferroresonant Transformers
	Overvoltages		> 1 minute		1.1 to 1.2 pu			
Voltage Unbalance			steady state		0.5 to 2%			
Waveform Distortion	DC Offset		steady state		0 to 0.1%			
	Harmonics		steady state	0 to 100th H	0 to 20%	Harmonic Spectrum, Total Harm. Distortion, Statistics	Nonlinear Loads, System Resonance	Filters (active or passive), Transformers (cancellation or zero sequence components)
	Interharmonics		steady state	0 to 6 kHz	0 to 2%			
	Notching		steady state					
	Noise		steady state	broad-band	0 to 1%			
Voltage Fluctuations			Intermittent	< 25 Hz	0.1 to 7%			
Power Frequency Variations			> 10 seconds			Variation Magnitude, Frequency of Occurrence, Mod. Frequency	Intermittent Loads, Motor Starting, Arc Furnaces	Static Var Systems

Why is PQ Important?



- What happens to a manufacturing process when a power quality problem occurs?
- Who is to blame?
- How do we work together to fix the problems?

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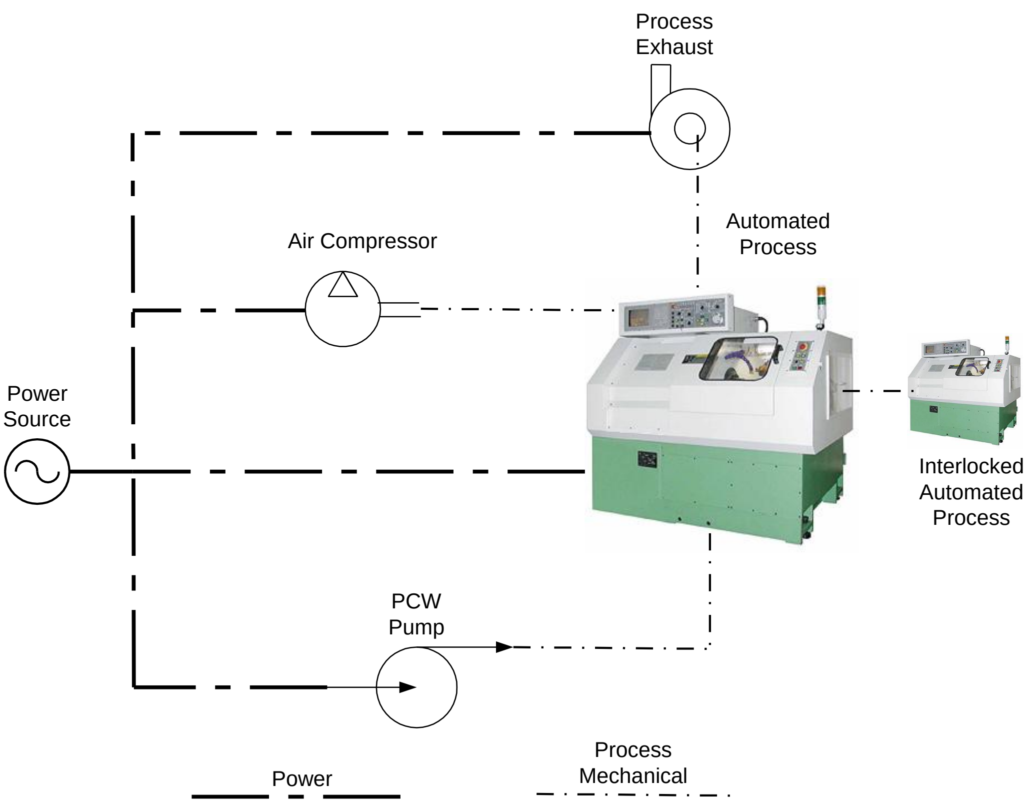
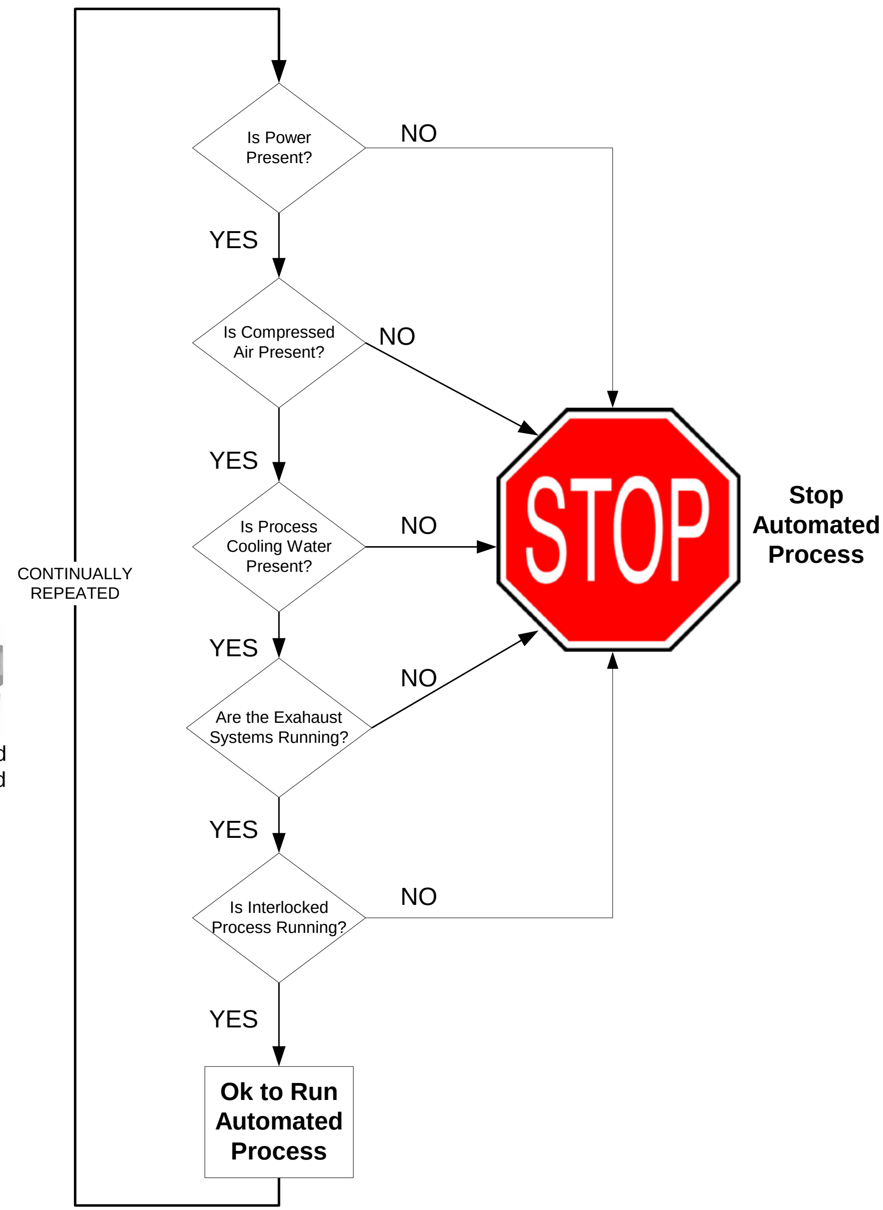
Interrelated Processes





Typical Reported Per Event Cost of PQ Disturbance

No.	Process	Reported Cost	Service Voltage	Load
1	Semiconductor	$1,500,000	69 kV	25 MW
2	Semiconductor	$1,400,000	161 kV	30 MW
3	Semiconductor	$ 700,000	12.5 kV	10 MW
4	Metal Casting	$ 200,000	13.8 kV	16 MW
5	Chemical Plant	$ 160,000	12.5 kV	5 MW
6	Pulp and Paper Mill	$ 110,000	161kV	100 MW
7	Aerospace Engine Machining	$ 100,000	13.8kV	10 MW
8	Food and Beverage	$ 87,000	12.5 kV	5 MW
9	Chemical Plant	$ 75,000	66kV	3 MW
10	Chemical Plant	$ 75,000	66kV	5 MW
11	Electronic Components	$ 75,000	12.5 kV	5 MW
12	Crystal Growth	$ 60,000	12.5 kV	1 MW
13	Chemical Plant	$ 46,175	66kV	30 MW
14	Wiring Manufacturing	$ 34,000	12.5 kV	2 MW
15	Chemical Plant	$ 18,000	12.5 kV	2 MW
16	Fibers Plant	$ 15,000	12.5 kV	1 MW
17	Paper and Packaging	$ 10,000	12.5 kV	4 MW
18	Plastic Bag Manufacturing	$ 10,000	480V	4 MW
19	Plastics	$ 7,500	12.5 kV	4 MW
20	Stainless Steel Manufacturing	$ 5,500	12.5 kV	2 MW

Automotive Reported as high as $700,000.

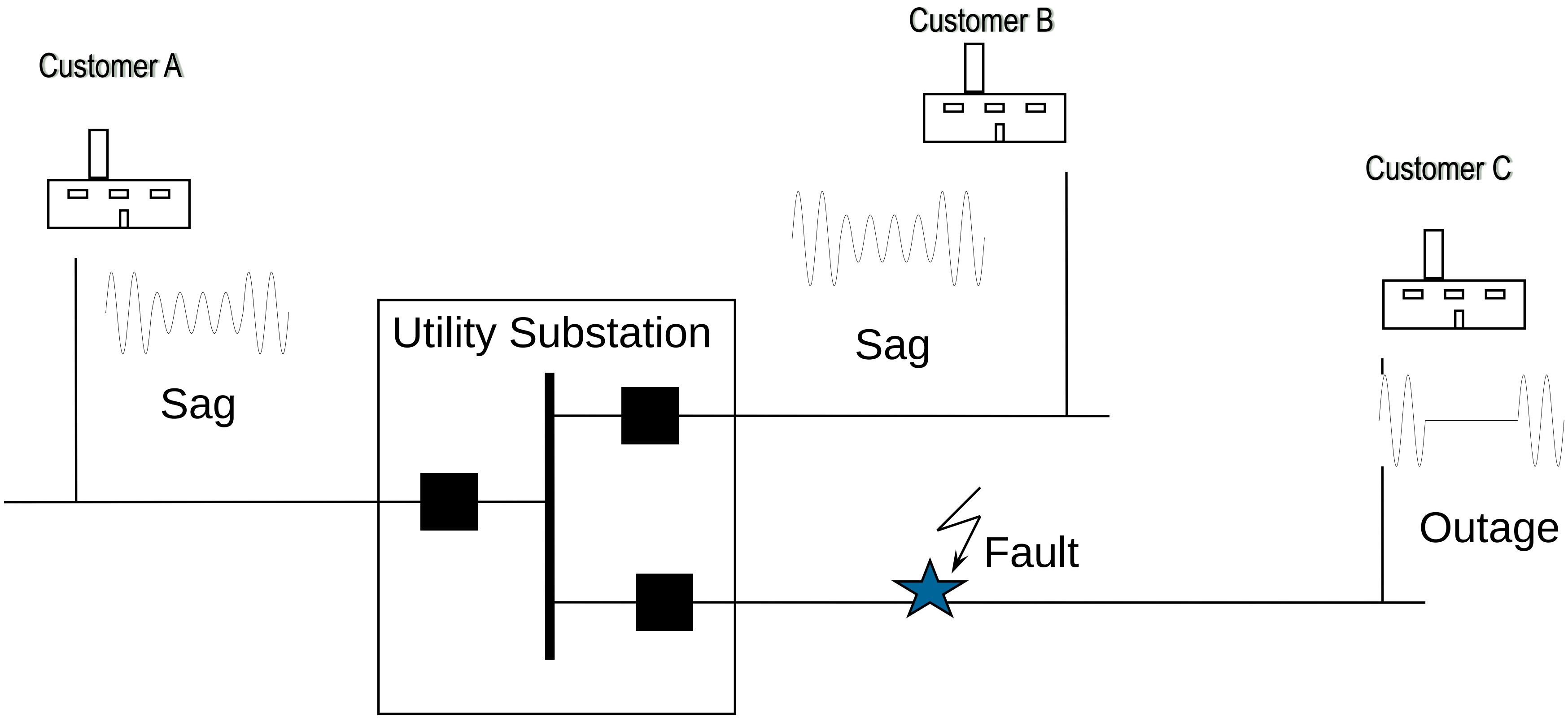
Reliability/Power Quality Myth 1

- Those annoying Sags, “brown-outs” and interruptions are due to insufficient utility capacity
  - especially when it occurs during peak summer periods
  - perception strong in mature or rapidly developing service areas
  - mis-information can add confusion

Reliability/Power Quality Reality 1

- Those annoying Sags and interruptions are most likely due to distribution faults and short circuits
  - interruptions (0 to 10% of nominal volts)
    - momentary in duration (up to 5 minutes duration)
    - sustained or extended duration (> than 5 min.)
  - voltage sags (10-90% of nominal volts)
    - resulting from fault clearing on parallel or “sister” circuits

Outage or Sag ?

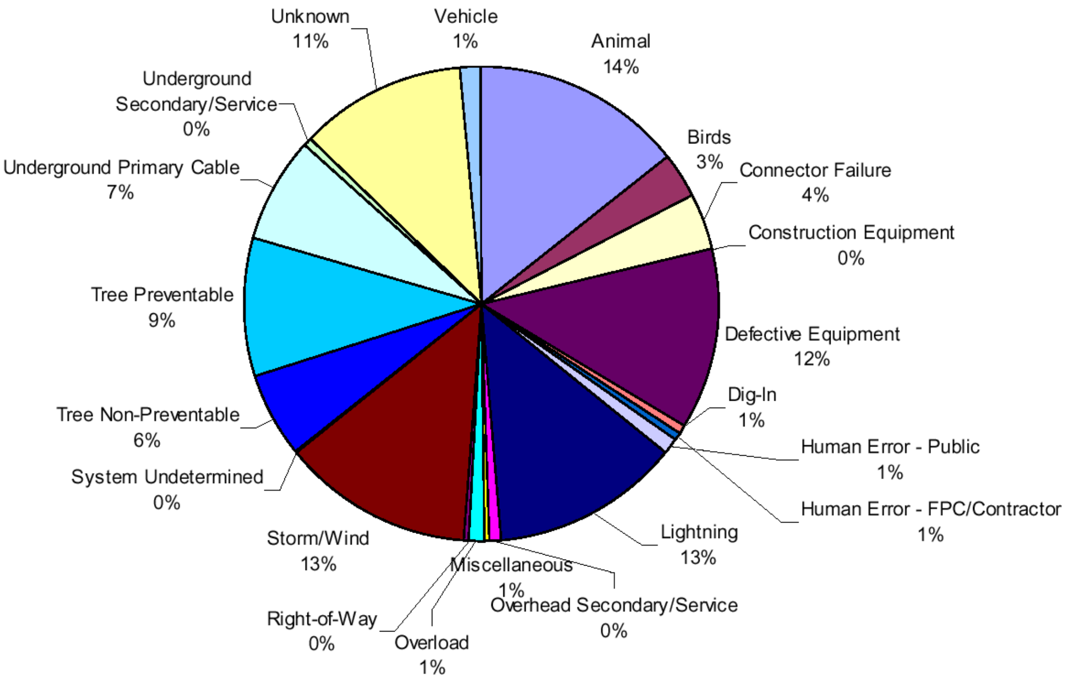


Targeting by Cause

Northwest US

By Occurrence		By Hours Out
Equipment Failure (29%)	1	Tree Contacts (27%)
Foreign Interference (16%)	2	Weather (21%)
Tree Contacts (13%)	3	Equipment Failure (18%)
Unknown (9%)	4	Foreign Interference (14%)
Weather (9%)	5	Unknown (6%)

Florida



EPRI Fault Study

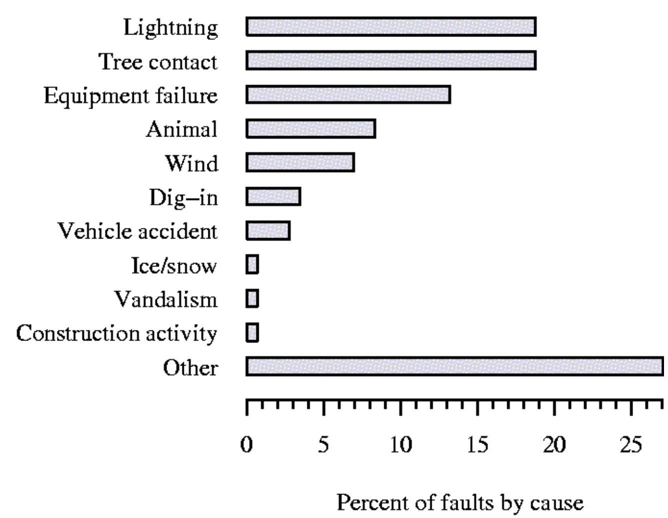
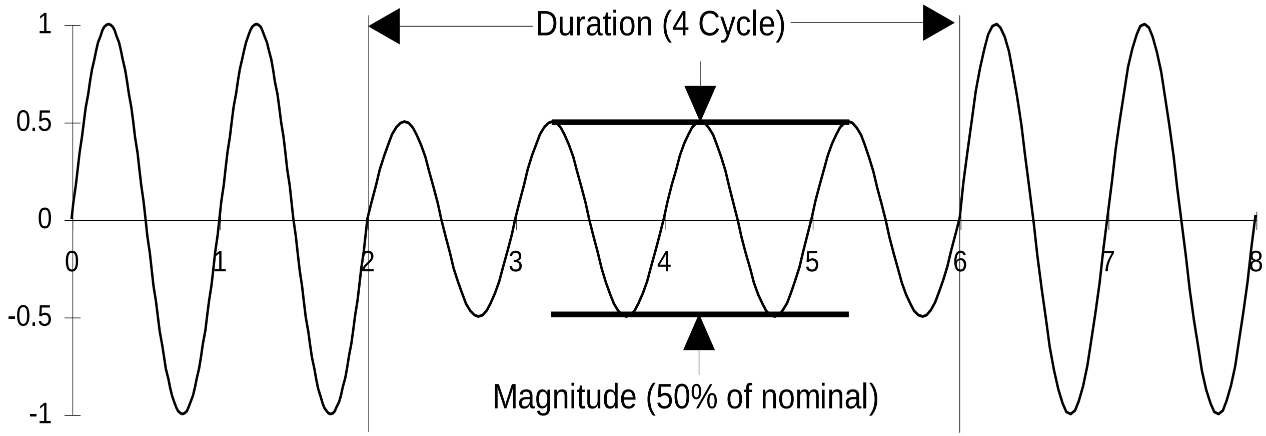


FIGURE 7.1
Tom Short, *Electric Power Distribution Handbook*, CRC Press, 2004

Effects of Voltage Sags

(MagDur)



- Lights may or may not flicker
- Equipment shutdown or malfunction
- Can result in production downtime an/or product loss

For every 1 momentary interruption a customer will see 8 voltage sags (EPRI DPQ Study)

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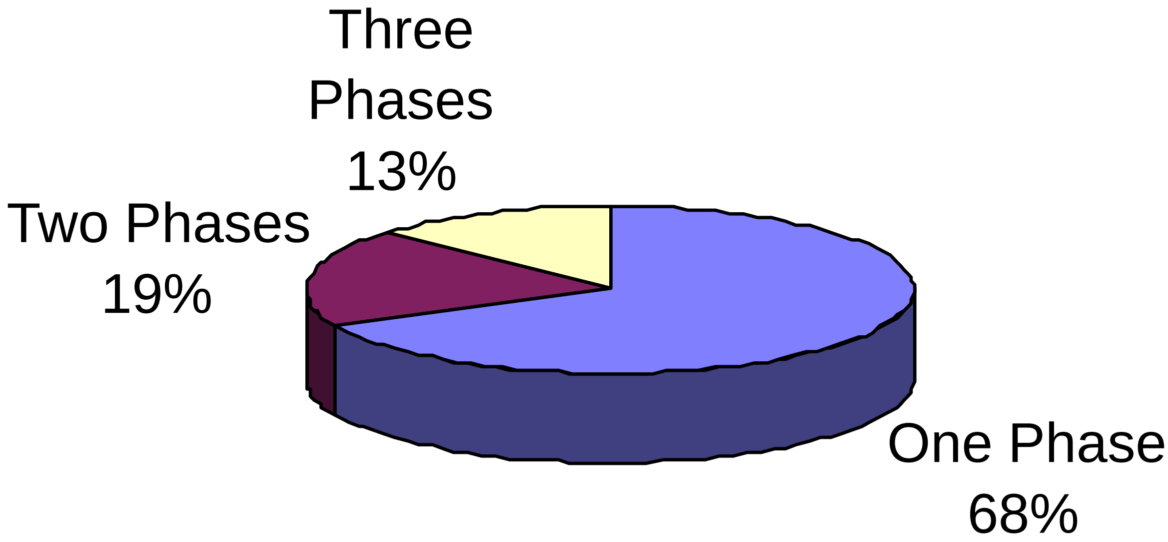
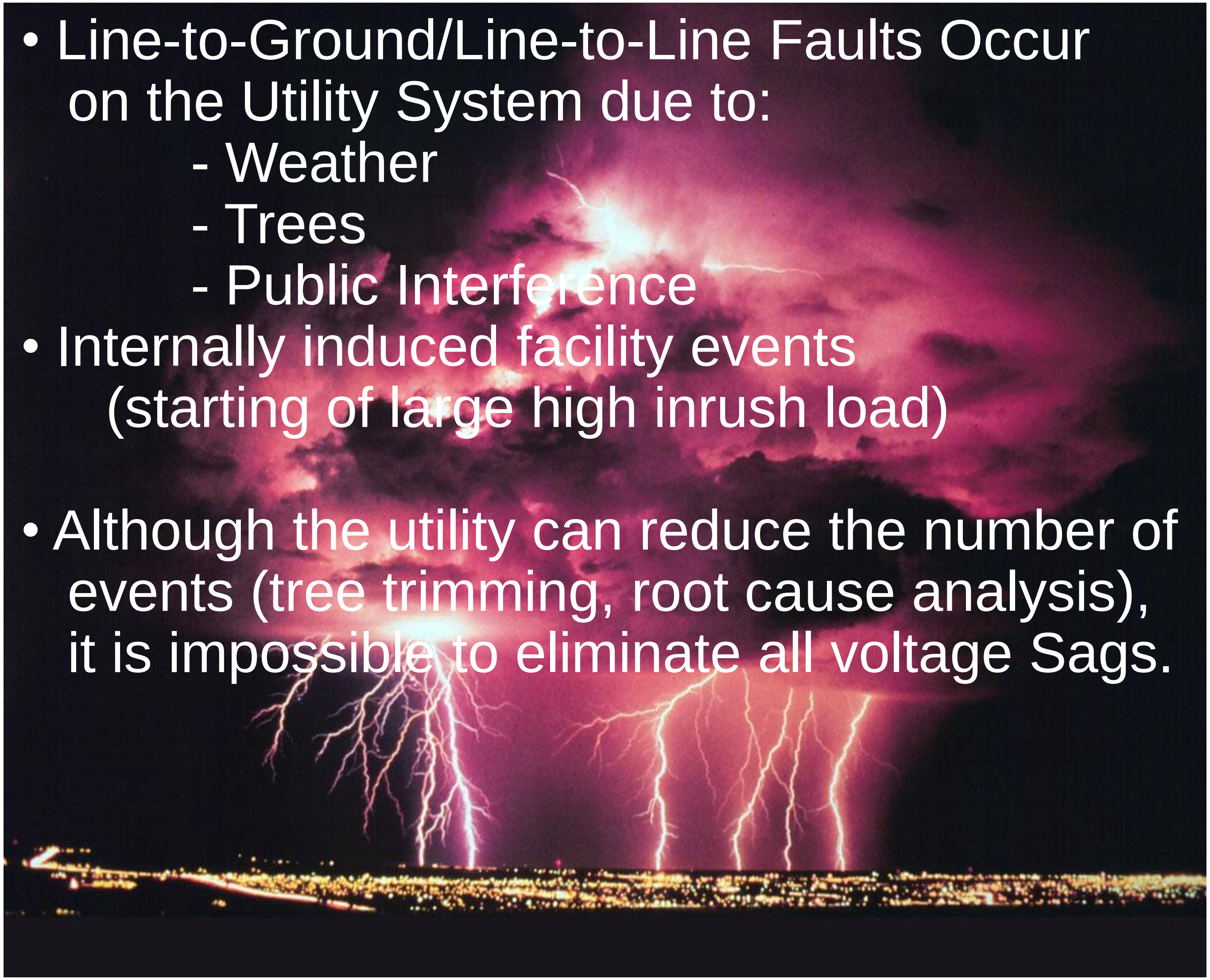
Voltage Sags - How Many Phases "sag"?



Source: EPRI Distribution Power Quality Study

Why Voltage Sags Occur...



- Line-to-Ground/Line-to-Line Faults Occur on the Utility System due to:
  - Weather
  - Trees
  - Public Interference
- Internally induced facility events (starting of large high inrush load)
- Although the utility can reduce the number of events (tree trimming, root cause analysis), it is impossible to eliminate all voltage Sags.

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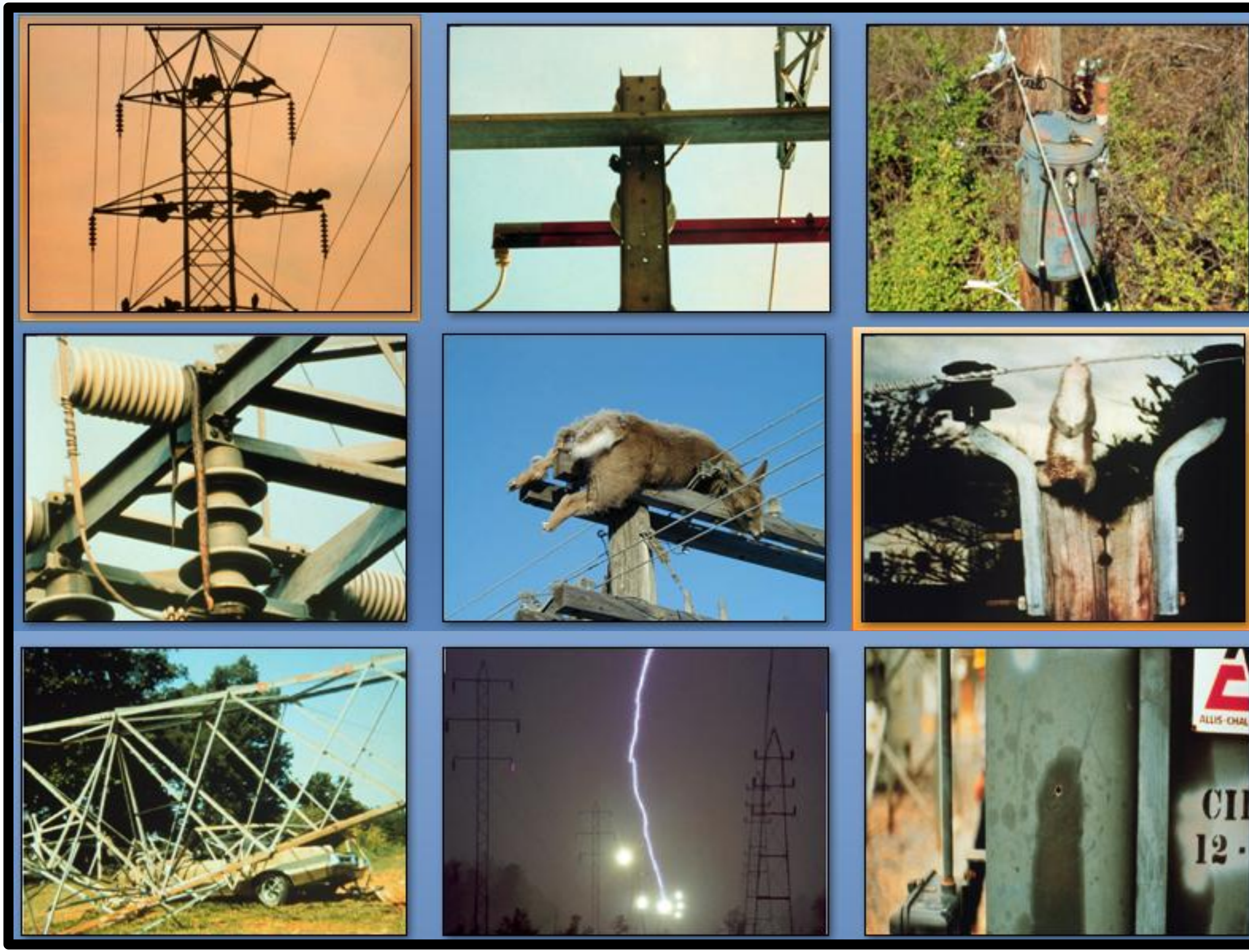
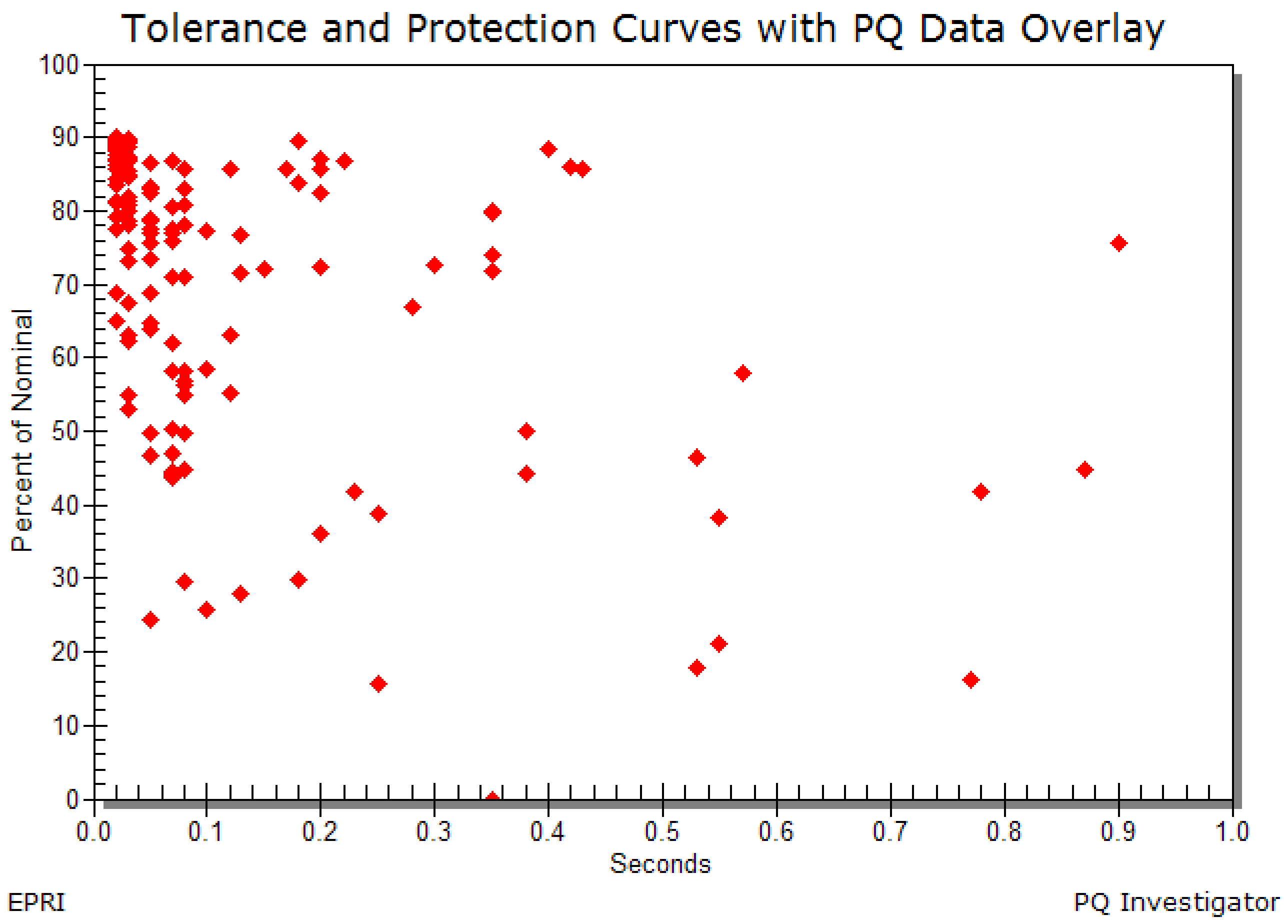


Rural Site 5 Minute Aggregation, 14 Months of Data



Rural Site Summary of Events

Interruptions	Count
Scheduled outages	2
Station Breaker outage, Bird contact pole fire near Site	1
Station Breaker operated, Weather lightning, tree contact	1

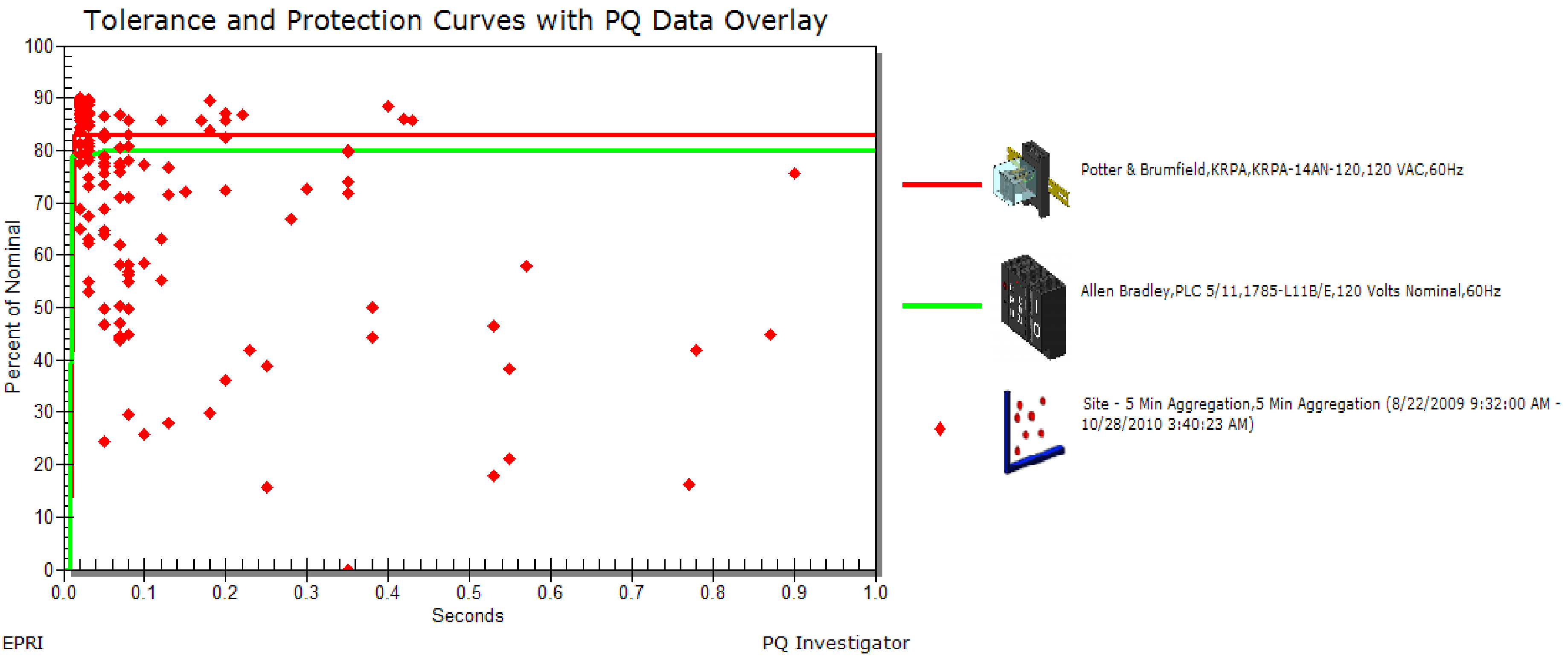
Voltage Sags	Count
Major Storm	6
Weather Lightning Storm	6
No Trouble Tickets/operations	26
Blown transformer fuse due to squirrel	10
TIR outage beyond protective Device	10
TOR outage beyond protective Device	15
Failed equipment	5
Blown fuse at Adjacent Industrial	2
Adjacent Industrial Substation Fire	1
Vehicle accident	1

Note:

TOR – Tree Outside of Right-Of-Way

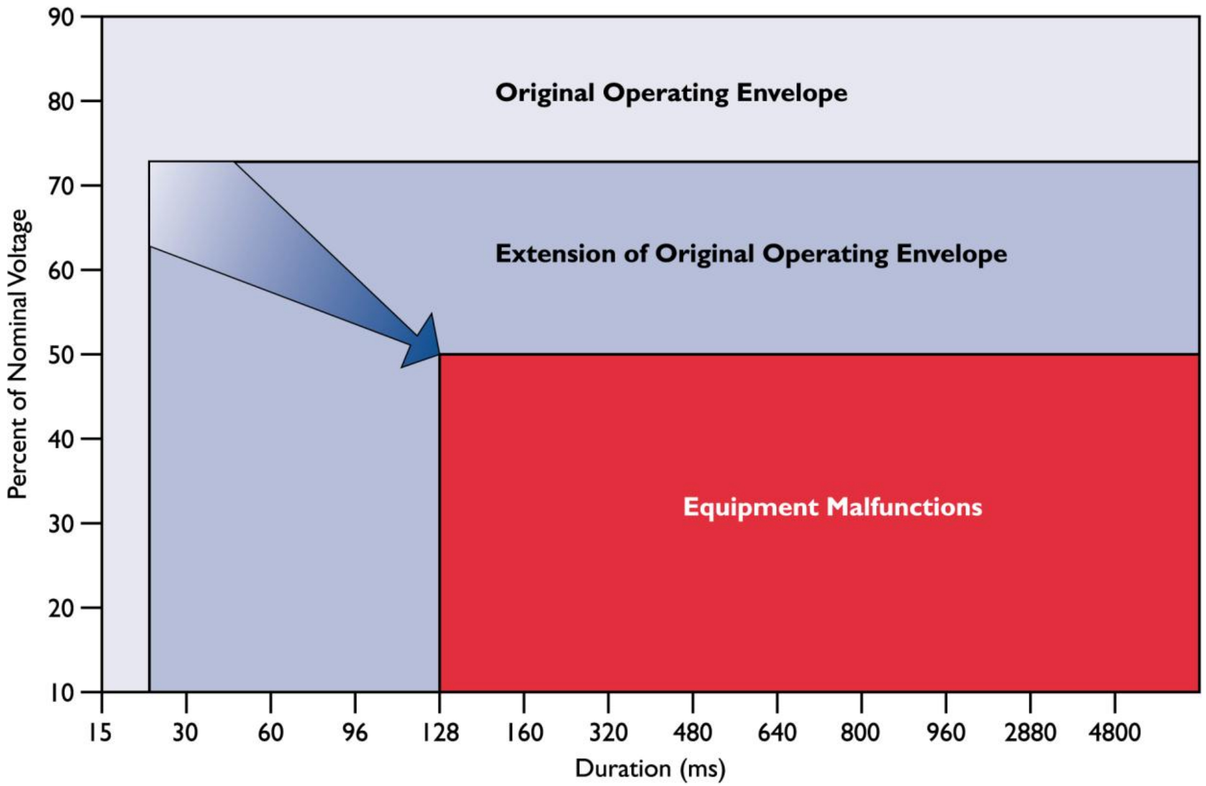
TIR – Tree Inside Right-Of-Way

Is it the Plant Equipment's Fault?



Goal – Extending the Operating Envelope

"Extending the operating envelope" of equipment means that we have to reduce the area of equipment malfunctions by enabling the equipment to ride through deeper and longer voltage sags.



Important Realization

- Utilities Share Responsibility
  - Tree Trimming, Lightning Arrestors, Grounding, Maintenance, Provide PQ information to industrials, etc
- Industrial sites Share Responsibility
  - Understanding Equipment Vulnerability, PQ Specifications, Power Conditioning, Proper Wiring/Grounding, etc
- Most effective solutions are reached when both sides work together to see what can be done

Voltage Sags and Solutions

Common Weak Links – AC Powered Relays, Contactors, Motor Starters, PLCs

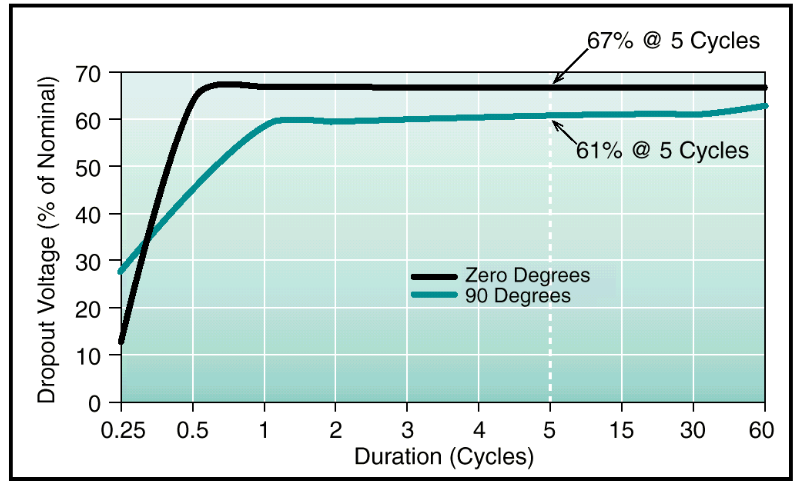


Figure 5. Composite Low-Voltage Tolerance of Relays

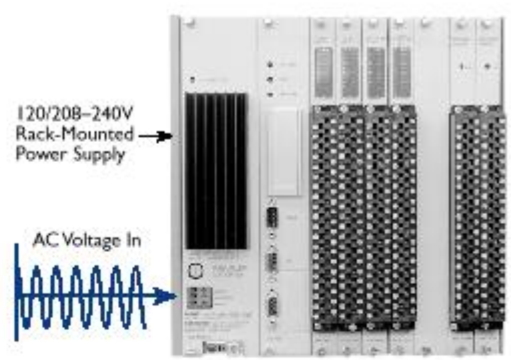
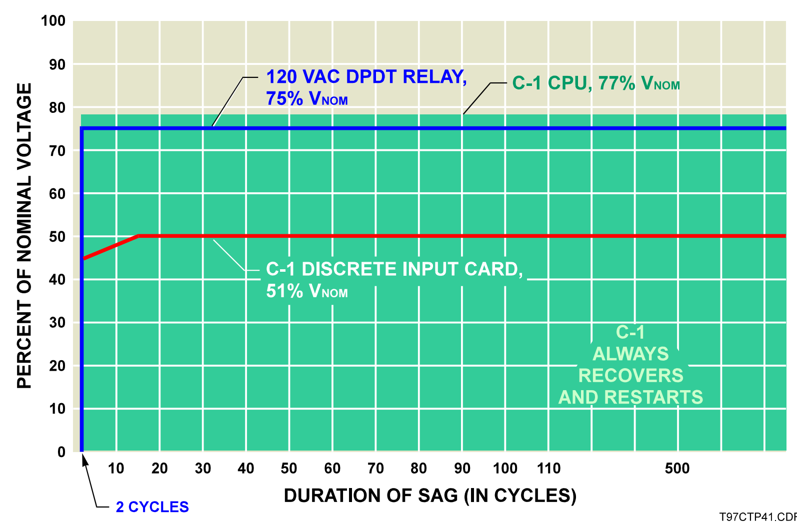
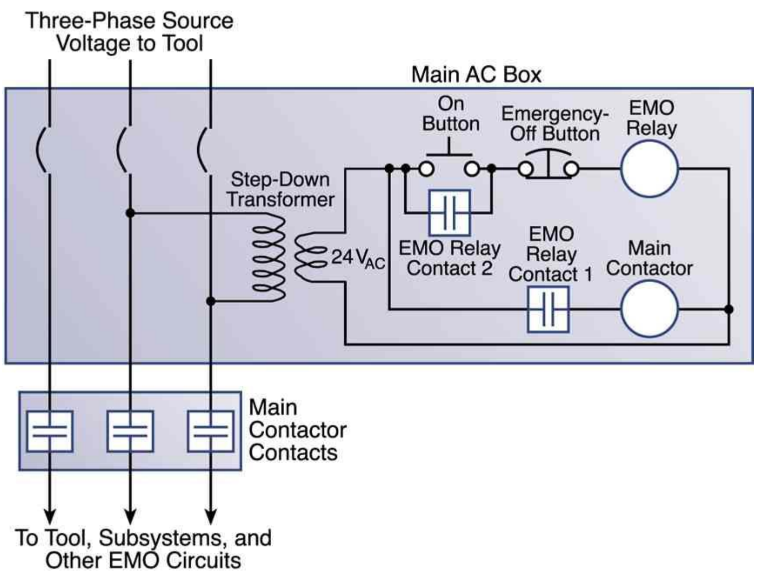
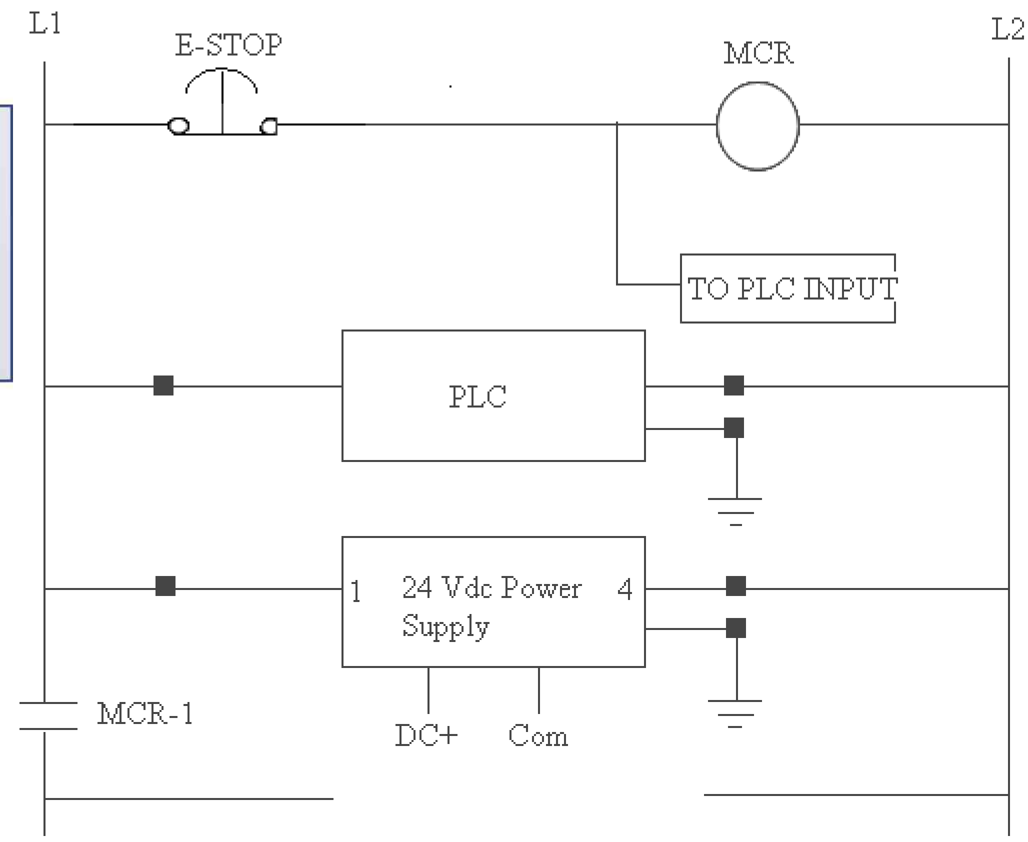


Figure 1. A rack-mounted PLC power supply that requires AC voltage (120/208-240 volts)



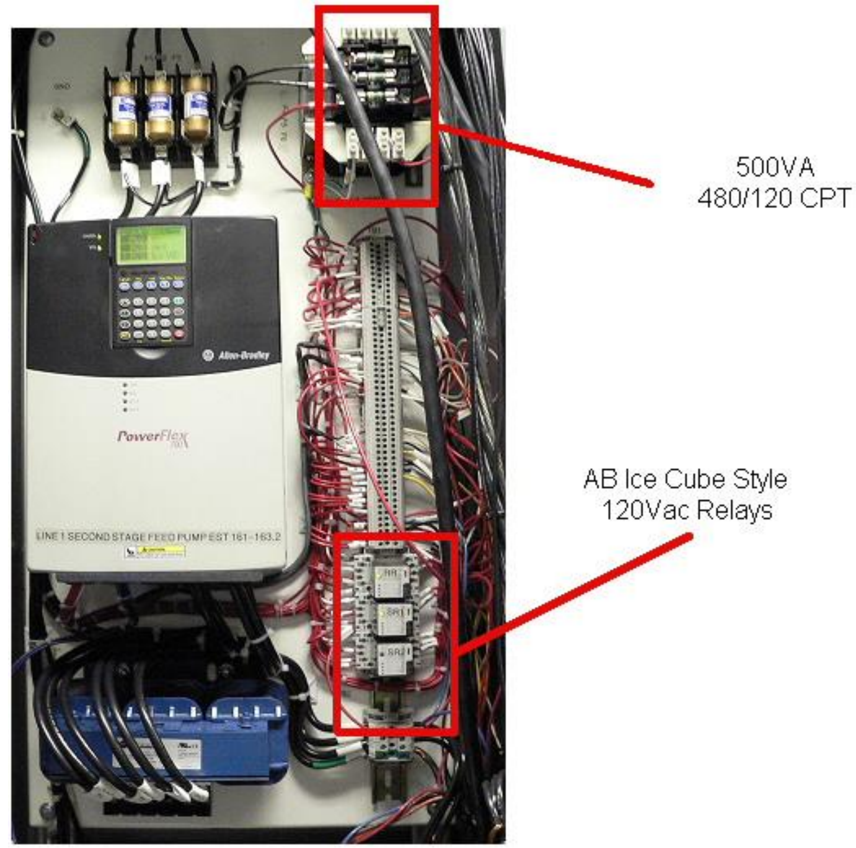
AC Circuits that can be Sensitive





Another Example Weak Link - Drive Interfacing Circuits

- AB Power Flex 700
- Drive is compliant to SEMI F47
- Utilizes Run Relay and Stop Interposing Relays (“ice cubes”).
- Powered from 500VA CPT in cabinet, circuit goes to field start and stop pushbuttons and back to relays in drive cabinet



Example Panel Analysis

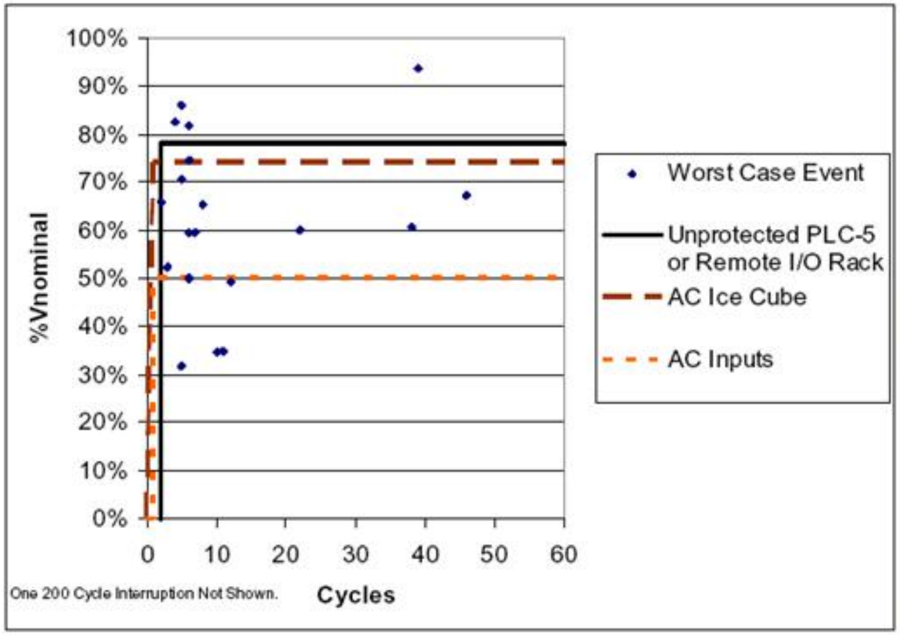
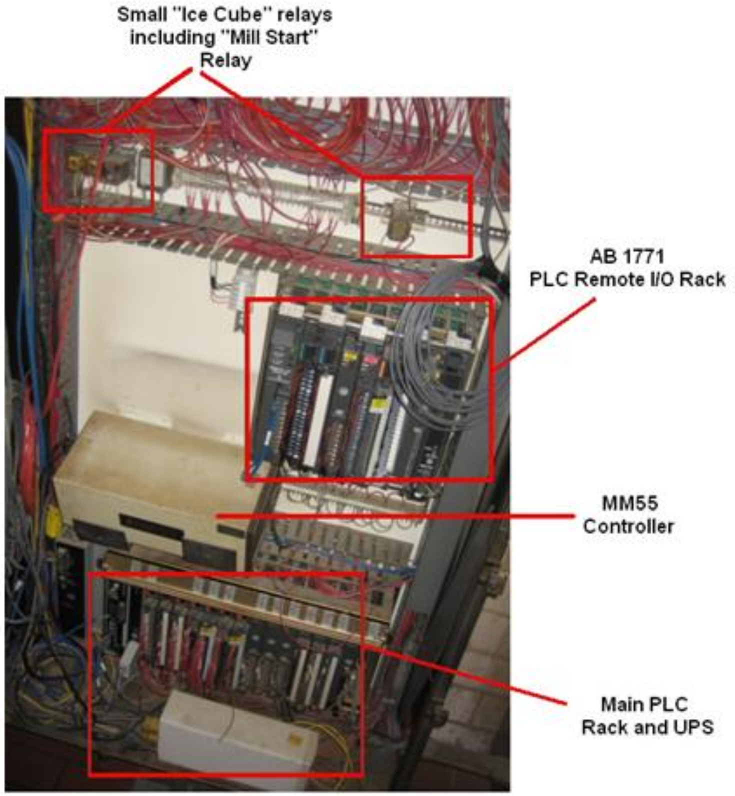
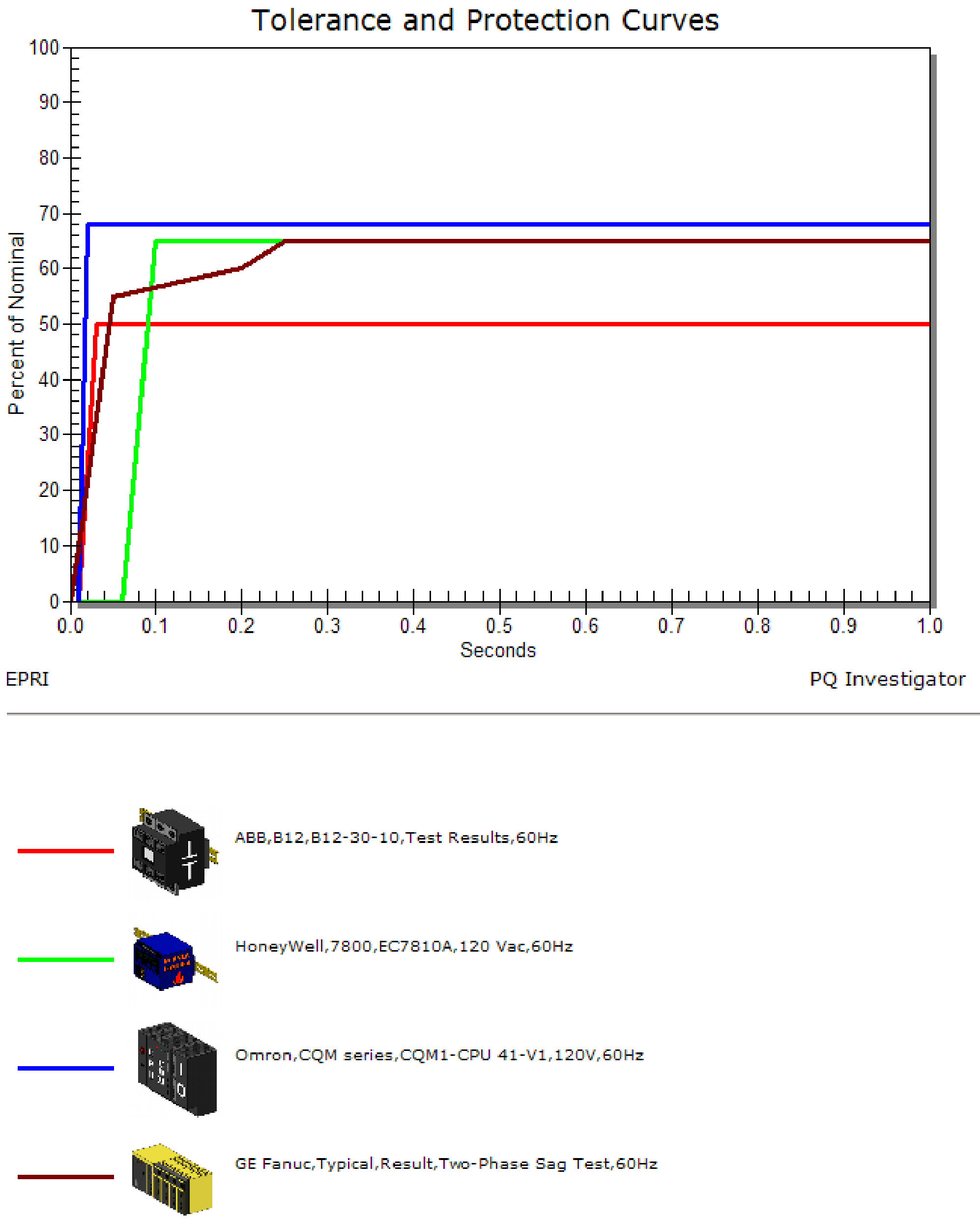


Figure 5.1-3
Expected Voltage Sag Ride-Through



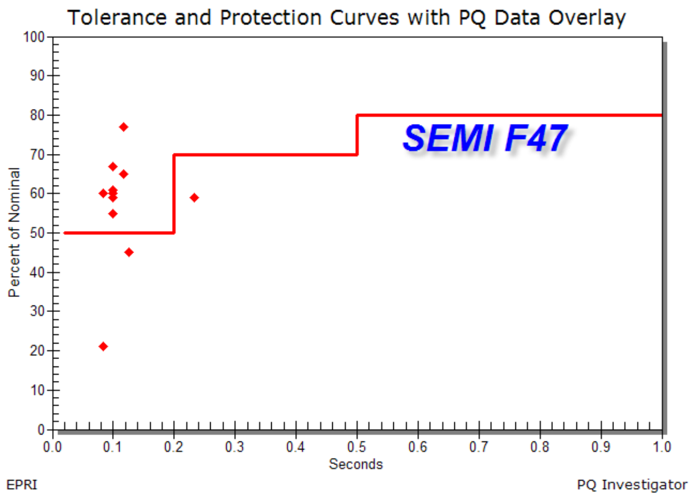
PQ Investigator Tool

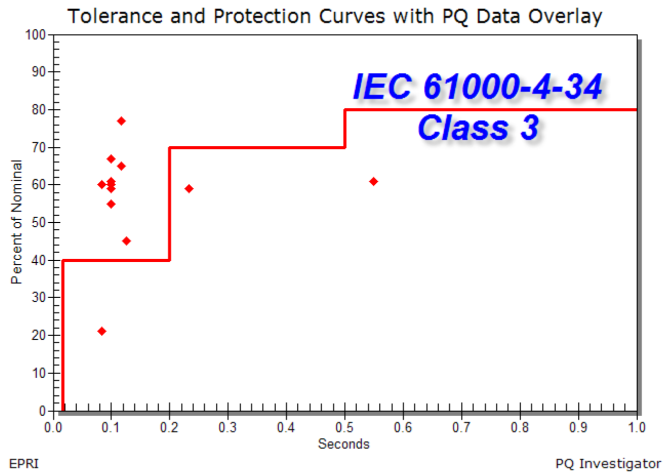
- EPRI has developed a new tool called PQ Investigator
- This tool allows for look up of hundreds of device ride-through curves
- Utilities may have access to the s/w and can help



Specify Voltage Sag Standards in Purchase Specs

- Example Specs
  - SEMI F47
    - From Semiconductor Industry
    - Most control OEMs have compliant hardware
  - IEC 61000-4-11/34
    - Class 3
  - IEEE P1668
    - (Balloting Soon)



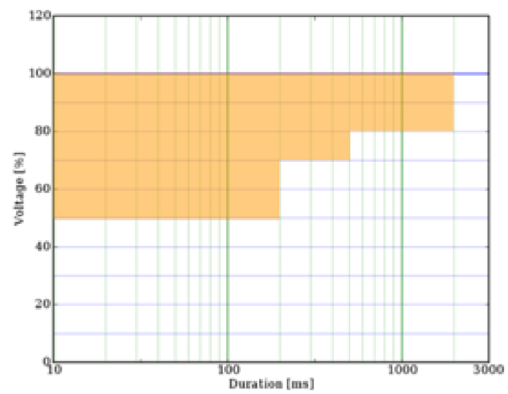


Draft IEEE P1668 Excerpt

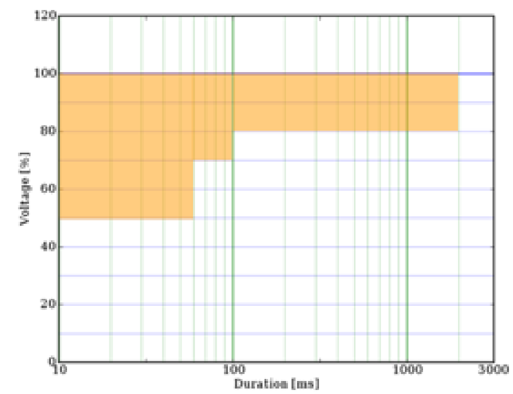
- 1,2, & 3 phase voltage sag requirements
- Comprehensive document:
  - Primer on Voltage Sags
  - Recommended test requirements
  - Test Procedures & Guidelines
  - Test Equipment Requirements
  - Certification and Test Report Requirements

Equipment Immunity Specification
IEEE P1668 Voltage Sag Immunity Requirement for Three-Phase Equipment

Immunity Curve for Type I & Type II Sags



Immunity Curve for Type III Sags



Type I and II voltage sag test points:

- 80% for 2 seconds
- 70% for 500 milliseconds
- 50% for 200 milliseconds

Repeat for test points for each phase-neutral and phase-to-phase combination.

Desired Type II Test Vector

Type II	Type II.A1	Type II.A2
☐	☐	☐

Pass/Fail Criteria

Full Operation	Self-Recovery	Assisted-Recovery
☐	☐	☐

Testing for Type III voltage sag required :

- 80% for 2 seconds
- 70% for 100 milliseconds
- 50% for 50 milliseconds

Pass/Fail Criteria

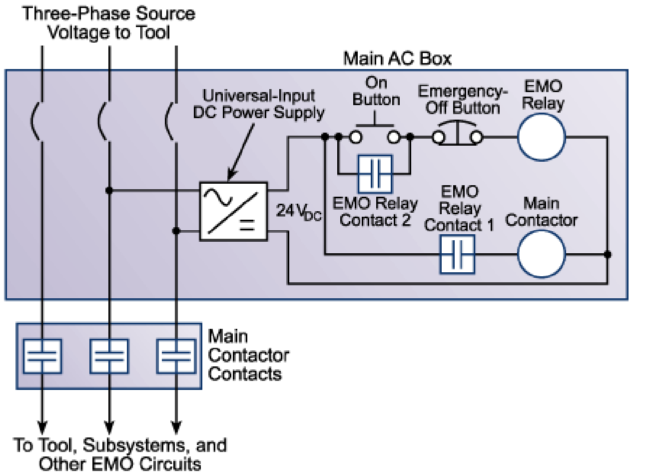
Full Operation	Self-Recovery	Assisted-Recovery
☐	☐	☐

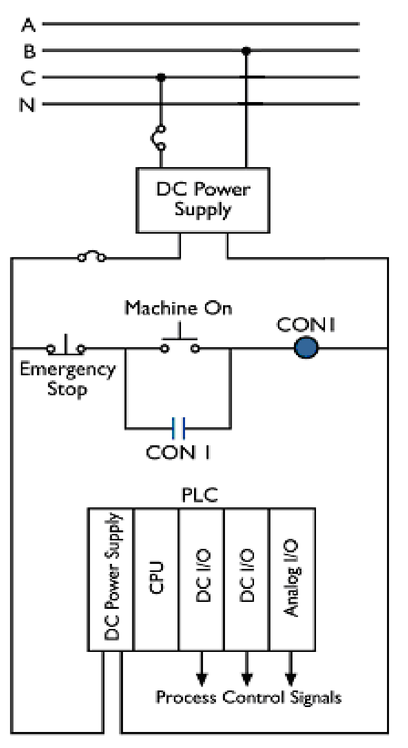
Testing Procedure Requirements: IEEE P1668

Design with DC Power

- One of the best methods of increasing the tolerance of control circuits is to use direct current (DC) instead of alternating current (AC) to power control circuits, controllers, input/output devices (I/O), and sensors.
- DC power supplies have a “built-in” tolerance to voltage sags due to their ripple-correction capacitors, whereas control power transformers (CPTs) and AC components do not have inherent energy storage to help them ride through voltage sags
- Many OEMs are moving in this direction to harden their equipment designs

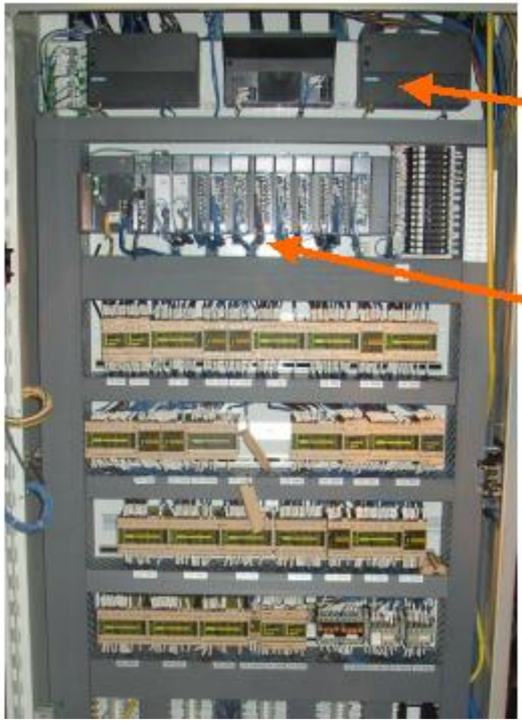
DC Powered Emergency Off Circuit





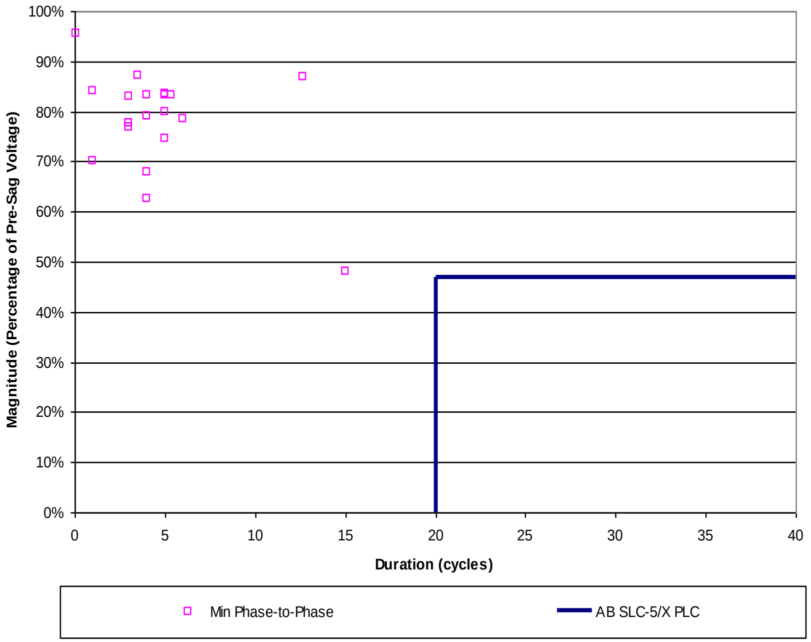
DC Powered PLC Circuit

DC Powered PLC System in Weld Shop



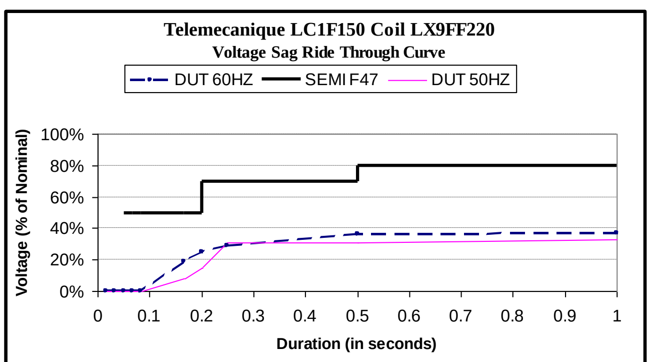
(3) Three phase input Siemens SITOP DC Power Supplies

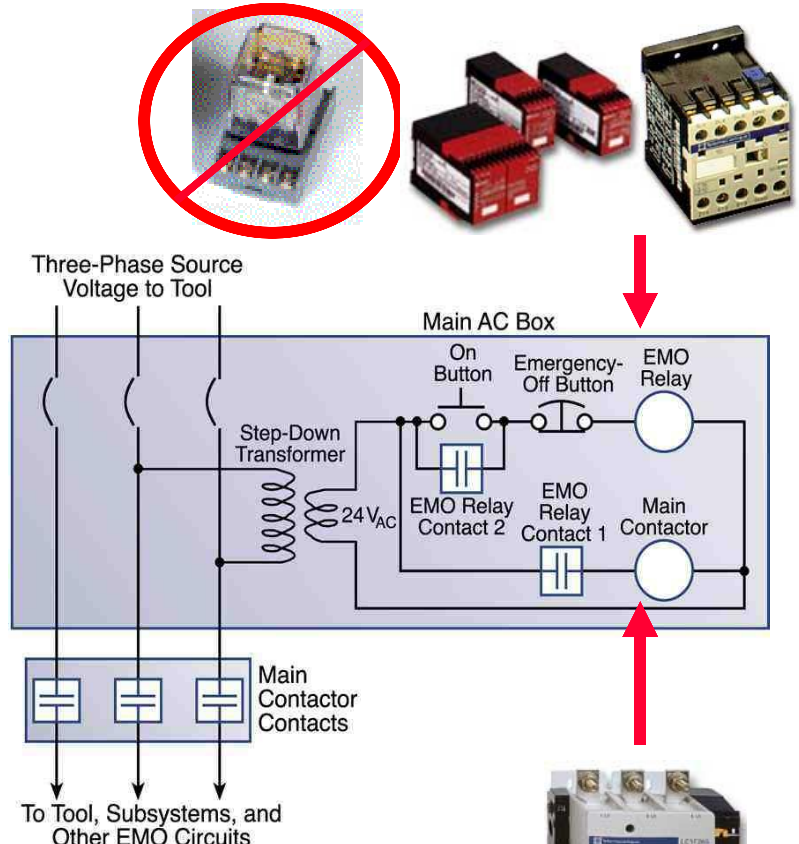
AB SLC-5/x PLC with DC I/O



Utilize Sag Tolerant Components

- IF AC Relays and Contactors are used in the semiconductor tool design, then utilize compliant devices.
- Consider response at both 50 and 60 Hz.
- Many components have been certified to SEMI F47.





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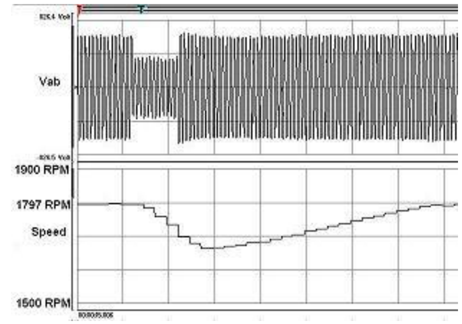
Examine Configuration Settings

- In most cases, drive manufacturers give users access to basic microprocessor program parameters so that the drive can be configured to work in the user's particular application.
- A drive's programming parameters associated with reducing the effect of voltage sags are seldom describes in one section of the user manual.



Parameter	Parameter Description
Automatic Reset	This parameter allows the drive to automatically reset some fault conditions, such as DC link undervoltage or overvoltage, without the need for operator/user intervention. This feature is used in conjunction with Automatic Restart.
Automatic Restart	This parameter defines the method in which the drive automatically restarts after a fault condition is over. Automatic Restart operations may only be used as outlined in NFPA 79. Equipment damage and/or personal injury may result if the Automatic Restart parameter is used in an inappropriate application.

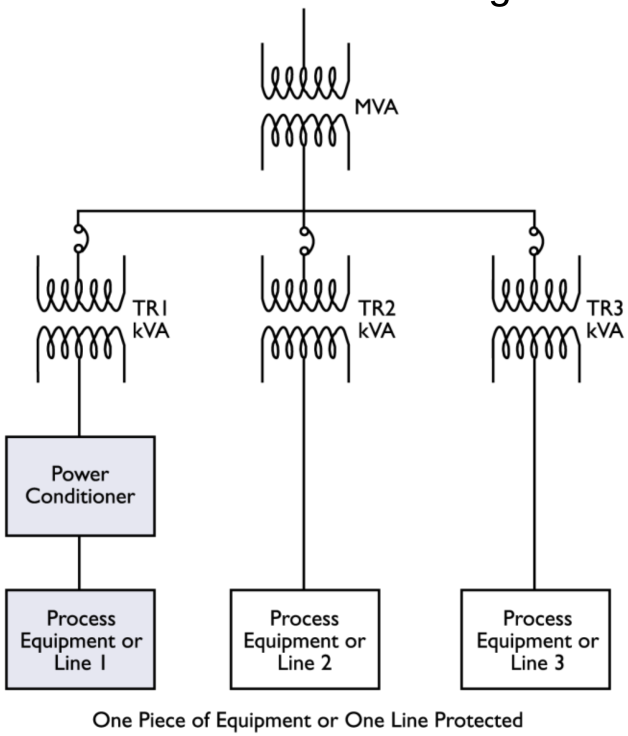
Parameter	Parameter Description
Kinetic Buffering	When the drive senses a DC link low-voltage condition, the drive uses the combined motor-load inertial energy to maintain a factory-programmed DC link voltage inside the drive by applying a braking force to the motor. This feature does not create a potential for extreme current or torque transients.
Motor Voltage Compensation	When the drive senses a DC link low-voltage condition, the drive's controller changes the inverter firing timing sequences to compensate for a reduced DC link voltage. The objective is to maintain as close as possible the desired output voltage for operating the motor and load.
Controlled Deceleration and Acceleration	When the drive senses a DC link undervoltage condition, the drive begins to decelerate the motor at a user-defined rate. When the undervoltage condition ends, the drive reaccelerates the motor back to the desired operating point. This feature is often used in processes with multiple drives operating in succession, where all drives are expected to operate in unison to maintain process quality. This feature works well for common DC bus drive systems.
Flying Restart	This parameter is similar to the parameter above with one major exception: Rather than restarting at a pre-defined frequency setting, the drive uses a search algorithm to determine the motor speed. Once the speed is recognized, the drive reaccelerates the motor to the desired operating point. The odds of the motor and load experiencing extreme current and torque transients are greatly reduced.

Other Considerations

- Make sure the device rated voltage matches the nominal voltage. Mismatches can lead to higher voltage sag sensitivities (for example 208Vac fed to 230Vac rated component).
- Consider Subsystem performance. Vendor subsystems must be robust for the entire system to be robust. Otherwise, power conditioning may be required for the subsystem.
- Consolidate Control Power Sources. This will make the implementation of any required power conditioner scheme much simpler and cost effective.
- Use a targeted voltage conditioning approach as the last resort. Apply Batteryless power conditioner devices where possible.

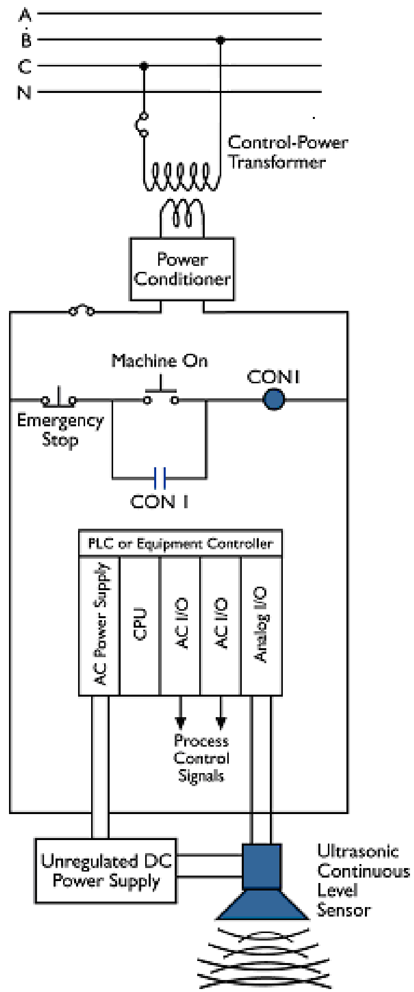
Example PQ Solution Levels

Machine or Subsystem Level Power Conditioning



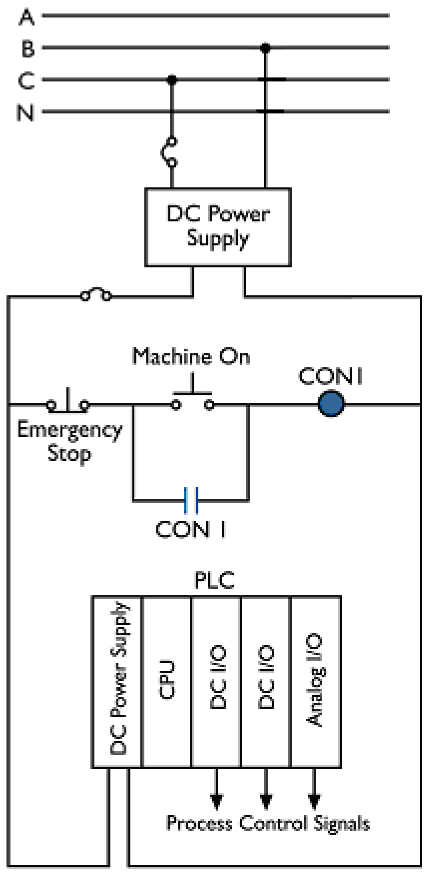
Control Level Power Conditioning

(1/10th to 1/20th of Machine Level Power Conditioner Cost)



Control Level Embedded DC Solution

(Best done by OEM in design phase)

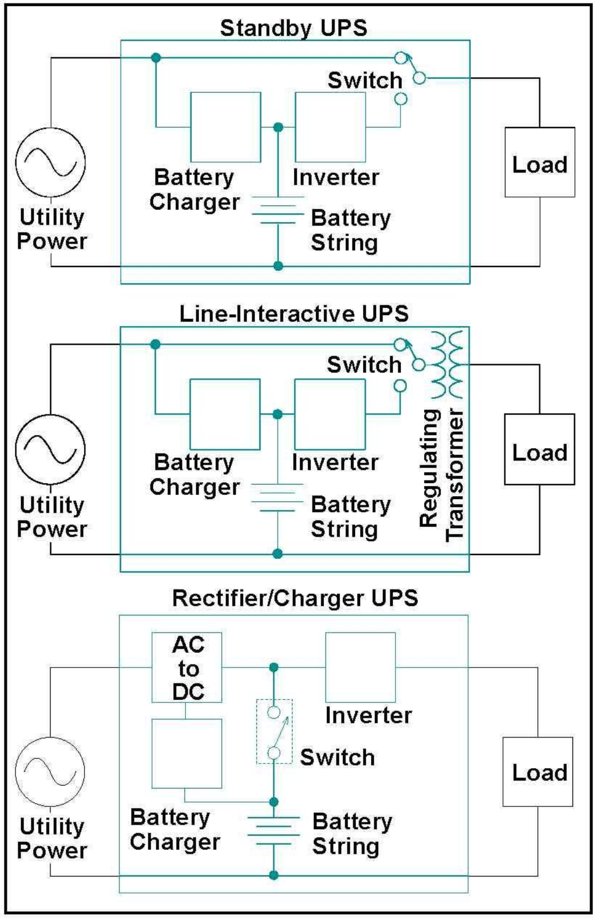


Uninterruptible Power Supply (UPS)

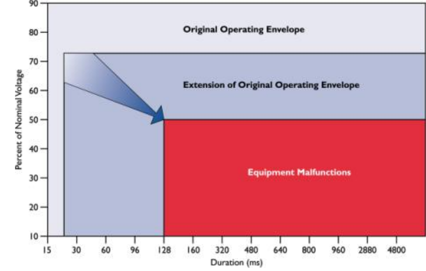
For Control Loads
Small 500Va to 3kVA
UPS Systems are sometimes Used

“Abandoned in Place” UPS Systems: A Common Problem

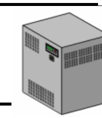
Battery Based UPS Are Often “Overkill”



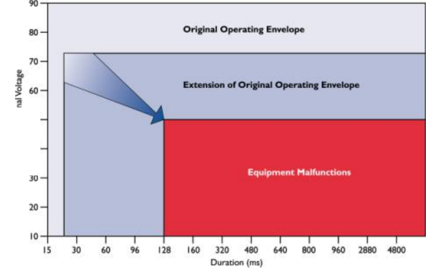
PQ Mitigation Devices

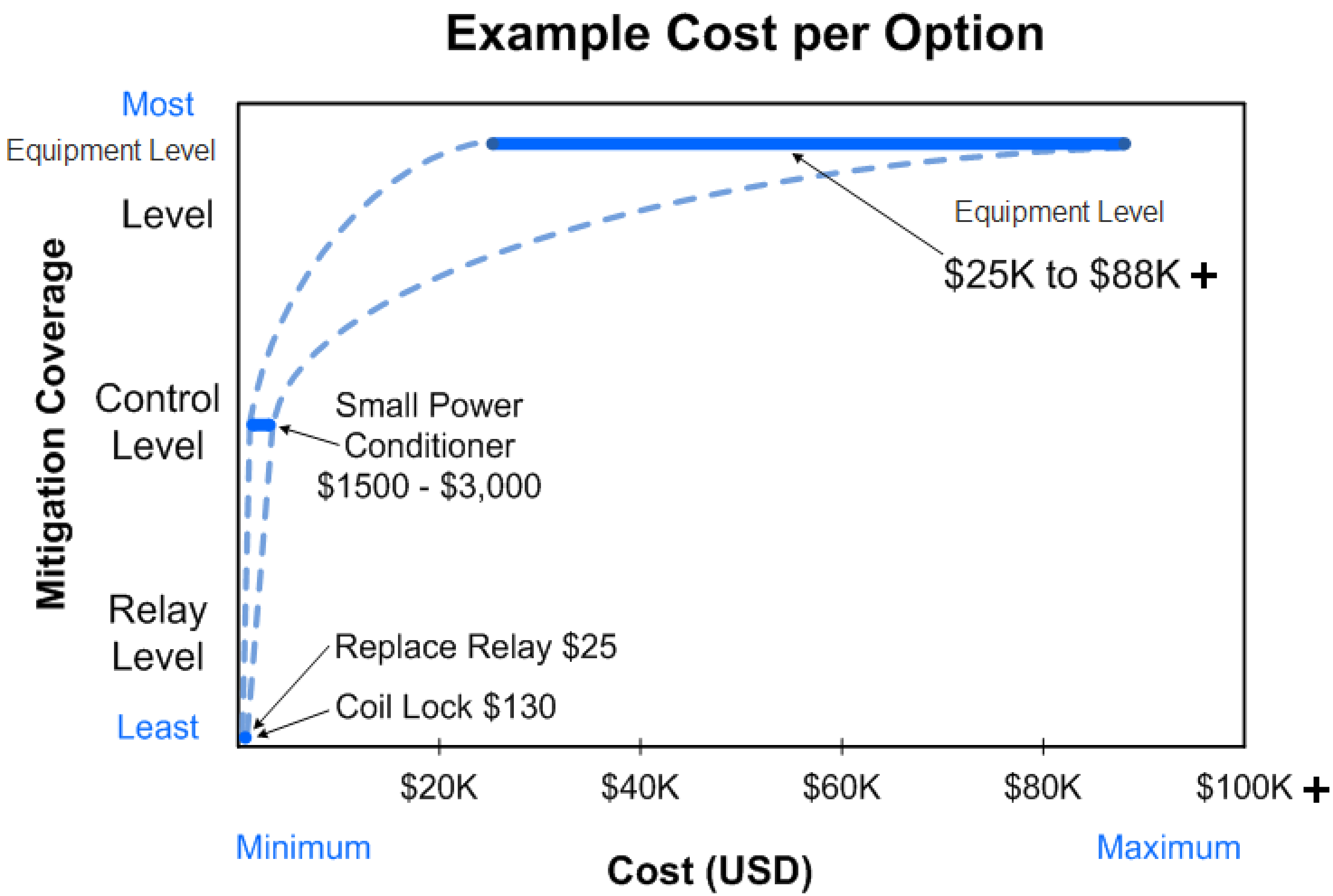


Comparison of Power Conditioning Devices

Application	Device	Coverage (Vnom) / Duration			Notes
		1 ϕ	ϕ - ϕ	3 ϕ	
3ϕ	ProDySC	0% / 2 sec.	30% / 2 sec.	50% / 2 sec.	at full load 
3ϕ	AVC (two rated models)	45% / 30 sec. 25% / 30 sec.	45% / 30 sec. 25% / 30 sec.	50% / 30 sec. 50% / 30 sec.	at full load 
1ϕ Contrl Ckt	PowerRide RTD	0% / 2+ sec.	0% A-B, B-C; 70-80% C-A / 2+ sec.	70-80% / 2+ sec.	3-phase Input, 1-phase Output 
1ϕ Contrl Ckt	MiniDySC	0% / 0.05 sec. 50% / 2 sec.	n/a	n/a	
1ϕ Contrl Ckt	CVT	40-50% / 2+ sec.	n/a	n/a	
1ϕ Contrl Ckt	VDC (6T Model)	37% / 2+ sec.	n/a	n/a	
1ϕ Contrl Ckt	Coil Hold-in (CoilLock and KnowTrip)	25% / 2+ sec.	n/a	n/a	for relays, contactors, motor starters

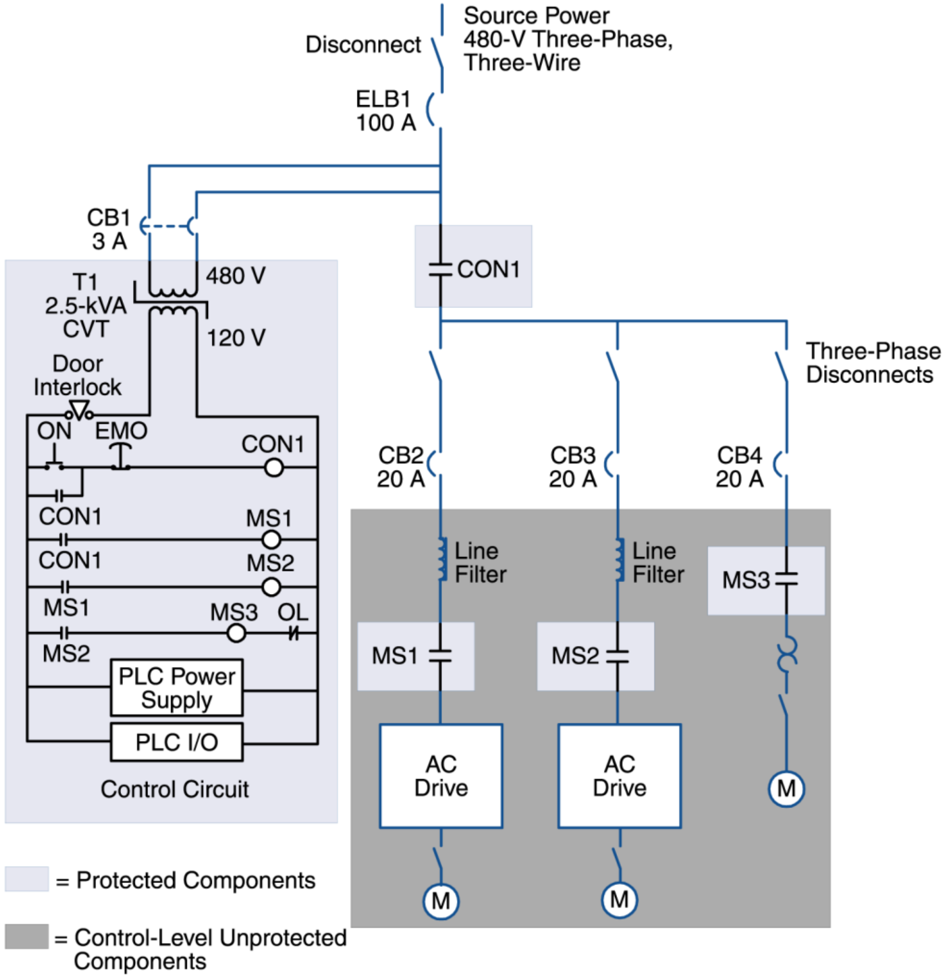

Generalized Example:
Control Level to Equipment Level
Cost vs. Coverage





Example Control Level Solution Application

- The CVT is protecting only the AC control components means that the selected power conditioner will be more affordable than one that could protect the entire machine.
- The ride-though of the AC drives in this example can be enhanced by modifying their programming, thus eliminating the need for a large power conditioner.



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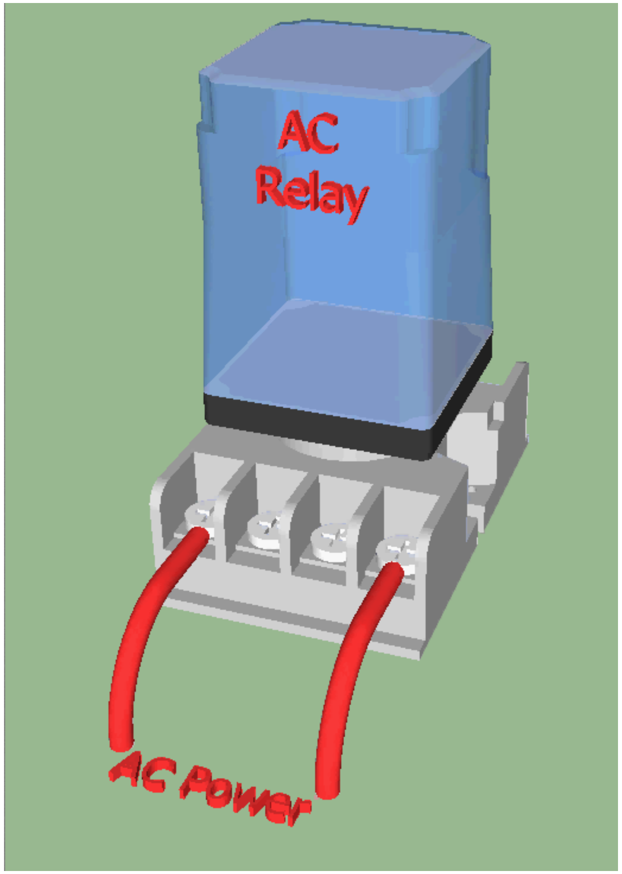
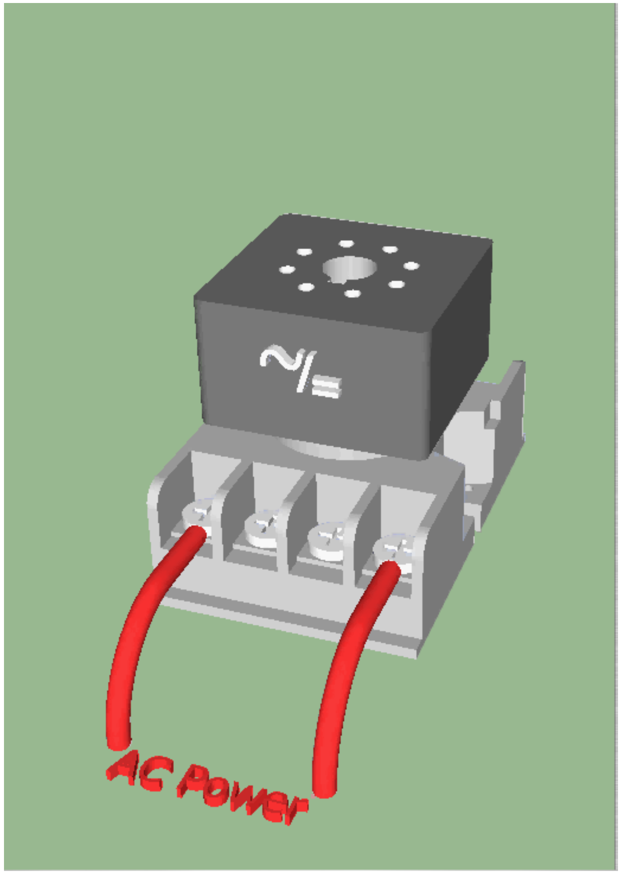
New Solution for an Old Problem: EPRI Nice Cube Block Concept & Prototype

Original "AC Ice Cube"

Drop out ~70% Vnom

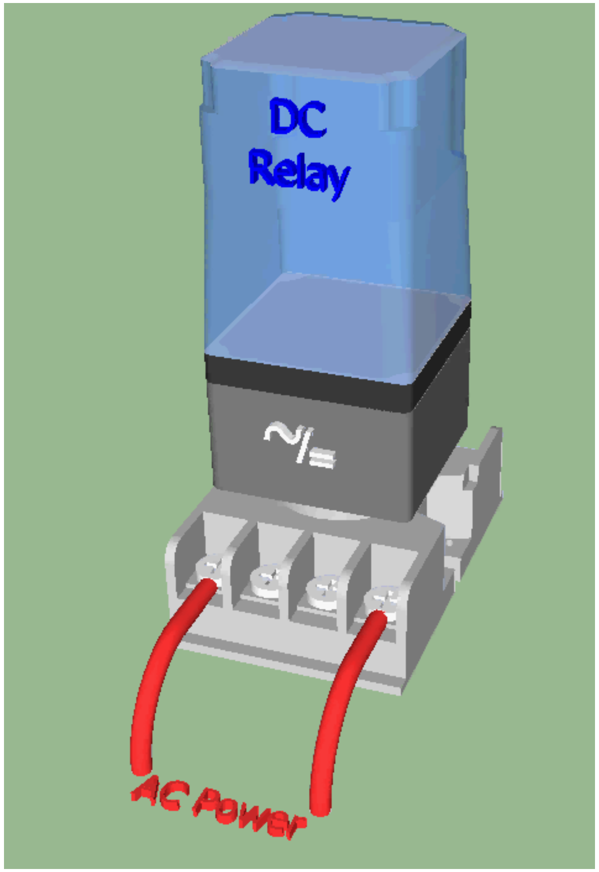


Remove "AC Ice Cube" Insert "Nice Cube" Puck Into Base



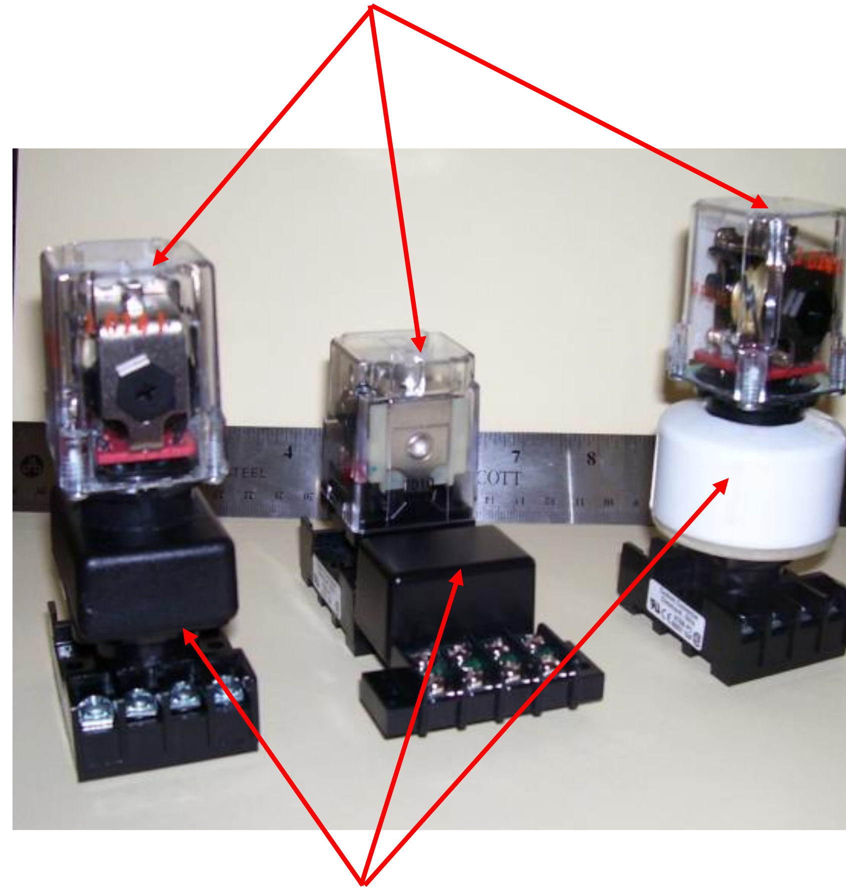
Insert "DC Ice Cube"

Drop Out ~ 25-30% Vnom



EPRI / PQSI Design Concepts for Nice Cube "Puck"/ "Brick"

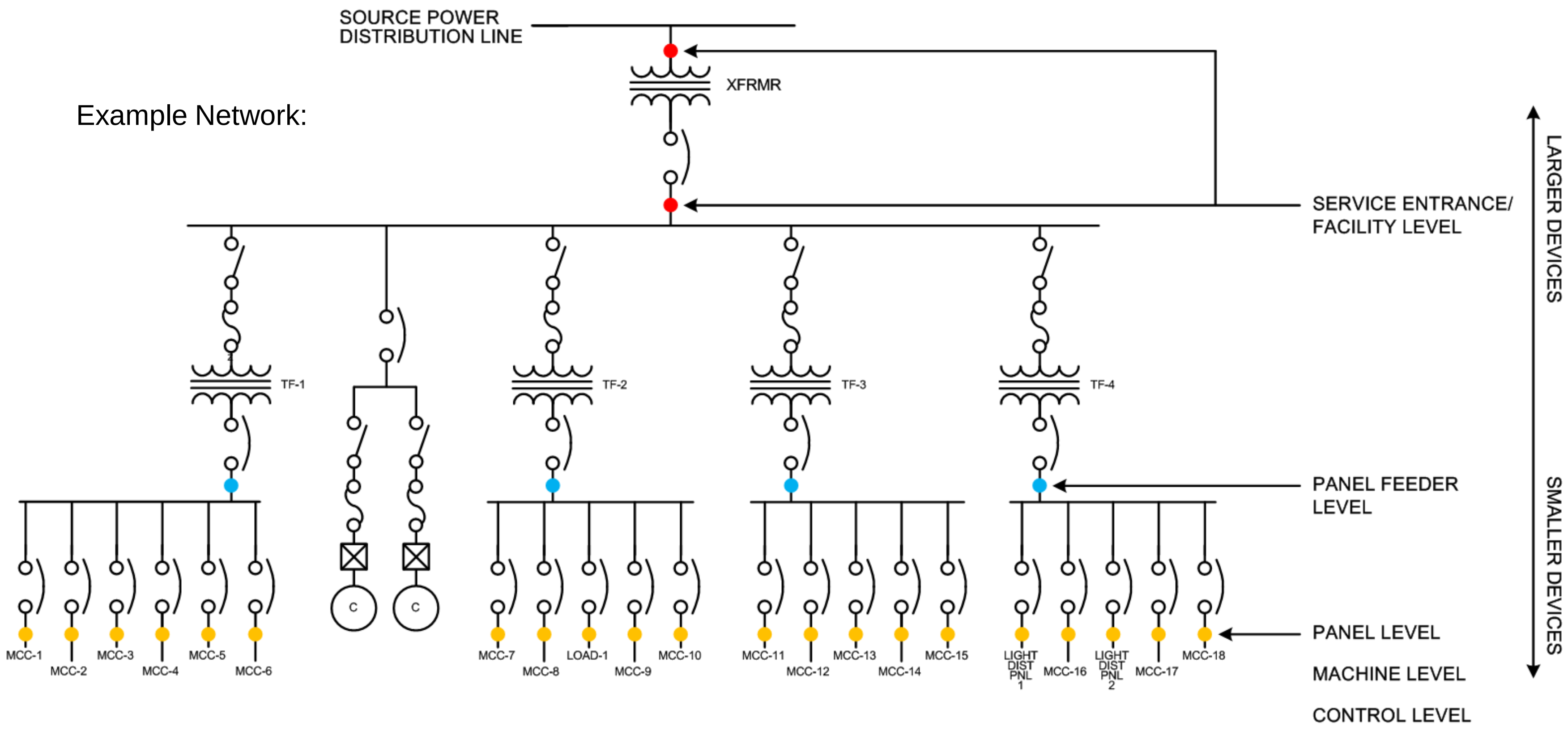
- Left concept:
  - Designated "Nice Cube #1" (Vertical)
  - Square "lego block" plugs into existing base
  - Keyed to plug in only one way
  - Off the shelf "lego like" enclosure for electronics
- Middle concept:
  - Designated "Nice Cube #2" (horizontal)
  - Block is offset to not add height to relay
    - Important where vertical space could be limited
  - Off the shelf "lego like" enclosure for electronics
- Right concept:
  - Nixed based on production cost
  - Puck is made from PVC and mounts on top.
  - Keyed to plug in only one way
  - Relay sticks up higher



Solution Application Points

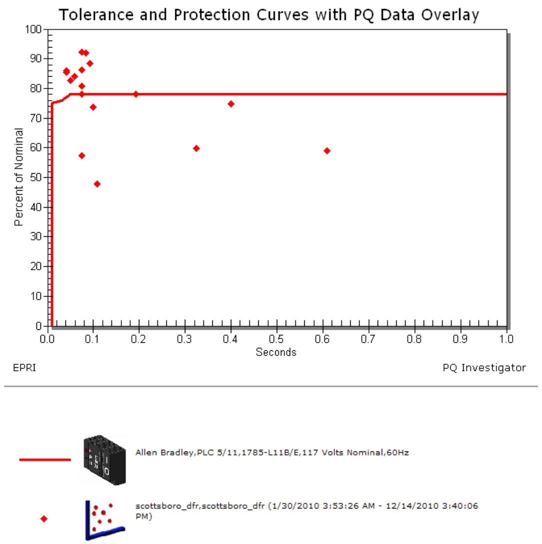
- Voltage Sags may be mitigated at a variety of locations
- Service Entrance, Panel Feeder, Panel, Machine, and Control Levels.

Example Network:

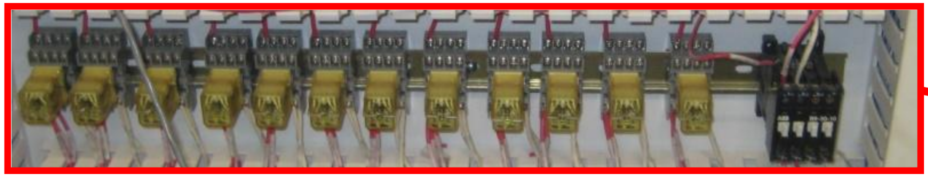


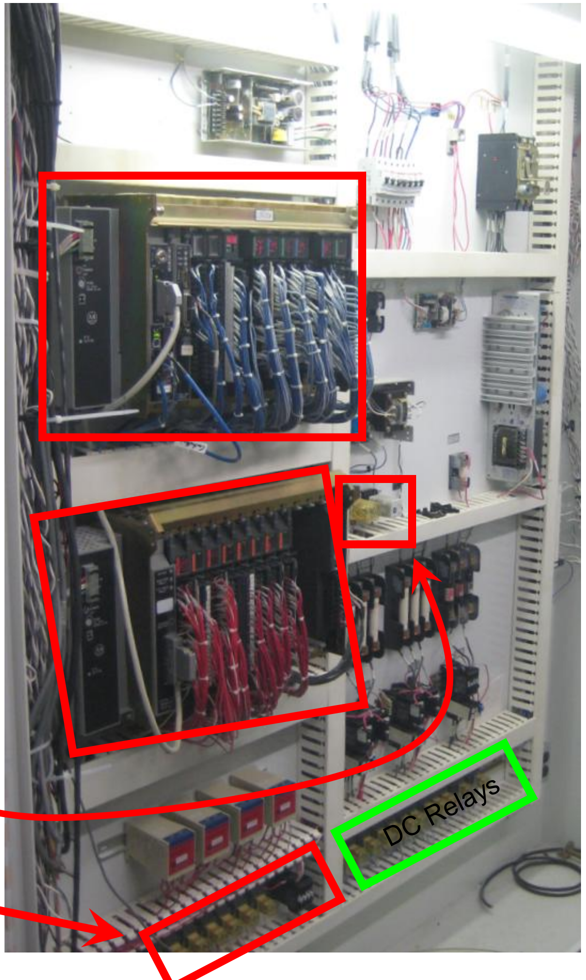
Example Problem – Multiple Cabinets Fed from Centralized Control Power Panels

- AB PLC 5
  - 78% Vnom
  - Remote rack – 72% Vnom
- Idec RY4S – ac "Ice Cube" relays
  - ~70% Vnom



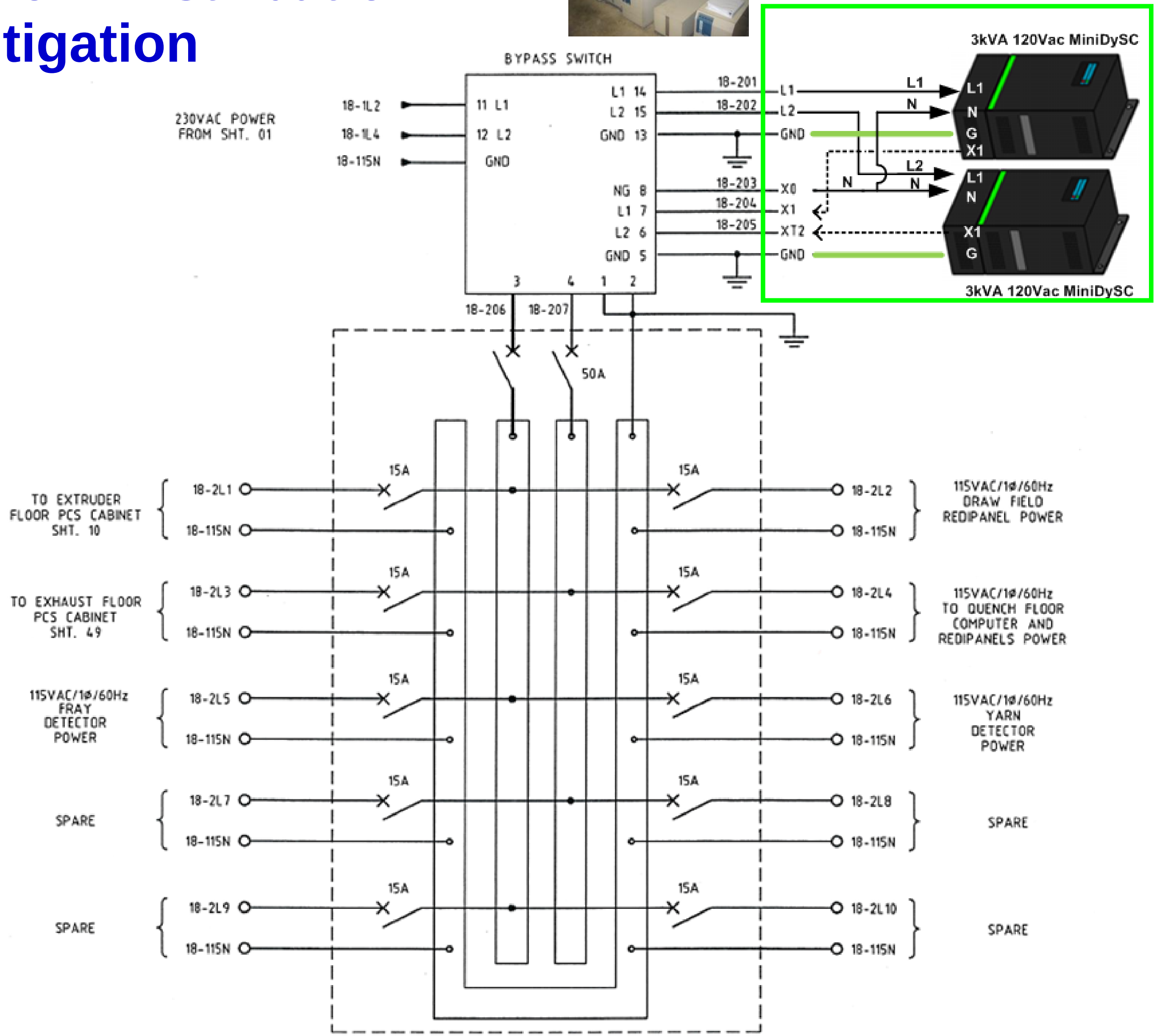
RR3B





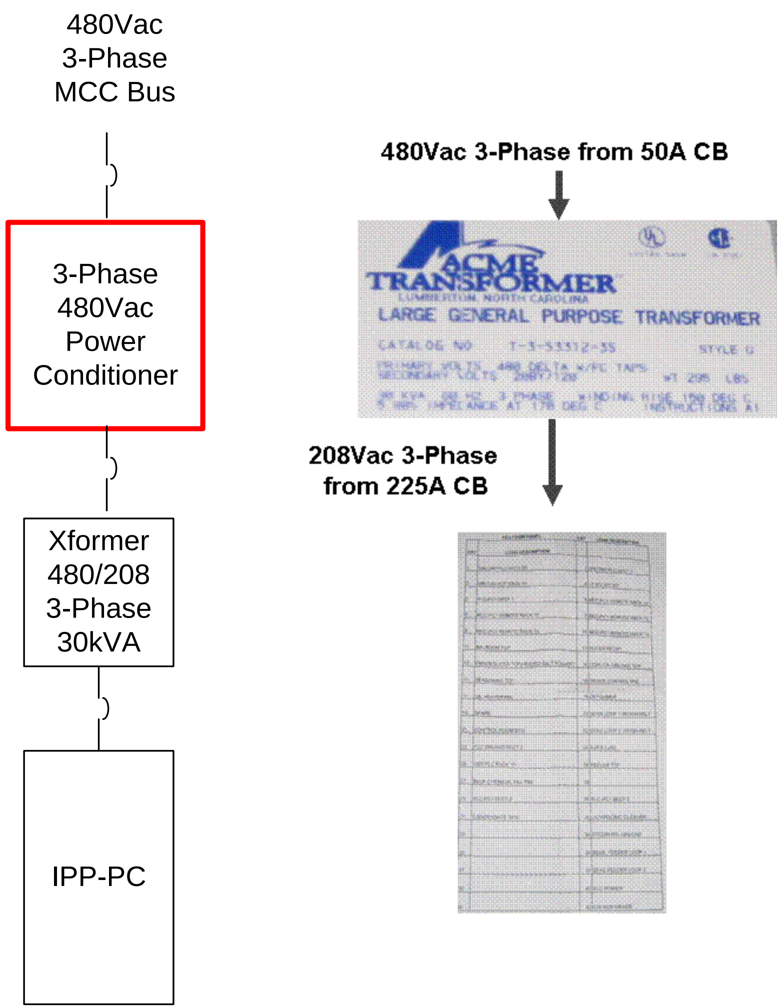
Example Solution: Distribution Panel Level Mitigation

- Remove abandoned UPS and use UPS bypass switch already in place
- Four distribution panels in room for Extruder lines plus one additional for other related control loads (5 total)



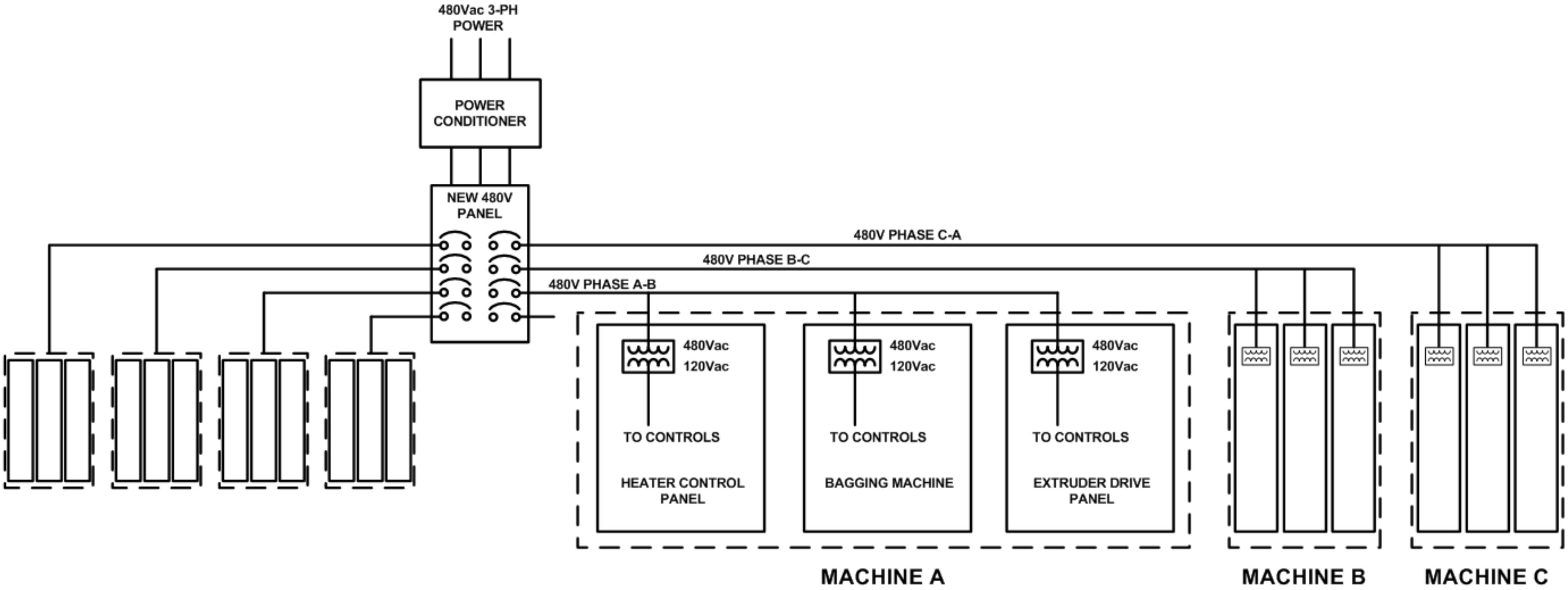
Another Distribution Panel Example

- Sometimes the most effective solution is to provide conditioned power for the entire IPP Panel. Advantages of this approach include:
  - Simplified Cut Over/Fewer Touch Points
  - Single Power Conditioner for many loads
  - When sized to support kVA of transformer, this approach will support future expansion in panels

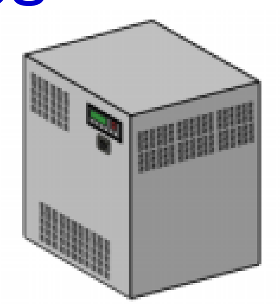


Example Control Level Option
(Area Wide Power Distribution for CPT Primaries)

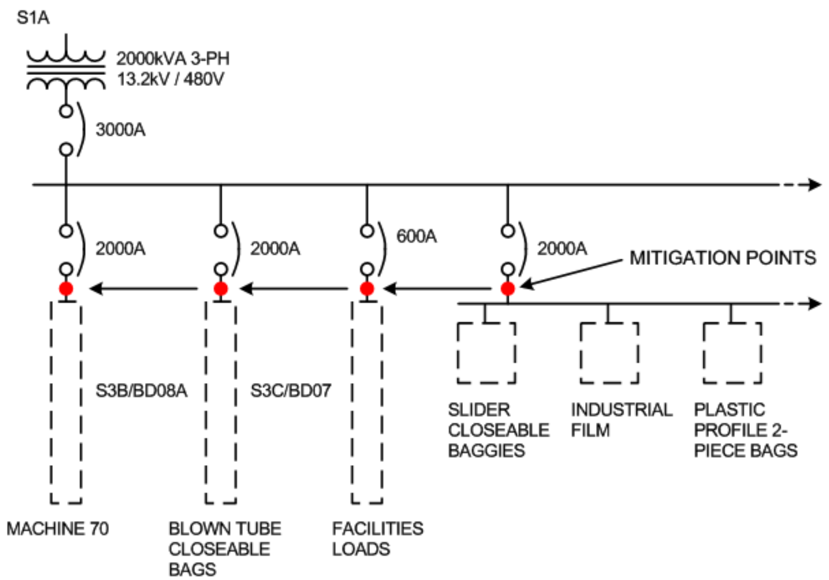
- Fewer, larger sag mitigation devices
  - Fewer touch points but more expensive mitigation devices
  - New 480Vac Panel, new conduit and wiring to machine controls
  - Labor costs



Feeder Level Mitigation Scenarios



- Multiple very large sag mitigation devices
  - Fewer installation points, less wiring, conduit, & labor
  - Higher Equipment Costs
  - More Comprehensive Coverage
  - Some Typical Voltage Sag Solutions
    - Omniverter AVC
    - Softswitching DySC



Conclusions

- It's a team effort to solve these problems, the utility, industrial/commercial, and sometimes consultants need to come together.
- Understanding why your equipment is vulnerable is paramount. You can't fix a problem without understanding the true cause.
- Moving forward (sometimes with some simple modifications) you can make industrial systems more robust. Don't forget including PQ standards in your purchase specs.
- Don't assume battery based systems are required. Smaller solutions may be more cost effective.

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Case Study: Power Quality Investigation of a Manufacturing Plant

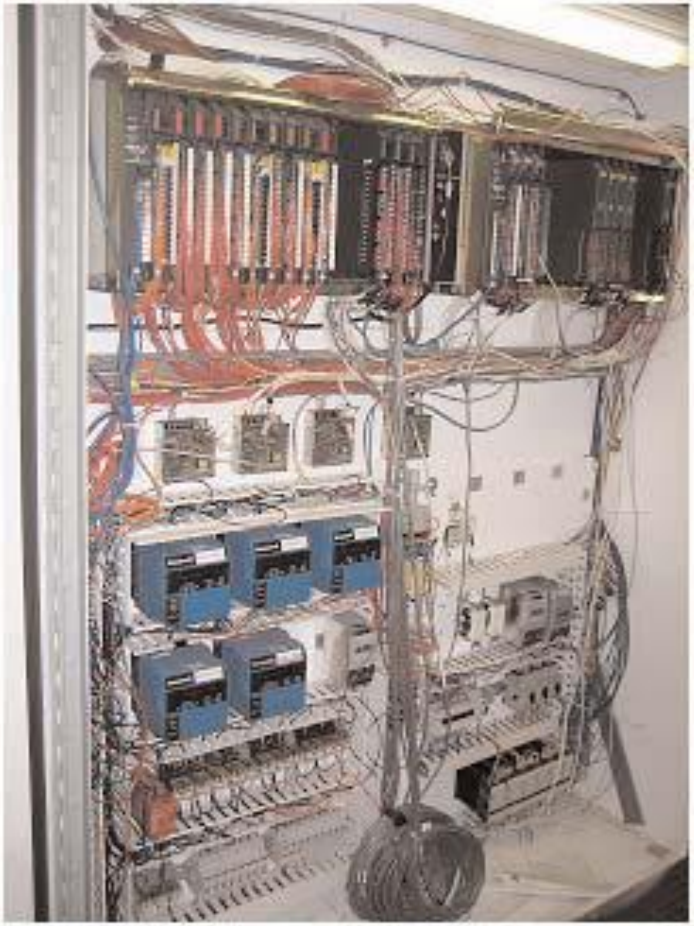
Introduction (1)

- Voltage sags and momentary outages caused equipment and process downtime events in the second half of 2005
- Power quality audit evaluated the most sensitive equipment in the plant to formulate the best approaches for hardening the equipment to these power quality events
  - inspected drawings, did on-site testing, physically examined the plant equipment and specifications, analyzed plant power quality data.
- Identified five critical product lines - Process Lines 1 thru 5.
  - All five were very susceptible to voltage sags.
- Several other areas were vulnerable to voltage sags
  - Boiler systems, air compressors, conveyor controls, and computer control areas.

Introduction (2)

- Prime examples: process lines 1 to 3
- Line 2: Allen Bradley programmable logic controller (PLC) fed by a small, local uninterruptible power supply (UPS).
  - Conrols: several National Electrical Manufacturers Association (NEMA) style starters and six TB Wood's E-trAC drives.
- One sub panel (powered by a generator) controls four small 120-Vac motors that pull the product out of the oven if the power is lost.
  - Controls require the PLC to remain on-line (via UPS).
  - The PLC operates the small motor starters using generator power through the output card to turn on the motor starters.

Process Line 2 Controls



PLC remote I/O racks, burner controls, numerous AC "ice cube" relays

Drive racks

Process Line 4 and 5

- Process Line 4 and 5 each use a 5-kVA constant voltage transformers (CVT) to provide conditioned power to only a few of the control cabinets.

Two 5kVA
Sola CVS Series CVTs
(for Process Lines 4 & 5)

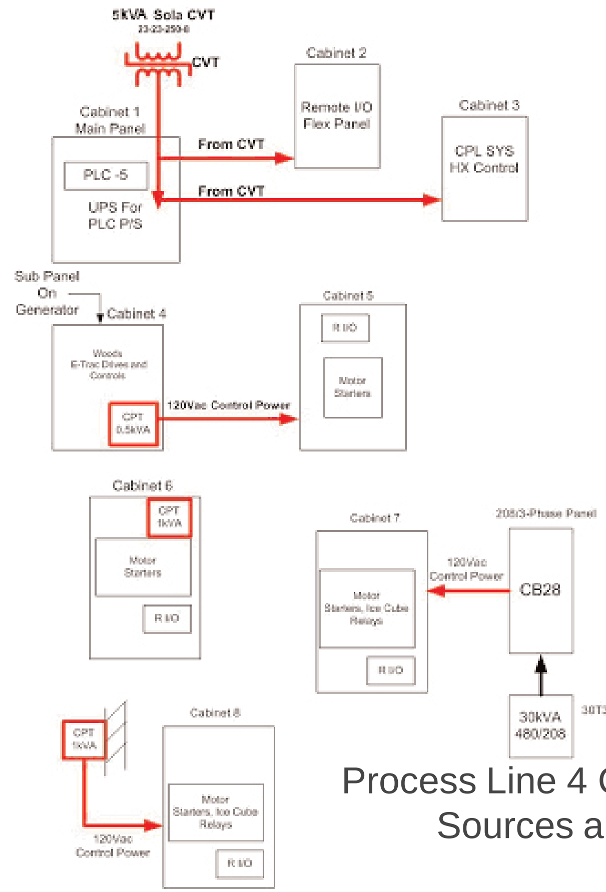
Model No.
23-23-250-8

CVT for Process Line 4 Loading

Single Phase Readings - 12/15/05 14:18:09			Voltage	Current
Summary Information			Voltage	Current
Frequency	59.96	RMS	116.32	4.63
Power		Peak	158.08	9.22
KW	0.50	DC Offset	-0.26	-0.05
KVA	0.54	Crest	1.36	1.99
KVAR	0.10	THD Rms	5.08	29.10
Peak KW	1.47	THD Fund	5.09	30.41
Phase	11° lag	HRMS	5.91	1.35
Total PF	0.94	KFactor		4.13
DPF	0.98			

CVT for Process Line 5 Loading

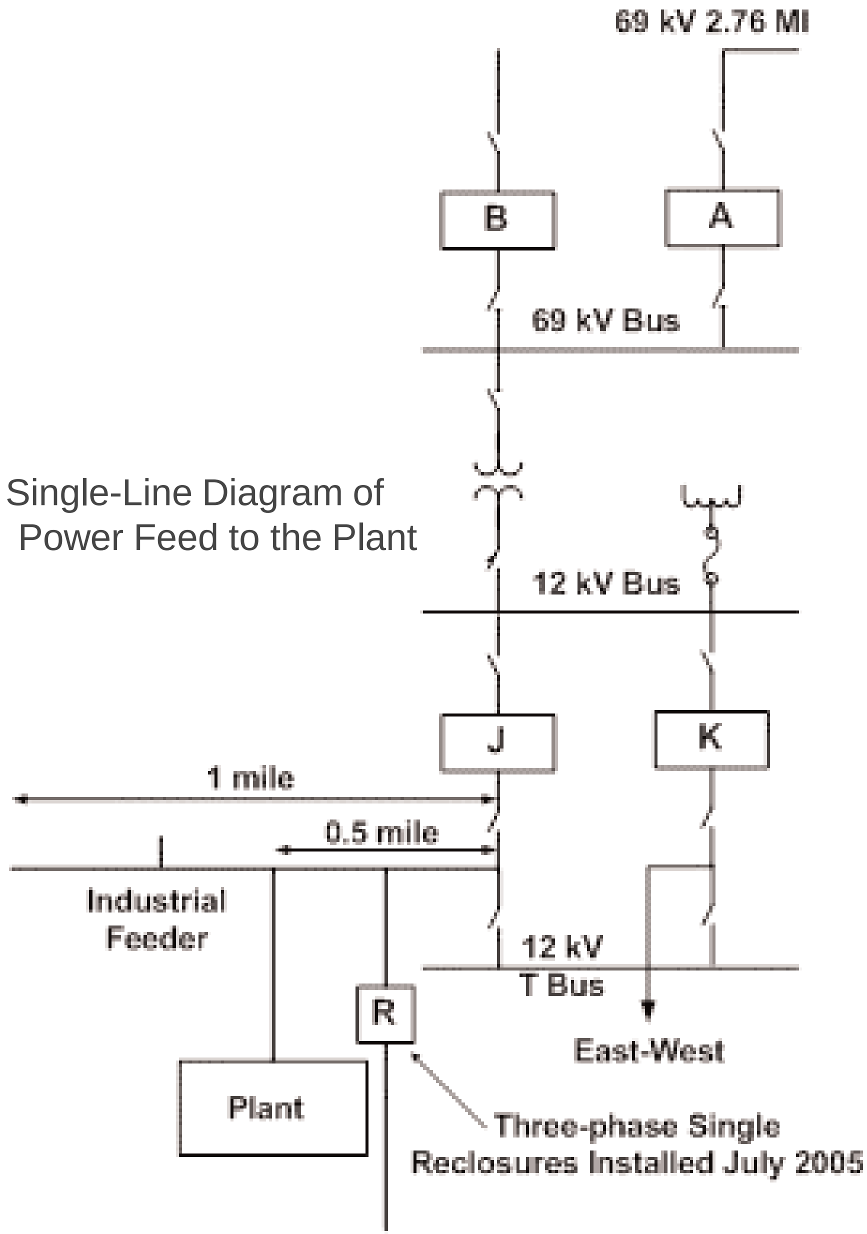
Single Phase Readings - 12/15/05 14:20:14				
Summary Information			Voltage	Current
Frequency	59.96	RMS	116.08	4.72
Power		Peak	156.12	9.67
KW	-0.51	DC Offset	-0.26	-0.04
KVA	0.55	Crest	1.34	2.05
KVAR	0.09	THD Rms	5.24	31.85
Peak KW	-1.51	THD Fund	5.25	33.60
Phase	170° lead	HRMS	6.08	1.50
Total PF	-0.92	KFactor		4.52
DPF	-0.99			



Process Line 4 Control Power
Sources and Routing

Power System Overview

- Plant is supplied from a 12-kV industrial feeder.
  - Derived from a 69-kV substation
- Plant is located approximately 0.5 miles from substation.
- Three single-phase reclosers were added on a lateral upstream circuit in July 2005,
  - should increase the power quality as seen by the manufacturer.

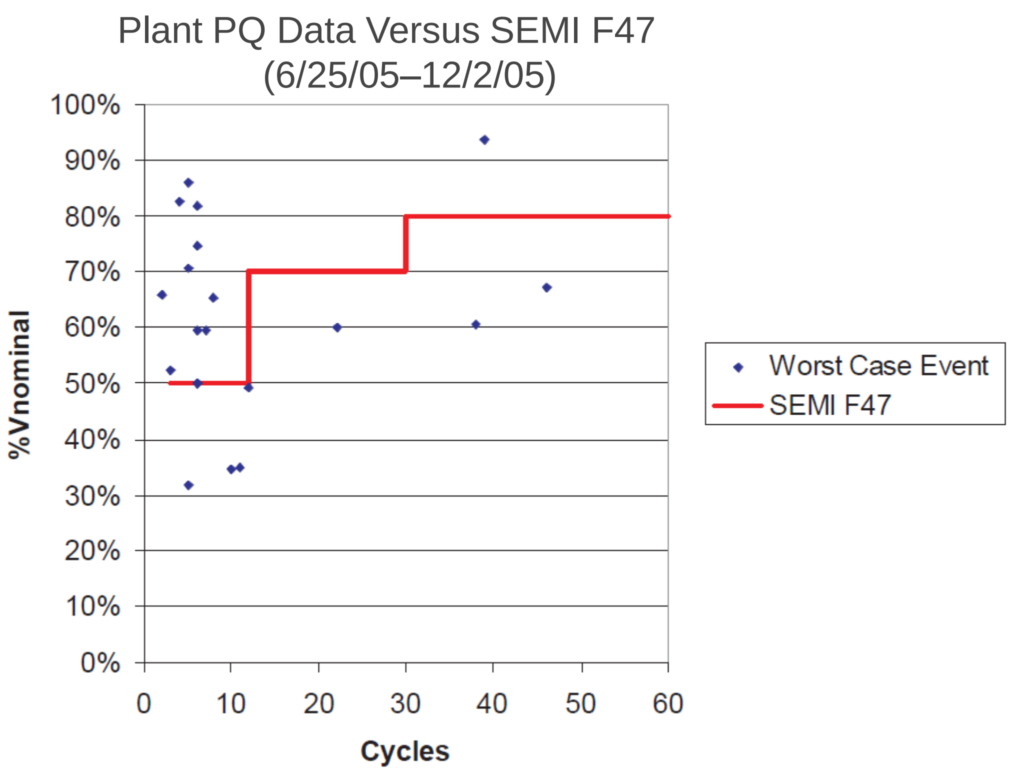


Single-Line Diagram of Power Feed to the Plant

PQ Data and Analysis (1)

- Utility reported events during the time frame from June 25, 2005, through December 2, 2005 (shown on next slide)
- Facility equipment compliant with the SEMI F47 power quality standard would have survived **11** of 20 events
- Equipment able to survive voltage sags to 30 percent of nominal for 1 second would ride through **19** of 20 events
  - Squirrel fault (December 1, 2005, 200-cycle Interruption)

PQ Data and Analysis (2)



*One 200-cycle interruption not shown

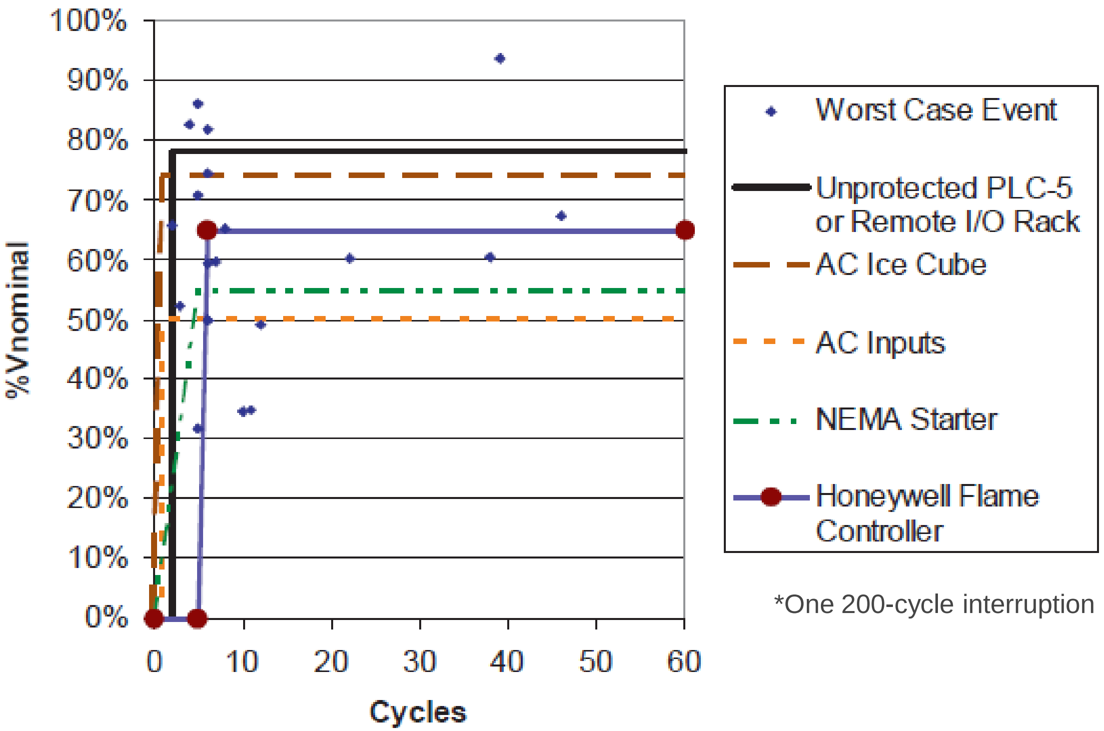
Summary of Power Quality Attributes for PLCs and AC Drives

Date	Sag Duration (Cycles)	Worst-Case Magnitude of Event	Cause
6/25/2005	2	66%	Storm in area, 69 kV lockout, wire down
6/25/2005	6	75%	Storm in area, 69 kV lockout, wire down
6/28/2005	5	86%	Storm in area (lightning), capacitor bank alarm
7/22/2005	10	35%	Storm in area (lightning)
7/22/2005	11	35%	Storm in area (lightning)
7/26/2005	7	60%	Storm in area (lightning), fuses blown on East West Circuit
7/26/2005	8	65%	Storm in area (lightning), fuses blown on East West Circuit
8/5/2005	5	32%	Storm in area (extreme lightning)
8/5/2005	6	59%	Storm in area (extreme lightning)
8/10/2005	6	82%	Storm in area (lightning), trip 69-kV line
8/10/2005	39	94%	Storm in area (lightning), trip 69-kV line
8/13/2005	3	52%	Storm in area (lightning)
8/13/2005	5	71%	Storm in area (lightning)
8/20/2005	38	61%	Storm in area (lightning)
8/20/2005	46	67%	Storm in area (lightning)
8/22/2005	12	49%	Connector failure on 12-kV circuit
8/22/2005	22	60%	Connector failure on 12-kV circuit
11/27/2005	4	83%	Unknown (subtransmission fault cleared itself)
12/1/2005	200	0%	Squirrel in customer substation
12/2/2005	6	50%	Tree contact with 69-kV line
12/2/2005	6	50%	Reclosing to try and find fault

PQ Data and Analysis (3)

- Based on the equipment used in Process Lines 2 and 3 and the results from previous EPRI tests, an expected ride-through curve may be created
  - Process Lines 2 and 3 would be expected to survive only 5 of the 22 recorded events based on its configuration.
  - This worst-case estimate assumes that voltage sags always occur on the most vulnerable phase.

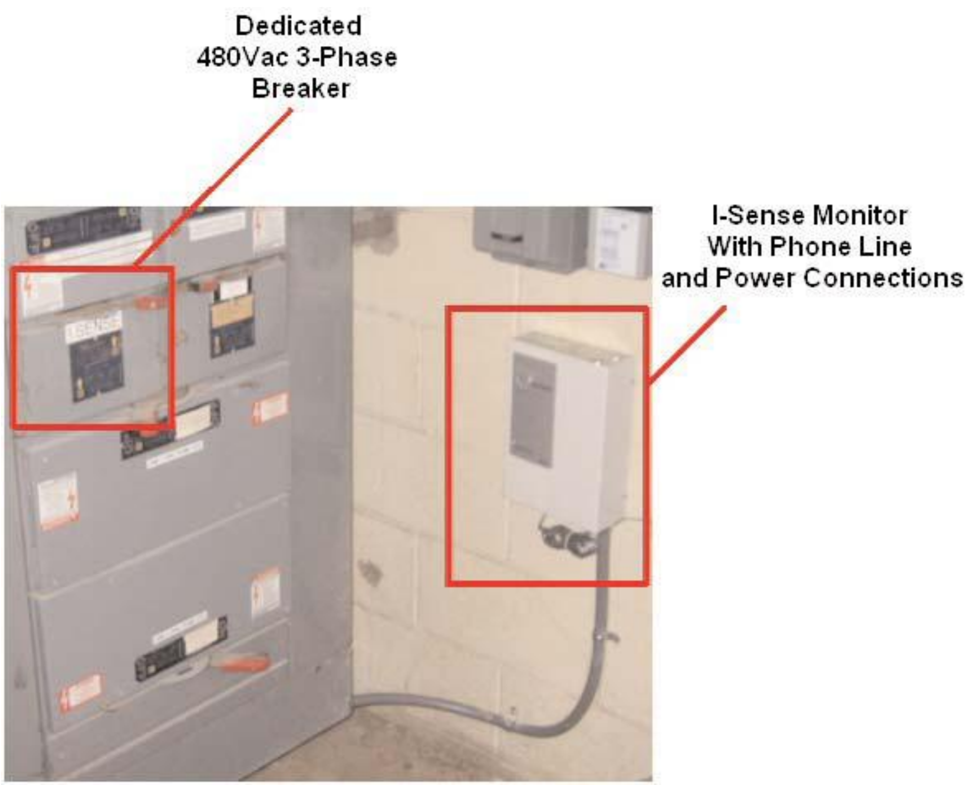
Expected Response of Process Lines 2 and 3 to Voltage Sags



*One 200-cycle interruption not shown

PQ Data and Analysis (4)

- An I-Grid power quality monitor was installed by the manufacturer on 12/14/2005.
  - Connected to a 480-Vac bus in the generator room.

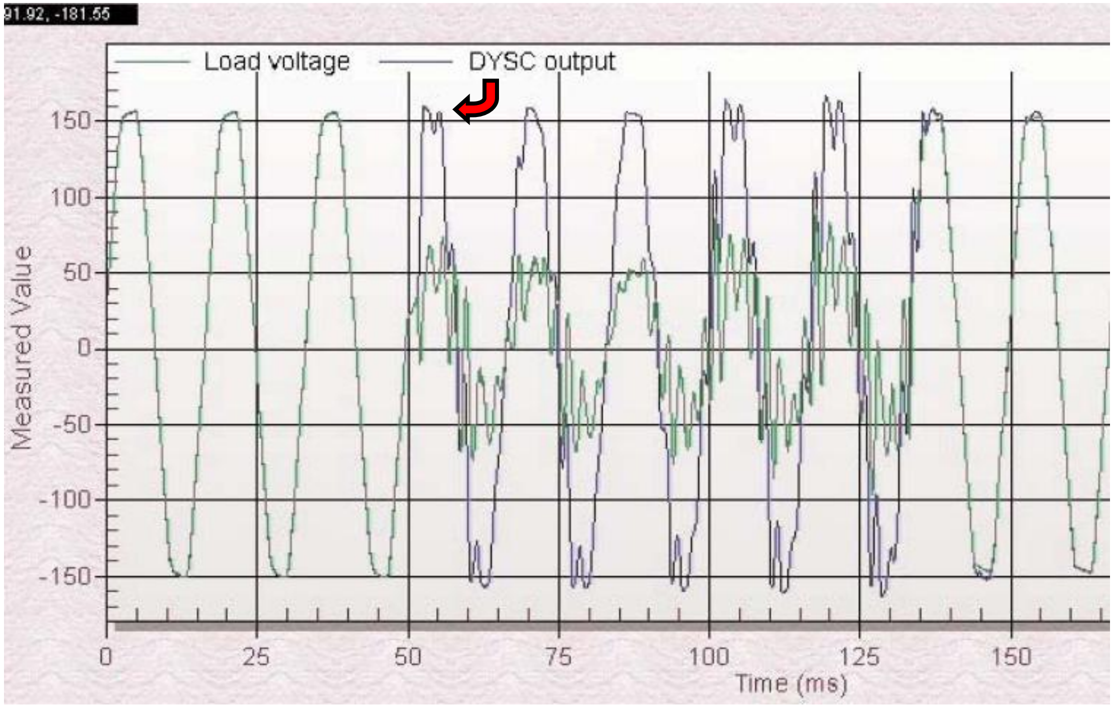


I-Grid Installation at the Plant

Analysis of Plant Susceptibilities (3)

- Final tests used a 1.5-kVA MiniDySC (Dynamic Sag Corrector) power conditioner on the control loads.
  - Cabinet controls survived a 30-cycle interruption before shutting down.

MiniDySC Product Compensated for Voltage Sag



Summary of Plant Analysis

- The audit revealed that several pieces of equipment had control power sourced from control power transformers (CPTs) or through ice-cube relays—both very susceptible to voltage sags.
- Analysis showed that a UPS solution may be ineffective as a bad and/or slow UPS could result in line trips.
  - Testing demonstrated that a voltage ride-through solution or an active sag corrector may more effective

Recommendations

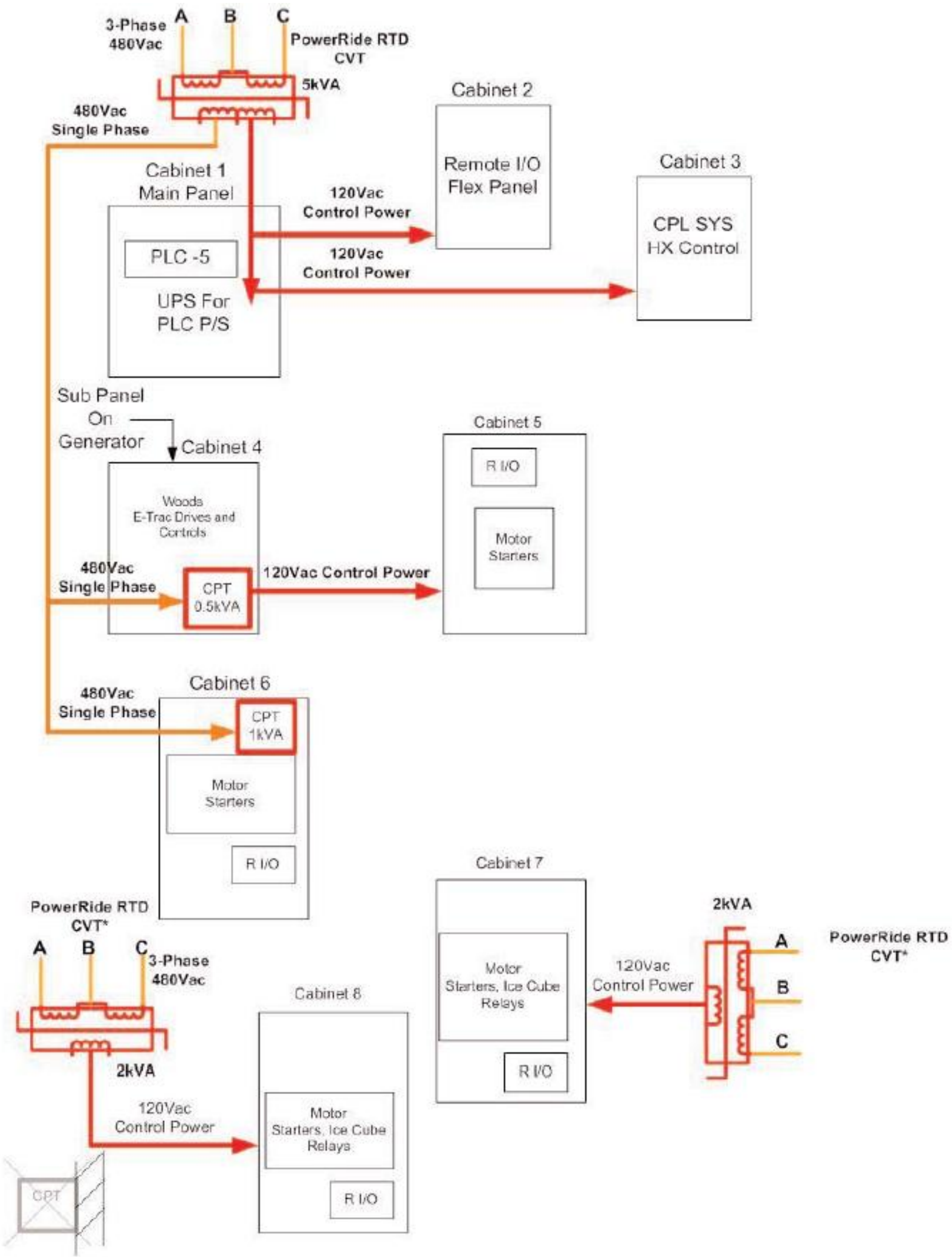
- Some recommendations based on the results of the analysis:
  - Power Conditioners
  - Consolidation of Loads
  - Adjusting Control Parameters

Power Conditioners (1)

- The product lines are spread out—control racks in various locations
- One larger power conditioner would be ideal; however, several separate power conditioners may be required
- One recommendation is to use the PowerRide ride-through device (RTD) at appropriate locations
  - Process Line 4 would need three RTDs
    - One 2.5 kVA unit wound for both 120-Vac and 480-Vac loads
      - 480-Vac output section for existing CPTs (estimated not to exceed 2.5 kVA)
      - 120-Vac output for 120-Vac loads (estimated not to exceed 2.5 kVA)
    - Other two units (2kVA each) installed in or near the cabinets

Power Conditioners (2)

PowerRide RTD Recommendation



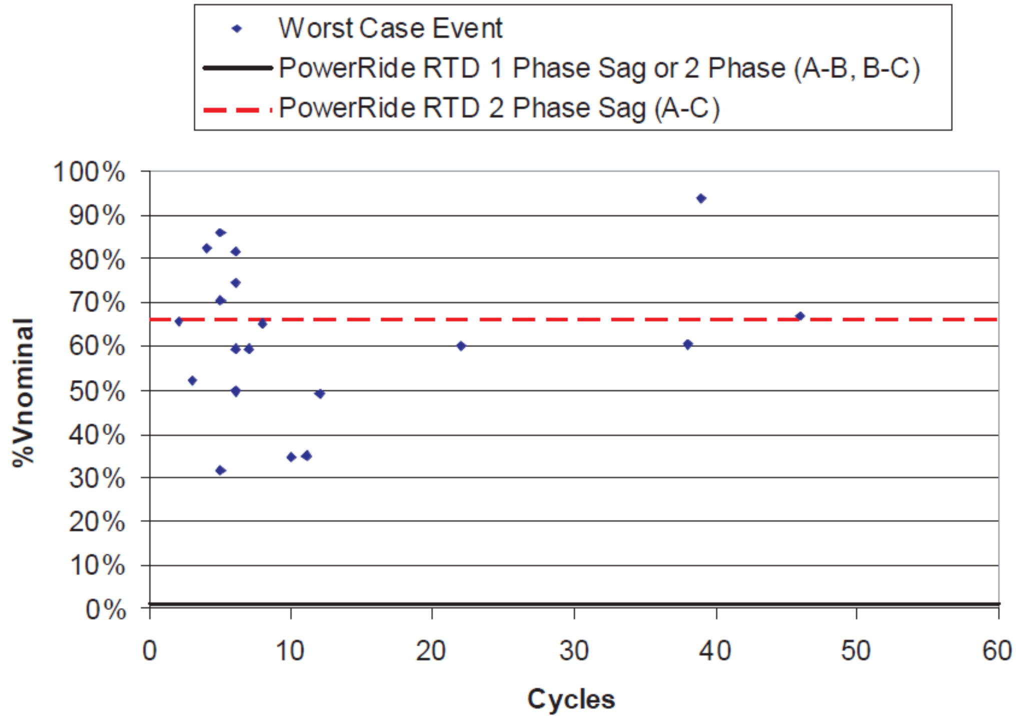
Power Conditioners (3)

- The PowerRide RTD -- a three-phase input, single-phase output CVT.
  - Allows the controls to survive single-phase voltage sags and momentary interruptions.
  - For momentary interruptions on phases A-B and B-C, the output remains at 100% *as long as Phase A-C remains at 66% or more*
  - For voltage sags on phase A-C, one expects a typical CVT response with the voltage dropping off at about 50% of nominal or less.

Power Conditioners (4)

- Given the response of the RTD, only the one momentary interruption event may have affected the process with this unit installed on the controls.

Expected Voltage Sag Response of PowerRide RTD Power Conditioner

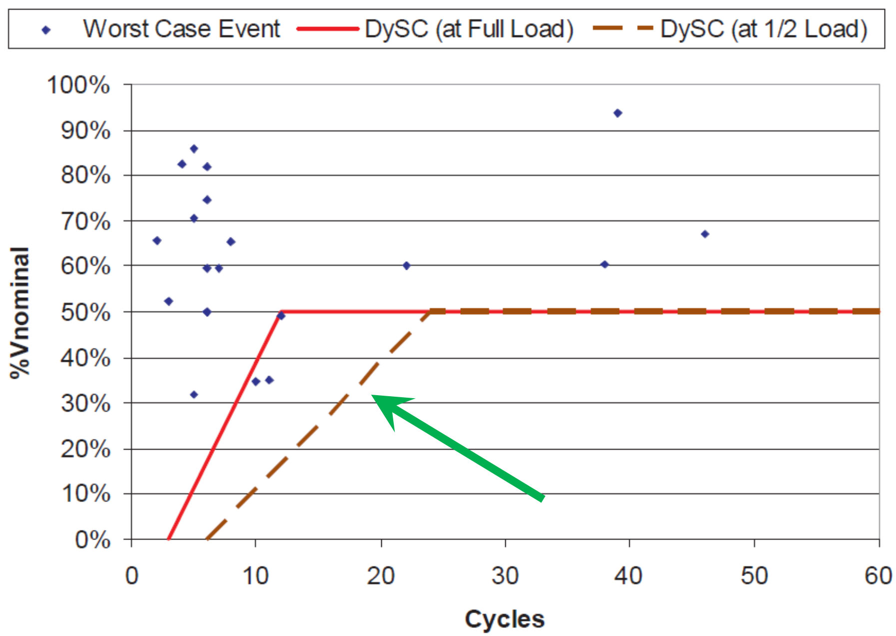


*One 200-cycle interruption not shown

Power Conditioners (5)

- Another option: use multiple DySC products
- Units in the plant may be lightly loaded with voltage sag ride-through performace closer to the half-loaded line.
- All but the one momentary interruption would be protected.
- With power-conditioning equipment, the UPS may be removed.

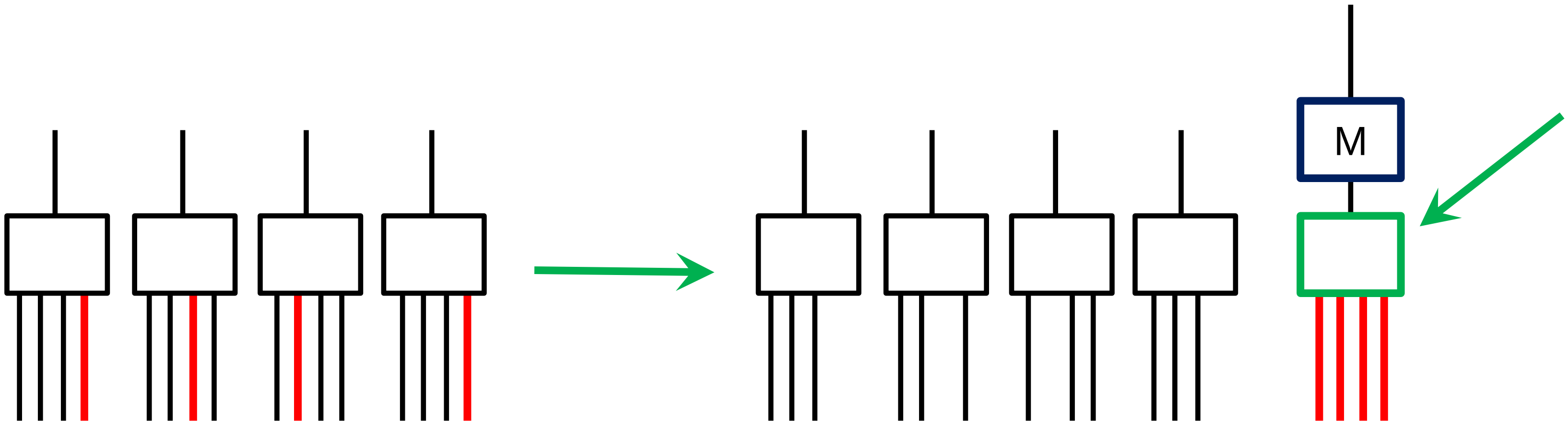
Expected Voltage Sag Response of DySC Power Conditioner



*One 200-cycle interruption not shown

Consolidation of Loads

- Several widely-dispersed loads may be combined on one panel several panels are only lightly loaded.
- Consolidation would allow more effective use of power-conditioning equipment (M).



Adjusting Control Parameters

- Adjustable-speed drives may be set up for the best voltage sag ride-through performance possible.
  - Voltage trip points may be adjusted
  - Built-in voltage sag ride-through features may be enabled.
    - *Chokes may be necessary to prevent damage!*

Magnatek GPD 305

- When a fault occurs during operation, the GPD drive can be programmed for auto-restart using parameter **n47**.
- The setting of this parameter either enables or disables the ride-thru feature of the GPD 305. The three settings are:
  - 0 = Disabled (Factory setting)
  - 1 = Enabled with a 2 sec ride-thru
  - 2 = Enabled with indefinite ride-thru, provided the control power is maintained.
- When set to "0" there will be no ride-thru available
- If enabled, the 305 will continue to operate during a momentary power loss of up to 80%, but if the loss exceeds the identified time period, the 305 will stop.

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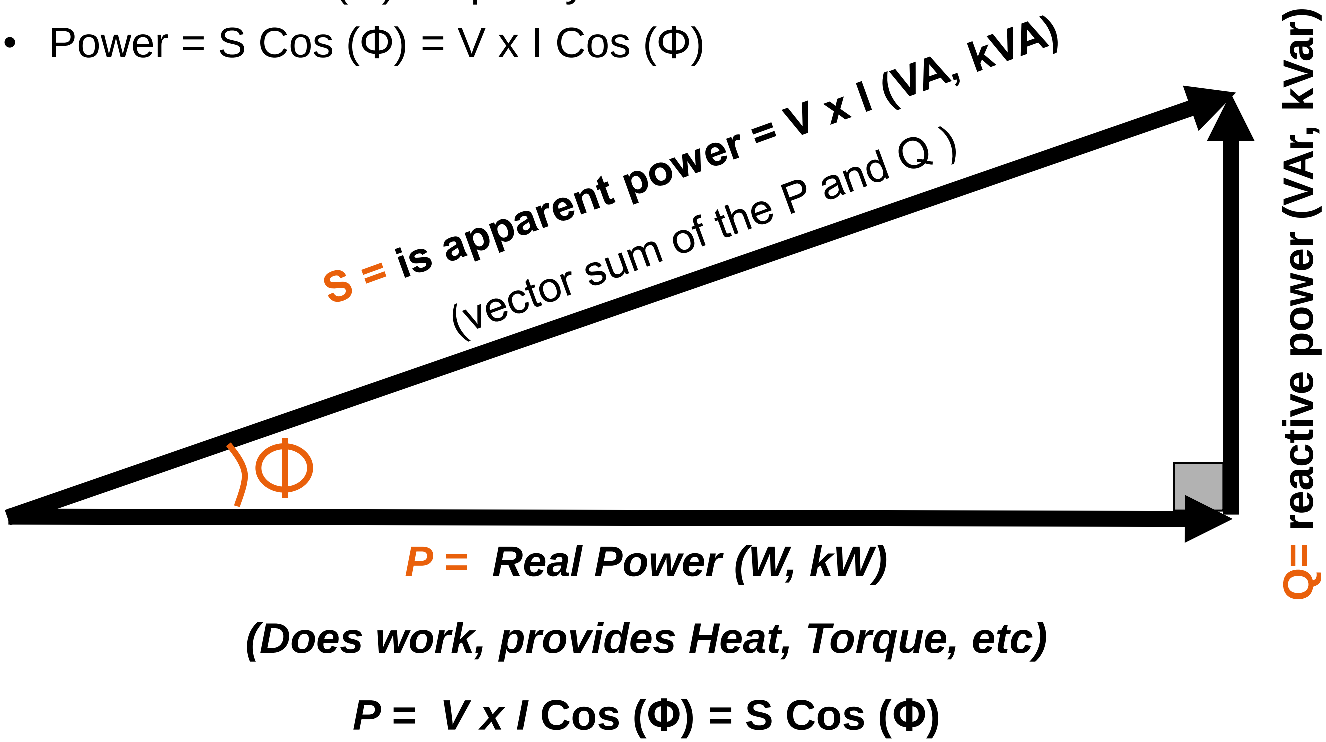
Implementation Results

- The plant estimated yearly losses due to PQ-related downtime in the $300,000 range
- EPRI's recommendations implemented in early June of 2006
- Site experienced a total of **103** events as reported by the I-Grid system.
  - 6 were outages (mostly weather related)
  - The remaining 97 recordings were aggregated into a subset of 40 actual events.
    - **18 to 19** would have shut the plant equipment down based on the previous history and the expected vulnerability of the unprotected equipment.
- **None** of the voltage sag events were found to affect production after the installation of the solutions.

PF Correction – Harmonic concerns/Solutions

Breaking Down AC Power….. The Power Triangle

- Power Factor (PF) = ratio of real power/apparent power (PF = P/S)
- Also PF = Cos (Φ) for purely sinusoidal waveforms
- Power = S Cos (Φ) = V x I Cos (Φ)

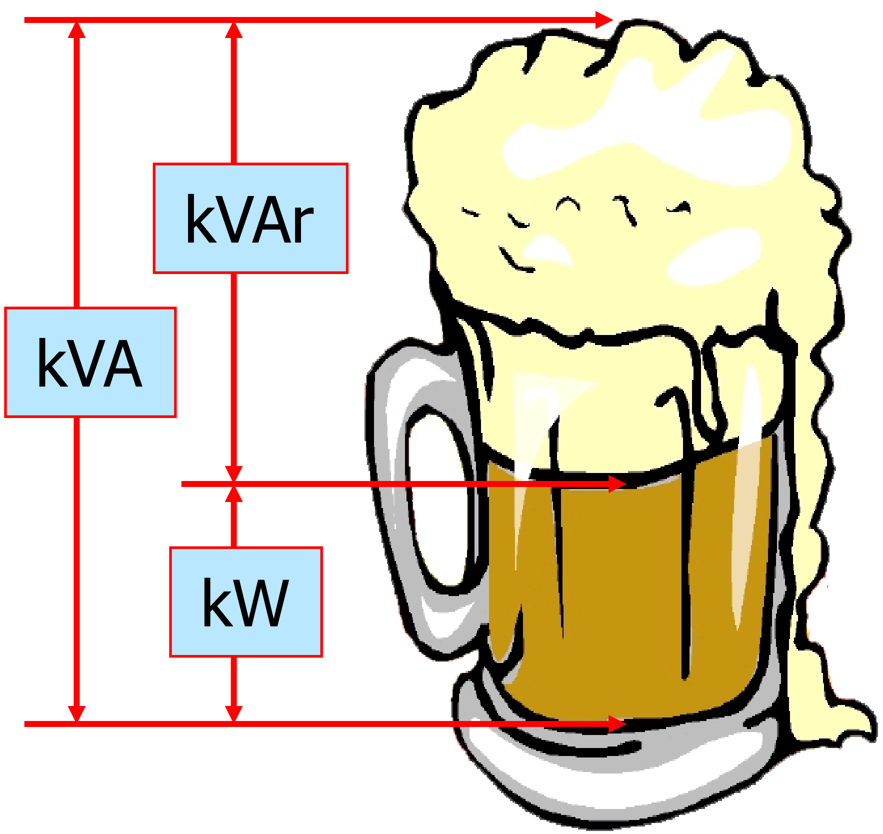


True versus Displacement Power Factor

- True power factor, or TPF, is the ratio between kW and kVA, including all the harmonics.
  - PF = P / S = kW / kVA
- Displacement power factor, DPF, is the cosine of the angle between the voltage and current. This is for the fundamental (60 Hertz) component only.
  - PF = Cos (Φ)
- When no harmonics are present, True Power Factor = Displacement Power Factor
- ***Capacitors Correct Displacement Power Factor***

PF and Beer – An imperfect but useful analogy.

- kW – The thirst quenching, good part. Does the work.
- kVAR – Foam. Does not quench the thirst.
- kVA – Total contents of the mug.
  - PF=kW/(kW+kVA)
  - PF=Beer/(Beer+Foam)
- For a given KVA: The more foam (the higher the percentage of KVAR), the lower the ratio of KW (beer) to KVA (beer plus foam). Thus, the lower the power factor.
- The less foam (the lower the percentage of KVAR), the higher the ratio of KW (beer) to KVA (beer plus foam). In fact, as foam (or KVAR) approaches zero, your power factor approaches 1.0.



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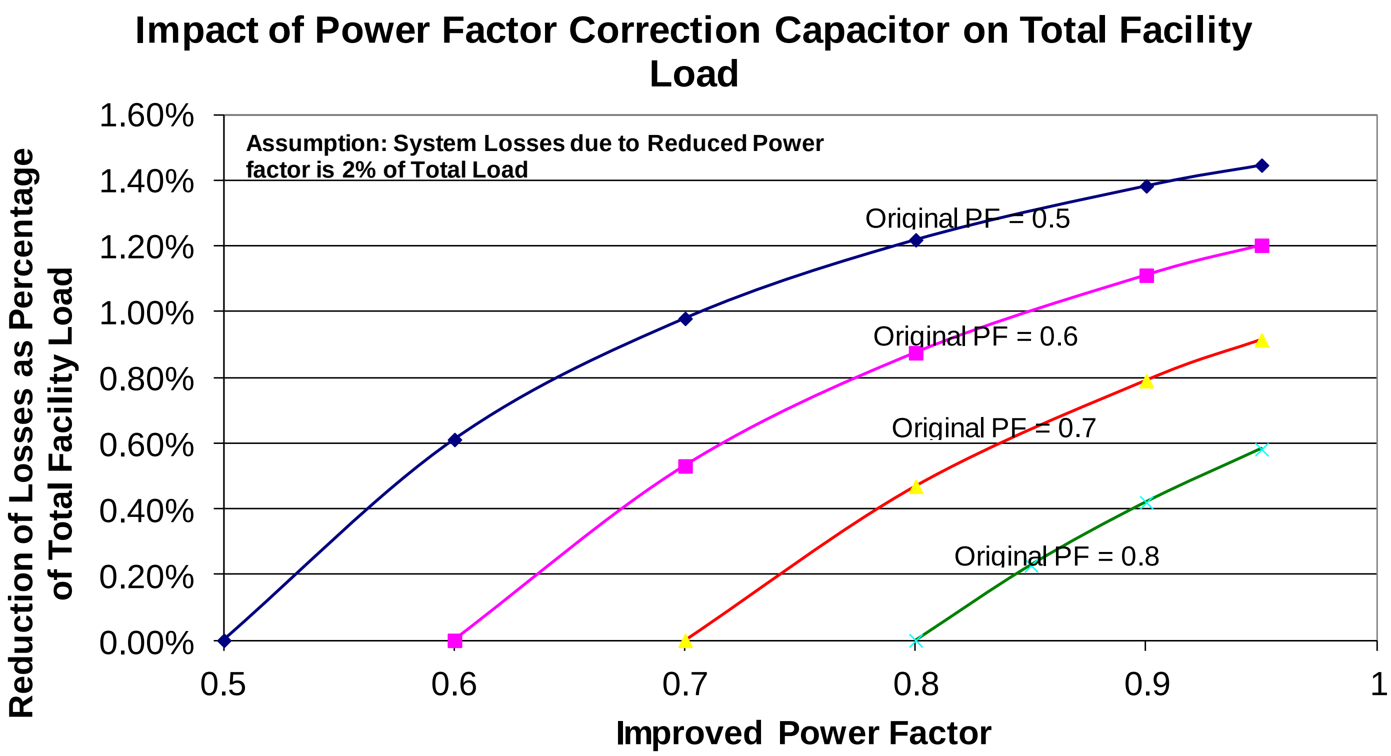
Overall Impact of Energy Savings as Percentage of Plant Total Energy Consumption



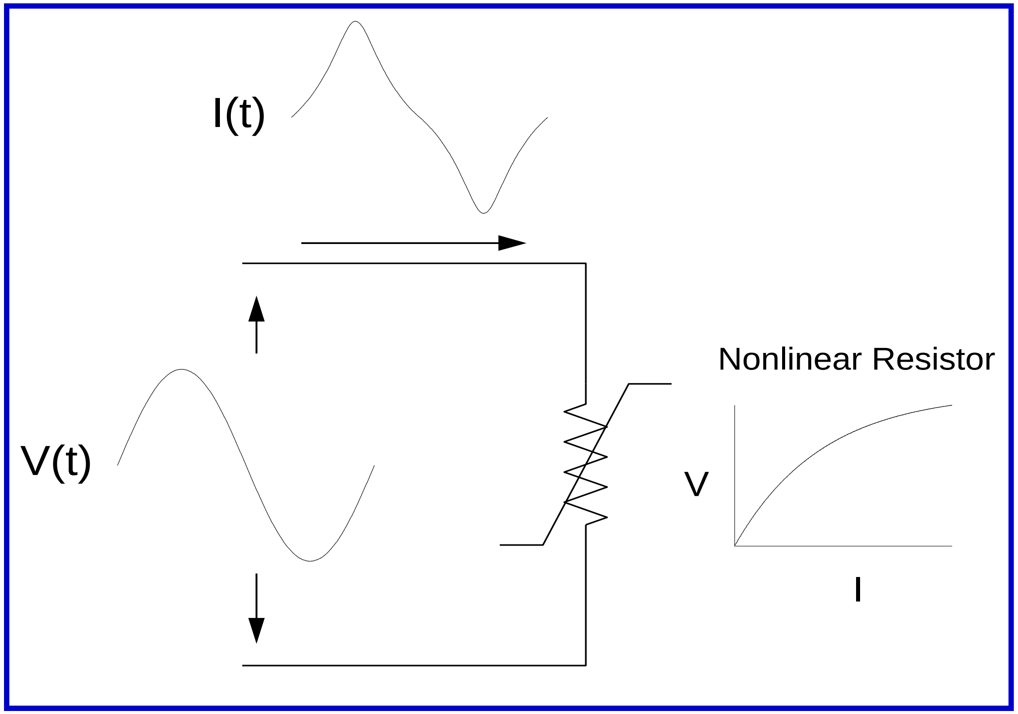
$$\%\ \text{Loss Reduction} = 100\left[1-\left(\frac{pf_{old}}{pf_{new}}\right)^2\right]$$

Harmonic Sources

- Harmonic distortion comes from nonlinear devices, principally loads
- Harmonic Sources
  - **Ferromagnetic devices** such as: transformers and motors
  - **Arcing devices** such as: arc furnaces, fluorescent lighting
  - **Power electronics**
- Excess harmonics can cause several problems
  - Overheating
  - Equipment failure
  - Increased losses
  - Mis-operations

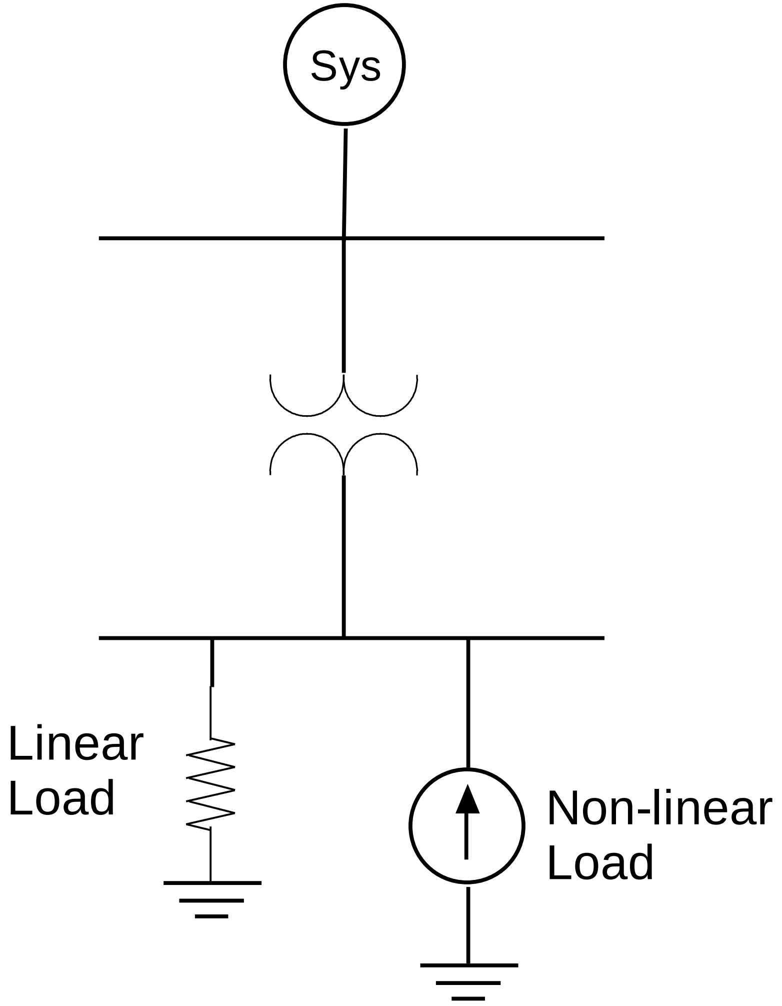
How Do Non-Linear Loads Generate Harmonics?

- A non-linear load is one in which the current is not proportional to the input current.
  - Non-linear → V vs. I is not a straight line



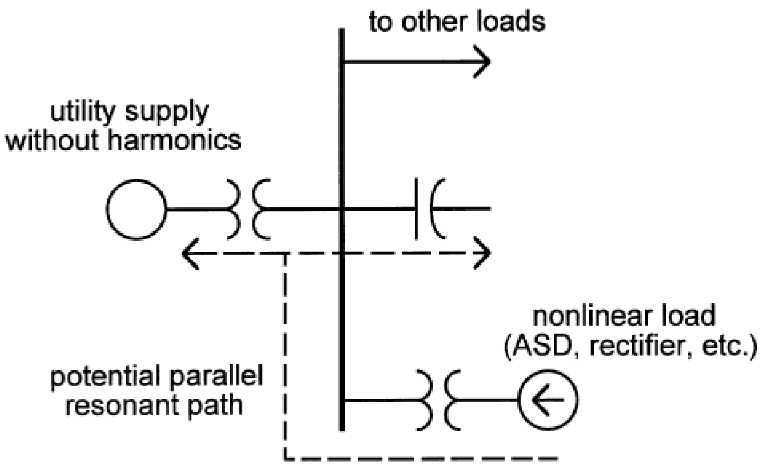
From Dugan, *Electrical Power Systems Quality*

Harmonic Current Flow

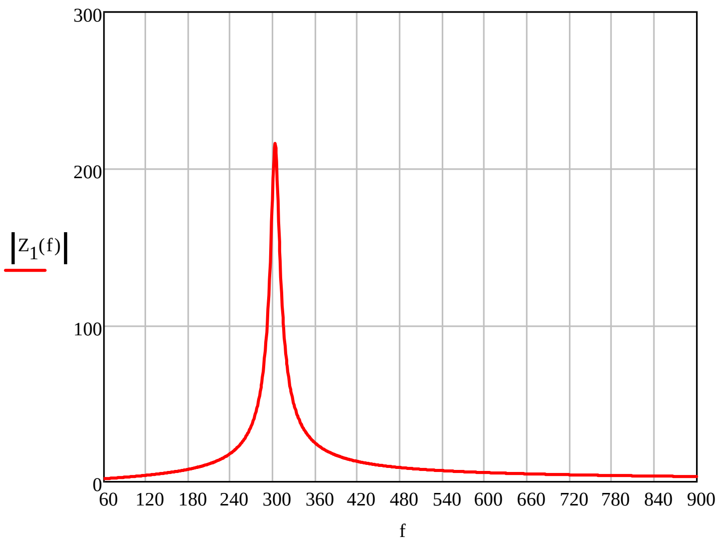


- Most harmonic producing devices are loads, e.g. a 6-pulse motor drive.
- Although these devices are loads, they “inject” harmonic current back into the system, and are therefore modeled as harmonic current “sources”.

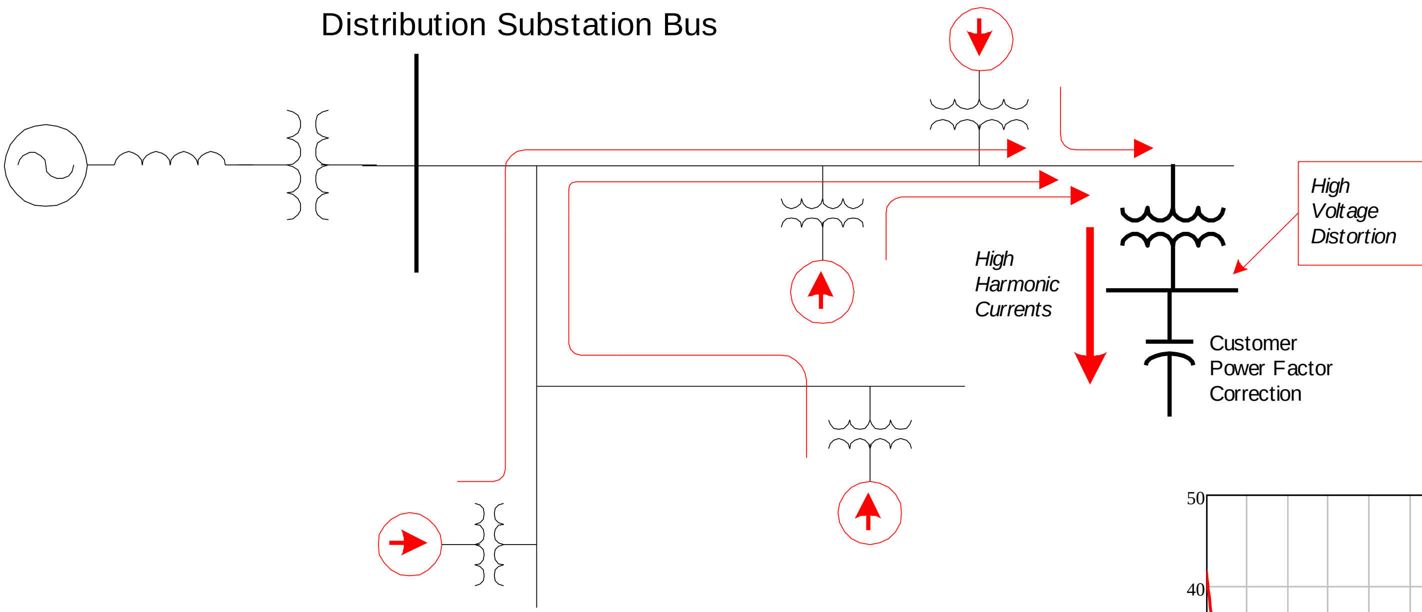
Parallel Resonance

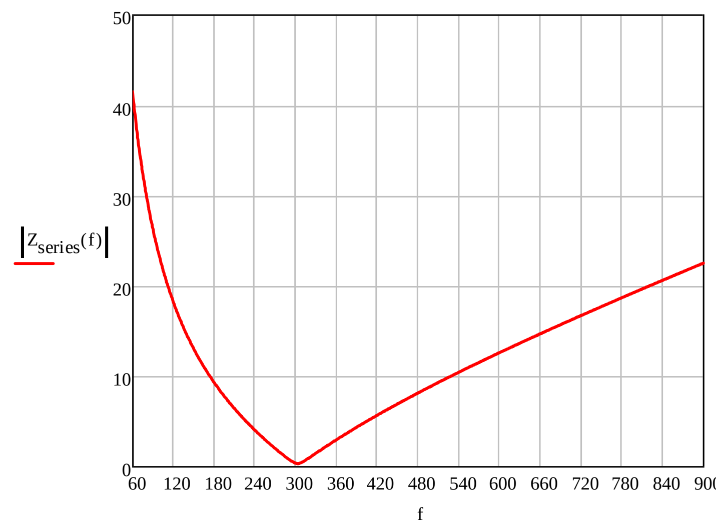


$$h_r = \sqrt{\frac{MVA_{sc}}{MVAR_{cap}}}$$



Series Resonance

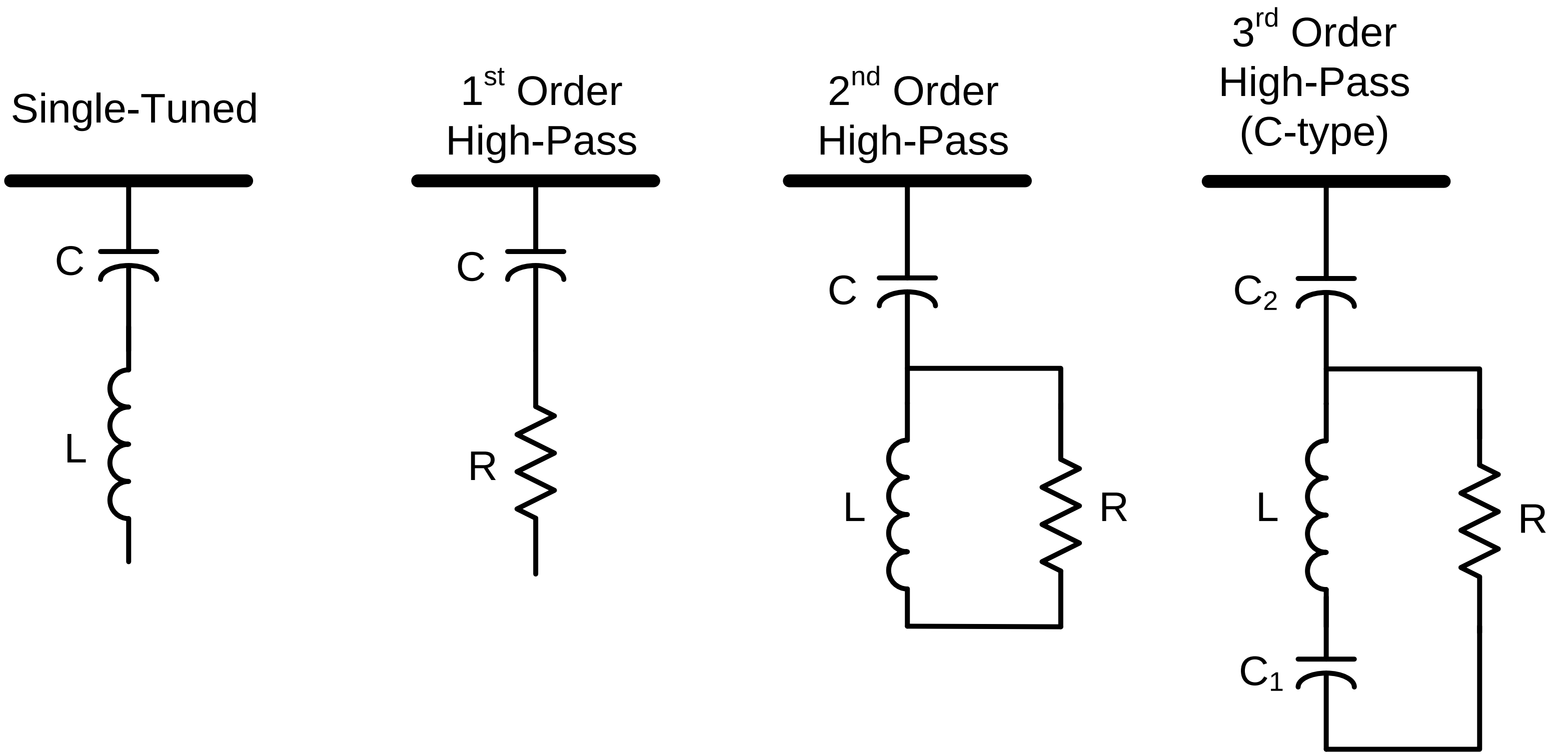




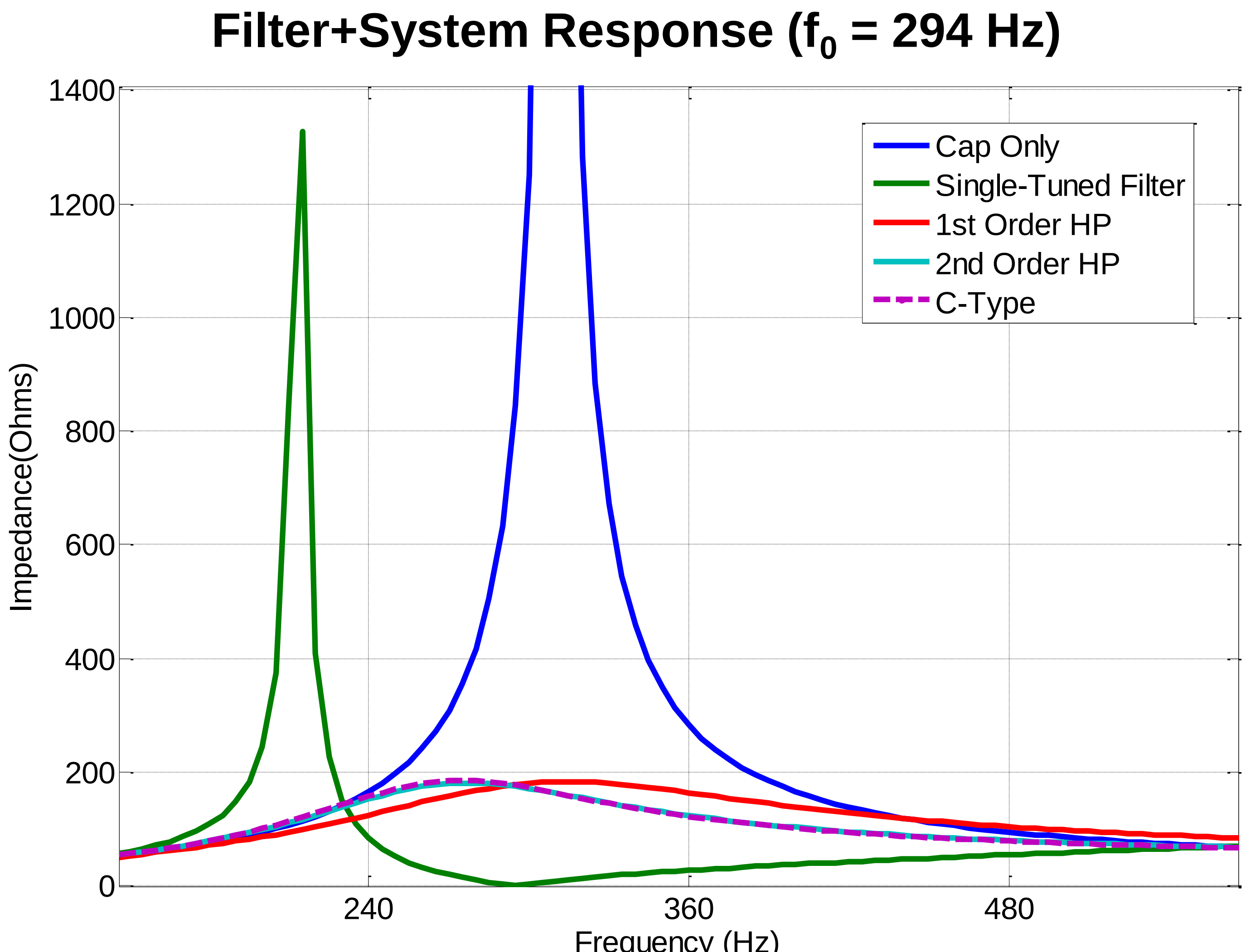
Devices for Controlling Harmonic Distortion

- Chokes for ASD applications
- Zig-zag transformers
- Passive Filters
- Active filters

Shunt Passive Filter Configurations



Shunt Passive Filter Frequency Response



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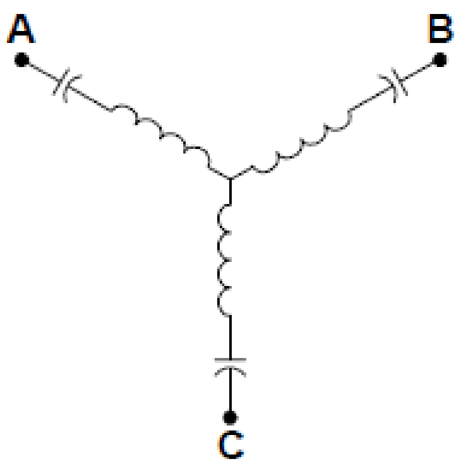
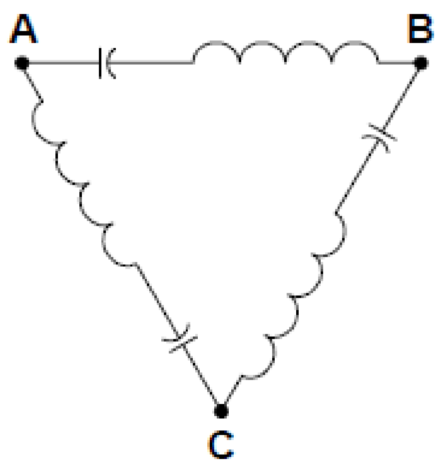
Effect of Notch Filter on the Frequency Response Characteristics

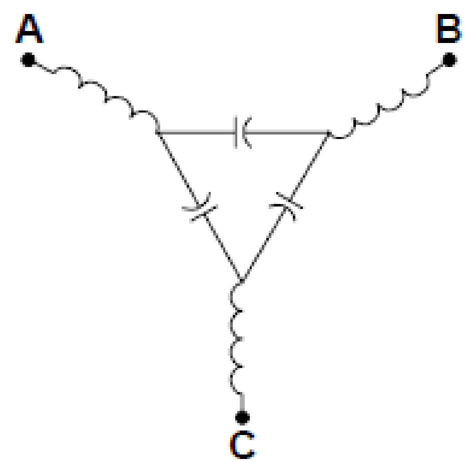
- Whenever a single capacitor bank is added to a system, a single resonant point is created.
- Whenever a single tuned harmonic filter bank is added to a system, two resonant points are created.
  - One low impedance point
  - One high impedance point

Effect of Notch Filter on the Frequency Response Characteristics

- Notch filters can be comprised of several different connections. The following all yield the same frequency response.







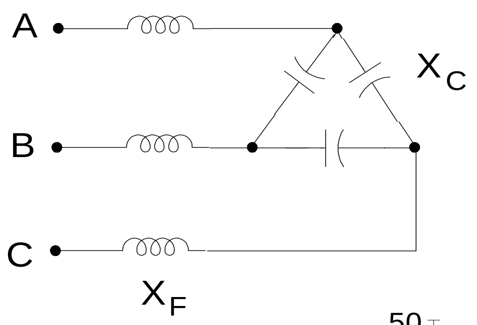
Most common for HV and MV applications

Most common for LV applications

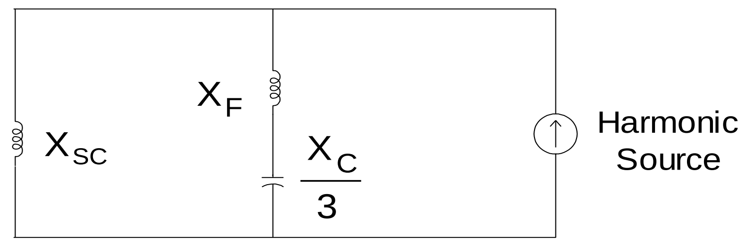
From IEEE Std. 1531-2003

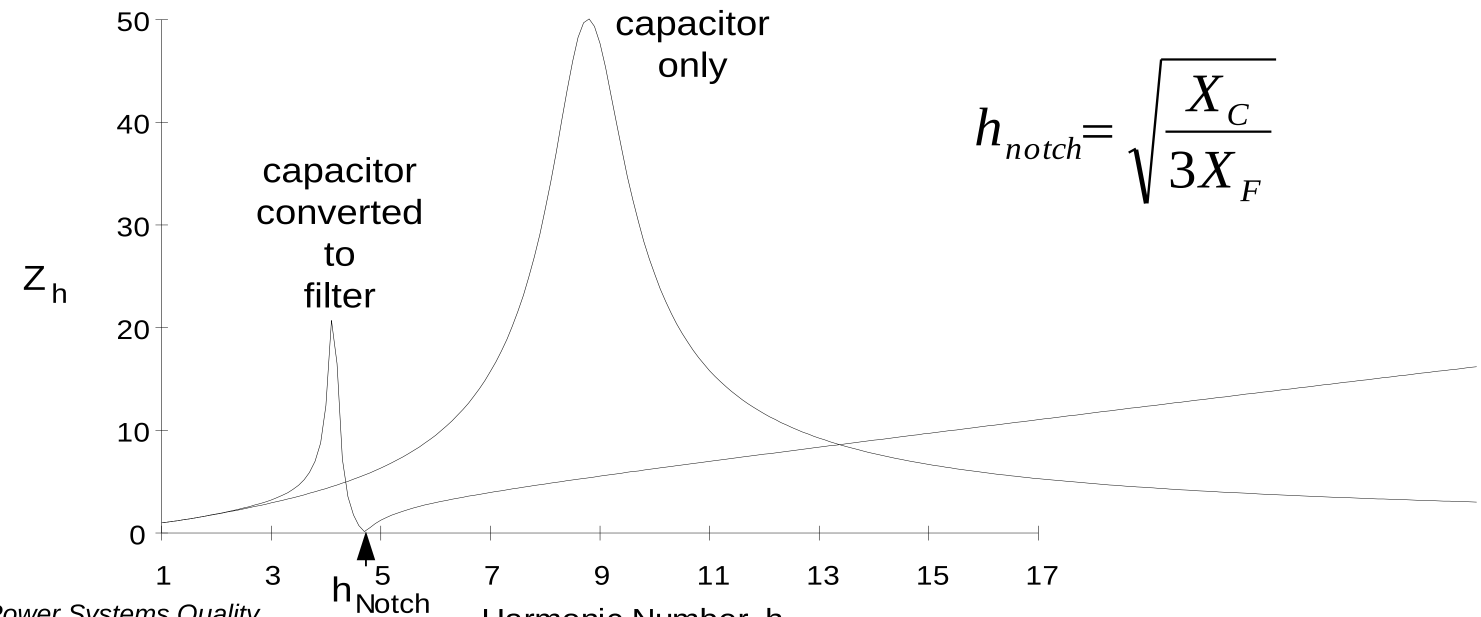
Effect of Notch Filter on the Frequency Response Characteristics

(a) Typical low voltage filter configuation.



(b) Equivalent circuit of system with filter.





$$h_{notch} = \sqrt{\frac{X_C}{3X_F}}$$

From Dugan, *Electrical Power Systems Quality*

Harmonic Filter Design

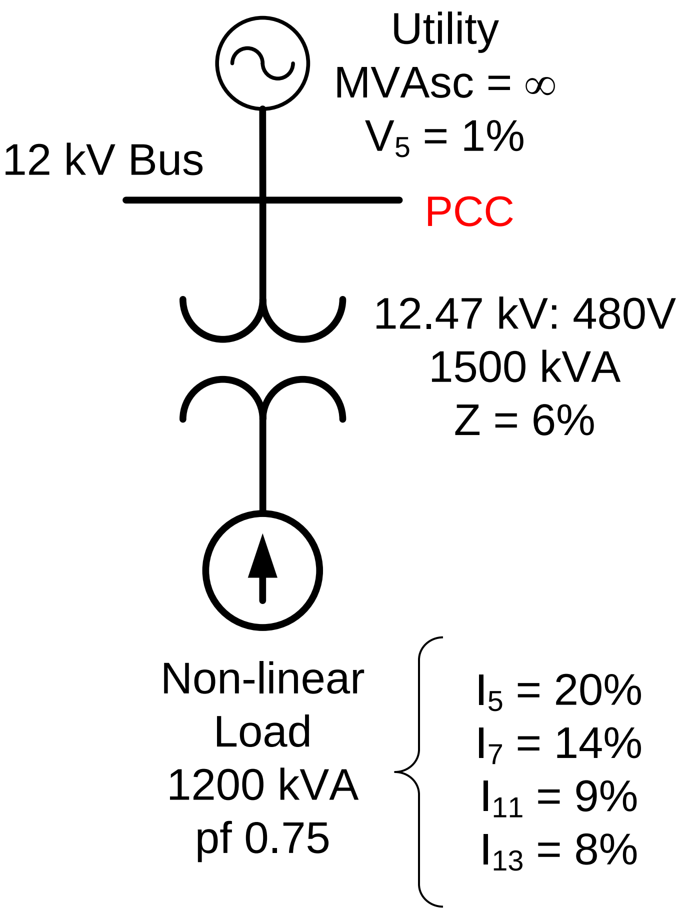
- Step 1 – Select the desired notch frequency
  - Select the lowest characteristic harmonic, and
  - Tune slightly less than desired harmonic
- Step 2 – Determine necessary reactive compensation (i.e. capacitor bank size) and voltage rating
- Step 3 – Based on filter tuning, determine filter reactor ratings.
- Step 4 – Evaluate filter duty requirements (IEEE Std. 18 IEEE Standard for Shunt Power capacitors)

Capacitors are intended to be operated at or below their rated voltage. Capacitors shall be capable of continuous operation under contingency system and bank conditions provided that none of the following limitations are exceeded:

a) 110% of rated rms voltage
b) 120% of rated peak voltage, i.e. peak voltage not exceeding 1.2 x (square root of two) x rated rms voltage, including harmonics, but excluding transients
c) 135% of nominal rms current based on rated kvar and rated voltage
d) 135% of rated kvar

Harmonic Filter Design Example

- Design a harmonic filter to improve the overall power factor to 0.95 lagging, and reduce the harmonic current emission at the PCC to the recommended limits in IEEE Std. 519.



Harmonic Filter Design Example

- Using Excel spreadsheet that is provided

SYSTEM INFORMATION:

Filter Specification (e.g., 5):	5	th
Three-Phase Capacitor Bank Rating:	750	kVAr
Rated Capacitor Bank Current:	722	Amps
Nominal Bus Voltage:	480	Volts
Capacitor Bank Current (actual):	577.4	Amps
Filter Tuning Harmonic (e.g., 4.7):	4.7	th
Capacitor Impedance (wye):	0.4800	Ω
Capacitor Impedance (delta):	1.4400	Ω
Filter Reactor Impedance:	0.0217	Ω
Filter Full Load Current (actual):	604.7	Amps
Filter Full Load Current (rated):	755.9	Amps
Transformer Nameplate Rating:	1500	kVA
Transformer Nameplate Impedance:	6.00	%
Load Harmonic Current:	27.20	% Fund
Utility Harmonic Current:	47.2	Amps

Operating voltage (bus voltage)

Inductive reactance at 60 Hz

Harmonic Filter Design Example

- Spreadsheet Results (cont.)

Power System Frequency:	60	Hz
Capacitor Voltage Rating:	600	Volts
Capacitor Frequency Rating:	60	Hz
Derated Capacitor Size:	480	kVAr
Total Harmonic Load:	1200	kVA
Filter Tuning Frequency:	282	Hz
Capacitor Rating (wye):	5526.22	µF
Capacitor Rating (delta):	1842.07	µF
Filter Reactor Rating:	0.0576	mH
Fundamental Frequency Compensation:	503	kVAr
Utility Side Voltage Distortion (Vh): *(Utility Harmonic Voltage Source)*	1.00	%
Load Harmonic Current:	392.6	Amps
Maximum Total Harmonic Current:	439.8	Amps

Rated voltage (nameplate)

Inductive reactance at 60 Hz

Harmonic current due to non-linear load

Harmonic current due to non-linear load + system

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Harmonic Filter Design Example

- Spreadsheet Results (cont.)

CAPACITOR DUTY CALCULATIONS:

Harmonic Filter RMS Current:	747.8 Amps	Fund. Freq. Capacitor Voltage:	502.8 Volts
Harmonic Capacitor Voltage:	73.1 Volts	Maximum Peak Voltage:	575.9 Volts
RMS Capacitor Voltage:	508.1 Volts	Maximum Peak Current:	1044.6 Amps

CAPACITOR LIMITS: (IEEE Standard 18-2002)

	Limit	Contingency	Actual	Value
Peak Voltage:	100%	120%	96%	576
RMS Current:	100%	135%	104%	748
KVAr:	100%	135%	88%	658
RMS Voltage:	100%	110%	85%	508

Harmonic Filter Design Example

- Spreadsheet Results (cont.)

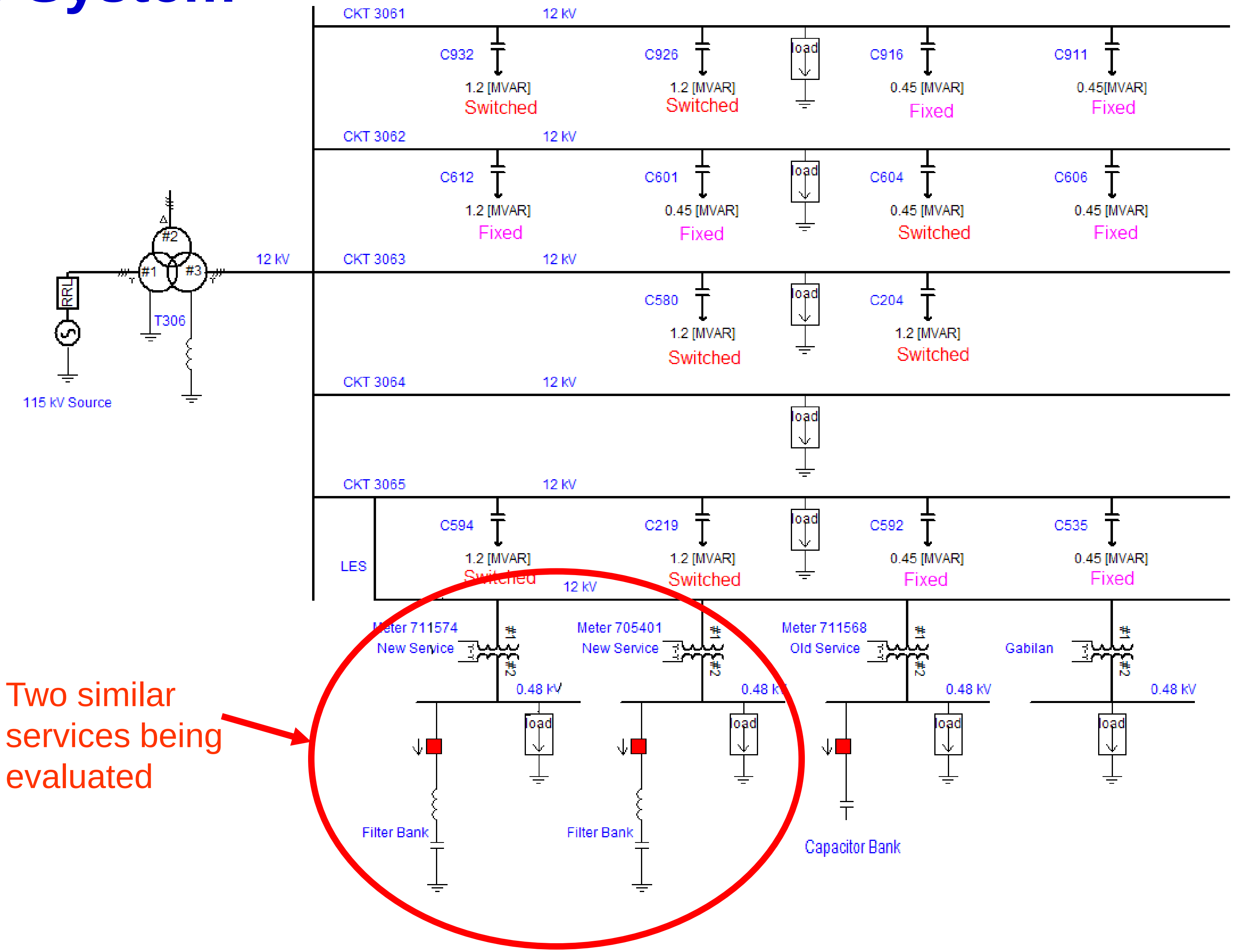
FILTER REACTOR DESIGN SPECIFICATIONS:

Reactor Impedance:	0.0217 Ω	Reactor Rating:	0.0576 mH
Fundamental Current:	604.7 Amps	Harmonic Current:	439.8 Amps
RMS Current Requirement:	747.8 Amps	Voltage Requirement:	277.1 Volts

Case Study – Plating Facility

- New facility supplied from 12 kV distribution system (2 similar services)
- Plant loads consist of a significant percentage of rectifier loads.
- Tuned capacitor banks (automatic systems) added to avoid power factor penalty and prevent harmonic resonance problems.
- 2 MVA supply transformer for each service.
- 0-650 kvar compensation for each service.
- Utility system has a number of capacitor banks on the feeder supplying the plant, as well as parallel feeders.
- Fuses blew in customer tuned banks shortly after they were energized. This situation was repeated again before leaving the filters off for investigation.

The System



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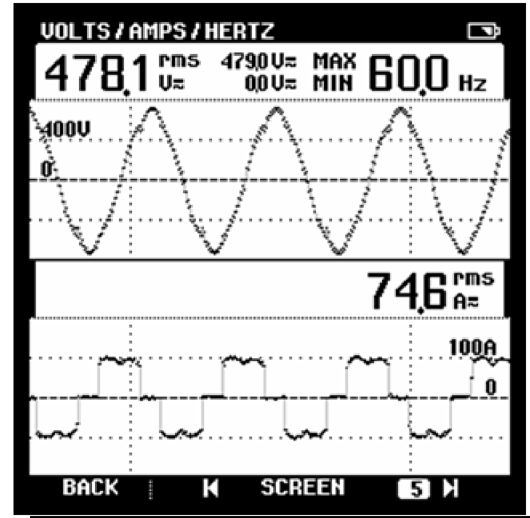
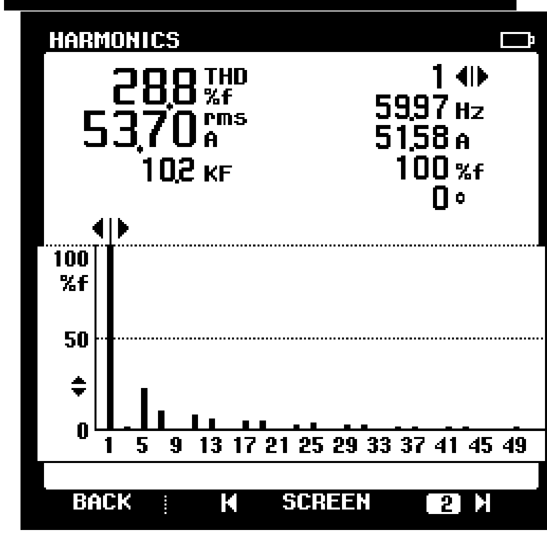
The 480 V tuned filter bank

- Bank was an automatic bank with a range of 0-650 kvar
- One 50 kvar step and 6 100 kvar steps allowing 50 kvar increments.
- Each step is tuned to 4.8 times the fundamental frequency.

Rectifier Loads





Initial measurement results

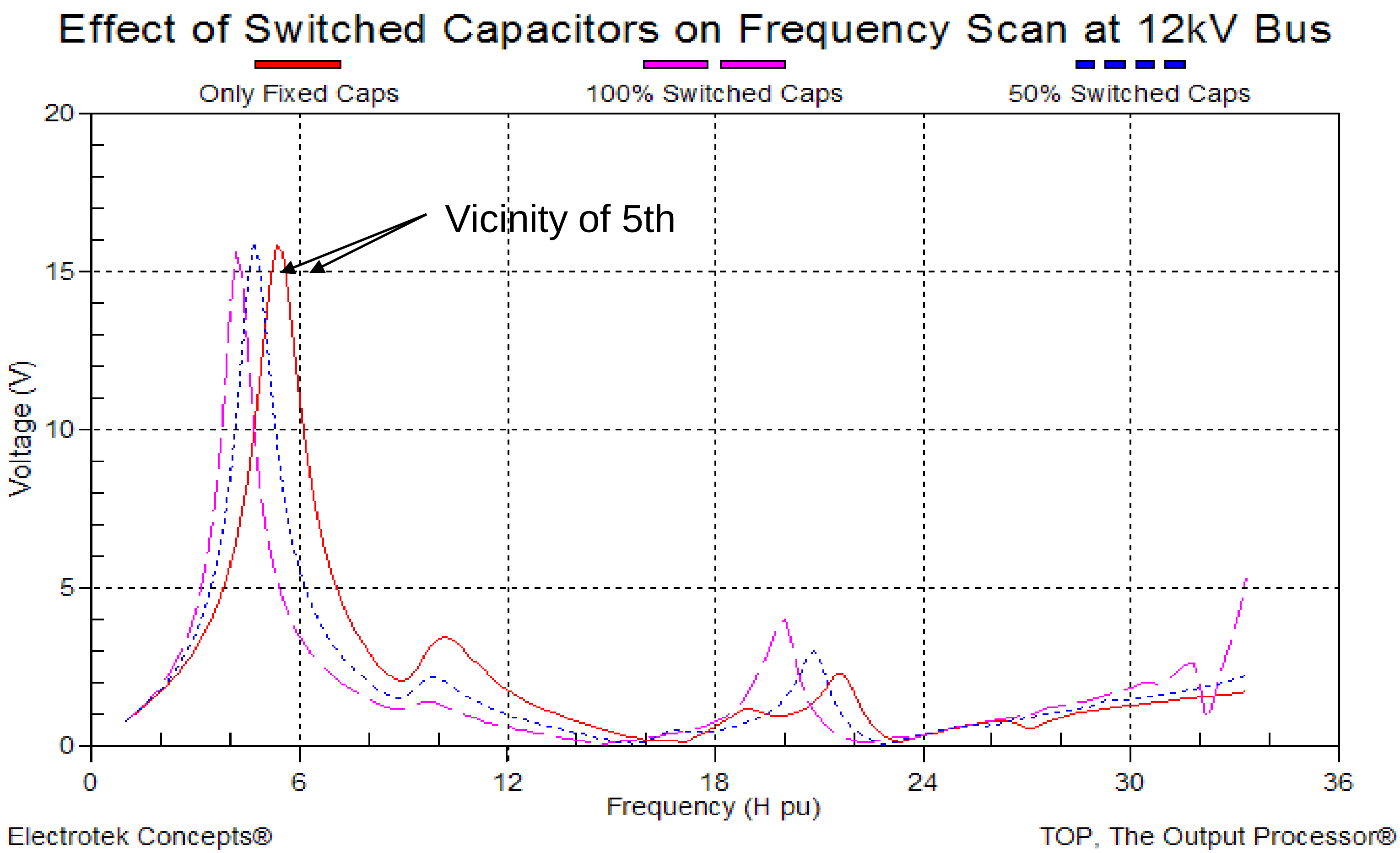
Measurements at the meter location to the facility (performed by utility)

1. PF Correction (filters) off
   - Vthd=3.7%, V5=2.5%, I=300 amps, Ithd=4.8%
   - Voltage spectrum has 3rd and 5th - 2.5% each
   - Current spectrum has some third (2%) but more 5th (4%)
2. PF Correction (filters) on
   - Vthd=2.8%, V5=1.3%, I=260 amps, **Ithd=35%**
   - Voltage spectrum still has 3rd (2.5%) but 5th is reduced (1.3%)
   - **Current spectrum is dominated by 5th - 30%**
   - kvar is reduced by about 50 kvar between the two cases indicating that only one 50 kvar tuned bank was probably in service

Some Conclusions:

- The power factor correction reduces the rms current by correcting the fundamental frequency power factor.
- However, the filters are absorbing a lot of fifth harmonic current from the power system. **This fifth harmonic loading from the power system could be the cause of the fuse blowing in the filter banks.**

Resonance conditions depend on the capacitors in service



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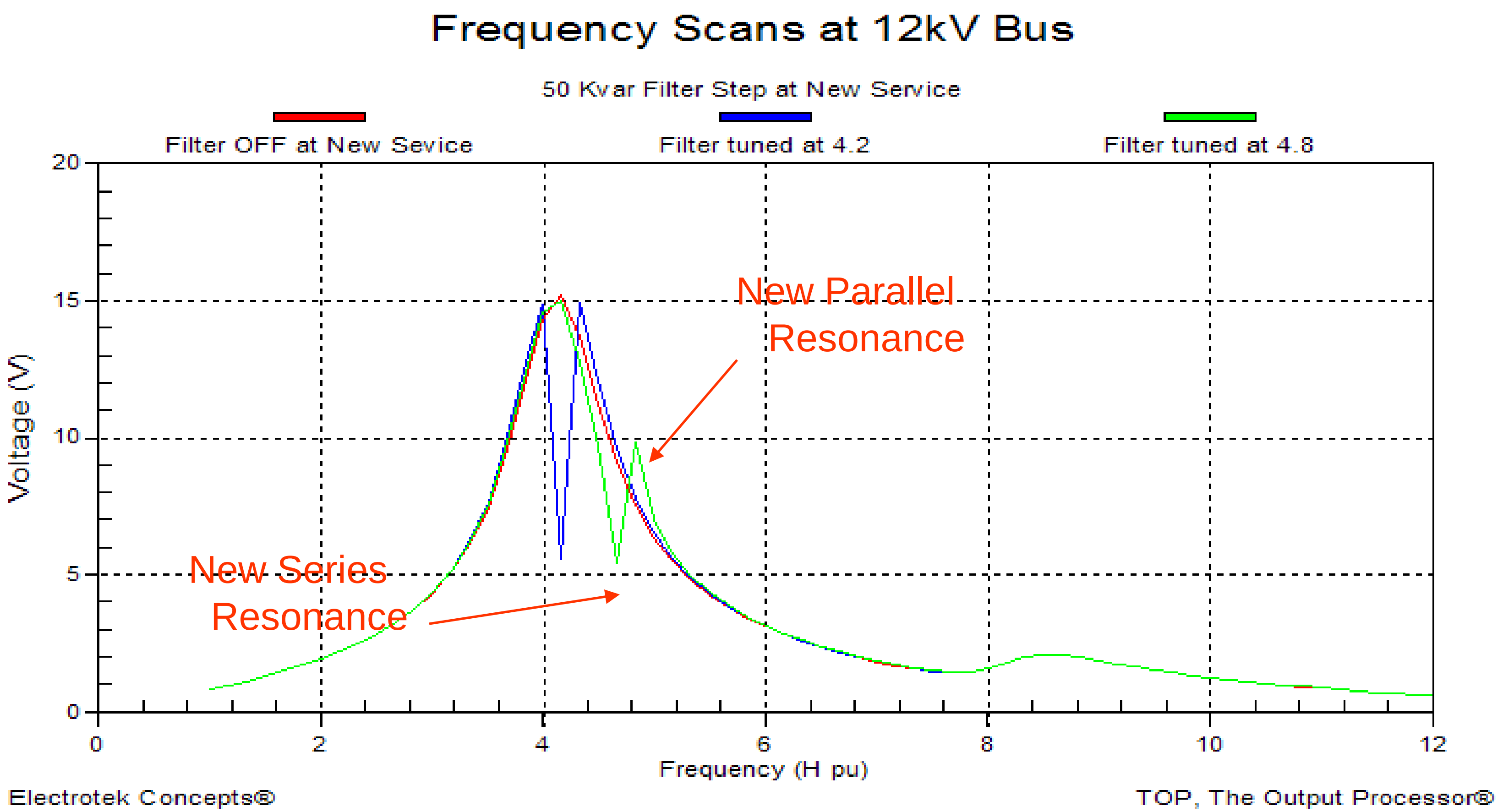
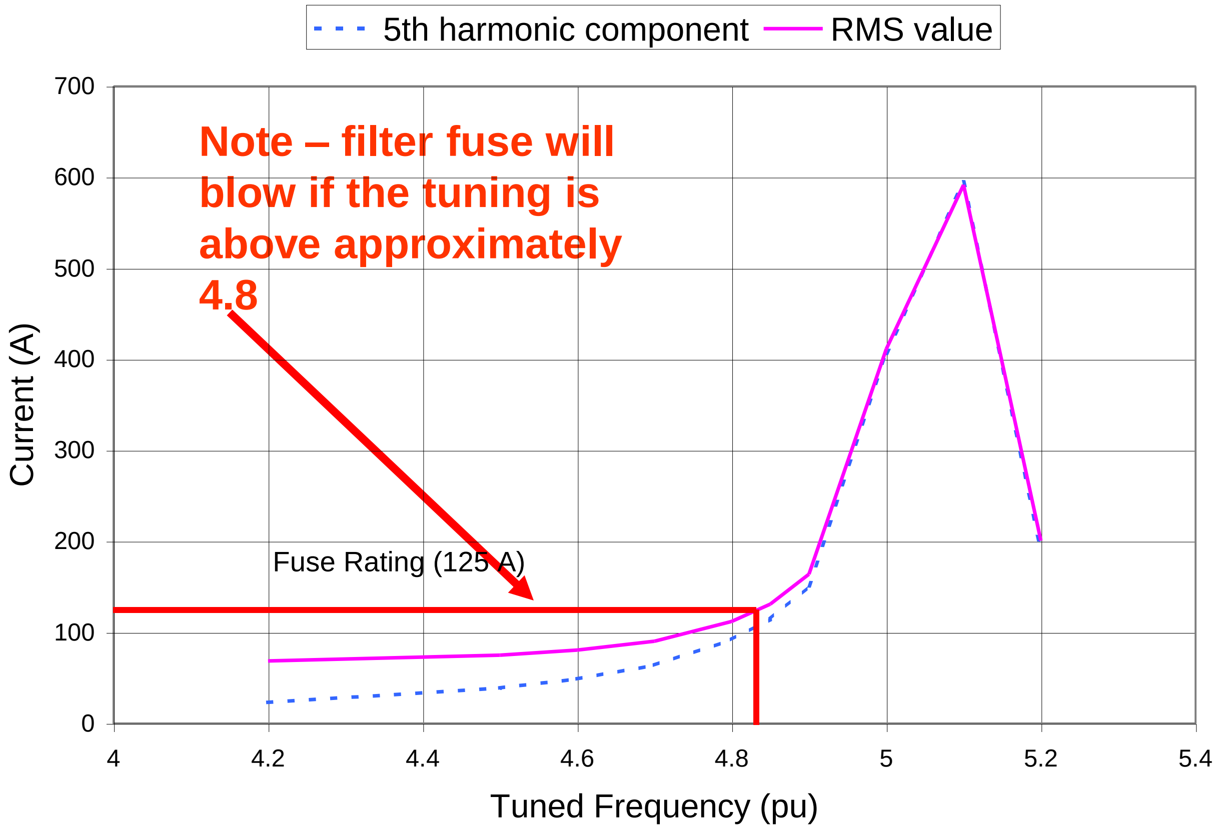
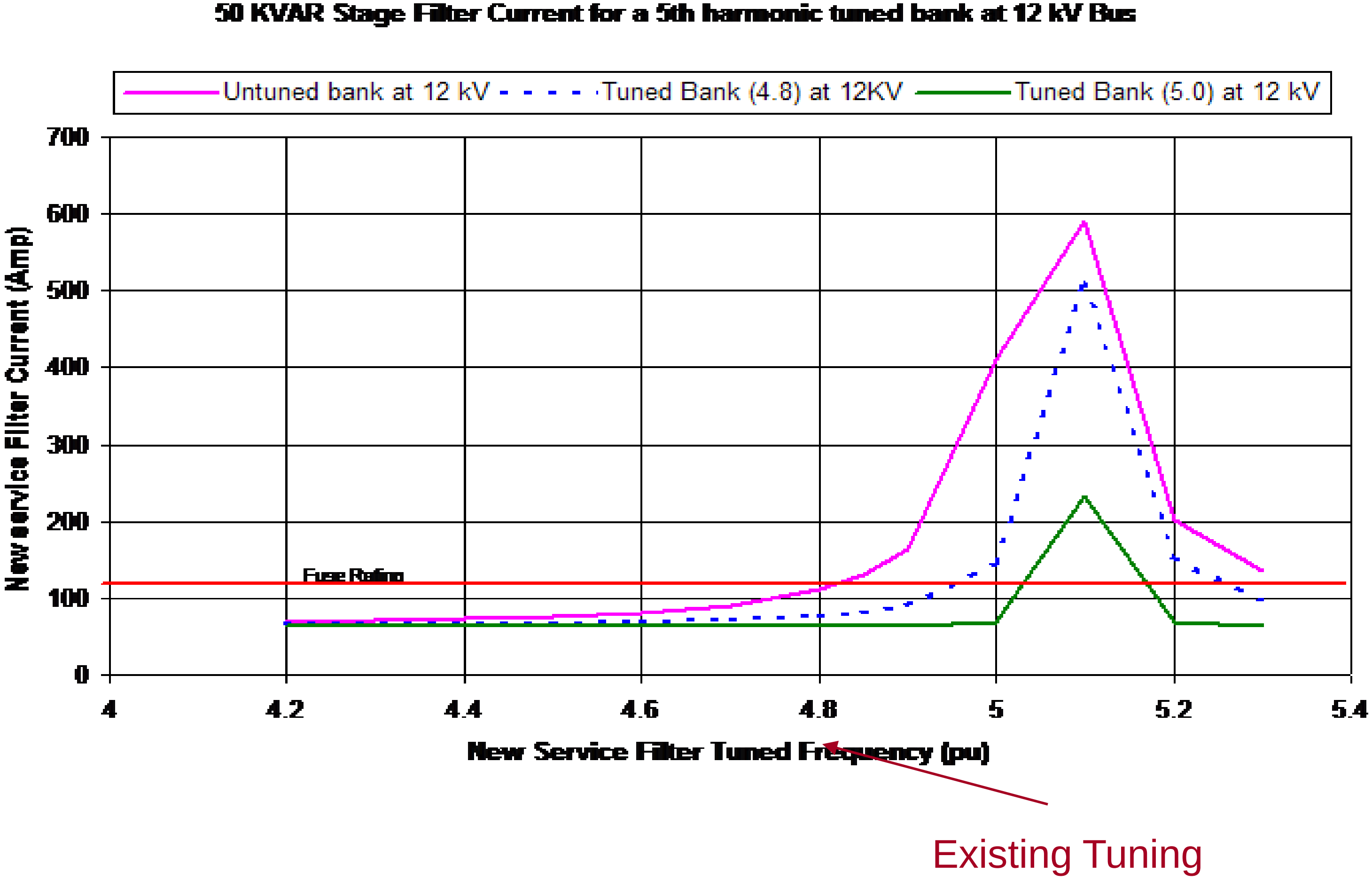
12 kV System Frequency Response With LV Filters in Service



Solution 1 – Detune the 480 V filter Bank



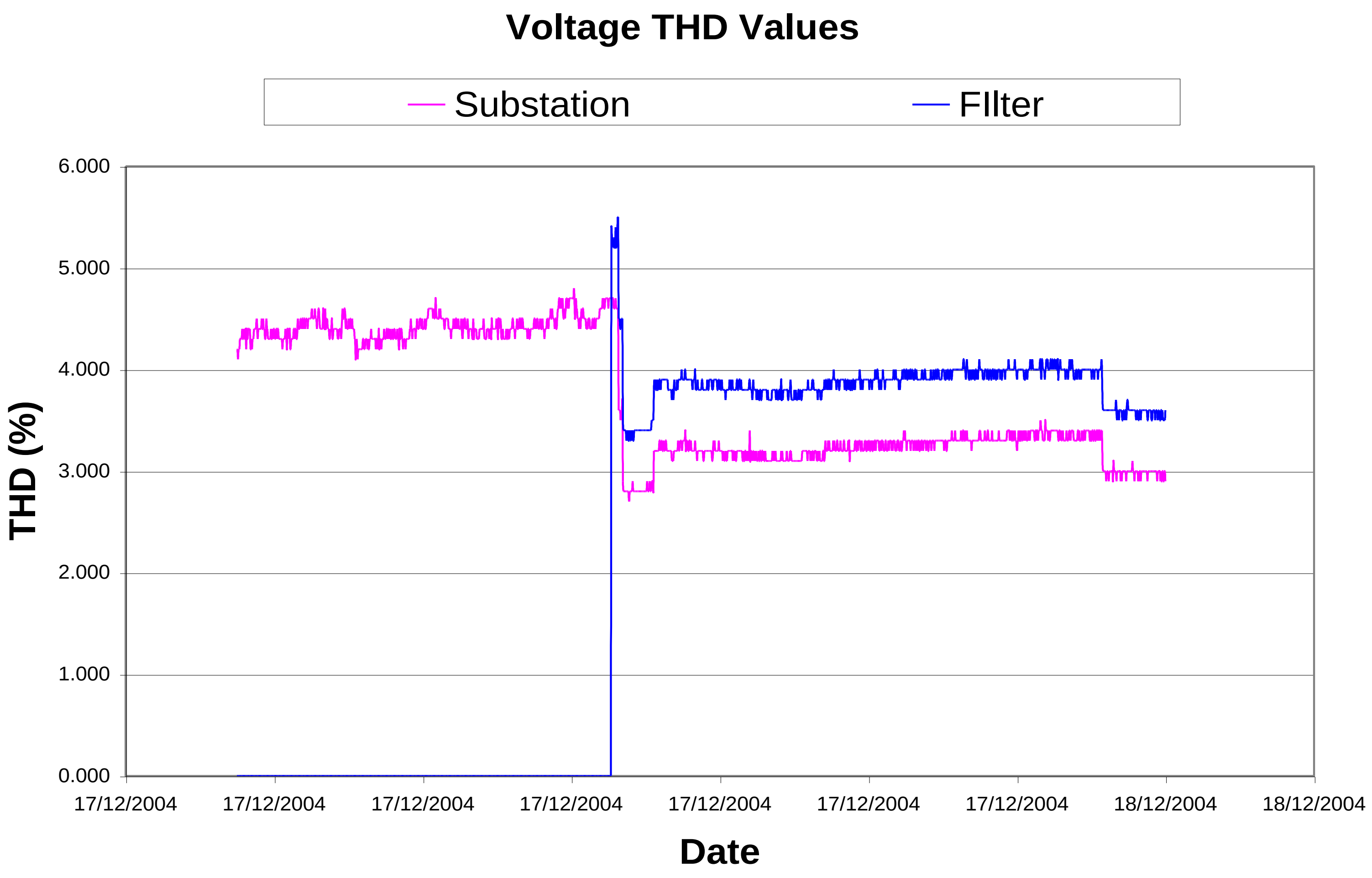
Solution 2 – Modifying a cap bank to filter on primary system



Filter configuration

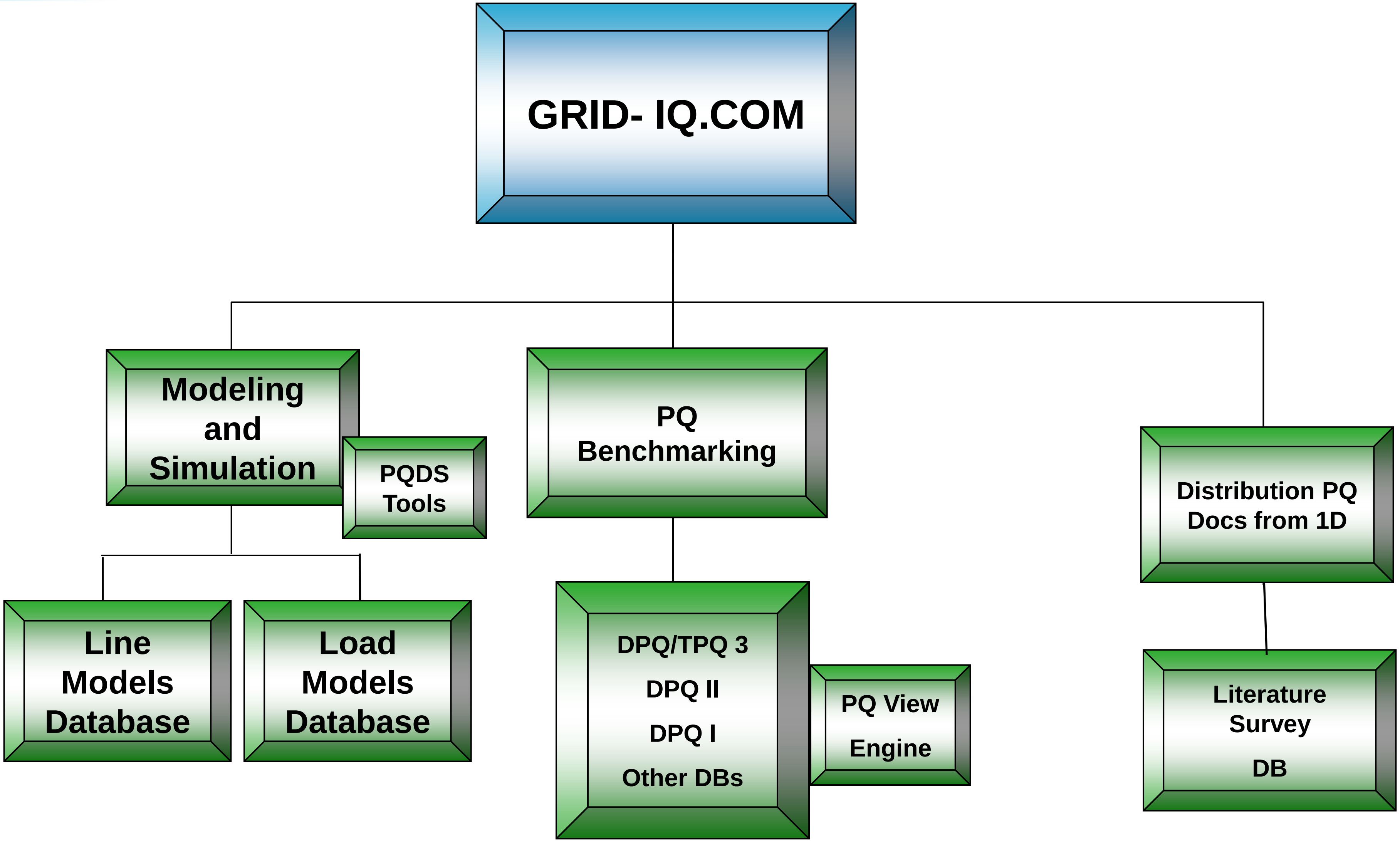
- Filter design developed with system simulations (SuperHarm) and Filter Design Spreadsheet.
- Solves 5^{th} harmonic resonance problem for all compensation levels
- Allows use of existing filters for the customer and helps other customers too
- Cost sharing

Results of Actual Filter Implementation –Impact on THD



Grid-IQ

Grid-IQ Overview



Circuit Model Database - Overview

- Library of models of distribution circuits
- Modeling platform: OpenDSS
  - Open source software developed by EPRI
  - http://sourceforge.net/projects/electricdss
- Approach
  - Circuit selection
  - Sanitization
  - Validation
- Plan

	2010	Existing	2012	2013
Number of Circuit Models	15	30	40-50	70-75

Circuit Model Database - Key Characteristics

Circuit Alias	Ckt1	Ckt2	Ckt3	Ckt4	Ckt5	Ckt6	Ckt7
System voltage (kV)	12.5	25.0	25/8.3	25/4.8	12.47	13.8	12.5
Sub primary Voltage (kV)	115.0	115.0	115	115.0	115.0	69.0	115.0
3-Ph SCC at Sub Sec. (MVA)	107	148	142	62	114	83	475
Number of customers	999	1102	1117	749	1379	704	5694
Percent residential by load	100	100	100	100	96	92	39
Service xfmr connected kVA	13793	19476	13086	13950	16310	16275	19320
Primary circuit miles total	48	44	72	60	48	79	8
Total feeder kvar	300	0	1800	2250	1950	600	2400
No. of feeders on the bus	6	2	2	1	1	1	14

Load Models

- KW, PF and Harmonic Spectrums
- Load Types
  - Modern Lighting
    - CFLs
    - LED lamps (2011)
    - Hybrid CFL
  - EV Chargers
  - PV Inverter
  - Computer Power Supply
  - Gaming Systems

Grid-IQ Harmonic Evaluation Module DEMO

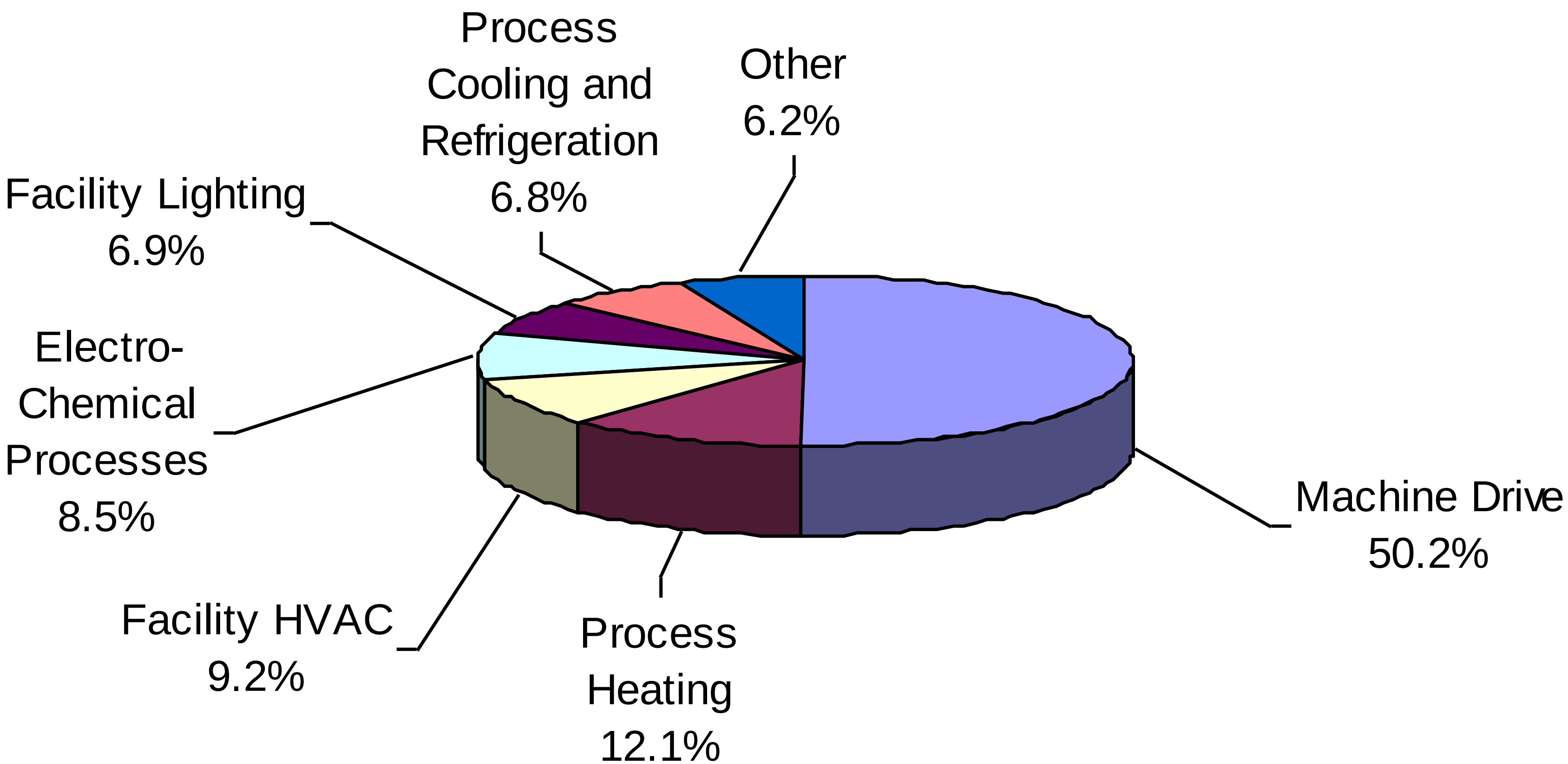
End PQ Session –

Break

Energy Efficiency Session

- Reduction of Thermal Losses/Waste Heat Recovery
- Upgrading of Lighting Technology and Controls
- Use of Premium Efficiency Motors
- Efficient Application of Adjustable Speed Drives
- Compressed Air Best Practices
- Chilled Water Systems
- Advanced Technologies
- ISO 50001/Superior Energy Performance
- FYI - DOE ITP Tools

Manufacturing Net Electricity Consumption



Total Net Electricity Consumption = 2,840 Trillion Btu, 2002

All Manufacturing Industries, NAICS 311-339

Source: Energy Information Administration, 2002 Manufacturing Energy Consumption Survey

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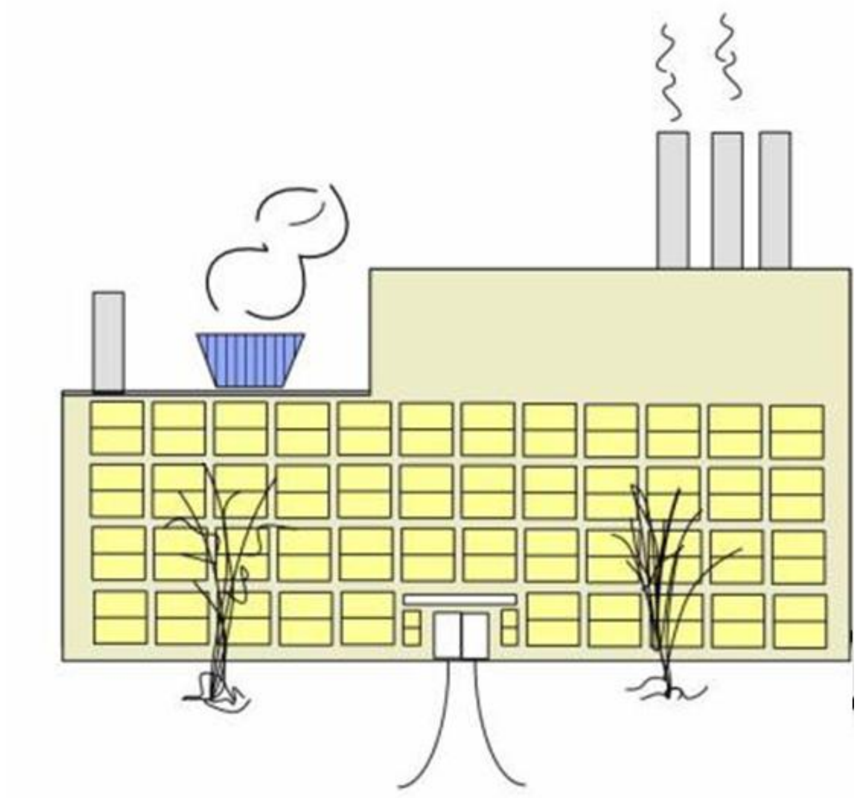
Reduction of Thermal Losses & Waste Heat Recovery

Waste Heat Recovery

- If a facility has process exhaust
  - Waste heat may be available!
  - Boiler Stacks
  - Afterburner/Abatement Systems
  - Furnace/Oven Exhaust



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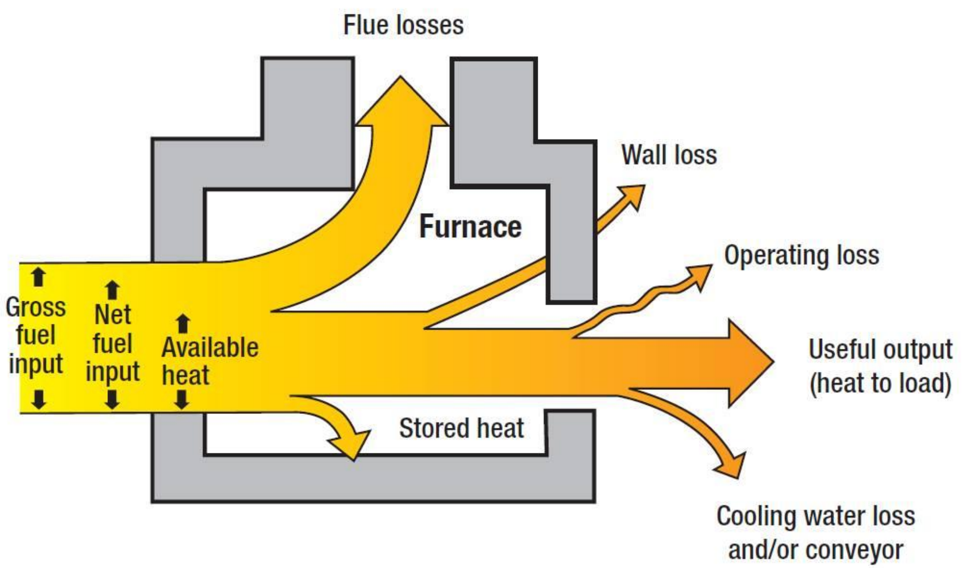
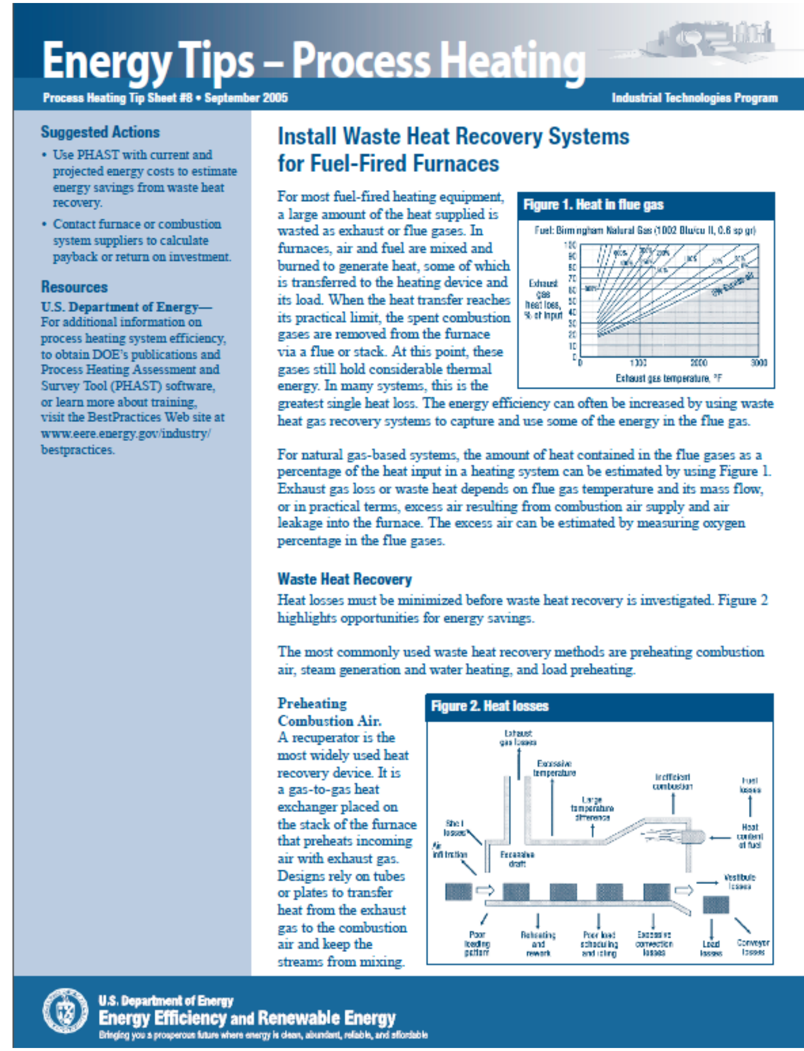
Waste Heat Recovery

- Benefits
  - Significant energy savings potential
  - Reduced energy costs
  - Reduced capacity/size requirements for boilers or furnaces
- Consider all waste streams to determine viability of appropriate waste stream recovery systems
  - Heat losses must first be minimized



Waste Heat Recovery

- Common Uses
  - Preheating combustion air
  - Steam generation
  - Water heating
  - Load preheating
- Methods
  - Heat Exchanger
  - Heat Pump
  - Steam turbine (CHP)
- Processes
  - Waste heat to heat
  - Waste heat to cooling/refrigeration
  - Waste heat to power



Energy Tips – Process Heating

Process Heating Tip Sheet #8 • September 2005

Industrial Technologies Program

Suggested Actions

- Use PHAST with current and projected energy costs to estimate energy savings from waste heat recovery.
- Contact furnace or combustion system suppliers to calculate payback or return on investment.

Resources

U.S. Department of Energy—For additional information on process heating system efficiency, to obtain DOE's publications and Process Heating Assessment and Survey Tool (PHAST) software, or learn more about training, visit the BestPractices Web site at www.eere.energy.gov/industry/bestpractices.

Install Waste Heat Recovery Systems for Fuel-Fired Furnaces

For most fuel-fired heating equipment, a large amount of the heat supplied is wasted as exhaust or flue gases. In furnaces, air and fuel are mixed and burned to generate heat, some of which is transferred to the heating device and its load. When the heat transfer reaches its practical limit, the spent combustion gases are removed from the furnace via a flue or stack. At this point, these gases still hold considerable thermal energy. In many systems, this is the greatest single heat loss. The energy efficiency can often be increased by using waste heat gas recovery systems to capture and use some of the energy in the flue gas.

Figure 1. Heat in flue gas

For natural gas-based systems, the amount of heat contained in the flue gases as a percentage of the heat input in a heating system can be estimated by using Figure 1. Exhaust gas loss or waste heat depends on flue gas temperature and its mass flow, or in practical terms, excess air resulting from combustion air supply and air leakage into the furnace. The excess air can be estimated by measuring oxygen percentage in the flue gases.

Waste Heat Recovery

Heat losses must be minimized before waste heat recovery is investigated. Figure 2 highlights opportunities for energy savings.

The most commonly used waste heat recovery methods are preheating combustion air, steam generation and water heating, and load preheating.

Preheating Combustion Air. A recuperator is the most widely used heat recovery device. It is a gas-to-gas heat exchanger placed on the stack of the furnace that preheats incoming air with exhaust gas. Designs rely on tubes or plates to transfer heat from the exhaust gas to the combustion air and keep the streams from mixing.

Figure 2. Heat losses

U.S. Department of Energy
Energy Efficiency and Renewable Energy
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

•See www.eere.energy.gov/industry

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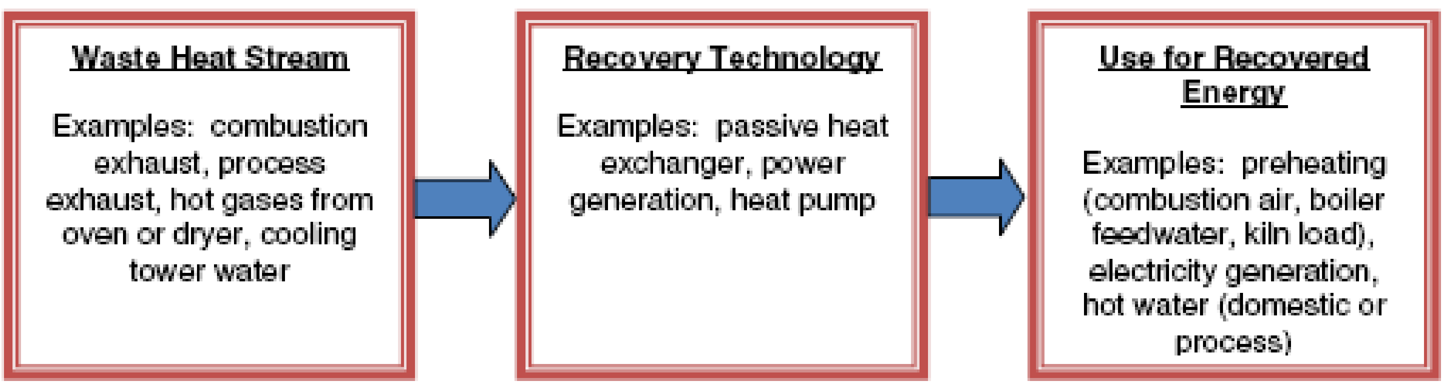
Waste Heat Recovery

- Three Key Elements
  - An available waste heat stream
  - A feasible recovery technology
  - A suitable application for the recovered energy

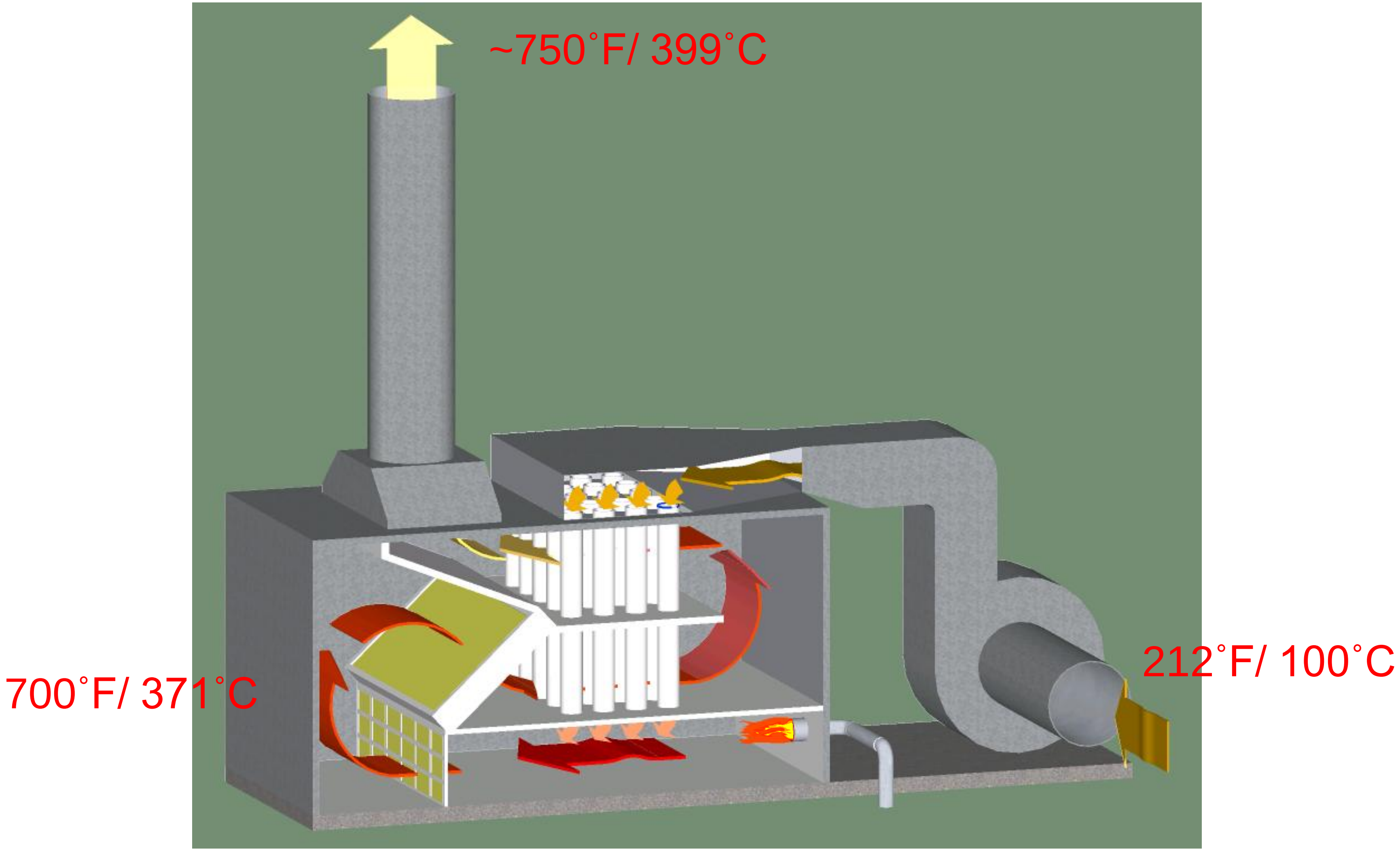


Ref:
Waste Heat Recovery in Industrial Facilities: Opportunities for Combined Heat and Power and Industrial Heat Pumps. EPRI, Palo Alto, CA: 2010. 1020134.

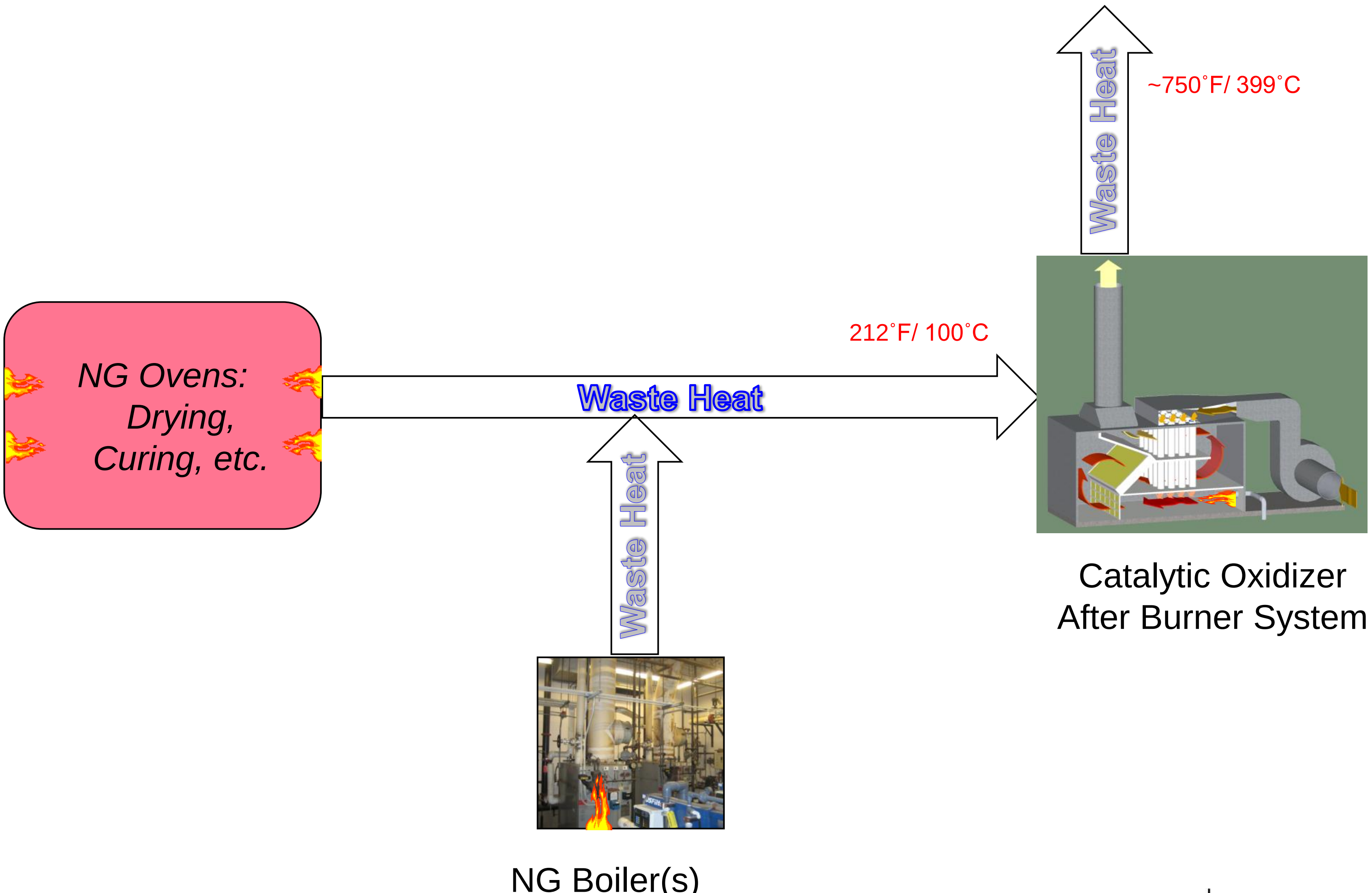
Feasible Recovery Technology

Temperature Classification	Waste Heat Source	Use for Recovered Energy	Technologies
High (>1200 °F)	• Furnaces – Steel electric arc – Steel heating – Basic oxygen – Aluminum reverberatory – Copper reverberatory – Nickel refining – Copper refining – Glass melting • Iron cupolas • Coke ovens • Fume incinerators • Hydrogen plants	• Combustion air preheat • Process steam • Power generation • Furnace load preheating • Medium or low temperature process needs	• Passive heat exchangers – Recuperators – Regenerators – Air preheaters – Regenerative/recuperative burners – Finned tube heat exchangers and economizers – Waste heat boilers • CHP – steam driven
Medium (450 – 1200 °F)	• Combustion exhaust streams – Steam boiler – Gas turbine – IC engine • Heat treating furnaces • Ovens – Drying – Baking – Curing • Cement kilns	• Combustion air preheat • Process steam • Power generation • Furnace load preheating • Feedwater preheating • Low temperature process needs	• Passive heat exchangers • CHP – Steam cycle – Organic Rankine cycle (ORC)
Low (< 450 °F)	• Combustion products from recovery systems – Gas fired boilers – Ethylene furnaces • Steam condensate • Cooling Water – Furnace doors – Annealing furnaces – Air compressors – IC engines – Refrigeration condensers • Ovens – Drying – Baking – Curing • Hot process liquids or solids	• Space heating • Domestic water heating • Low temperature process needs	• Heat pump (increase temperature to useful range) • ORC

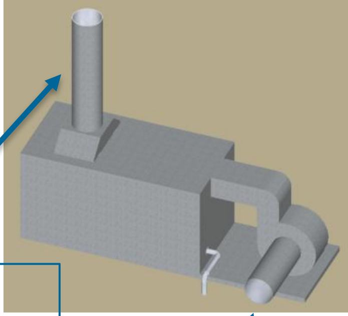
Typical Catalytic Oxidizer After Burner System



Example Waste Heat Recovery Opportunity



Example Medium Waste Heat Availability At Plant Site



Tin= 212°F/ 100°C → Afterburner System → Tout= 750°F/ 399°C

V=3900 ft/min = 19.8 m/sec

$$\mathbf{V} = V \times A = (19.8 m/sec)(0.3295 M^2) = 6.52 m^3/sec$$

$$\rho@100^\circ C = 0.946 kg/m^3$$

$$\mathbf{m} = V\rho = (6.52 m^3/sec)(0.946 kg/m^3) = 6.17 kg/sec$$

$$\mathbf{Q} = (m)(Cpavg)(\Delta T) = (6.17 kg/sec)(1.039 kj/kgK)(399^\circ C - 100^\circ C)$$

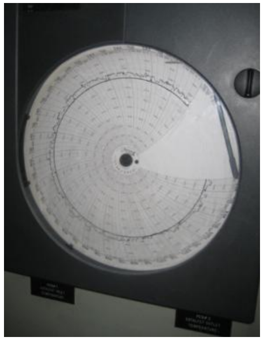
$$\mathbf{Q} = \sim 2MW @ \sim 750^\circ F$$

$$\mathbf{Q} = \sim (2 \times 10^6)(3.413) = 6.54 \times 10^6 BTU/Hr$$

Chart Recorder

Exhaust heat

~750˚F/ 399˚C



Average Anemometer Measurements

~3900ft/min 19.8m/s

Average Thermocouple Measurements

~211.6˚F/ 100˚C

Waste Heat from Afterburner Systems: ~6.54 MM BTU/Hr Thermal ~ 2 MW Electric

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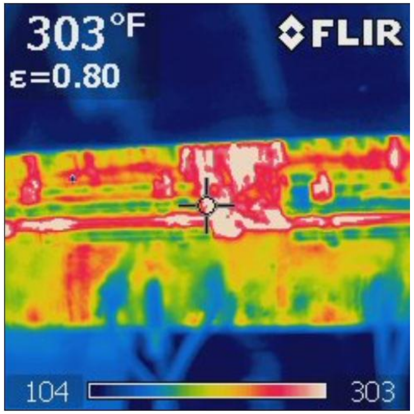
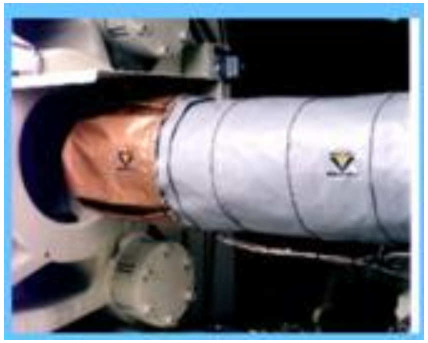
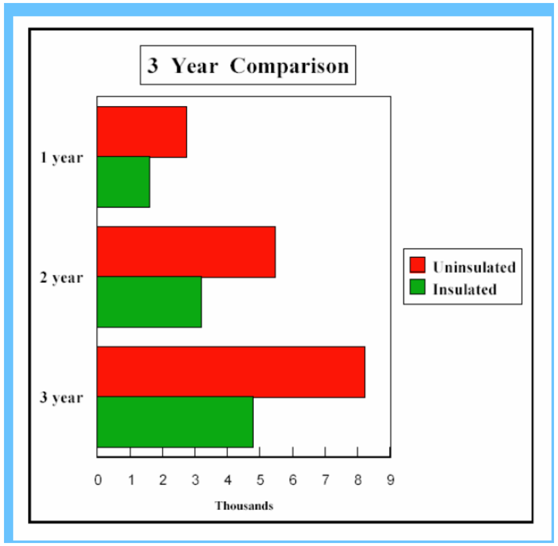
Example Plant Reduction of Thermal Losses/Waste Heat Recovery Example – Plastics Extrusion

- Extruder barrels are electrically heated…. uninsulated Extrusion melt barrels are a source of waste heat
  - If building space is conditioned, waste heat adds load to the HVAC in warm months
- Custom made blankets with Velcro closures are available for easy on-off and for adjustments.
- *Studies have shown up to 30% energy savings on barrel heater power usage with insulation.*



Injection Molding/ Extrusion Melt Pipes





Ref: Energy Efficient Injection Molding Operation, Babu Joseph, SCE Vishu Shah, Consultek, 4/17/2003

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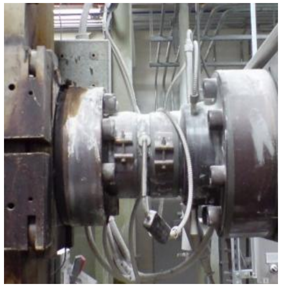
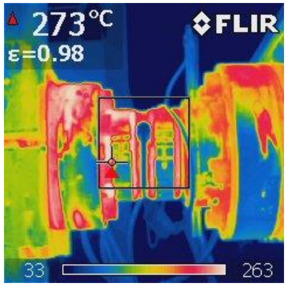
Example ECM – Insulation of Extruder Melt Pipes

- Operating Hours 6240/year, $0.0734/kWh
- Conditioned Space
- 6 extruders
- 18 kW Barrel Heater Rating
- 50% Heater Diversity
- 80% Effectiveness of R5 Insulation blankets
- Payback ~ 4 months





ECM No. ____			Insulate Extruder Barrels
Cost/kWh		0.0734	Average kWh Costs
Operating Hrs/yr		6240	
Is mfr space conditioned?		1	(0-No, 1-Yes)
Number of extruders		6	
Barrel Heater Rating		18	kW each unit or ~average size across all units
Machine Diversity		100%	Percentage of time machine is on
Heater Diversity		50%	Percentage of time heaters are on when machine runs
kWh/yr Heater Usage		336,960	
kWh/yr HVAC Impact		84240	If space conditioned, estimate 1/4 of heater power will impact HVAC
Total kWh/yr due to extruder heaters		421,200	
Effectiveness of Blankets		80%	Expected Effectiveness of R5 Insulation over bare metal
kWh/yr saved by blankets		336,960	
Estimated Yearly Savings	$	24,733	
# Complex Blankets		3	Estimated at $1,200/blanket for multibarrel or long barrels
# Simple Blankets		3	Estimated at $600/blanket for simple or short barrels
Total Blanketing Cost	$	5,400	Estimated Total Cost for blankets
Utility Incentives	$	-	Note if applicable
Net Estimated Cost	$	5,400	Total cost minus any incentives
EstimatedPayback		0.22	Years
		3	Months

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Example Compressed Air Cooling Water Waste Heat Reclamation

- The plant utilizes the heat from the compressed air system to heat manufacturing space in winter.
- Cooling water loop fed through heat exchanger in the winter for space heating.

Compressed Air Cooling Water Waste Heat Reclamation

300 HP
Gardner Denver Air
Compressor

Heat Reclamation in
Winter (110˚F Air)
(installed cost ~ $25k)

Water
Cooling Bed

Upgrading Lighting Technology and Controls

Areas for Lighting Improvement

I. Replace Incandescent lamps with fluorescent or compact fluorescent lamps (CFLs)

II. Upgrade fluorescent fixtures with improved components

III. Install lighting controls to minimize energy costs

IV. Employ New Lighting Technologies

Ref: aee CEM training material

Potential Lighting Energy Savings Opportunities

- Fluorescent Upgrades
- De-Lamping
- Incandescent Upgrades
- HID Upgrades
- Controls Upgrades
- Daylight Compensation

Ref: aee CEM training material

Opportunities in End Use Energy Efficiency: Compact Fluorescent Lamps

- Savings from replacing all incandescent bulbs with CFLs in a US household: **~1200 kWh/yr**

CFLs use ~2/3 to 3/4 less than incandescent bulbs

- Savings nationwide if all households switched:
  - Total residential electricity consumption reduced by **~10%**
  - US electricity consumption reduced by **~3.7%**

>113 million US households

Upgrading Fluorescent Fixtures

- Improved fluorescent lamps

  T-8, T-10, T-12 Tri-phosphor lamps

  New T5 Lamps

  New Induction Lamps
- Electronic Ballasts
  - Standard non-dimmable ballasts
  - Consider dimming ballasts
  - New program-start ballasts T5 and T8
- Reflectors

Ref: aee CEM training material

Lighting Comparisons: Metal Halide vs. Others

Fixture & lamp #	W/lamp	rated life	initial lumens/ lamp	mean lumens/ lamp	lumens/ fixture	kWh/yr, 24/7 (8760 hrs)	Cost at $0.065/ kWh
T5, 2-lamp	54	25K-36K	5000	4700	9K-10K	946.08	$ 61.50
T5, 3-lamp	54	25K-36K			13K-15K	1419.12	$ 92.24
T5, 4-lamp	54	25K-36K			18K-20K	1892.16	$ 122.99
T5, 6-lamp	54	25K-36K			28K-30K	3153.60	$ 204.98
T8, 2-lamp	28	20K-24K	3100	2567	5.1K-6.2K	490.56	$ 31.89
T8, 3-lamp	28	20K-24K			7.7K-9.3K	735.84	$ 47.83
T8, 4-lamp	28	20K-24K			10.3K-12.4K	989.88	$ 64.34
T8, 6-lamp	28	20K-24K			15K-18.6K	1690.68	$ 109.89
T12, 2-lamp	55	20K	2650	2047	4.1	1716.96	$ 111.60
Metal Halide	400	20K	40000	29000	29K	4029.60	$ 261.92

Lighting study is a good idea

Fluorescent Retrofits

- Existing System: T12 lamps with Magnetic Ballasts
- Retrofit Alternatives:

1. T12 low wattage lamps (34W) – replace lamps only
    - Less light, less energy consumption
2. T8 (32W) – replace lamps and ballasts
    - Same light, less energy consumption, better color, rendering , less map flicker, less ballast hum
    - Can operate 4 lamps per ballast
    - Can be tandem wired
    - Electronic ballasts can be parallel wired

6 Fixture T8s

Skylights used with T12s

Ref: aee CEM training material

Control Schemes for High Bay Lighting*

Entire Aisle Control from Ends

Entire Aisle Control from Ends & Middle

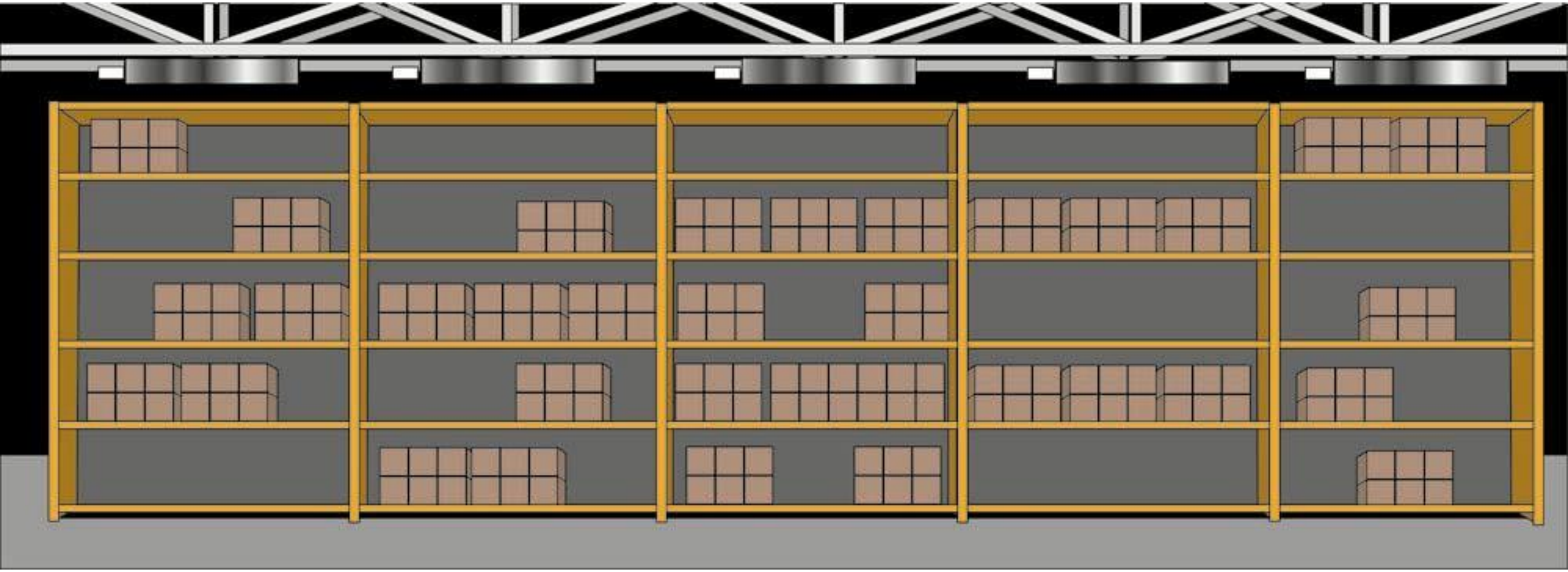
Individual Fixture Control

Individual Fixture Control w/ Lights On Ahead

* Program-start ballast

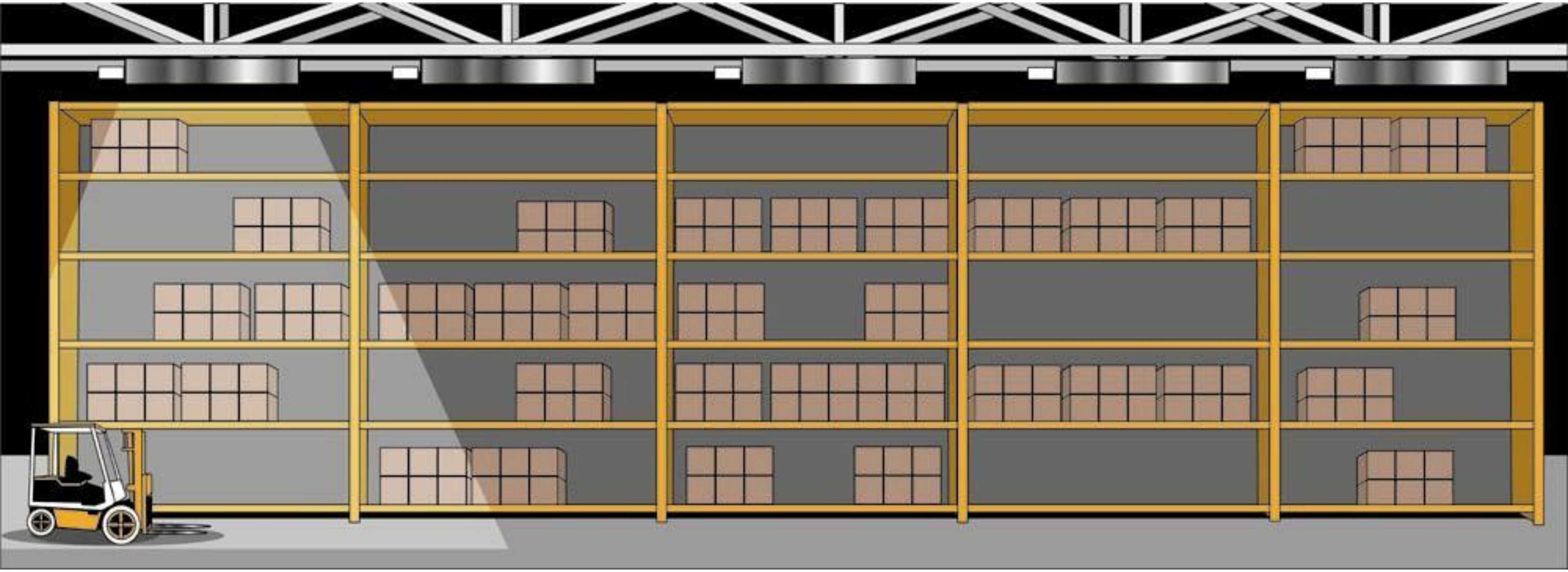
Ref: sensor switch

Individual Fixture Control



Ref: sensor switch

Forklift Enters Aisle – First Light Comes On



Ref: sensor switch

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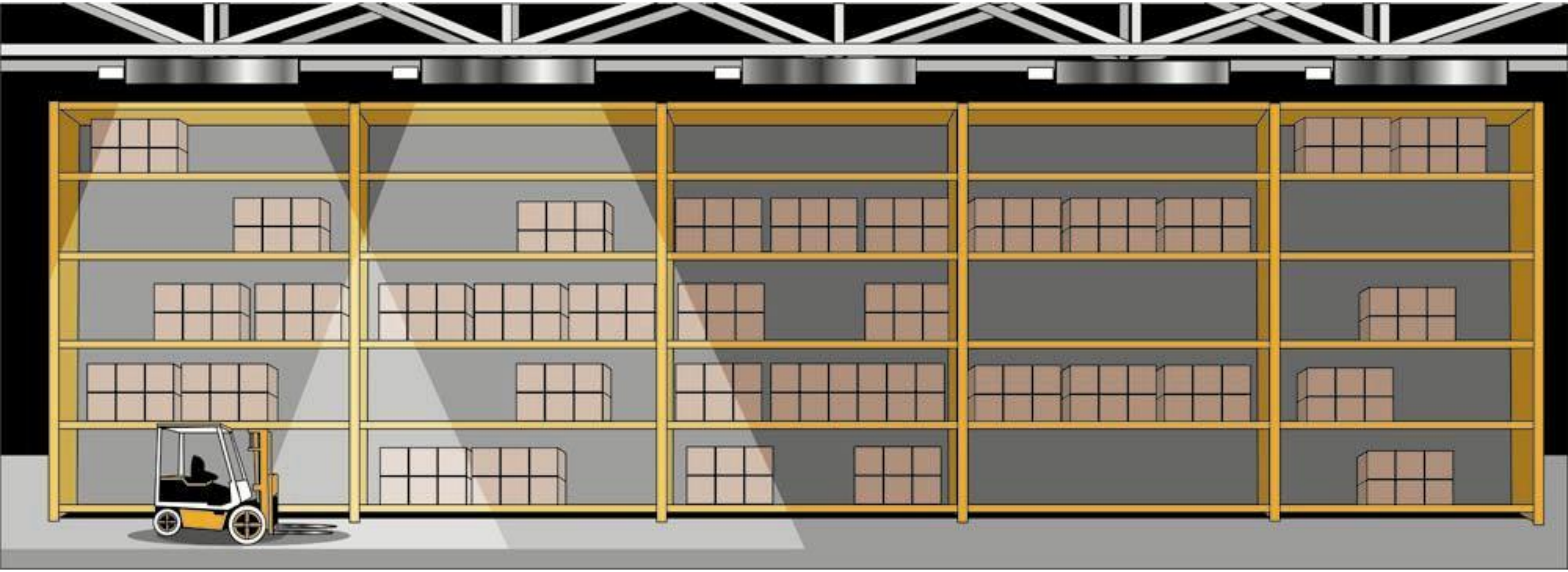
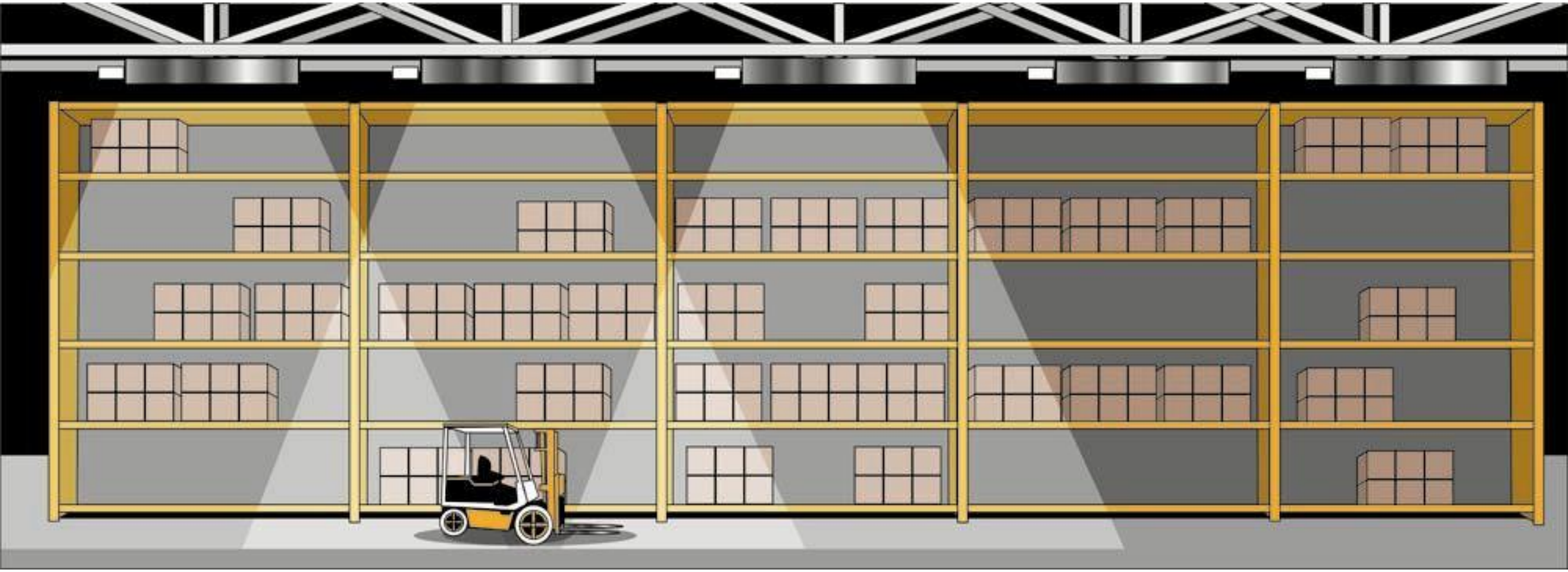
Each Lights Comes on Directly at Forklift



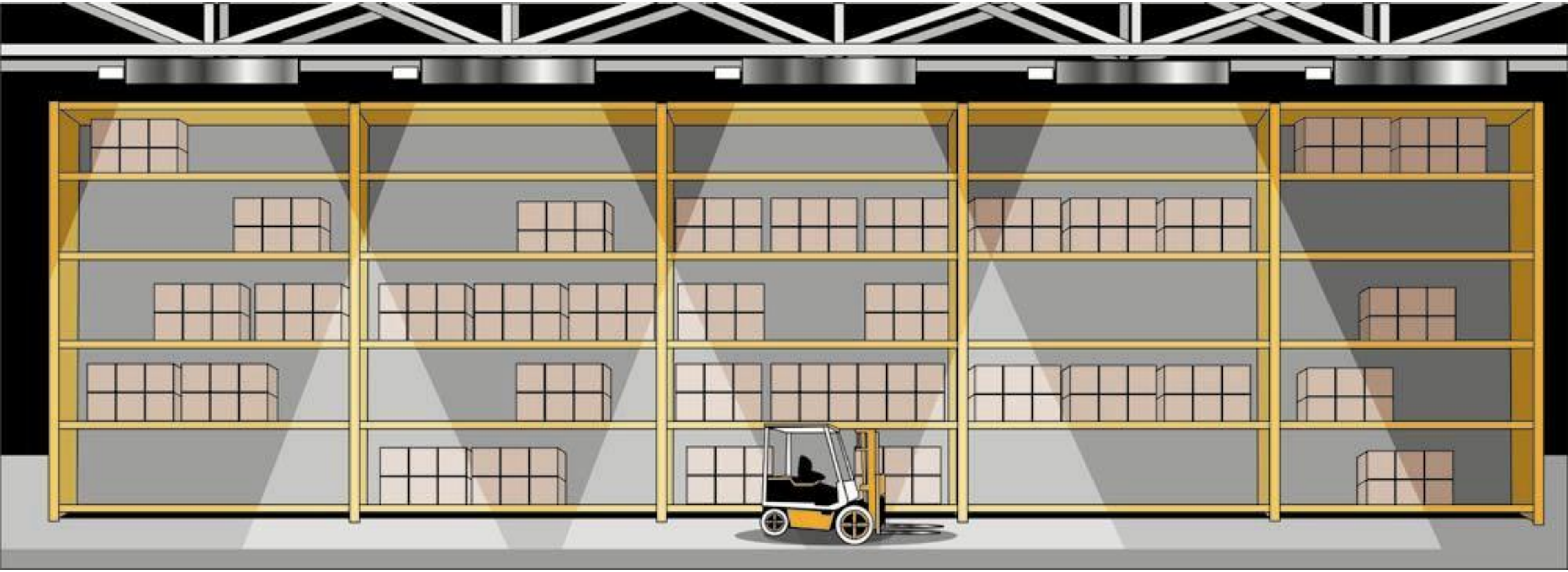
Ref: sensor switch

Each Light Comes on Directly at Forklift



Ref: sensor switch

Light Comes on Directly at Forklift



Ref: sensor switch

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Light Comes on Directly at Forklift

Ref: sensor switch

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Lights Start Turning Off Behind Forklift

Ref: sensor switch

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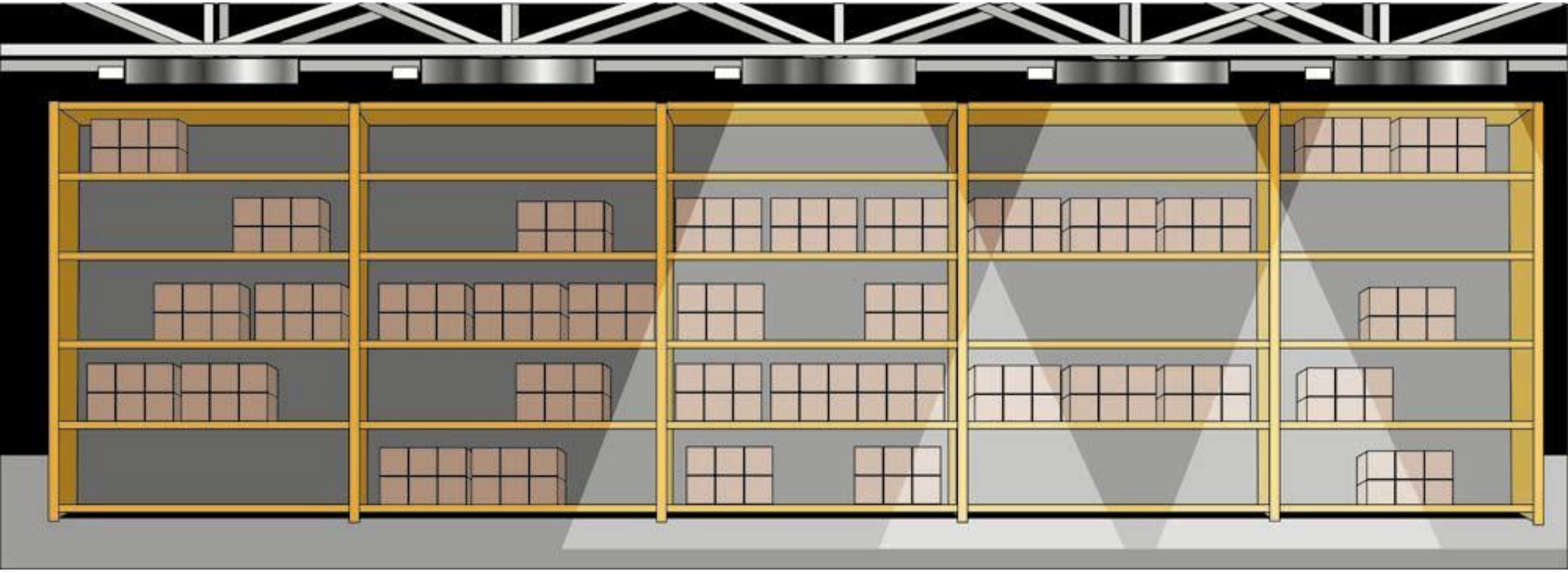
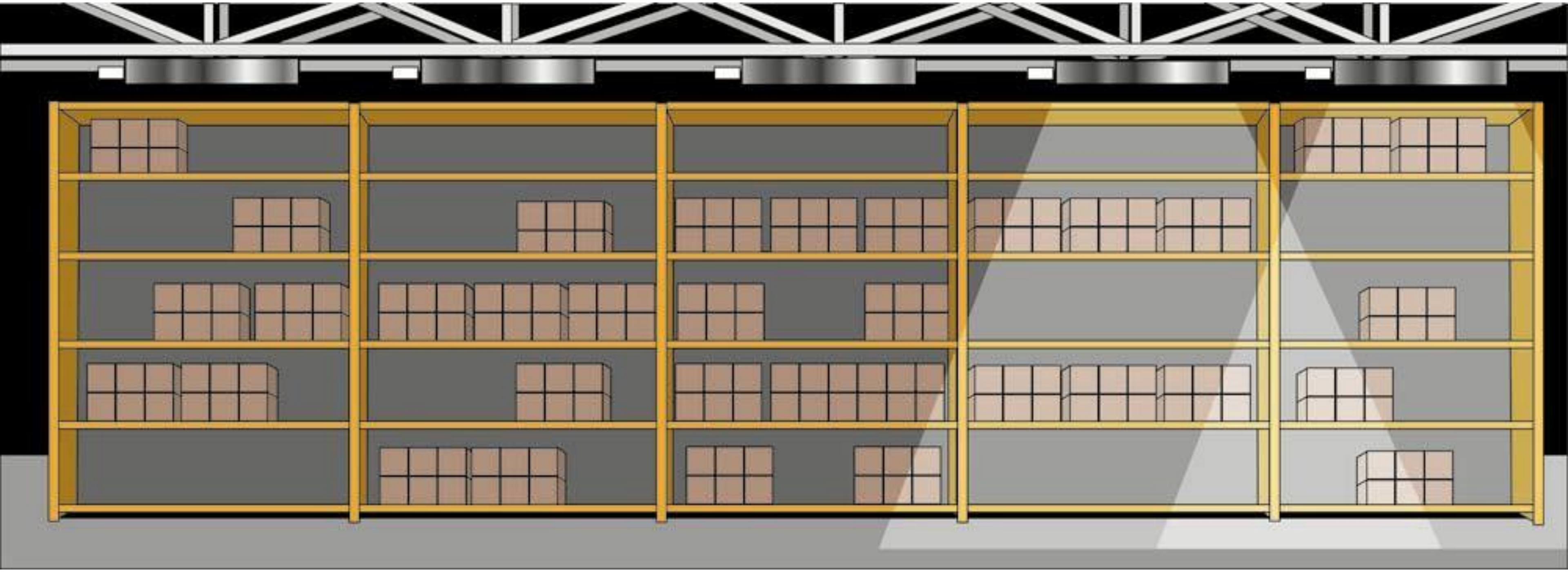
Forklift Leaves Aisle, Lights Continue to Turn Off



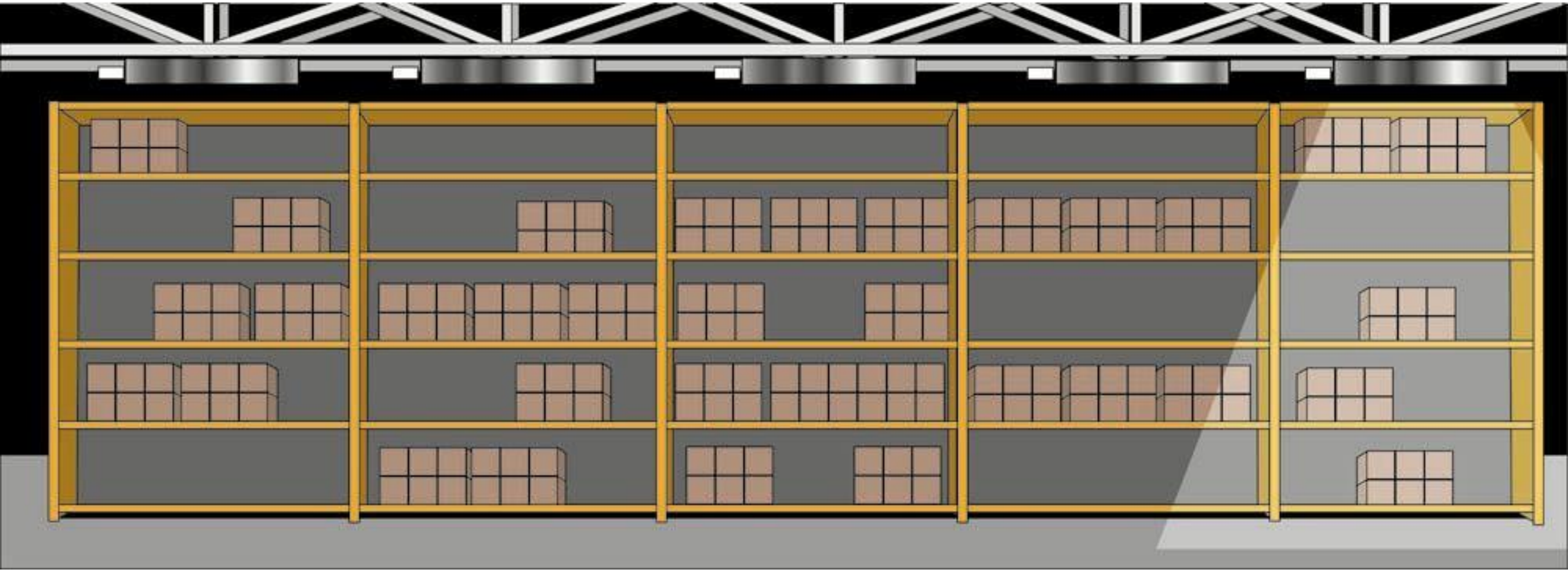
Ref: sensor switch

Forklift Leaves Aisle, Lights Continue to Turn Off



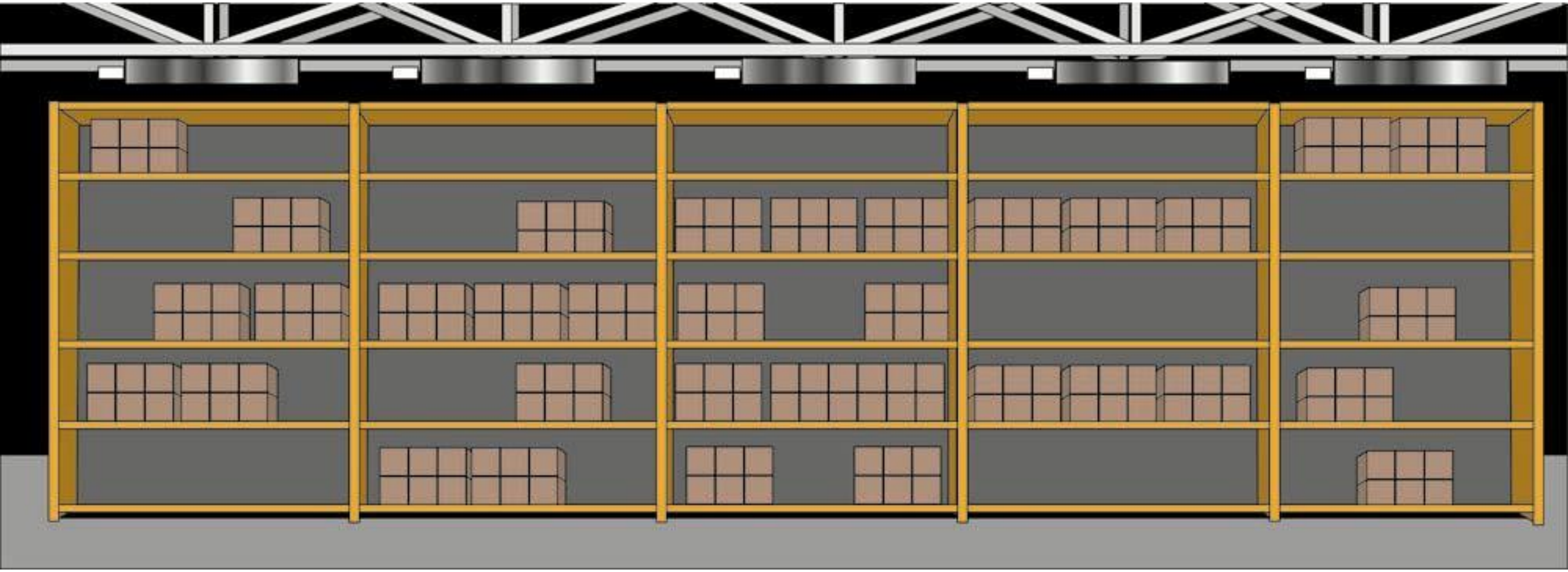
Ref: sensor switch

Forklift Leaves Aisle, Lights Continue to Turn Off



Ref: sensor switch

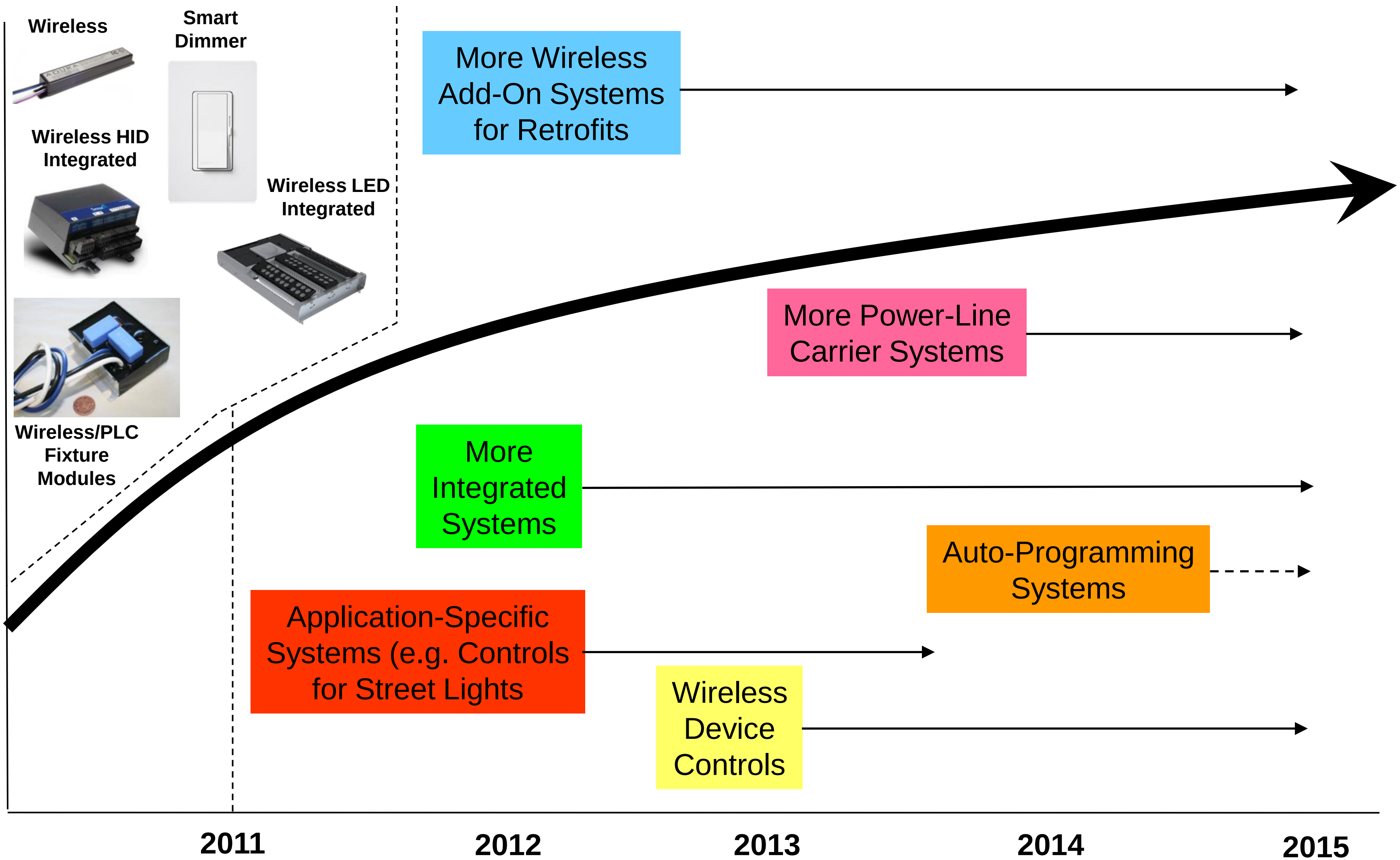
Lights Finish Turning Off



Ref: sensor switch

Lighting Controls: EPRI Research Trajectory

2011 & the Next 4 Years of Progressive Research



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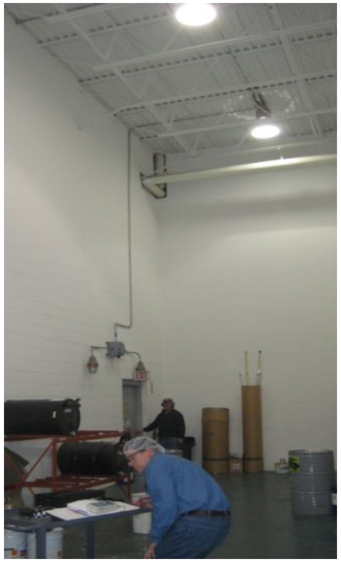
Example Lighting Assessment

- The plant primarily uses Metal Halide Fixtures for lighting in the two main buildings
- Each fixture accounts for ~458W of power, continually on
  - Bldg 1 ~466 units
  - Bldg 2 ~ 337 units
- Median Light Value directly under Metal Halide fixtures ~ 27 fc



Lighting Measurements

	Fixture Height	Meter Height	
	27'	3.5'	
Bldg	**Area**	**Location**	**Measurement (fc)**
1	Warehouse	Under Fixture	28.5
1	Warehouse	In between two fixtures	38
1	Warehouse	Under Fixture	30
2	Storage	Under Fixture	11.5
2	Mixing Area	Under Fixture	25.12
2	at Foyer corner	Under Fixture	27

Example Lighting Assessment

- Lighting on 24x7

- Estimated Lighting Load/Costs

  ~367kW or 3.22MWh/year

  ~$237,000 k/year in power costs

Lighting Measurements

Example Lighting Assessment

- Forty-Eight (48) T12 8 foot fixtures were found in the mezzanine storage area.
- The lights were left on at switch by top of stairs although there was no one present.
  - Approximate cost/day of leaving lights on 48 x .2kW x $.0736/kW x 24hrs/day = $16.90/day, ~$6000/year
- The lights could be replaced with more efficient technology and/or add an occupancy sensor. *
- Utility may have incentive for occupancy sensors that could be placed where light switch is now –set for long delay.

* May be addressed through operational procedure

Example Lighting Assessment

- Potential change out:
  - (4) Bulb T5HO Fluorescent ~234W / fixture
  - (6) Bulb T8 Fluorescent ~222W/fixture
  - (6) Bulb T5HO Fluorescent ~324W/fixture
- Assuming one for one replacement with Metal Halides
- Estimated lighting load/costs (4) Bulb T5 HO Fixture

~187kW or 1.9 MWh/year

~$121k/year in power costs

~$116k/year Savings

Payback including installation expected to be less than 1 year with Utility incentive included.

	400W Probe-start MH	320W Pulse-start MH	(4) F54T5HO Fluorescent	(6) F54T5HO Fluorescent	(6) F32T8 "High Lumen" Fluorescent
Number of Lamps	1	1	4	6	6
Service life	20,000 hours @ 10 hours/start	20,000 hours @ 10 hours/start	24,000 hours @ 10 hours/start	24,000 hours @ 10 hours/start	28,000 hours @ 10 hours/start
Initial lamp light output	36,000 lumens	30,000 lumens	20,000 lumens	30,000 lumens	18,600 lumens
Ballast	Probe-start magnetic	Pulse-start	Program start	Program start	Instant start
Ballast factor	1	1	1	1	1.18
Initial system light output	36,000 lumens	33,000 lumens	20,000 lumens	30,000 lumens	21,948 lumens
Lamp watts	400W	320W	216W	324W	192W
System watts	458W	350W	234W	351W	222W
Relative system watts	100%	76%	51%	77%	48%
Initial system efficacy	79 lm/W	94lm/W	85 lm/W	85 lm/W	99 lm/W
Mean lumens	23,500 lumens @ 40% of lamp life	26,400 lumens @ 40% of lamp life	19,000 lumens @ 40% of lamp life	28,500 lumens @ 40% of lamp life	20,851 lumens @ 40% of lamp life
Lumen maintenance	65%	80%	95%	95%	95%
Maintained system efficacy	51 lm/W	75 lm/w	81 lm/W	81 lm/W	94 lm/W
Color rendering	65 CRI	65 CRI	82-85 CRI	82-85 CRI	85 CRI
Starting Time	4 minutes	2 Minutes	<1.5 seconds	<1.5 seconds	<1 second
Re-strike Time	10 minutes	4 Minutes	<1.5 seconds	<1.5 seconds	<1 second
Color temperature	3000-4000K	3600-4200K	3000-5000K	3000-5000K	3000-5000K

Ref: accessfixtures.com

New Lighting Technologies – Induction Lamps

- Induction lamps
  - Long Life --- 100,000 hours for lamp and ballasts
  - Philips QL lamps in 55W, 85W, and 165W
  - New application with reflector to replace metal halides as signs lights for road and commercial signs.
  - Lasts four times as long

Courtesy: Lithonia

Ref: aee CEM training material

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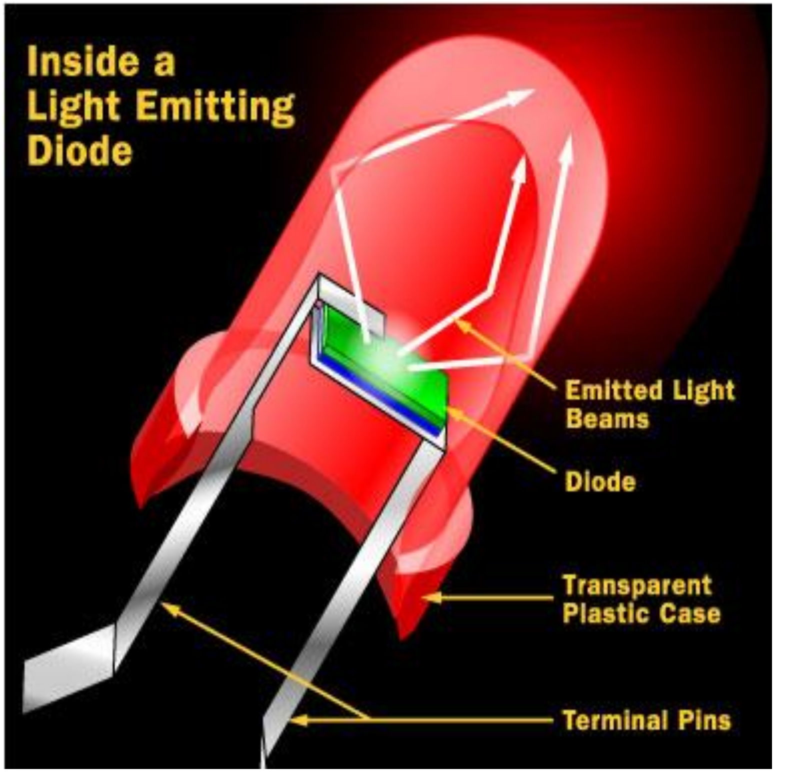
New Lighting Technology - LED lighting

- 80% of all new exit lights are LED Lights
- Other uses:
  - Traffic Signals
  - Commercial Advertising Signs
- EPRI is working on LED street light demonstration project



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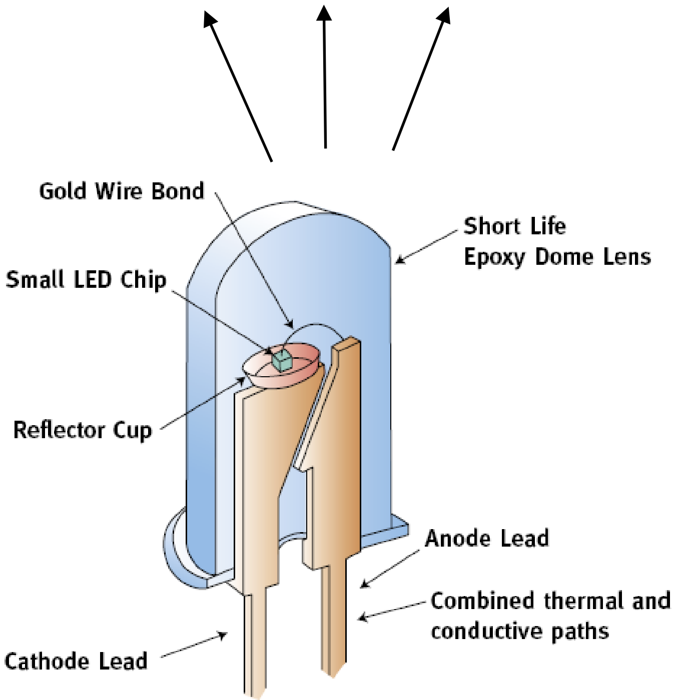
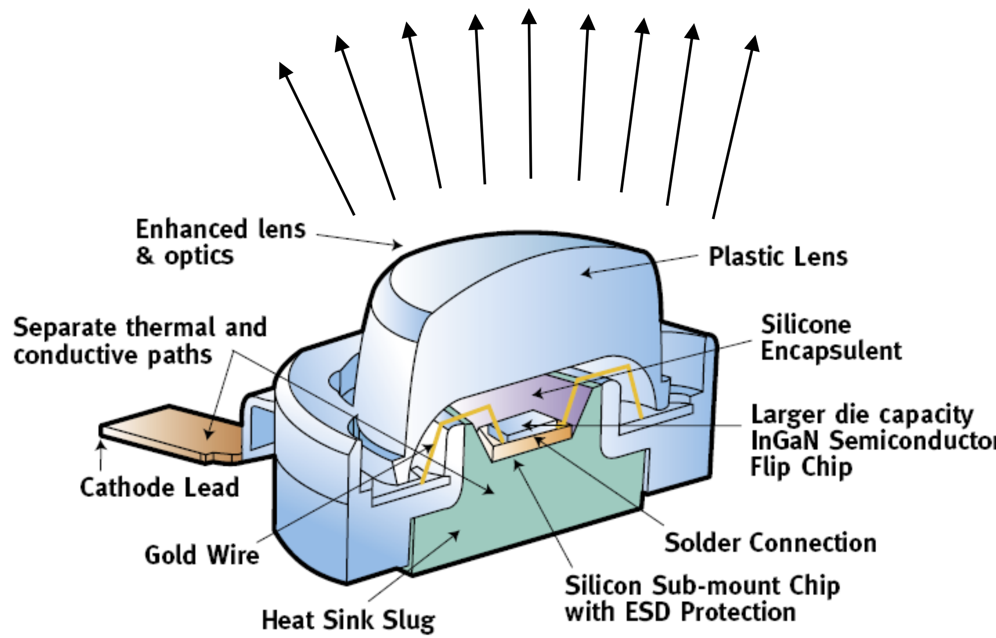
Basic and Advanced LED Lighting Technologies

Fewer Light Rays Exit the Lens



More Light Rays Exit the Lens



Basic Technology

Lower Efficiency

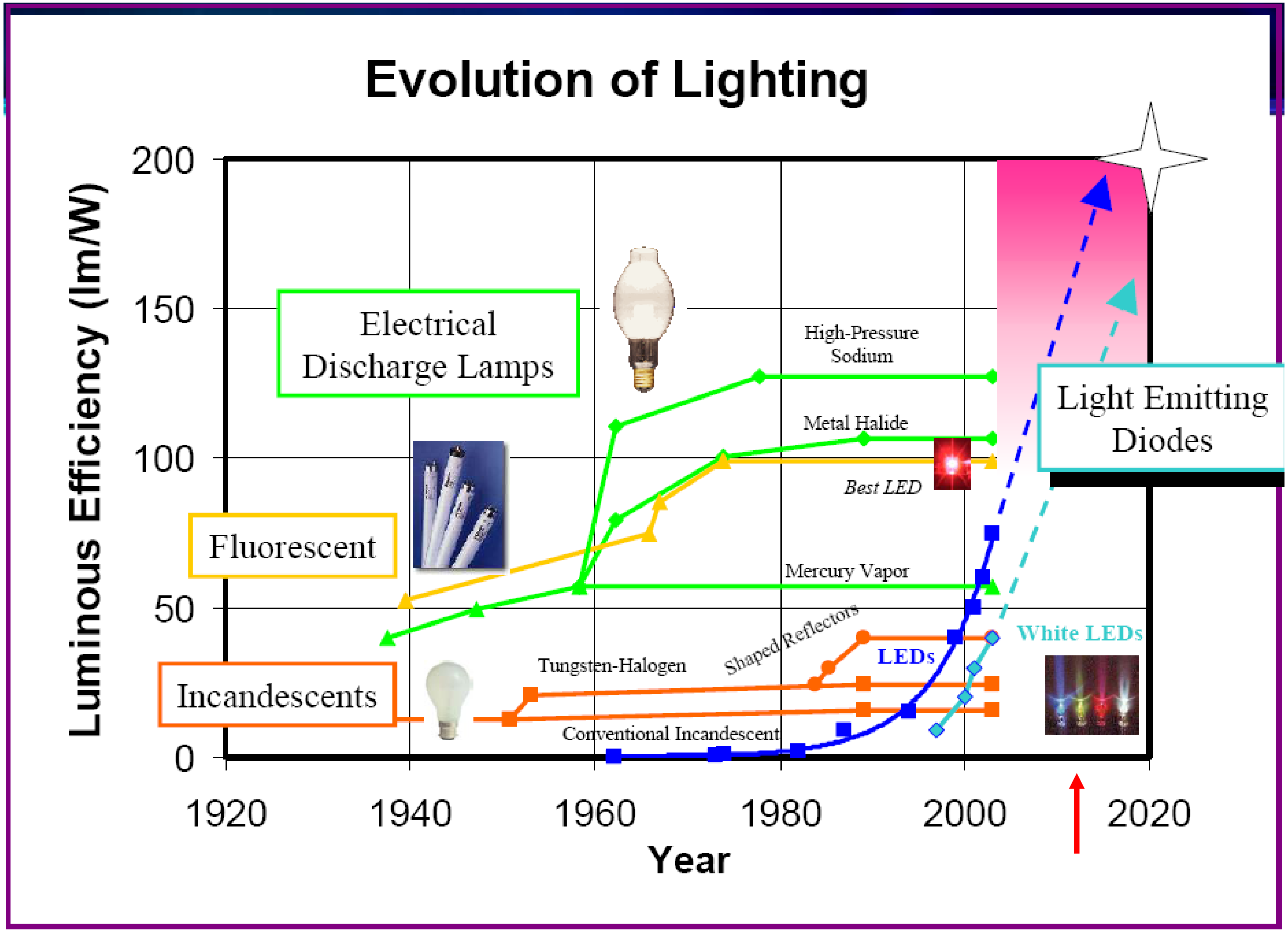
Advanced Technology

Higher Efficiency

Courtesy: Philips Lighting

Efficacies of Different Common Light Sources

Incandescents, Fluorescents, HIDs, and LEDs



Courtesy: Lumaleds

Comparison of LED and HID Lighting

HID				LED				
HID Lamp	Photopic Initial Delivered Lumens	Photopic Average Delivered Lumens	System Watts	Recommended Number of Light Bars	Recommended Photopic Initial Delivered Lumens	Recommended Photopic Average Delivered Lumens Over 50,000 hours	System Watts	Energy Savings %
PS 70 (H)	3,500	2,200	90	2	3,400	3,230	55	-39%
PS 100 (H)	5,650	3,550	127	2	3,400	3,230	55	-57%
PS 150 (V)	9,800	7,200	190	4	6,800	6,460	104	-45%
MH 175 (V)	9,800	6,300	210	4	6,800	6,460	104	-51%
MH 250 (H)	13,250	8,300	289	5	8,500	8,075	128	-56%
PS 320 (H)	21,000	15,500	368	7	11,900	11,305	183	-50%
MH 400 (H)	22,700	14,500	455	9	15,300	14,535	232	-49%
PS 400 (H)	28,000	22,000	450	12	20,400	19,380	306	-32%
HPS 70	4,450	3,900	105	2	3,400	3,230	55	-48%
HPS 100	6,650	6,050	130	2	3,400	3,230	55	-58%
HPS 150	11,150	10,100	188	4	6,800	6,460	104	-45%
HPS 250	19,600	19,000	300	6	10,200	9,690	153	-49%
HPS 400	35,000	32,000	460	9	15,300	14,535	232	-50%

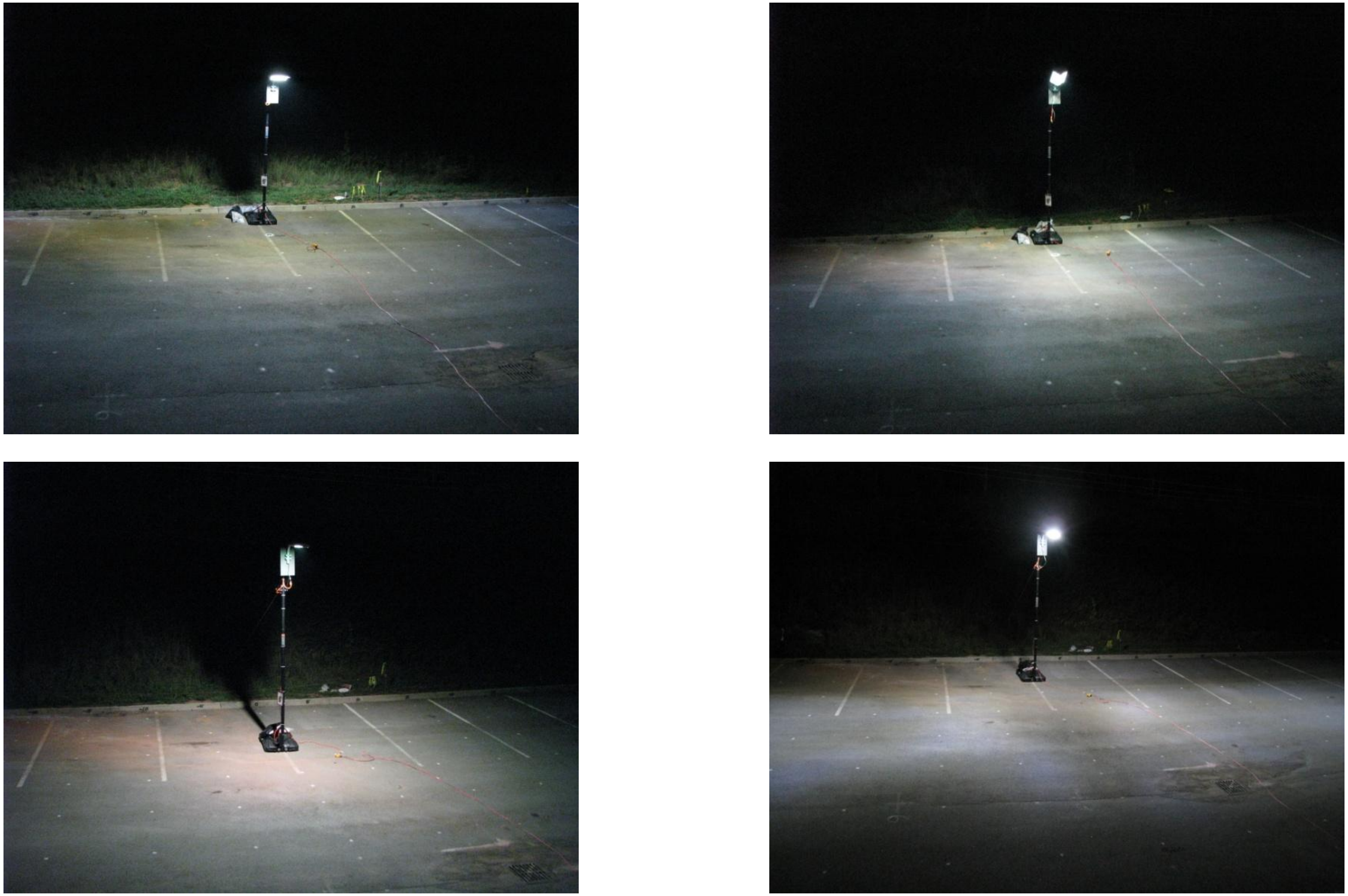
Ref: Beta-Kramer

LED* for Street and Area Lighting

Source: http://betaled.com/docs/Comparison%20Chart-Gen%20B-Oct2008.pdf Retrieved February 2009.

LED – Light Emitting Diode, a semiconductor material that when energized emits light.

Light Patterns and Color Vary



Example Audit Outdoor Perimeter Lighting Replaced with LED

- The plant has replaced 20 of their 96 outdoor metal halide lights (454W each) with LED units (56W each).
  - Saving $1760/year
- LED units will cost less per year to operate, but payback is over 9 years.
- Replacing all outdoor units with LEDs could save $6.7k/year, but at a current expense of about $61k.

Technology	Cost/Fixture	Total Fixtures	kW/Fixture	Hrs/Year	KW Total	kWH Total	Cost/kWH	Cost/Year	
Metal Halide	$216	1	0.458	4380	0.458	2006.04	0.05	$100.30	
LED	$800	1	0.056	4380	0.056	245.28	0.05	$ 12.26	
							Savings	$ 88.04	
							Costs	$800	
							Payback	***9.04***	***Years***

Use of Premium Efficiency Motors

Electric Motor Use and Energy Savings in US

- U.S. Installed Base is 90 Million Electric Motors
  - Industrial & Commercial Electric Motors is 40 Million
- According to DOE estimates (1998), potential industrial motor system energy savings using mature, proven, cost-effective technologies range from 11-18 percent of current annual usage or 62 to 104 billion kWh per year in the manufacturing sector alone
  - Savings is valued up to $5.8 billion
  - Reduction of CO_2 emissions of about 29.5 million metric tons annually
- DOE (2010) estimates that the new small motor efficiency rule will save 2.46 quads (1 quad = 10^15 BTU) of cumulative energy over 30 years (2015–2045)
  - 2.13 quads of savings result from standards on capacitor-start (single-phase) motors
  - 0.33 quads of savings result from standards on polyphase motors

Global Perspective

- Electric motor-driven systems makes up about 19 percent of the global electricity demand
  - This is more than twice as much as the next-largest user, lighting
- Electricity consumption by motors could double to 13,360TWh per year by 2030
  - Equivalent to emitting 8,570 million tons of CO_2
- End users are now spending about $565 billion on electricity to power electric motors
  - This could increase to $900 billion by 2030 without improvement
- Use of high-efficiency motors alone could cut energy consumption by 4-5%
- By adopting the best technologies, the world's electricity demand could be cut by 3,890TWh a year by 2030
  - Equivalent to reducing CO_2 emissions by 2,490Mt

Source: IEA, Energy-Efficiency Policy Opportunities for Electric Motor-Driven Systems, 2011

Motors and Drives - Minimum Energy Performance Standards (MEPS)

1-200HP: **76.7-93.5%**
Pre-EPAct

1992

1-200 HP: **82.5-95%**
EPAct (USA)[1]

1998

Eff 1: High
Eff 2: Improved (equiv to EPAct)
Eff 3: Standard Efficiency Classes
CEMEP (Europe)[2]

2007

1-200 HP: **85.5-96.2%**
201-500 HP: **96.2%**
NEMA Premium Efficiency
EISA 2007 (USA)[3]

2008

1-500 HP
IE1: Standard
IE2: High (equiv. to Eff2 and EPAct)
IE3: Premium Efficiency Classes
IEC 60034-30 (Worldwide)[4]

2010

0.25–3 Hp (2-digit frames)
DoE Small Motor Efficiency
10 CFR Part 431 (USA)[5]

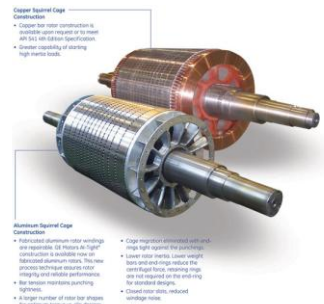
2015

Super-Premium (**IEC 60034-30 IE4: 15% lesser losses than IE3/NEMA premium**) and migration to drive integrated systems[6]

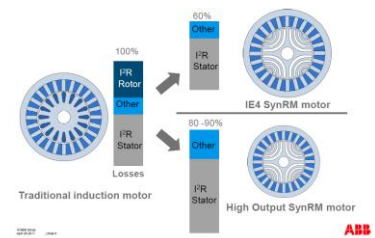
Ultra-premium Efficiency (**1-2% > IE3/NEMA Premium**)

Standard induction motors

Induction motors better lamination, tighter tolerance, better winding

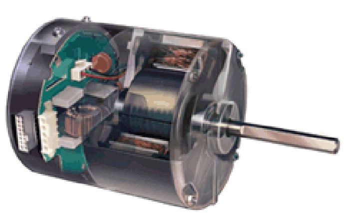


Copper rotor/superconducting motors
Motors with ceramic bearings
Enhanced magnetic texture steel (EMTX)



Increasing penetration of variable speed motor systems (BLDC, Switched reluctance, PMSM motors)

PM motors (DLPMSM) and other advanced motors (SynRM) needed to meet IE4



Direct drive applications to improve system efficiency

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Motors and Drives (Footnotes from previous slide)

[1]EPAct 1992 covered only general purpose motors in the 1-200 HP range

[2]European CEMEP was a voluntary standard with three efficiency classes EFF1-3; now replaced by IEC 60034-30

[3]EISA 2007 standards mandatory for new motors from December 2010. Expands standards to all general purpose motors upto 500HP as well as Type II motors

[4]IEC60034-30 mandates all motors in EU to meet IE3 by January 1, 2015

[5]Small motors are defined as 2-digit frames not part of EISA 2007. Standard will be mandatory from 2015

[6]EISA Future efficiency standards to focus on IE4 and introduction of drives to increase energy savings

Electric Motor Use

- Process motor systems account for 63% of all electricity used in industry
- Most motors are at least 30% under loaded
- A third of motors are run below 50% load

United States Industrial Motor Systems Marketing Assessment Executive Summary, U.S. Department of Energy, December 1998

Motor Decisions Matter web site

"Introduction to Premium Efficiency Motors" - by the Copper Development Association

Induction Motor Losses (1)

- Induction Motor Losses
  - Power Loss
  - Magnetic Core Loss
  - Friction and Windage Loss
  - Stray Load Loss

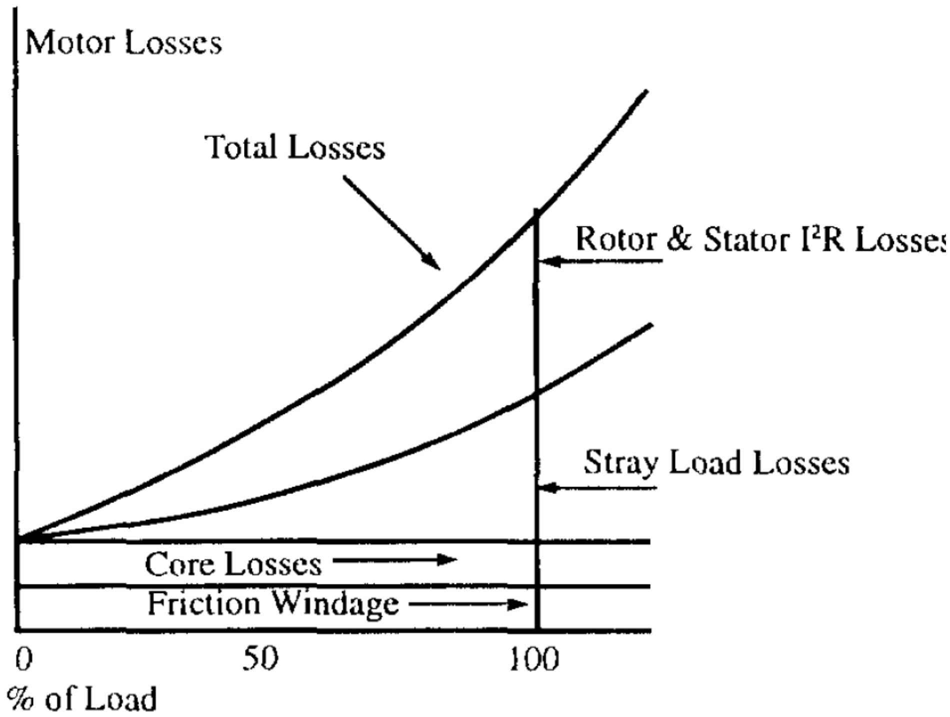
"Introduction to Premium Efficiency Motors" - by the Copper Development Association

EASA, Understanding Energy Efficient Motors. [Online]. Available: http://www.easa.com/indus/ee_399.pdf

Type of Loss	Typical % of Losses 4-Pole Motors	Factors Affecting These Losses
Stator winding losses	35 to 40	Stator conductor size and material
Rotor losses	15 to 20	Rotor conductor size and material
Stator core losses	15 to 20	Type and quantity of magnetic material
Stray load losses	10 to 15	Primarily manufacturing and design methods
Friction and windage	5 to 10	Selection/design of fans and bearings

Reference: NEMA Stds. MG 10-1994, Table 2-2.

The above values show the typical loss distribution for medium induction motors. Speed, size, and enclosure type lead to wide variations in some of these proportions, particularly the core and friction and windage losses.



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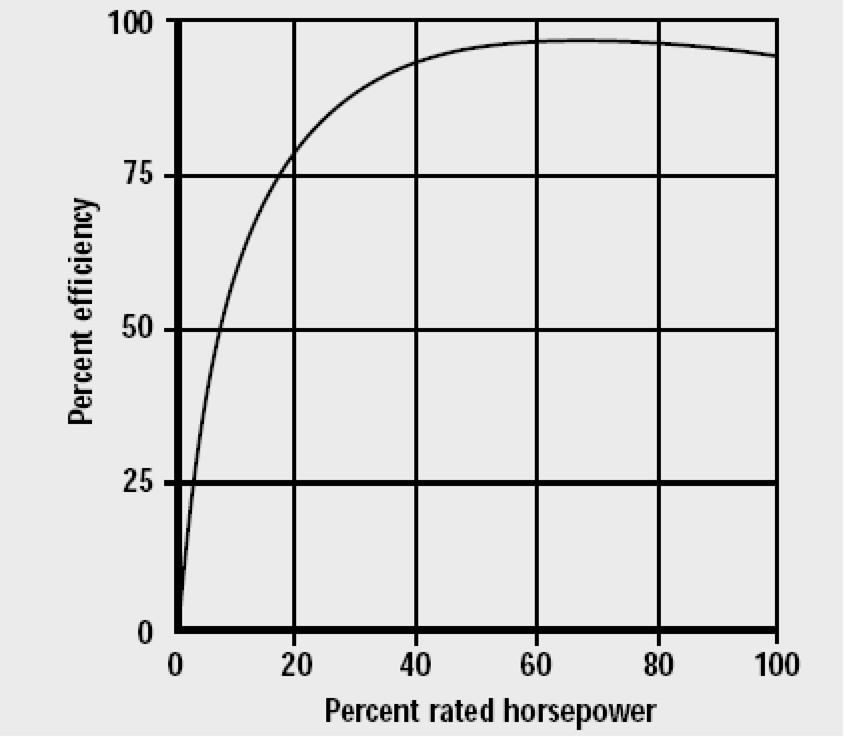
Induction Motor Losses (2)

- Power losses (also called I^2R losses) and stray load losses appear only when the motor is operating under load
- Power losses are comprised of stator and rotor I^2R losses
  - They are therefore more important — in terms of energy efficiency
  - Stator losses may make up to 66% of power losses
- Magnetic losses can account for up to 20% of total losses

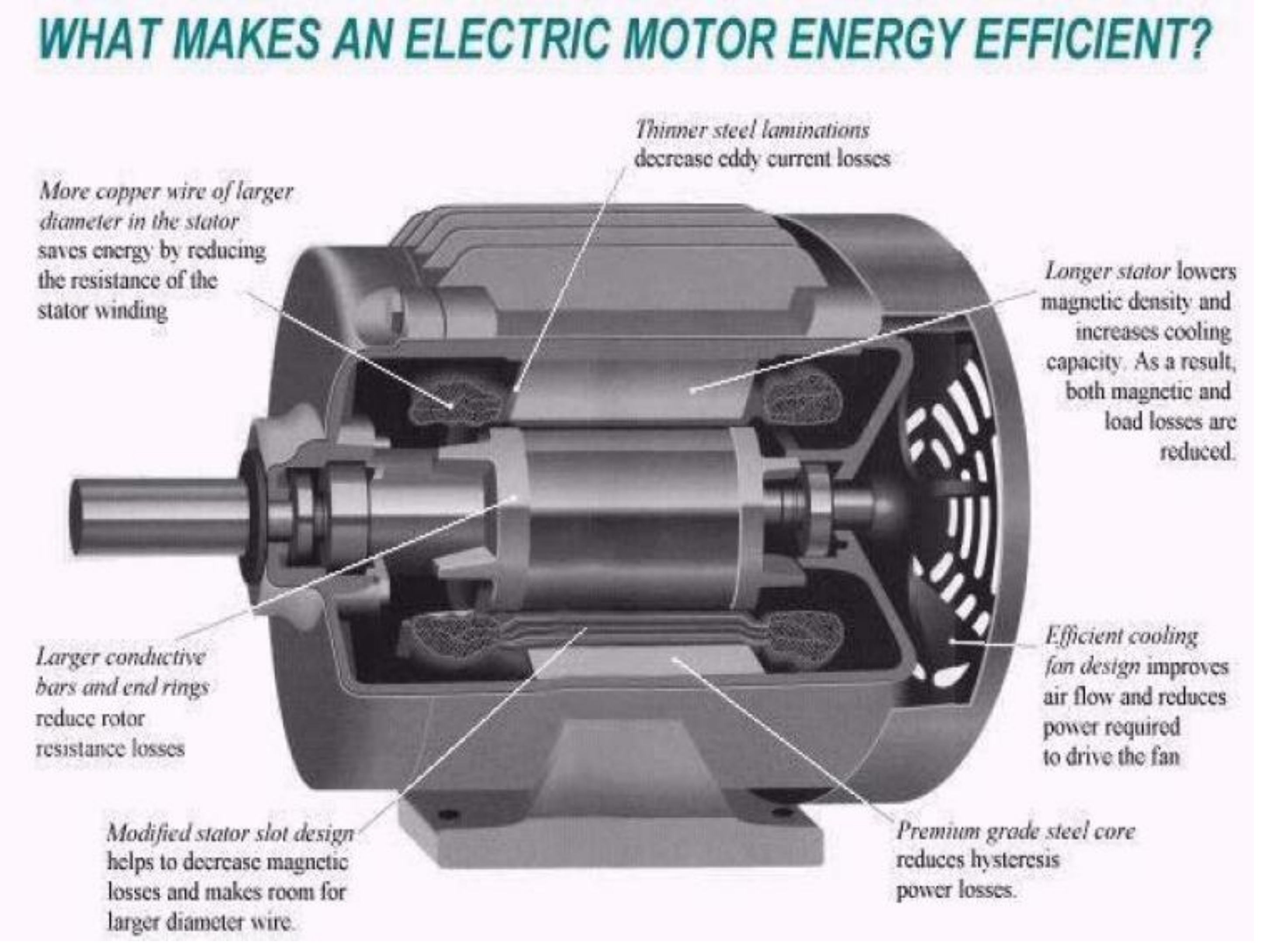
"Introduction to Premium Efficiency Motors" - by the Copper Development Association

Typical Induction Motor Efficiency



EASA, Understanding Energy Efficient Motors. [Online]. Available: http://www.easa.com/indus/ee_399.pdf

Improving Induction Motor Efficiency (1)



http://www.iea.org/Textbase/work/2006/motor/Benkhart%20APT%20May%2016.pdf

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Efficiency Opportunity Through Motor Rewinding

- Traditional fast rewinding can decrease efficiency by 20%
- Since motors are frequently operated for 20 to 30 years, a motor may be repaired 3 to 5 times in its service life
- For every new motor sold, approximately 2.5 motors are repaired
- Improper rewinding can significantly decrease motor efficiency (actual numbers vary from source to source, but in the range of 5-20%)
- Sophisticated rewind can increase efficiency
- Improved methods of rewinding failed motors can contribute an additional 4.8 billion kWh (DOE, 1998)

Guidelines for maintaining motor efficiency during rebuilding, Electrical Apparatus Service Association (EASA), 1999

Induction Motor Energy Opportunities Summary

- Use of copper rotors can decrease rotor losses
- Use of thinner laminations may decrease magnetic losses
- Use of better steel lamination materials
- Careful motor selection based on load
- Proper operation – balanced supply, less voltage harmonics…
- Specialized rewinding can improve efficiency
- The next step – Super Premium Efficiency Motors
- Large scale improvements also possible in single-phase induction motors

Good Place to Start – Your Spare Inventory

- *Its Rarely Justifiable to replace a motor before failure.*
- *Tools like DOE's ITP Motor Master + can help you find more efficient replacements.*

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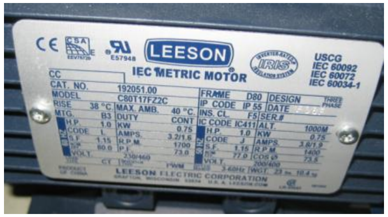
Example Motor Efficiency Assessment

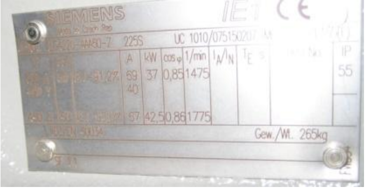
- Plants keeps many backup motors in spares
- In some cases, plant replaces process motors with like units or rewinds for larger motors if possible.
- Replace failed motors with like units
  - DOE ITP Motormaster+ not being used for determining most efficient motor replacements.
- As plant equipment is not new, "like" motors may not be most efficient.

1 hp, 80% => 85.5% Premium

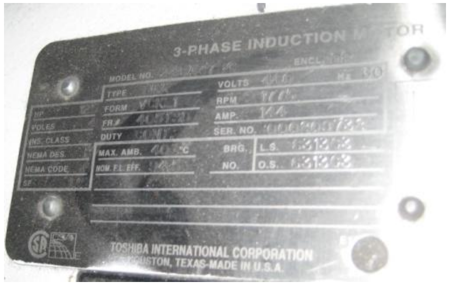


5hp, 87.5% => 91.7% Premium

50hp, 87.5% => 95.0% Premium



125hp, 94.5% => 95.8% Premium



Example Motor Efficiency Recommendations

- Assessment of motor efficiency of inventory is in progress from nameplate data
  - Spot analysis shows that there are opportunities for energy efficiency savings
  - 50 hp range may represent largest opportunity for this customer
- Recommend detailed inventory against Motor Master + and Motor Master + International
  - Begin procuring more efficient ***replacement*** motors
  - Focus on units with highest savings/year versus motor cost
    - (e.g. payback for 50hp premium efficiency motors ~3 years based on list price)

ECM No. _____ Use Premium Efficient Motors

Cost/kWh	0.0734	Average kWh Costs						
Operating Hrs/yr	8000							
Motor Loading	75%	% Loaded						
Motor Size (HP)	kW	Existing Eff.	Cost/Year (A)	Prem. Eff.	Cost/Year (A)	Savings/Year	No. in Plant	Savings/Year
1	0.7456	0.8	$ 410	0.855	$ 384	$ 26	30	$ 792
5	3.728	0.875	$ 1,876	0.917	$ 1,790	$ 86	50	$ 4,297
50	37.28	0.875	$ 18,764	0.95	$ 17,282	$ 1,481	25	$ 37,033
125	93.2	0.945	$ 43,434	0.958	$ 42,845	$ 589	10	$ 5,894
						Estimated Yearly Savings		$ 48,016

A. Cost per Year calculated by (kW)x (Motor Loading)x(Hours/Year)/Efficiency

B. From Motor Master Plus List

Remember Load Factor (% Loaded)

- Theoretical:
  - kW Saved = 0.746 * hp * [(1/eff. Motor 1)- (1/eff. Motor 2)]

- Actually:
  - kW Saved = 0.746 * hp * LF *[(1/eff. Motor 1)- (1/eff. Motor 2)]
  - Where LF = Load Factor (percent of full load)

- If actual load is less than 50% of its nameplate, efficiency nameplate is meaningless.
- Part load efficiency number would be to needed accurately to calculate
  - i.e. 75%, 50%, 25% load efficiencies

Watch Out for Direct-Coupled Centrifugal Loads when estimating energy efficiency

- Energy Efficient motors have less slip.
  - Motor will run a few rpm faster
- For direct-coupled centrifugal loads (Pumps and Fans), this can result in an increase in work output
- When the high efficiency motor is expected to save from 3% to 5% of full load hp, this can eat away at savings.

- Example: A new motor runs 10 rpm faster
- Speed Ratio:

  1760/1750= 1.006
- Affinity Laws:

  $(N_2 / N_1)^3 = HP_2 / HP_1$

  $HP_2 = HP_1 * (N_1 / N_2)^3$

  Hp increase= (1.006)^3=1.02

  2% Energy Use Increase

Cogged and Synchronous Belts

- Standard V-belt drives can stretch up to 3% of the original length throughout the life of the belt.
  - If proper tension is not maintained, the required friction can be lost and the belt can slip. When slip occurs, additional heat is generated between the belts and grooves.
- At the time of proper installation, V-belts can run between 95-98% efficiency. The efficiency then falls to an average of approximately 93% during normal operation.
- Cogged V-Belt could save about 2% on energy, uses same pulleys as V-belt, ~95% Efficient
- Synchronous belts (also called timing, positive drive or high-torque drive belts) are on average about 5% more efficient than standard V-belts., ~ 98% Efficient
  - Require installation of mating toothed drive sprockets

V-Belt drive
~ 93% Efficient

Cogged Belt Drive

~95% Efficient

Synchronous Belt Drive
~98% Efficient

Ref: US DOE Energy Tips- Motor Systems, Replaced V-Belts with Cogged or Synchronous Belt Drives

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Cogged and Synchronous Belts

ECM No. ____	Replace V-Belt with Cogged or Synchronous Belt	
Cost/kWh	0.05	Average kWh Costs
Operating Hrs/yr	8760	
V-Belt Efficiency	0.93	Typical Value over lifetime
Cogged-Belt Efficiency	0.95	Typical Value over lifetime
Synchronous Belt Efficiency	0.98	Typical Value over lifetime
Motor Size	100	Total HP
Motor Efficiency	0.9	Percent
Motor Power Usage	83	kW
Motor Diversity	100%	% of time Motor is running
Load Diversity	75%	Average Load
Net Hours Base Loaded	6570	
Power Savings Cogged Belt	1.7	kW
Power Savings Synchronous Belt	4.2	kW
Yearly Energy Use with V-belt	544,580	kWh
Energy Savings Cogged Belt	11,465	kWh
Energy Savings Synchronous Belt	27,785	kWh
Estimated Yearly Savings Cogged Belt	$ 573	
Estimated Yearly Savings Synchronous Belt	$ 1,389	
Cost/Cogged Belt	$ 250	Site & App specific
Cost/Synchronous Belt and Sprockets	$ 1,000	Site & App specific
Estimated Payback Cogged Belt	5.23	Months
Estimated Payback Synchronous Belt	9	Months

Remember:
For centrifugal fans and pumps, which exhibit a strong relationship between operating speed and power, synchronous belt sprockets must be selected that take into account the absence of slippage.

Operating costs could actually increase if slippage is reduced and a centrifugal load is driven at a slightly higher speed.

Ref: US DOE Energy Tips- Motor Systems, Replaced V-Belts with Cogged or Synchronous Belt Drives

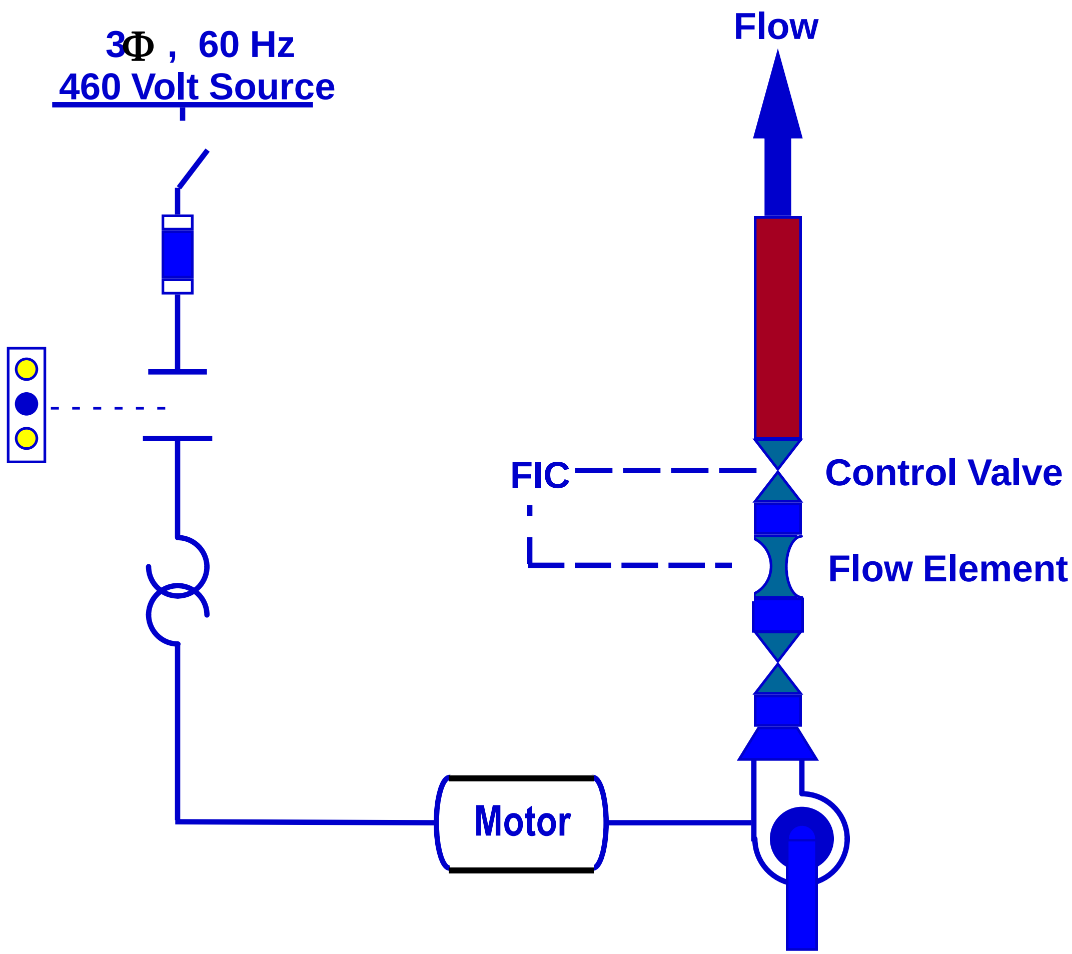
Efficient Application of Adjustable Speed Drives

Constant Speed Control

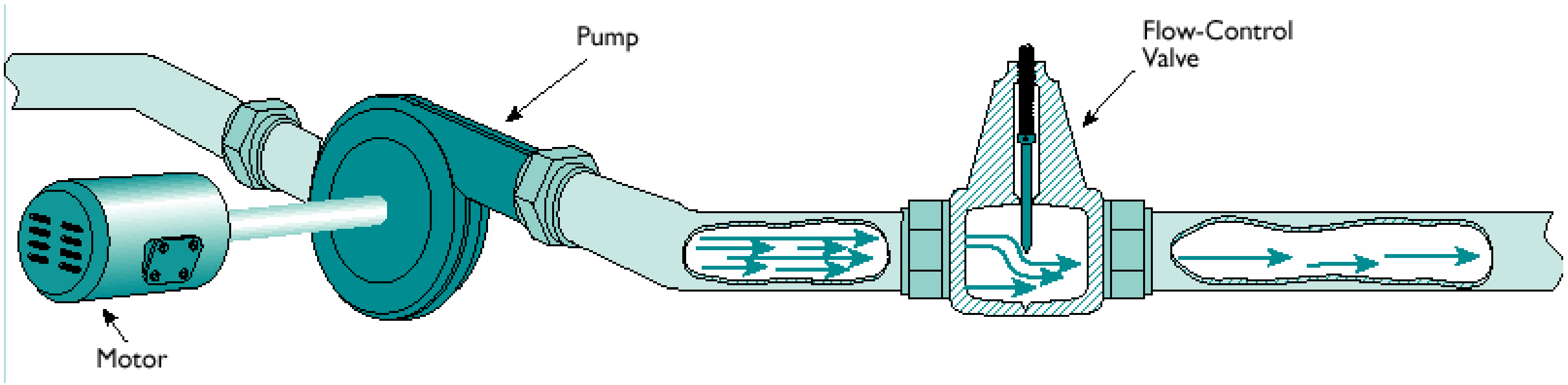
- Equipment is typically oversized to meet most extreme system requirements
- Motors are upsized to the nearest horsepower about the required for the oversized equipment
- In most cases, full performance is not required by the system
- The motor is usually in continuous full speed operation.

Running a motor at full speed wastes energy ($$$$) when full output is not required by the process.

Constant Speed Control Example

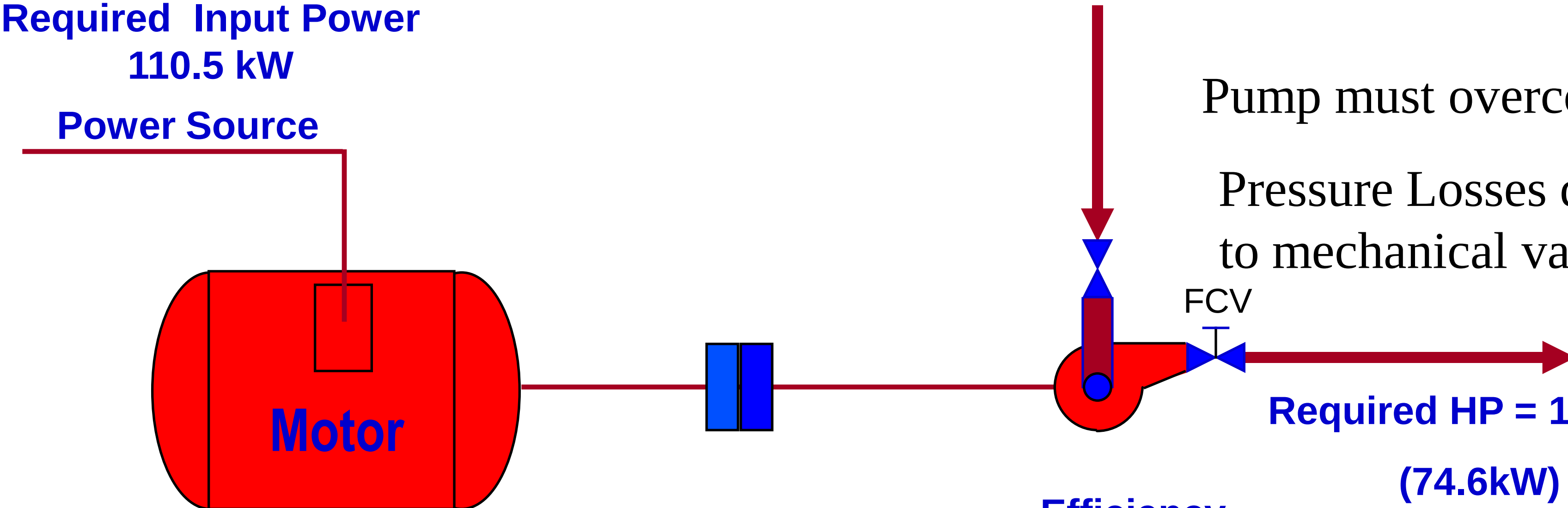


Motor Driven Process Using Flow Control Valve



Constant Speed

Required Input Power
110.5 kW
Power Source



Pump must overcome Pressure Losses due to mechanical valve

Required HP = 100
(74.6kW)

Efficiency
0.90

Efficiency
0.75

$$\text{Input kW} = \frac{\text{HP} \times .746 \text{ kW}}{\text{System Efficiency}}$$

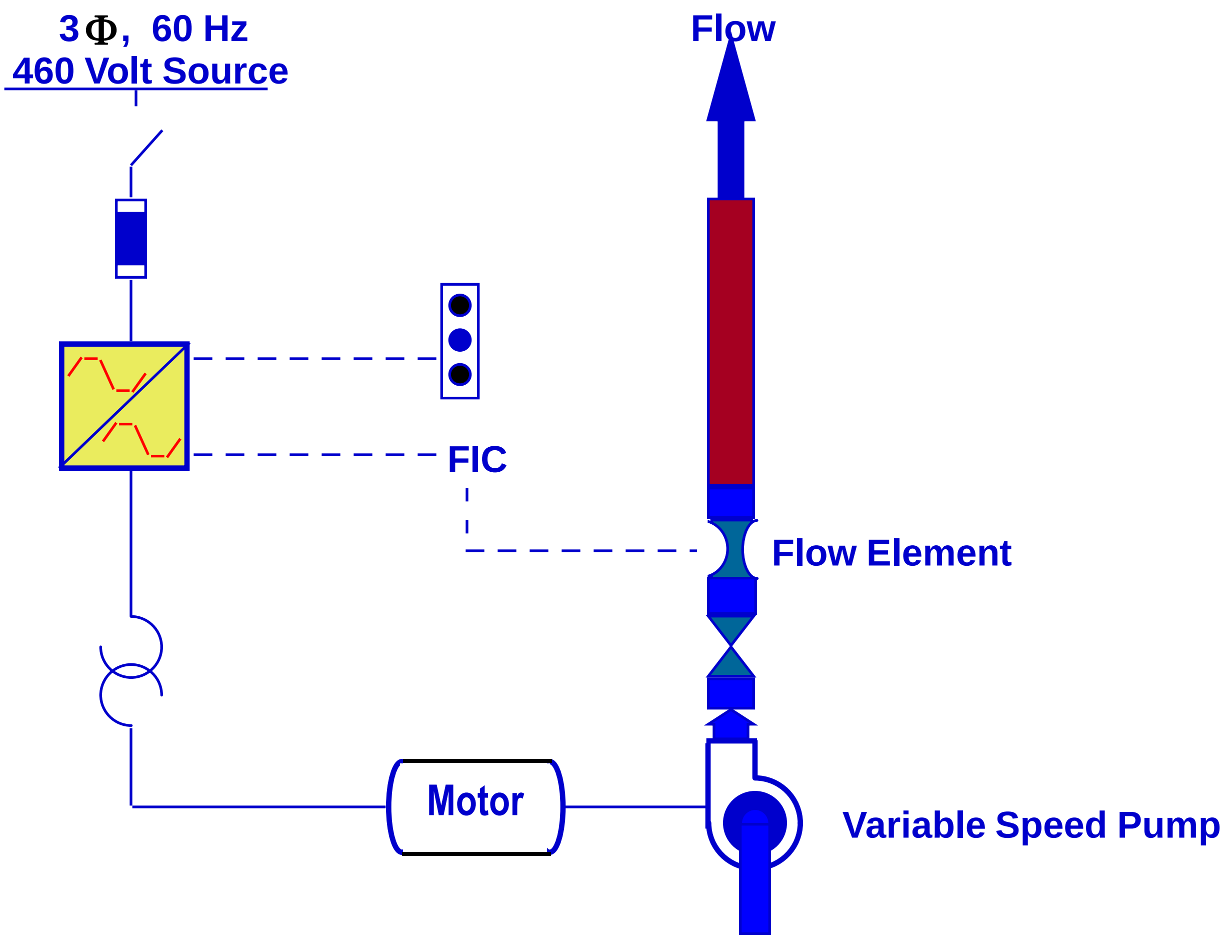
$$\text{Input kW} = \frac{100 \times .746}{.9 \times .75} = 110.5 \text{ kW}$$

Adjustable Speed Control

- Valves, clutches, brakes, and dampers typically adjusts the output of the equipment, wasting energy to varying degrees.
- Variable Speed Drives (a.k.a. Adjustable Speed Drives (ASDs) save energy by modulating the output of the motor to satisfy the changing system requirements.

ASDs Allow for Energy Efficient Control of Process Outputs

Adjustable Speed Control Example



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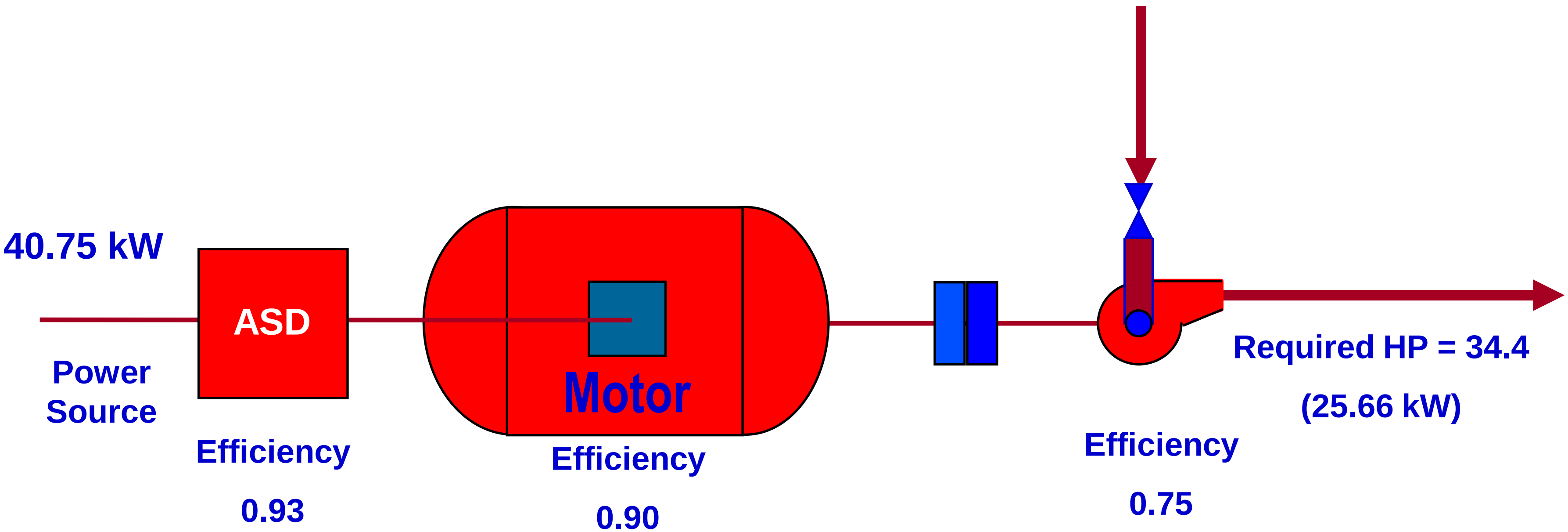
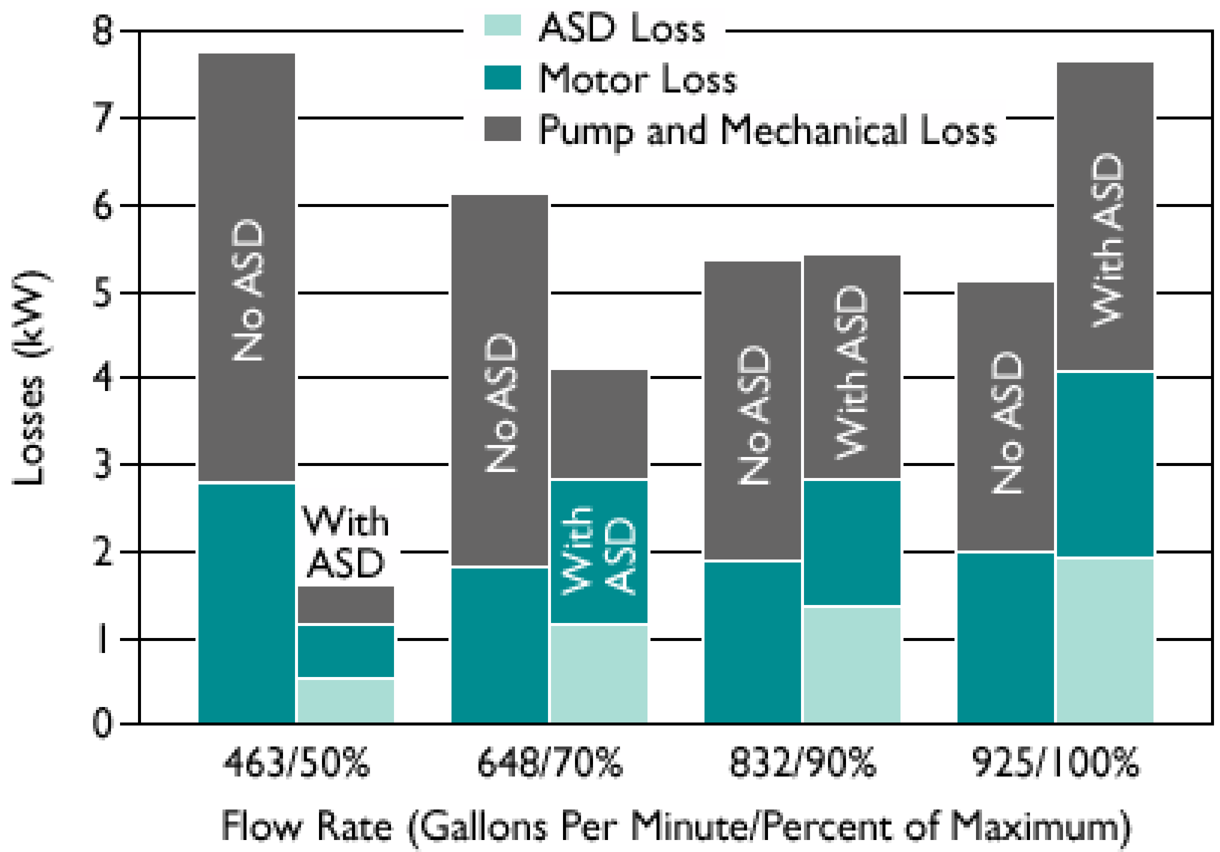
Adjustable Speed



$$\text{Input kW} = \frac{\text{HP x .746 kW}}{\text{System Efficiency}}$$

$$\text{Input kW} = \frac{34.4 \times .746}{.93 \times .9 \times .75} = 40.75 \text{ kW}$$

Example Losses In System Elements With Mechanical Control Versus ASD Control at four load Levels



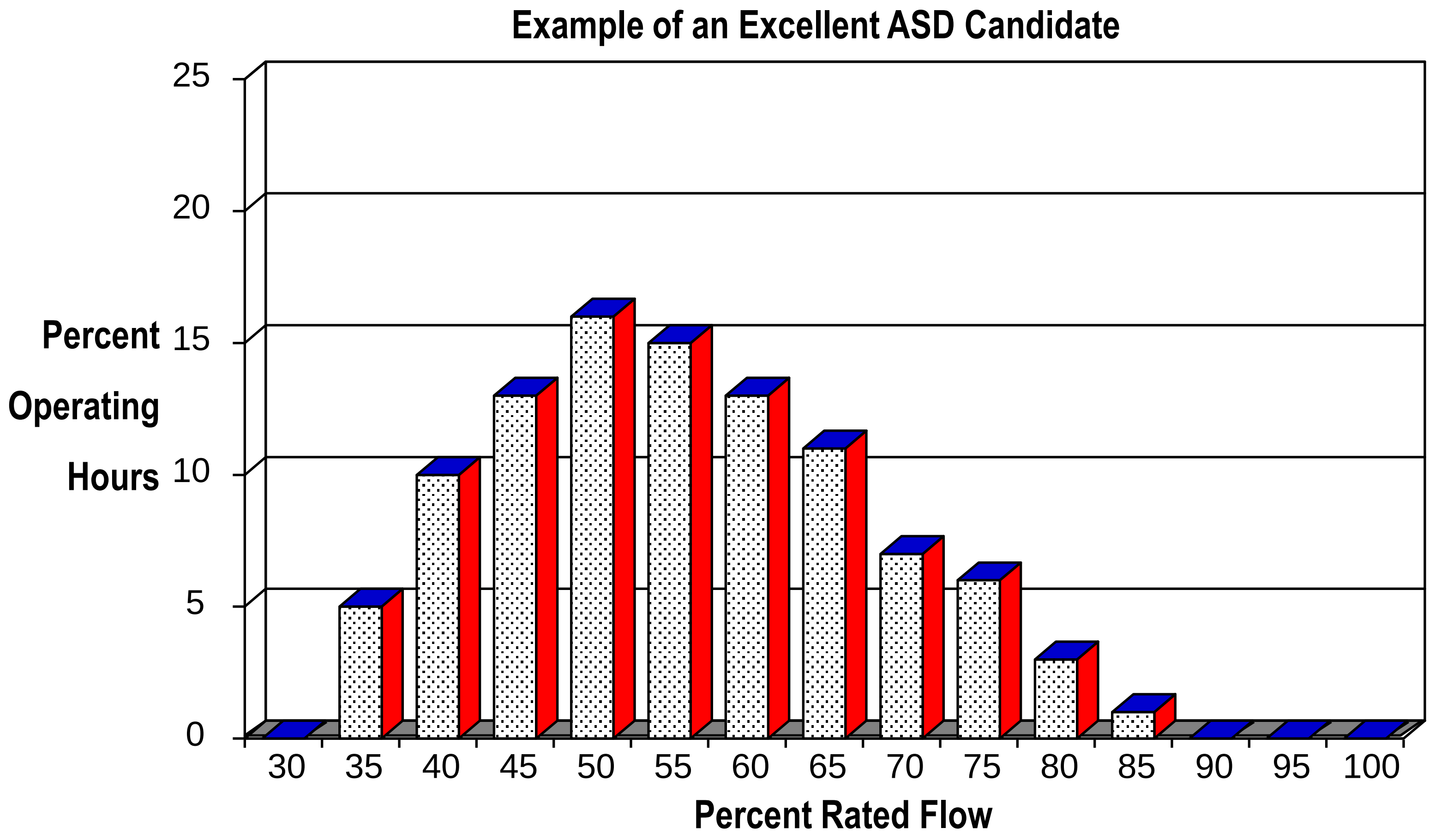
Screening Methodology

- Good Candidate for ASD if:
  - High Annual Operating Hours
  - Variable Load Characteristics
  - Moderate To High Horsepower Rating

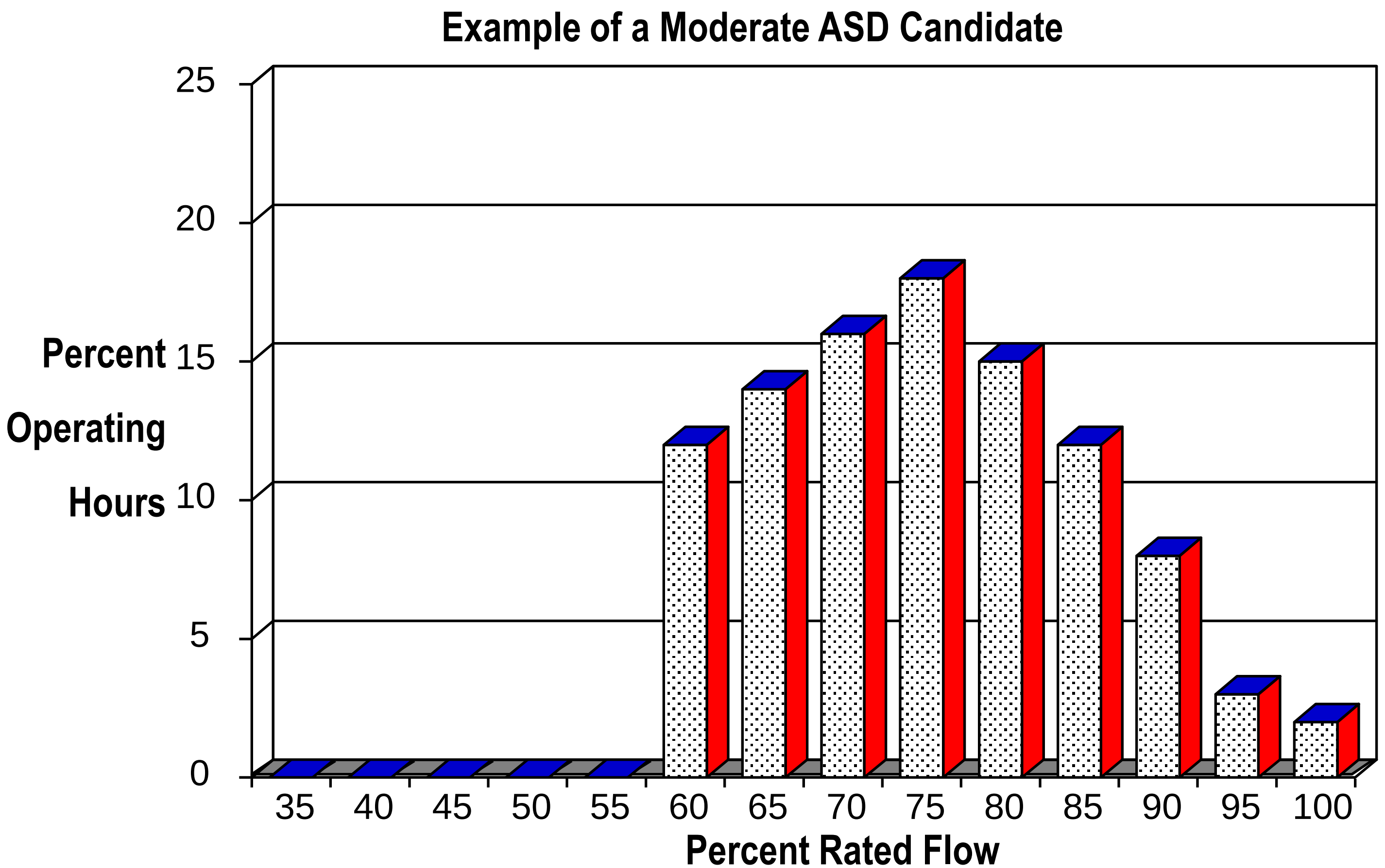
Required Information

- Motor Horsepower Rating
- Annual Equipment Operating Hours
- Fraction of Time Operate at Less Than Rated Load
- Amount of Flow Variation

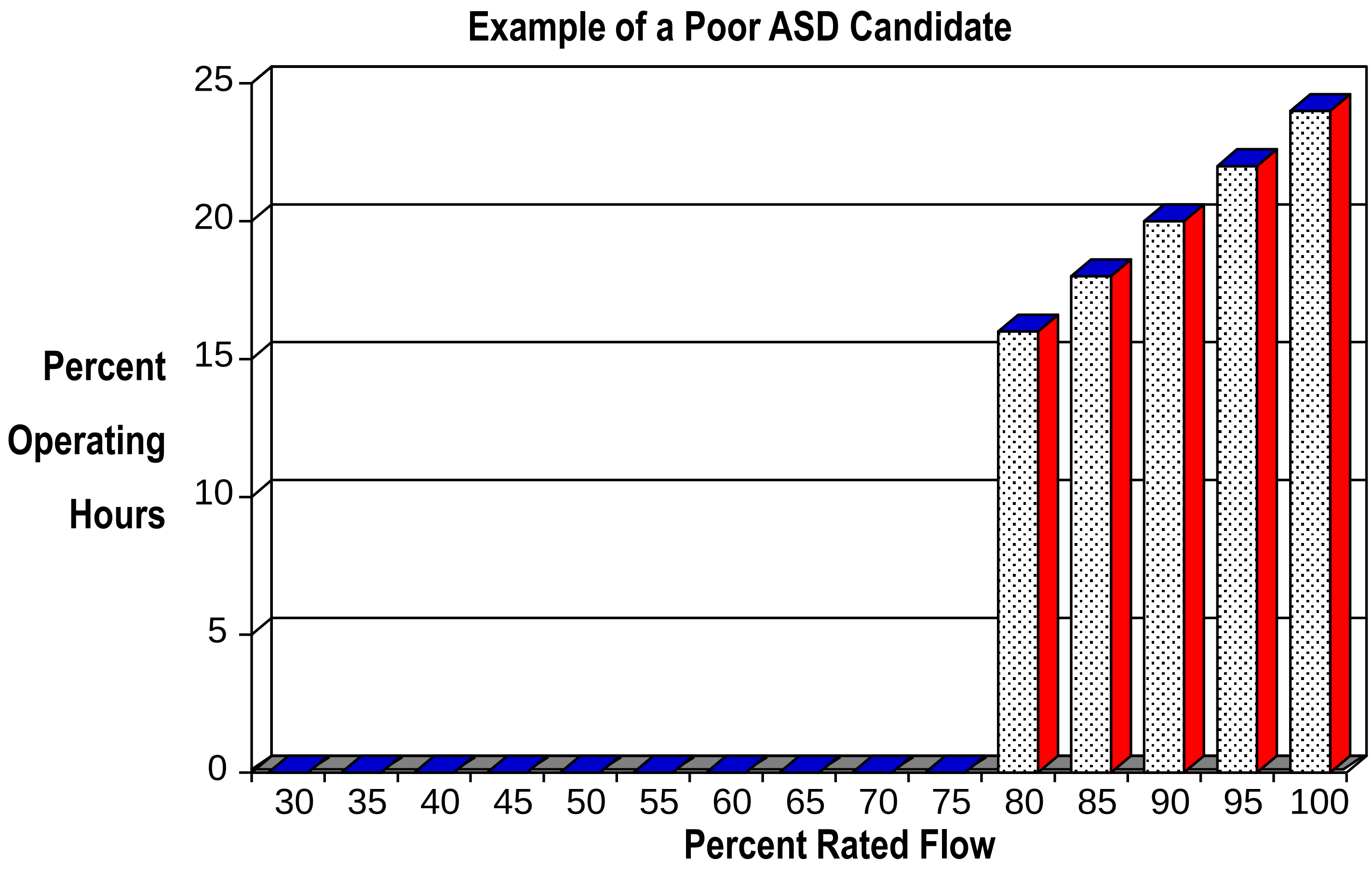
Load Duty Cycle – Excellent Candidate



Load Duty Cycle – Good Candidate



Load Duty Cycle – Poor Candidate



Example Findings in Plant

- The combustion blowers on the 5 kilns before the rotating drum dryers all utilize 60hp Motors with a throttling damper.
- Initial tests and measurements show that the operating point for flow, fan is loaded about 50% - therefore a VFD could be more feasible.

Combustion Blower

Throttling Damper

Damper Controlled at 20% Open

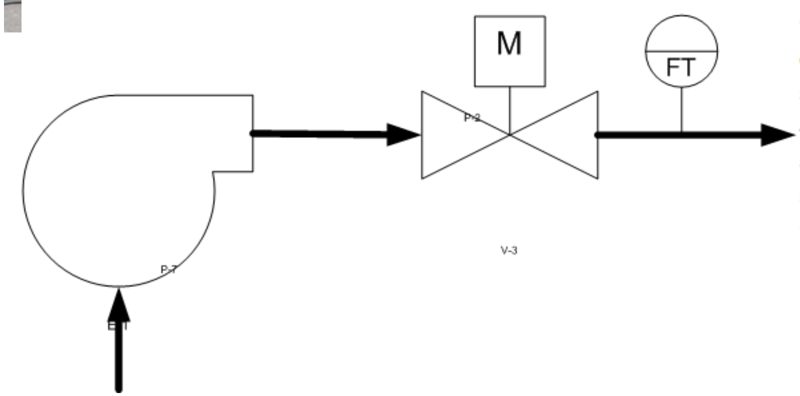
Measured Power:

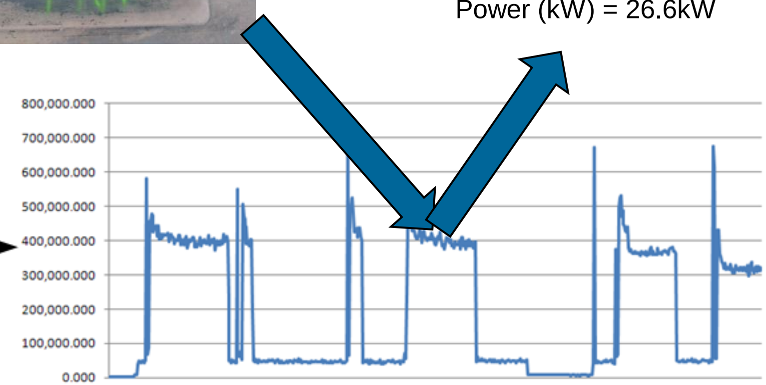
Voltage480 Vac

Avg Phase Current 35.6 Amp

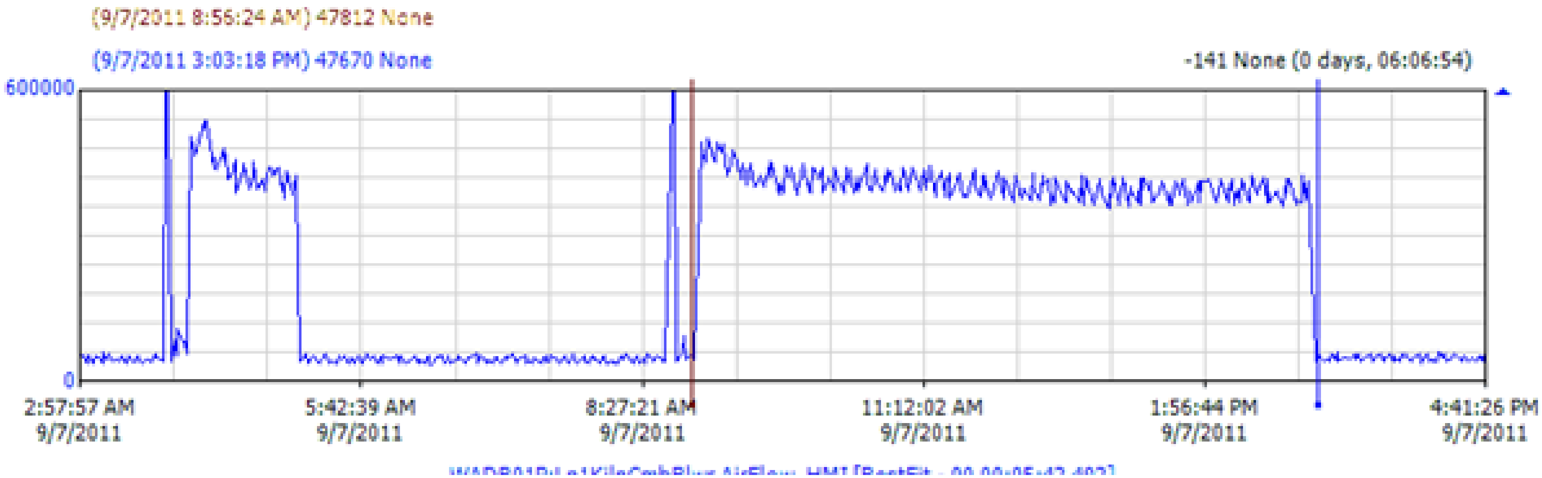
PF0.9

Power (kW) = 26.6kW

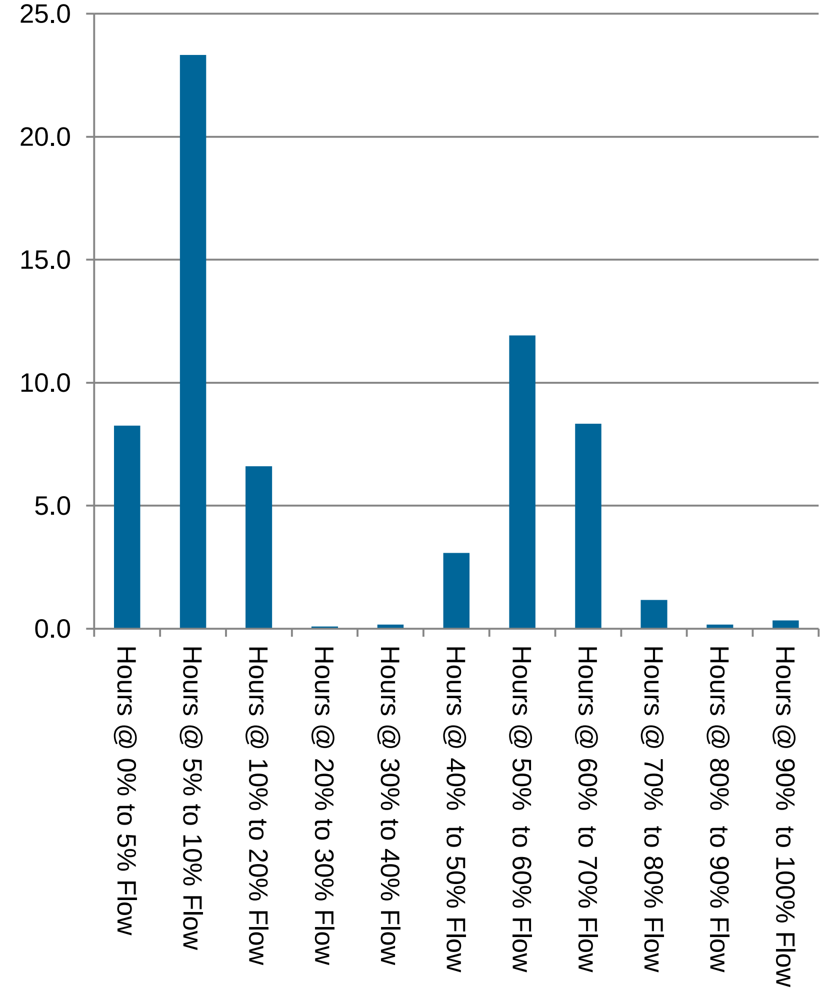


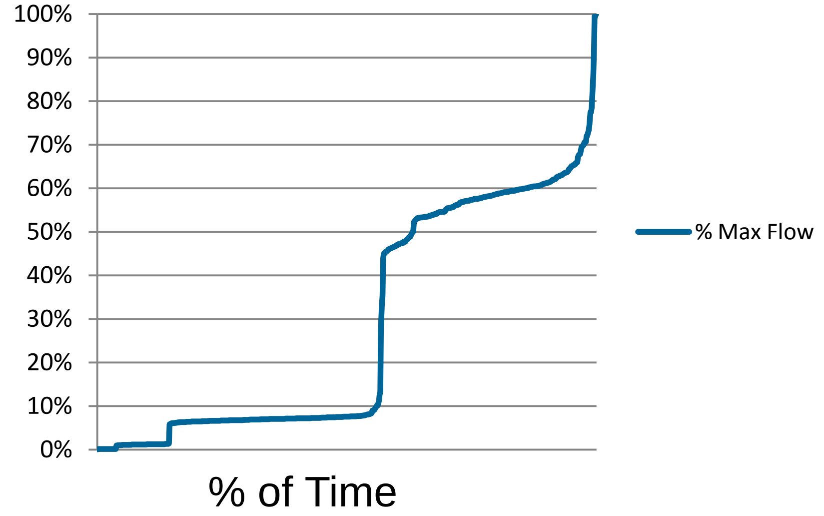


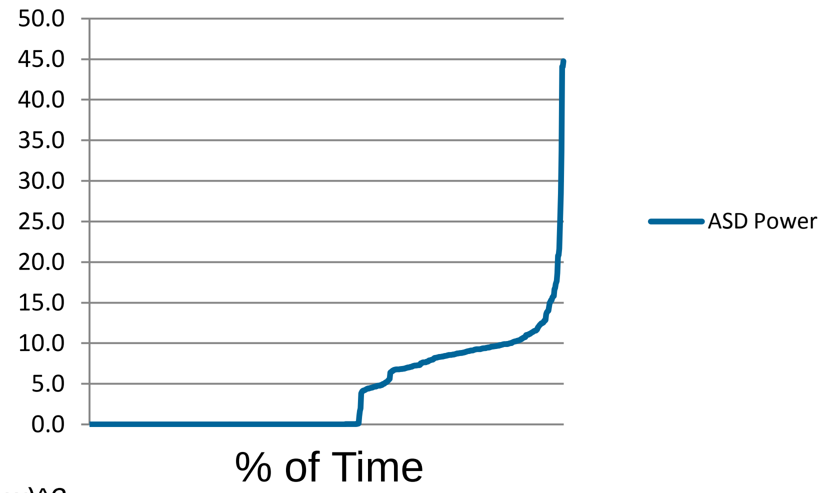
Candidate 1 – Combustion Blower



Good Drive Candidate: Combustion Blower



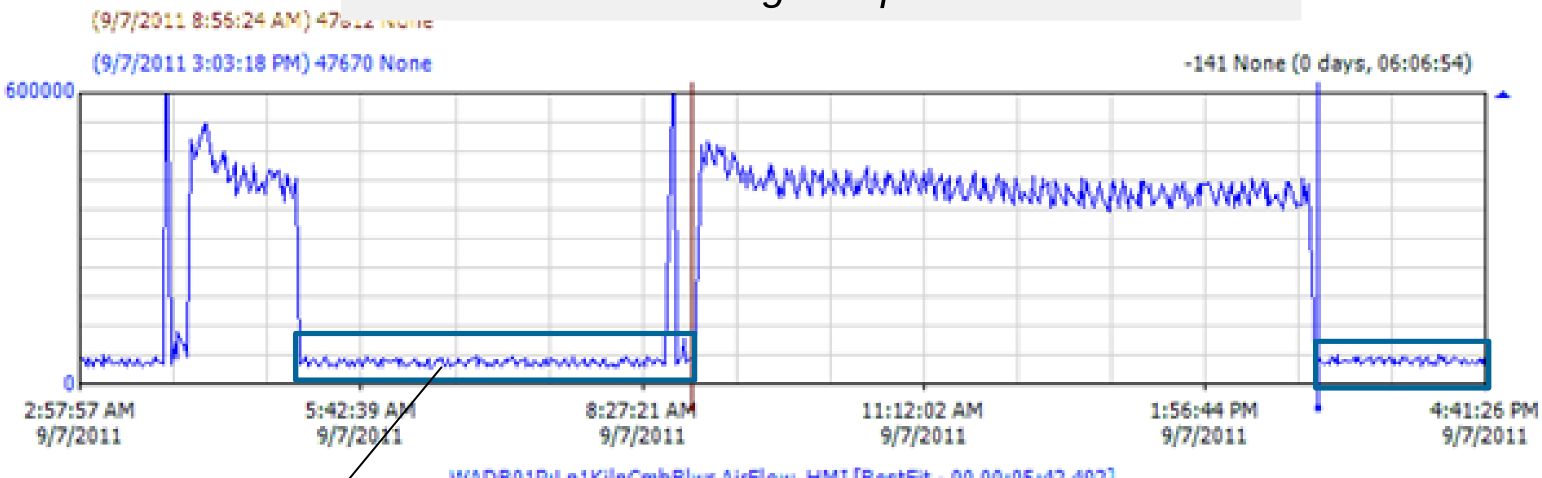




*~ASD Power => HP*0.746(Flow/Max Flow)^3*

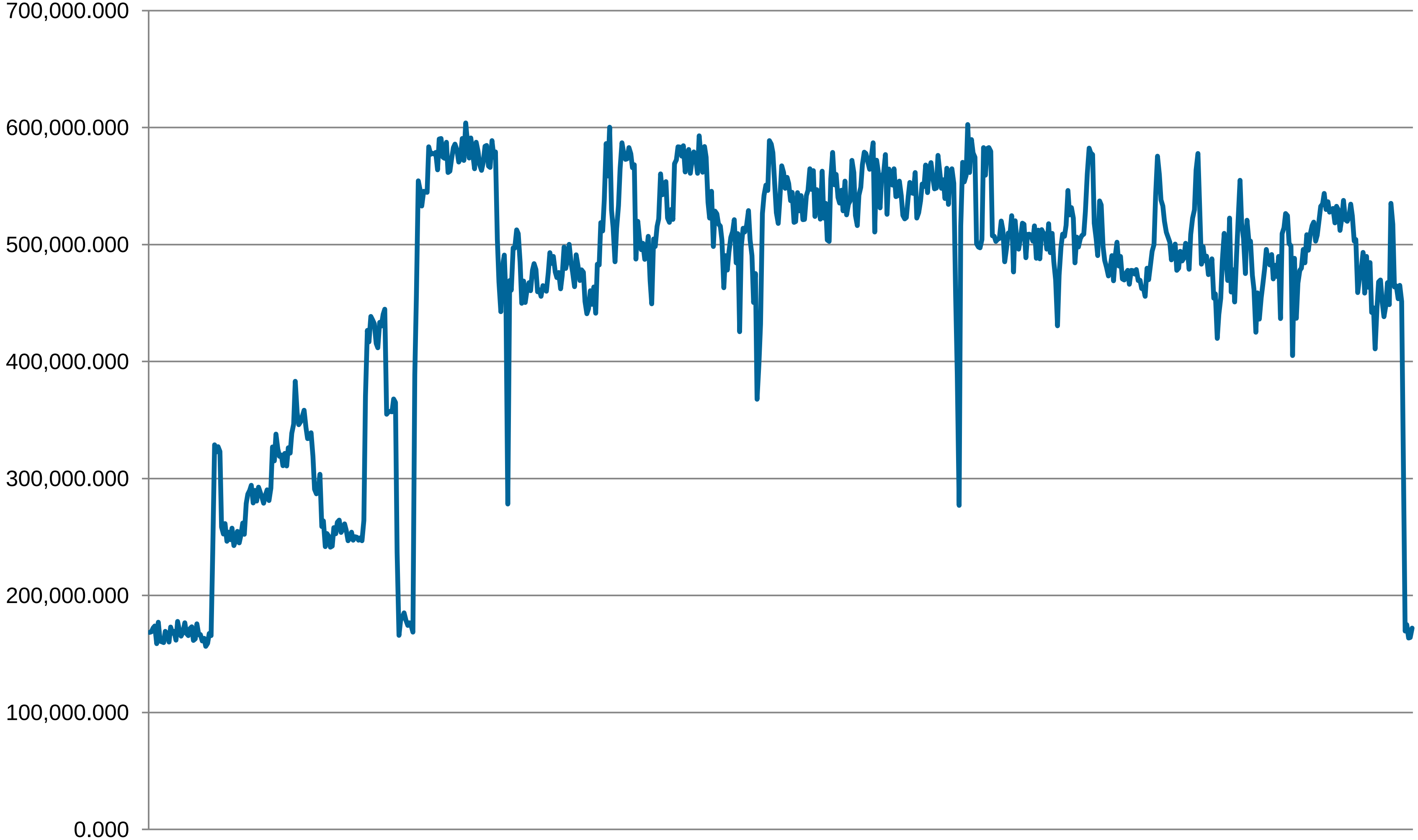
ECM – Turn off Blower!

…Combustion blowers are manually controlled via SCADA by operator. Found several instances of hours of “dead heading” a fan with the throttling damper closed.



Turn MOTOR OFF When Damper is Fully Shut!

Candidate 2 – Dryer Blower



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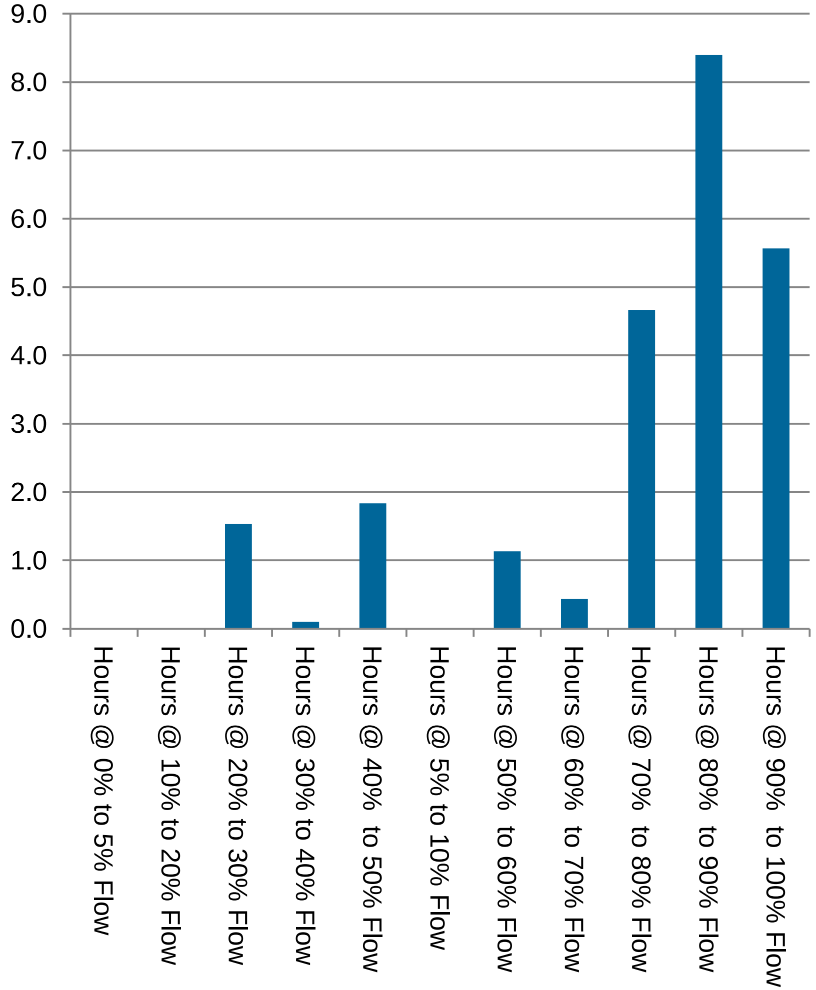
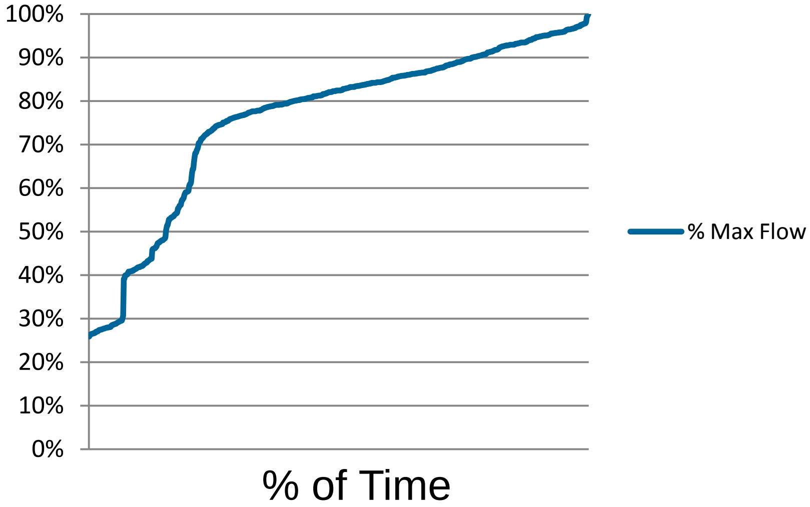
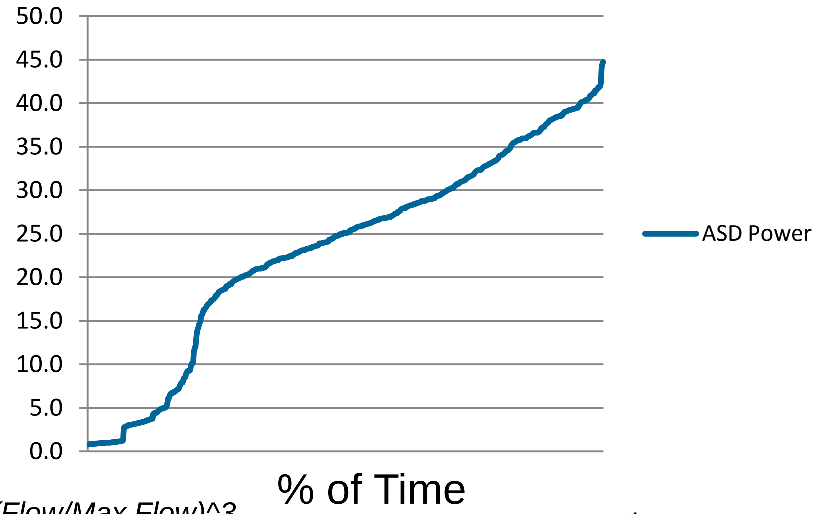
Poor Drive Candidate: Dryer Blower







*~ASD Power => HP*0.746(Flow/Max Flow)^3*

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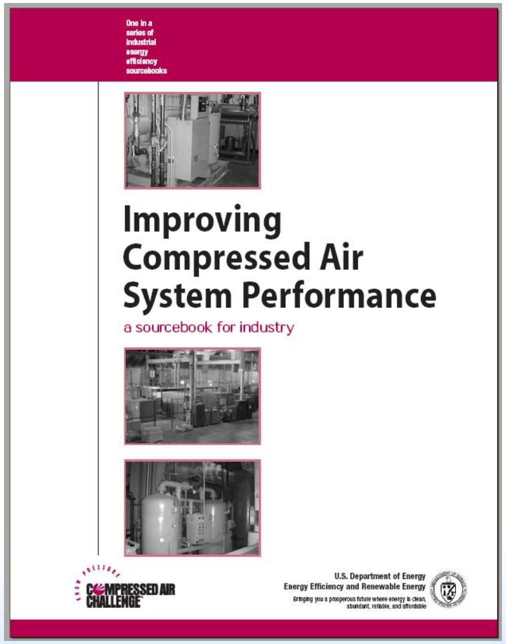
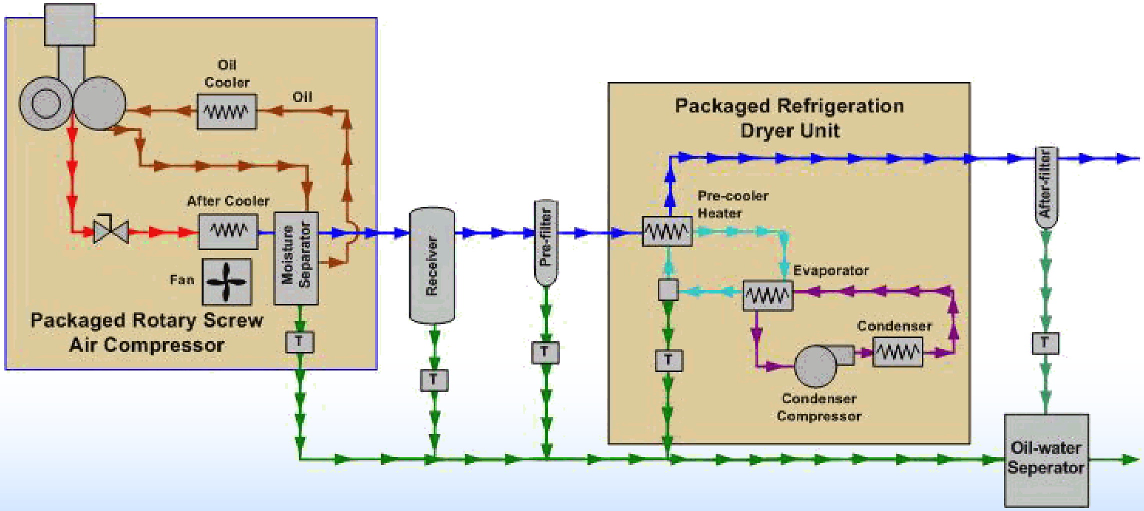
Compressed Air Best Practices



Excellent Resource: Improving Compressed Air System Performance: A Sourcebook for Industry, US DOE



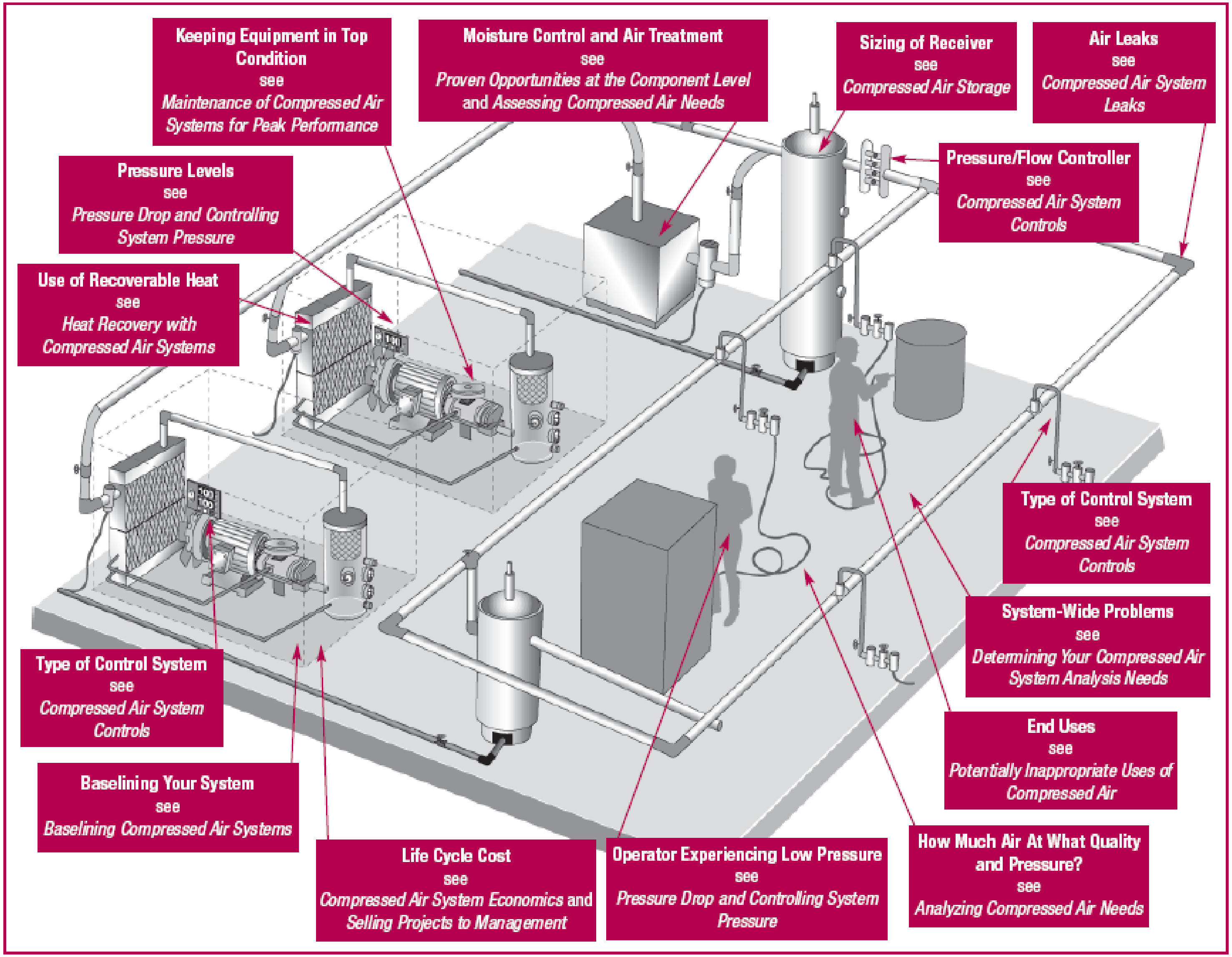
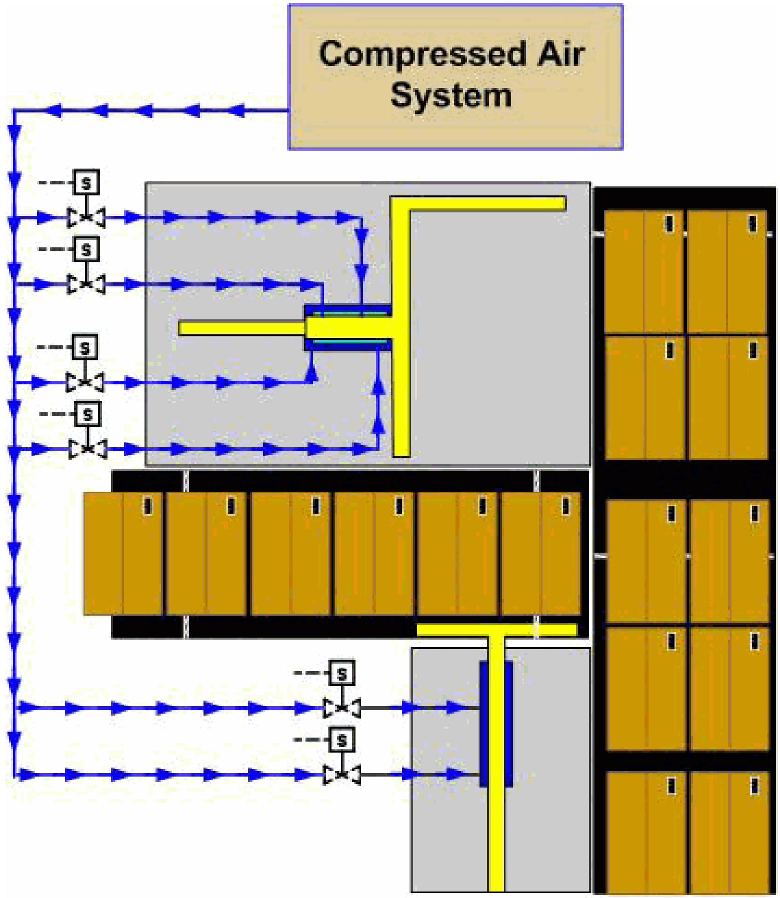


Diagram Ref: Improving Compressed Air System Performance: A Sourcebook for Industry, US DOE

Appropriate and Inappropriate Use

- Use if safety enhancements, significant productivity gains, or labor reductions result (typically 10% to 15% efficient)
  - Pneumatic tools, packaging/automation equipment, conveyors, etc.
- Inappropriate Uses
  - Open blowing, sparging, aspirating, atomizing, transporting liquids or light solids, cooling operations, vacuum generation, abandoned equipment
    - Low-pressure blowers may be a more efficient alternative

Ref: EPRI PQ Investigator



Appropriate Use –Automation Operation

Ref: Improving Compressed Air System Performance: A Sourcebook for Industry, US DOE

Example Inappropriate Use….

- Compressed air found being improperly used to hold open boiler intake damper.
- 90 PSI, ~1/4 dia
  - Estimated Cost ($.05/kWh) ~$4,500/year in waste

Watch Those Leaks!

- Leaks
  - Keep < 10% of compressor capacity
  - May be calculated as shown
- Establish a Leak Prevention Program
- See www.eere.energy.gov

At $.05/kWh:

- a $100/year leak cannot be felt or heard
- a $400/year leak can be felt but not heard
- a $700/year leak can be felt and heard

From *Fundamentals of Compressed Air Systems* course notes, Compressed Air Challenge

	Size	Cost per Year
●	1/16”	$523
●	1/8”	$2,095
●	1/4”	$8,382

Costs calculated using electricity rate of $0.05 per kilowatt-hour, assuming constant operation and an efficient compressor.

Ref: Improving Compressed Air System Performance: A Sourcebook for Industry, US DOE

Leakage (cfm free air) = $(V \times (P_1 - P_2)/T \times 14.7) \times 1.25$

where:
- V is in cubic feet
- P_1 and P_2 are in psig
- T is in minutes

Leak Detectors – Ultraprobe 15,000

- Leaks
  - -air
  - -steam
  - (44kHz)
- Motor Bearing Analysis

Example
Compressed Air Survey

- Plant had 12 air compressors
  - All Constant Speed
  - 200hp and 125 hp units
    - 94.5% to 95% efficient
  - No trim compressors
- Compressed air used extensively throughout plant for product positioning in production lines.

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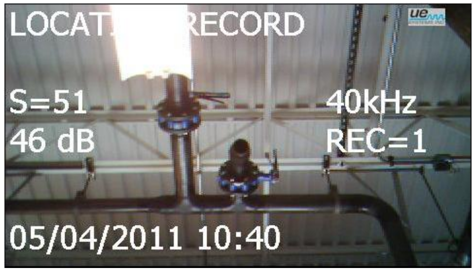
Example Compressed Air Survey

- 15 Leaks found in spot survey
  - In compressor rooms
    - At backup compressor connection
    - Around air dryer connections
  - Throughout plant
    - Line “A” (partial walkdown)
    - Adjacent Line (partial walkdown)
  - ~ $7,000-$8,000/year in losses from those identified – likely much higher overall



Backup Compressor Connection

Piping above Dryer

Ultraprobe 15000


Checking Piping Leaks Above Air Dryer

Pressure and Electricity Costs

- ***High pressure air costs more to produce than lower pressure air.***
- ***For the example system operating at 100 psig, rule of thumb, every 2 psi equates to a 1% increase in energy costs.***

100 HP Compressor Calculation

Compressor	***100***	***hp***
Annual Operation	8760	hours
Electricity Cost	0.0734	$/kWh
Motor Efficiency	0.9	Efficiency

Annual Electricity Cost $53,296

Annual Cost = (hp motor)(0.746)(hours/year)($/kWh)/(motor efficiency)

Header Pressure	Energy Cost Increase	Cost/Year
100	0%	$ 53,296
102	1%	$ 53,829
104	2%	$ 54,373
106	3%	$ 54,927
108	4%	$ 55,493
110	5%	$ 56,071
112	6%	$ 56,660
114	7%	$ 57,262
116	8%	$ 57,877
118	9%	$ 58,505
120	10%	$ 59,147

Bottom Line: Look for opportunities to lower overall system pressure!

Use Outside Air for Compressor Air Make Up

- Air can be compressed more efficiently when the intake air is cooler.
- Rule of Thumb - Power required by air compressor reduces by 1% for every 3˚C / 5.4˚F drop in inlet air temperature.
- Example: Plant has 200 hp air compressor, 8000 hours/year operation, 95% efficient Average inside air temp = 74 deg F, Average outside air temp =60 deg F, $0.0734/kWh

ECM No. ____ Bring in Outside Air for Compressor Air Make Up		
Cost/kWh	0.0734	Average kWh Costs
Operating Hrs/yr	8000	
Air Compressor Size	200	Total HP
Motor Efficiency	0.95	Percent
Compressor Power Usage	157	kW
Compressor Diversity	100%	% of time compressor is on
Load Diversity	75%	% of time at or near full load
Net Hours Base Loaded	6000	
Average Inside Air Temp	74	Deg F
Average Outside Air Temp	60	Deg F
Reduction Factor	2.6%	Power Reduction Factor = 1-(T outside/T inside)
Estimated Electricity Consumption Decrease	4.1	kW
kWh/yr saved	24,720	
Estimated Yearly Savings	$ 1,814	
# of required intakes	1	
Estimated cost	$ 1,750	Based on $1750 per intake
Utility Incentives	$ -	Note if applicable
Net Estimated Cost	$ 1,750	Total cost minus any incentives
EstimatedPayback	0.96	Years
	12	Months

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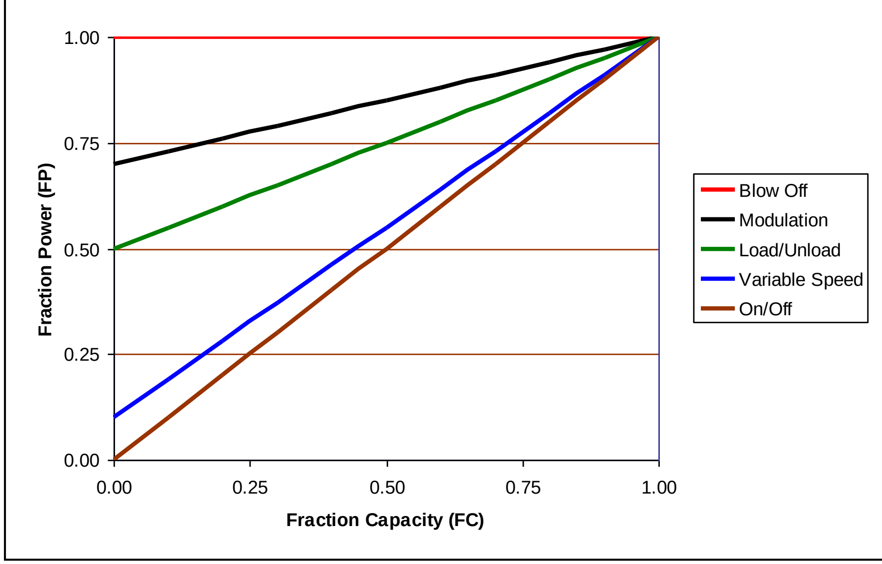
Power/Output Relationships by Control Type



- **Blow Off** –To avoid surge, centrifugal compressors may discharge compressed air to the atmosphere to control compressed air output to the system.
  - Blow-off control is the least efficient method of controlling compressed air output, since input power remains constant as the supply compressed air to the system decreases.
- **Modulation Control** - the position of the inlet air valve is modulated from full open to full closed in response to compressor output pressure.
  - Modulation control typically employs PID control with a narrow control range about ± 2 psig. Inlet modulation is a relatively inefficient method of controlling compressed air output.
- **Load/Unload Control** – Load/Unload on control points from 90 psig-100 psig.
  - Power is drawn when unloading (60% to 30%) of full load.
- **Variable-Speed Control** - Rotary-screw air compressors can be equipped with variable frequency drives to vary the speed of the screws and the corresponding compressed air output.
  - As in other fluid flow applications, the variation of speed to vary output is extremely energy efficient.
- **On/Off Control** - The compressor turns on and begins to add compressed air to the system when the system pressure falls to the lower activation pressure. Typical lower and upper activation pressures would be 90 psig and 100 psig.
  - On/off control is the most efficient type of part-load control, since the compressor draws no power when it is not producing compressed air.

Compressed Air Storage

- Stores compressed air until needed
- Use of compressed air storage tanks can
  - Smooth out demand events during peak periods.
    - 2 psi increase in header pressure can lead to 1 to 2 percent higher energy consumption
    - Smoothing out these peaks reduces energy use
  - Control the rate of pressure drop to end use
  - Protect critical pressure applications from other events in the system.
    - Providing some PQ ride-through as well!
      - If plant has storage tanks, PQ issues are normally not an issue with the compressed air

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Example Compressed Air Survey

- Air Knifes (many)
  - From main air compressor system
    - ~ $1800+/year
  - From local 1.5kW blower (measured at motors)
    - ~$1,100/Year
- *Plant uses air at 100 to 120 psig*
  - *Potential to lower pressure to reduce energy consumption*
  - *10 psig rise in pressure can result in 5% power increase*

Air Knife


Local Blower on Process Line

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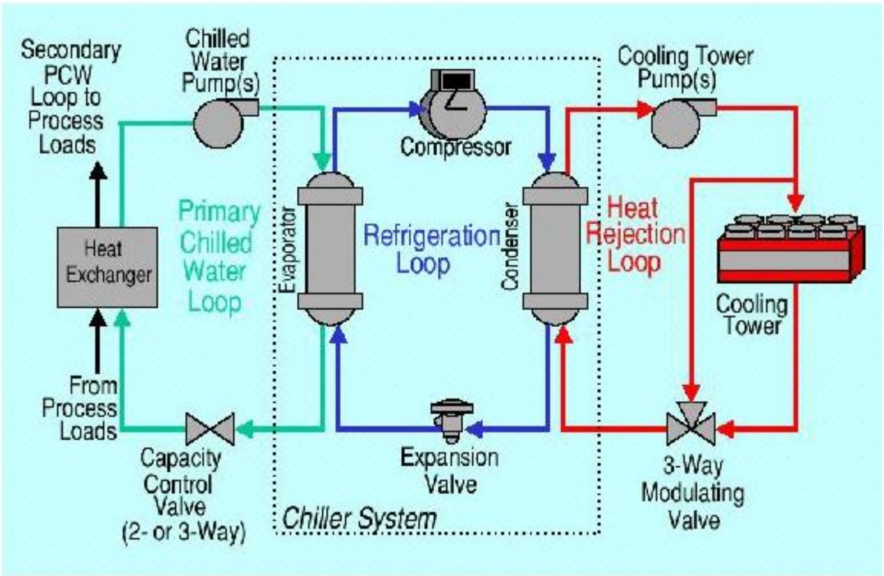
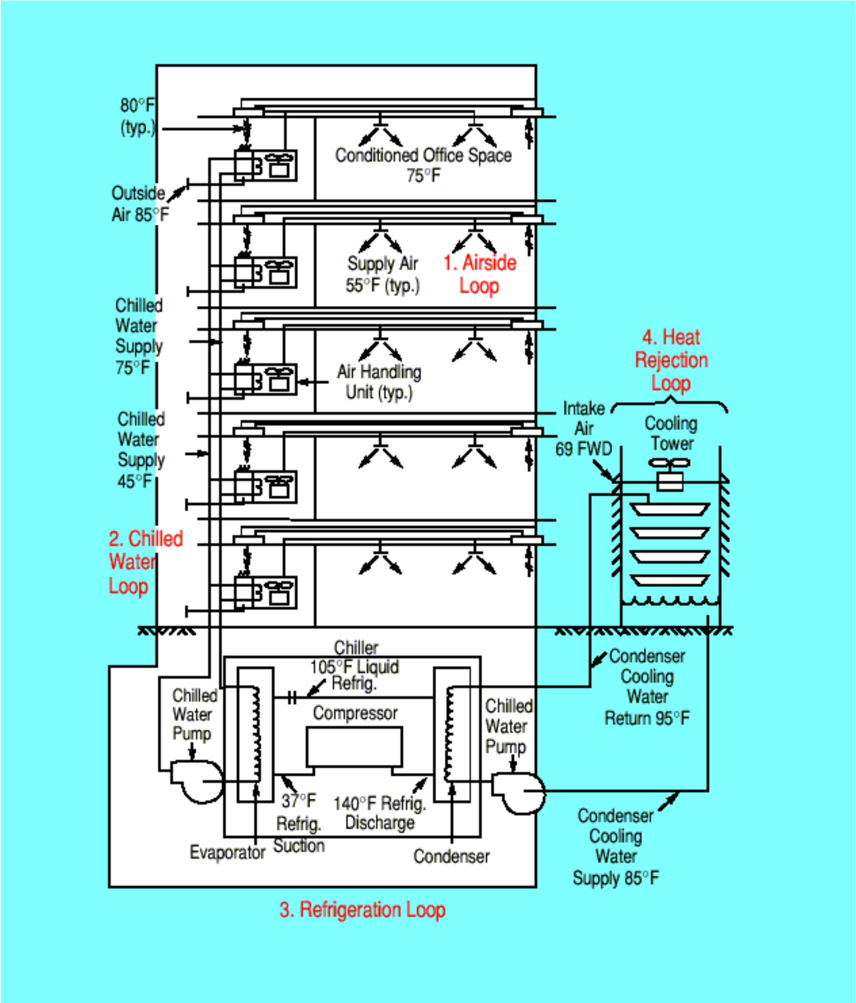
Chilled Water Systems

Chilled Water Systems

- The plant/building Chilled water system can represent a large part of the overall load.





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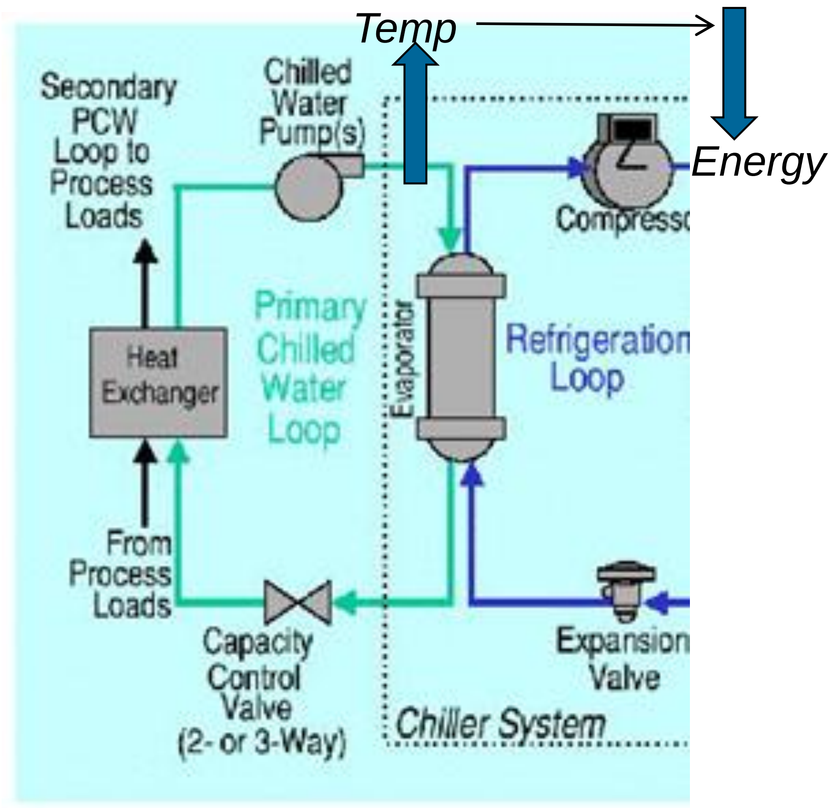
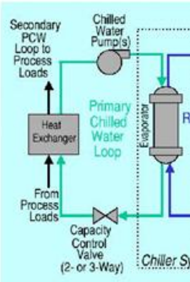
ECM – Reset the Supply Water Temperature

- Increasing the chilled water supply temperature can decrease chiller electricity consumption significantly.
- As a Rule-of-Thumb: ***Raise Chilled Water*** Temp by 1 deg F for 1.7% decrease in compressor energy consumption.



ECM - Reset Chilled Water Temp



ECM No.___ Raise Chilled Water Temp		
Cost/kWh	0.0734	Average kWh Costs
Operating Hrs/yr	8760	
Chiller Tonnage	1000	Tons
kW/Ton	0.6	Based on Type
Chiller Compressor Power Usage	600	kW
Chiller Diversity	100%	Percentage of time chiller is on
Compressor Diversity	50%	% of time at or near full load
kWh/yr Compressor Usage	4380	
Current Chilled Water Temp	42	Deg F
Proposed Chilled Water Temp	55	Deg F
Estimated Electricity Consumption Decrease	133	kW
kWh/yr saved	580,788	
Estimated Yearly Savings	$ 42,630	
Estimated Payback	Immediate	

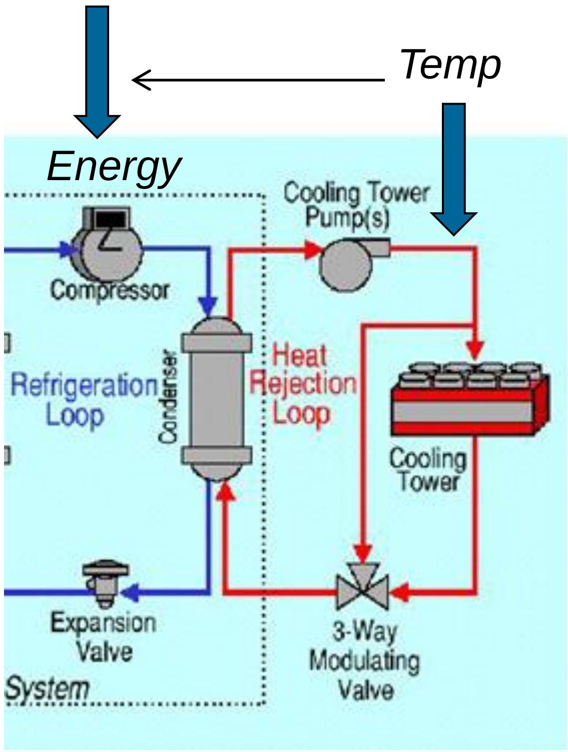
Available Capacities

- **Reciprocating** machines are manufactured in capacities from 0.5 to 150 TR*. Air-cooled **reciprocating** chillers have an energy usage of 1.0–1.3 kW/ton while water cooled chillers have energy usage between 0.7 and 1 kW/ton.
- Air cooled screw chillers are available with cooling capacities between 70 tons and 500 tons and energy usage between 1.1 and 1.5 kW/ton. Water cooled screw chillers are available with cooling capacities between 70 tons and 750 tons and energy usage between 0.65 and 0.9 kW/ton.
- **Centrifugal chillers** are generally manufactured in capacities from 90 to 1,000 tons, with most units falling in the range of 150 to 300 tons. Centrifugal compressor chillers are the most energy efficient chillers with energy usage between 0.5 and 0.6 kW/ton.

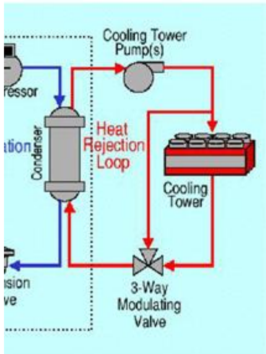
*** Tons of Refrigeration**

ECM- Reduce Condenser Water Temperature

- Chillers operate more efficiently when the condensers are provided with cooler water.
- As a Rule-of-Thumb, for every 1 deg. F temperature drop in condensing water temp, a 1% savings can be expected.
- This is accomplished by changing the cooling tower water temp set point.



ECM- Reduce Condenser Water Temperature



ECM No.___	Reduce Condenser Water Temp	
Cost/kWh	0.0734	Average kWh Costs
Operating Hrs/yr	8760	
Chiller Tonnage	1000	Total Tons
kW/Ton	0.6	Based on Type
Chiller Compressor Power Usage	600	kW
Chiller Diversity	100%	Percentage of time chiller is on
Compressor Diversity	50%	% of time at or near full load
kWh/yr Compressor Usage	4380	
Current Cooling Tower Setpoint	85	Deg F
Proposed Cooling Tower Setpoint	75	Deg F
Estimated Average Temperature Reduction	5	
Est. Chiller Electricity Consumption Decrease	30	kW
kWh/yr saved	131,400	
Estimated Yearly Savings	$ 9,645	
Estimated Payback	Immediate	

- Plant must check chiller mfr make sure that proposed set point is not below the min recommended condenser water setting.

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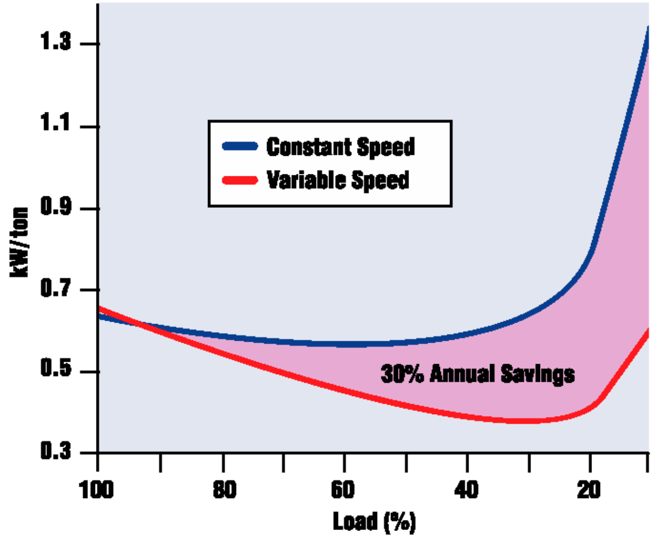
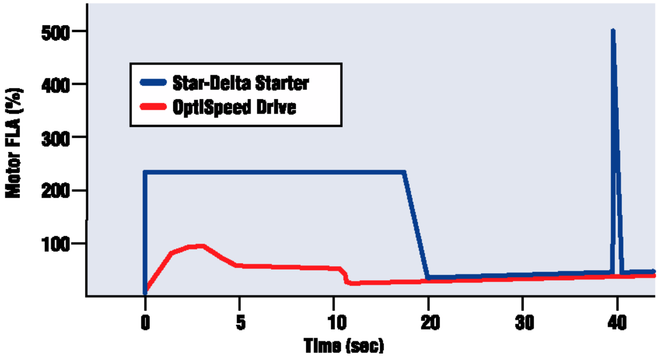
Use of ASDs on Chillers



Inrush Current



An OptiSpeed drive is the single largest energy-saving retrofit you can apply to your chiller plant.

From York Optispeed Literature

(1-3 year payback)

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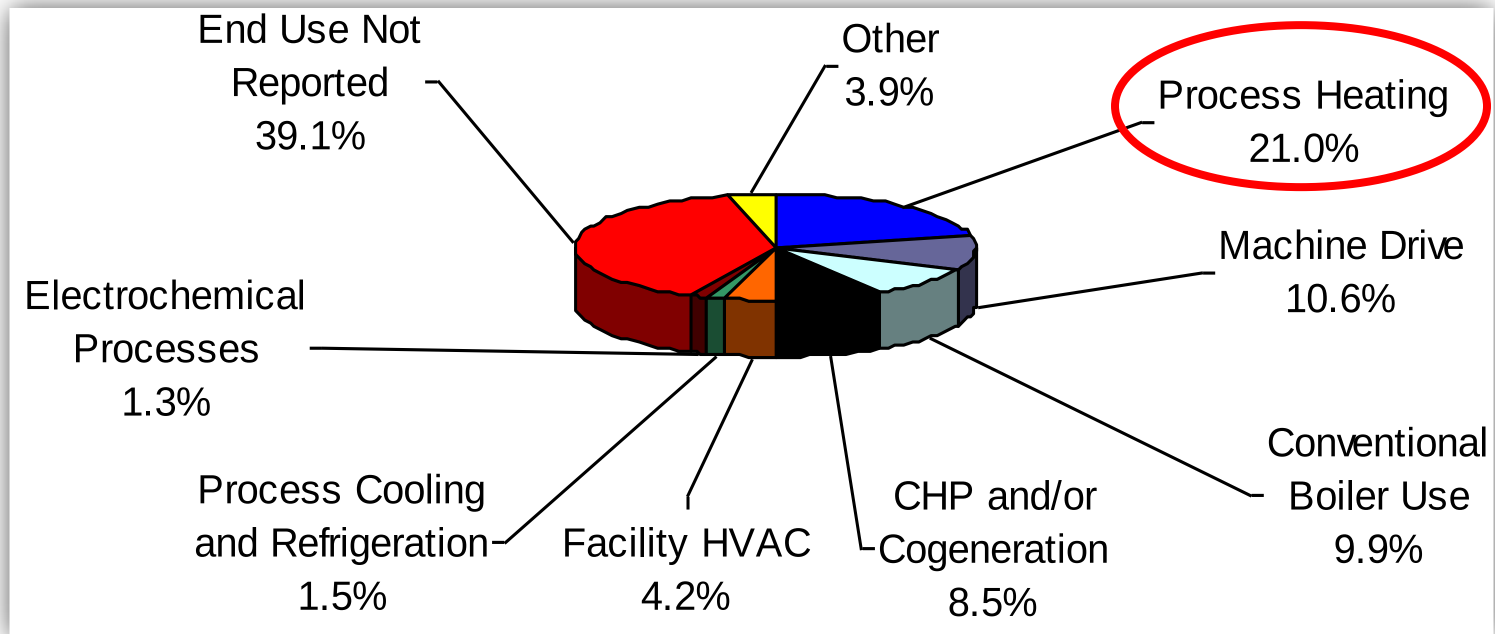
Advanced Technologies in Process Heating

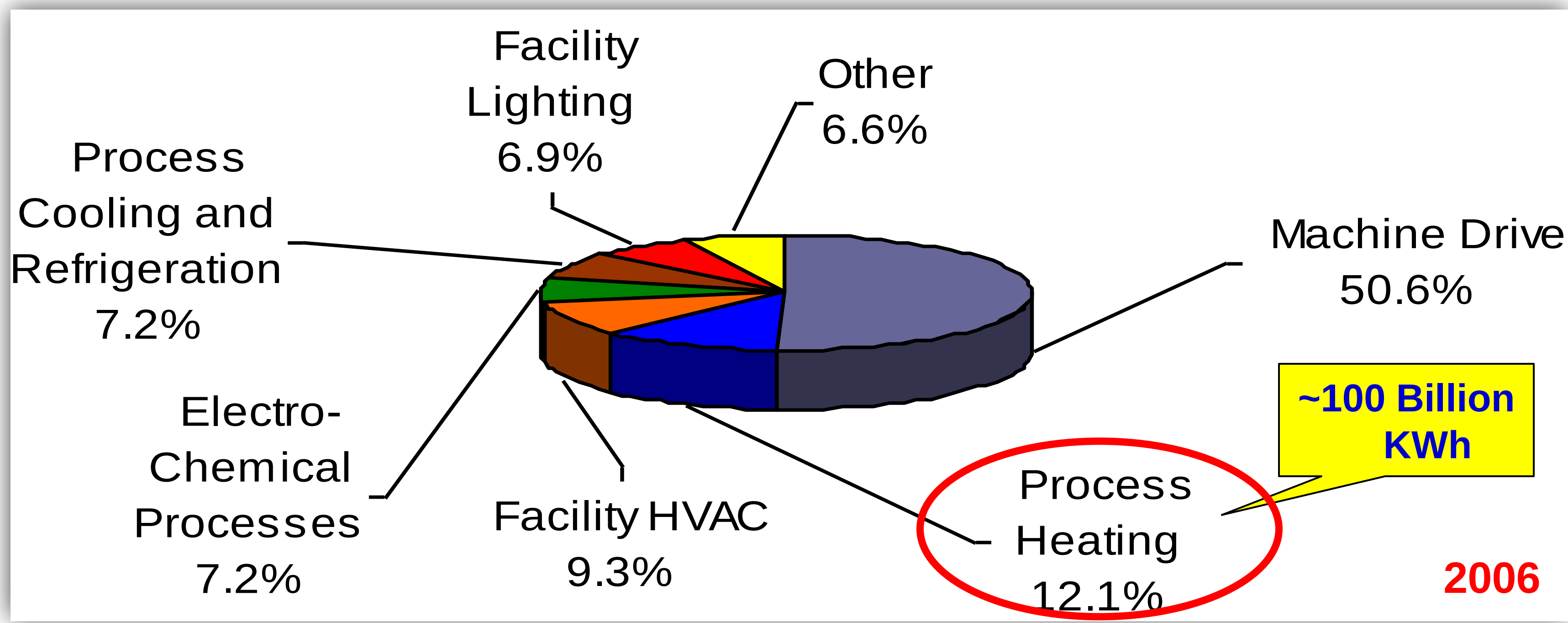
Why is Process Heating Important?

- Process heating accounts for
  - **21% (1/5th)** of total industrial energy use
  - **2 to 15%** of total industrial production cost
- Process temperature range: 300 – 5,000+ºF



Source: Energy Information Administration, 2006 Manufacturing Energy Consumption Survey

Industrial Net Electricity Consumption (End Use)

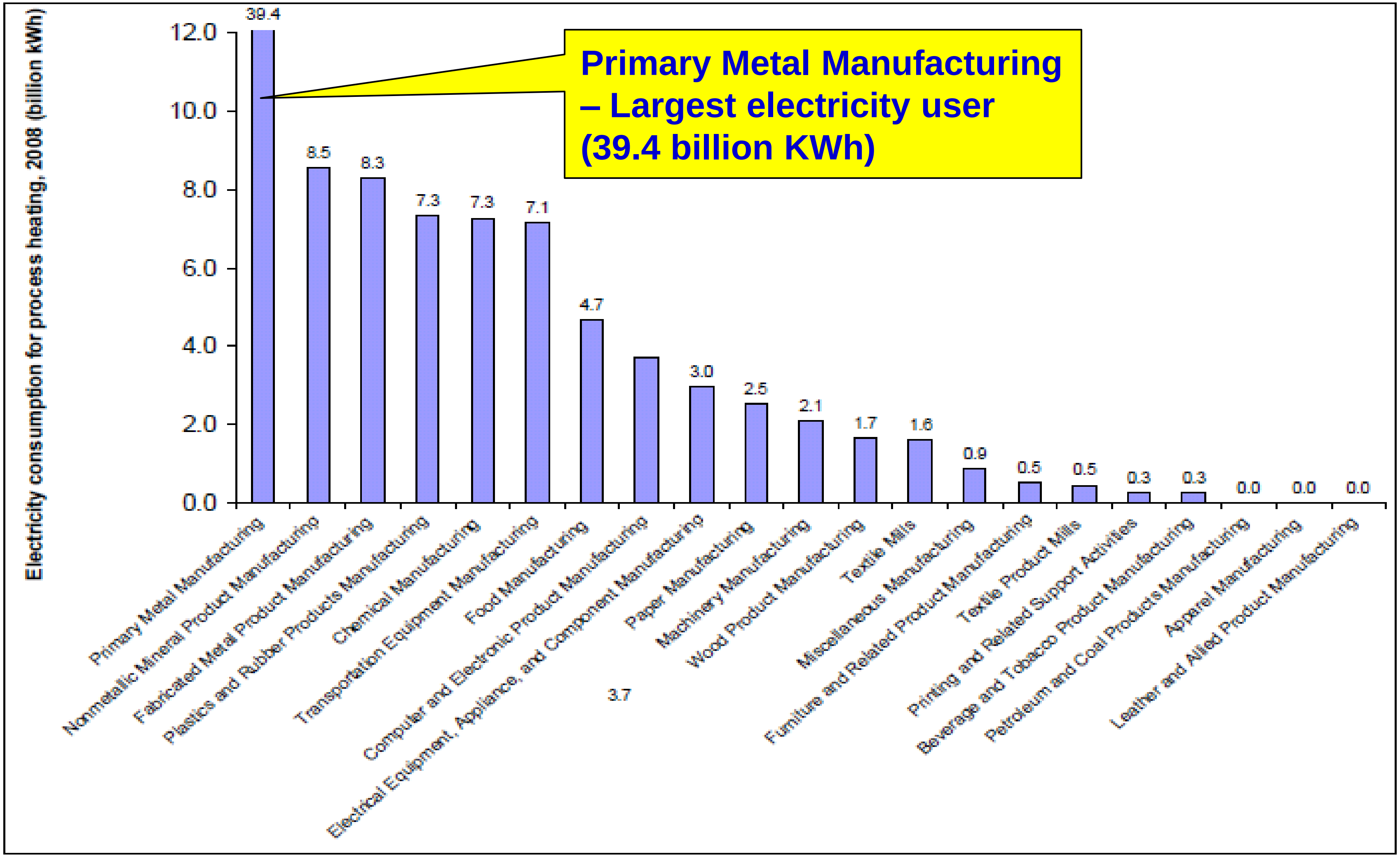


- Process Heating uses **12.1%** of total net electricity in manufacturing and increasing annually
- Total Industrial Net Electricity Consumption

  = 2,850 Trillion Btu (= 834 Billion KWh)

Source: Energy Information Administration, 2006 Manufacturing Energy Consumption Survey

Manufacturing Process Heating - Consumption of Electricity by Sector, 2008



Source: *Electrotechnology Reference Guide*. EPRI, Palo Alto, CA: 1022334.

What is Process Heating?

Supplying heat to materials in

- Furnaces
- Ovens
- Heaters
- Thermal oxidizers
- Dryers
- Boilers
- Other heating equipment

Source: U. S. Department of Energy -Energy Savings Assessment (ESA) Process Heating Assessment and Survey Tool (PHAST) Introduction, Arvind Thekdi, 2007

Process Heating System Components

- **Heating devices:** generate and supply heat
- **Heat transfer devices:** move heat from source to product
- **Heat containment devices:** e.g. furnaces, heaters, ovens
- **Heat recovery devices**
- **Support Systems:** e.g. sensors and controls, materials handling, emission control, safety, other auxiliary systems

Categories of Process Heating

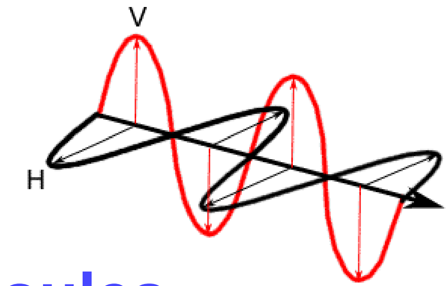
- Combustion-based

Boilers and steam generators	Muffle furnaces
Atmosphere generators	Ovens
Blast furnaces	Radiant tube heat treat furnaces
Crucible furnaces	Reverberatory furnaces
Dryers	Salt bath furnaces
Indirect process heaters	Solid waste incineration
Kilns	Thermal oxidizers

- Heat recovery and heat exchange
- **Electric Processes**

Resistance	Electromagnetic Waves	
Induction	**- Infrared (IR)**	**- Radio Frequency (RF)**
Plasma Arc	**- Microwave (MW)**	- Ultraviolet (UV)

A Flashback to High School Physics



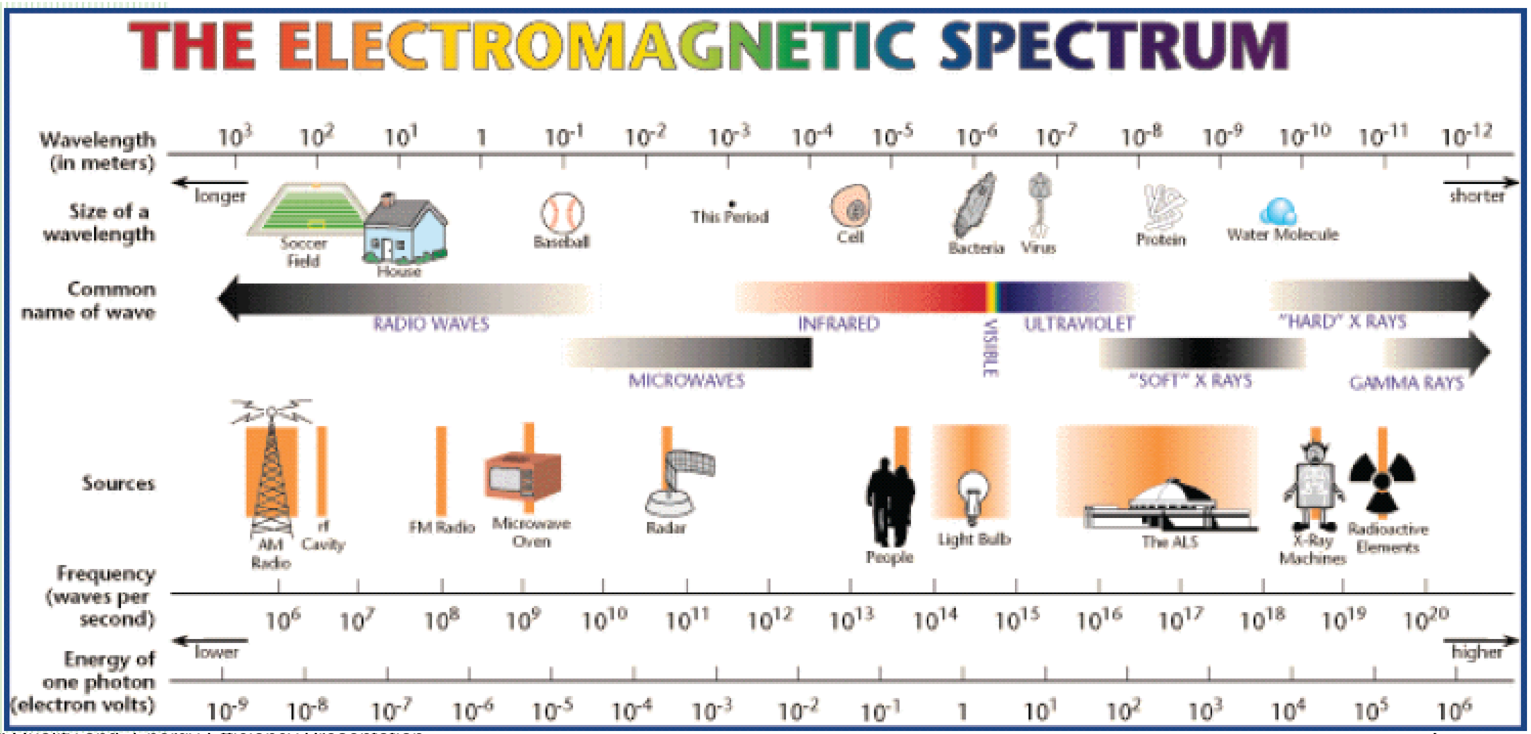
Wave Length ↑ **Energy** ↓

E= hc/λ Joules

h=Plank's Constant

C= Speed of light

λ = Wavelength



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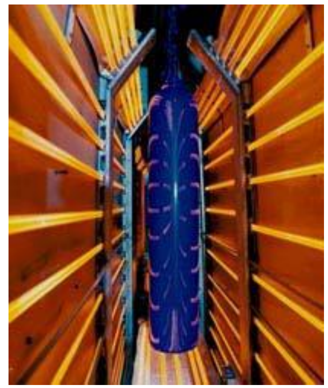
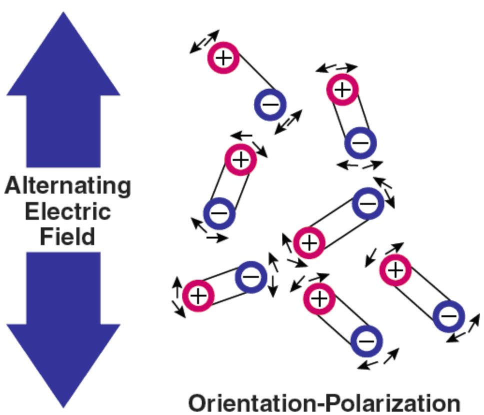
Four Technologies ...Three Industries

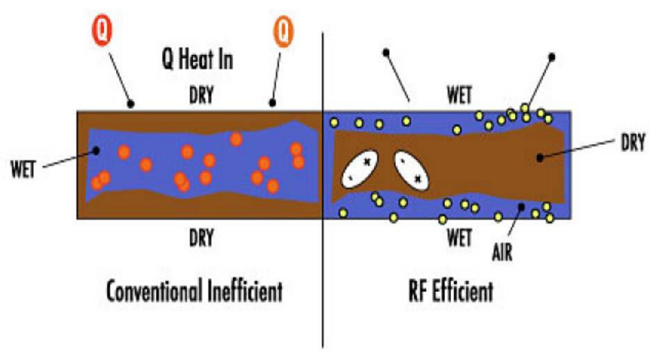
Induction Heating



Infrared Heating



Microwave Heating

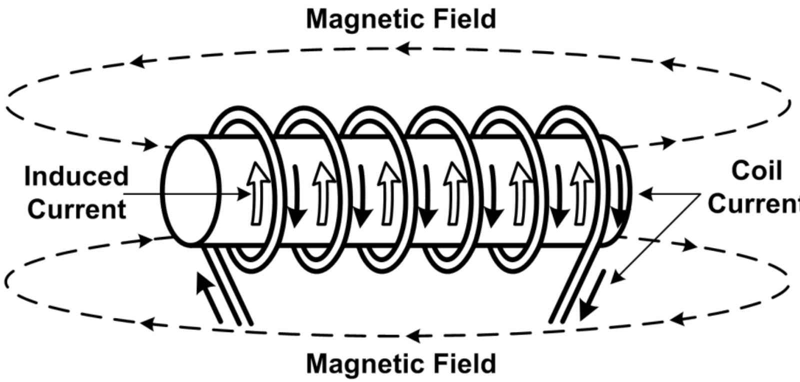


Radio Frequency Heating

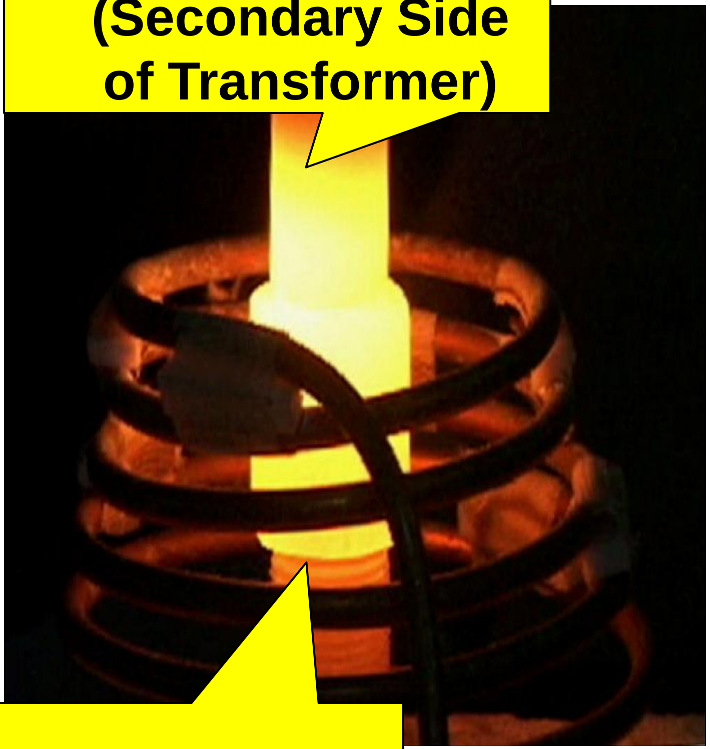
Industries:

- Food
- Paper
- Chemical

Induction Heating



- Used for heating directly, heat treating or melting conductive materials, typically metals.
- Similar to Transformer – Eddy current heating
- Plastics and other nonconductive materials (e.g., chemicals) often can be heated by first heating a conductive material that transfers heat to the nonconductive material.
- Frequency: 60Hz to 800KHz
- Power rating: 1 - 3,000KW

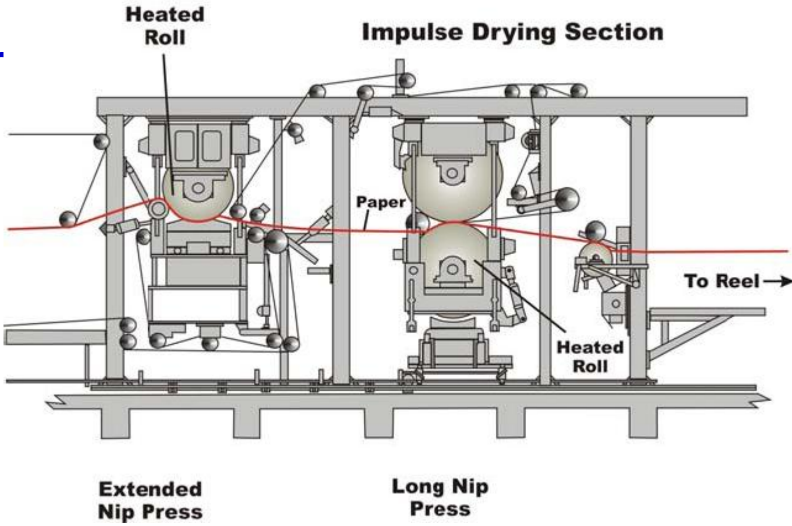


Induction Heating – Advantages

- Rapid heating of parts: Development of heat within the workpiece by induction provides much higher heating rates
- Fast start-up of equipment
- Lower energy costs: When not in use, the induction power supply can be turned off thus saving energy.
- Easier process control and monitoring: It is easier to control repeatability and monitor the process on a part-by-part basis since it is not a batch process.
- Compact footprint: Induction heating installations are generally much smaller than conventional gas fired heating furnaces for equivalent throughput.

Example of Induction Heating Application – Paper Industry: Paper Drying

- New approach for evaporating water from the moist web to produce a dry sheet of paper
- Impulse dryers can be retrofitted to existing machines
- Typical modern newsprint machine producing 180,000 tons of paper would save 60 Million KWh (216,000 GJ) per year
- Advantages:
  - Uses 50% less energy to remove water than conventional dryers
  - Produces improved quality paper

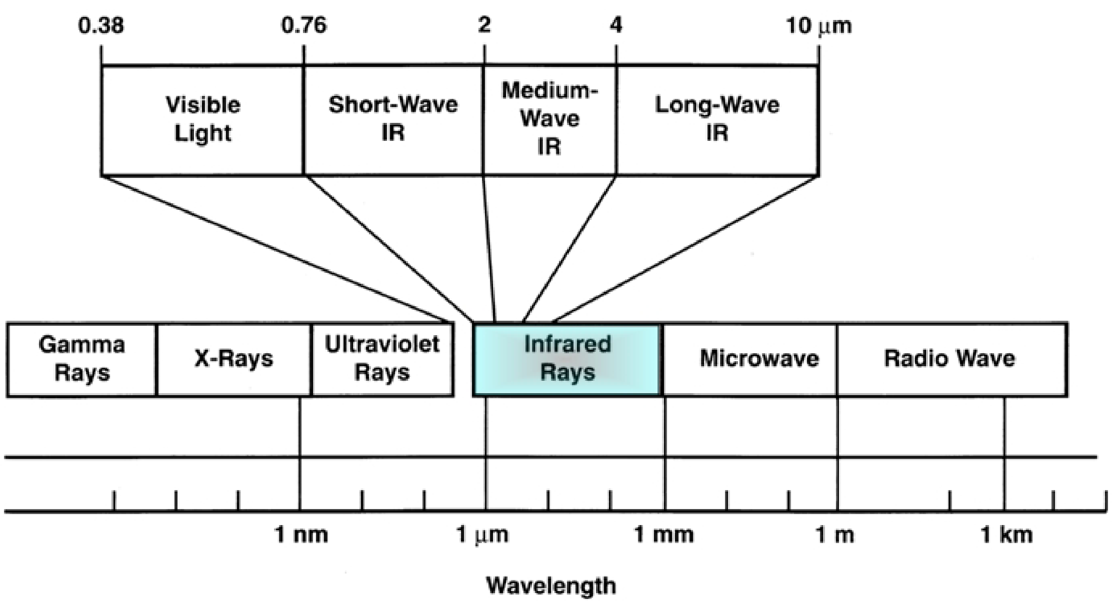


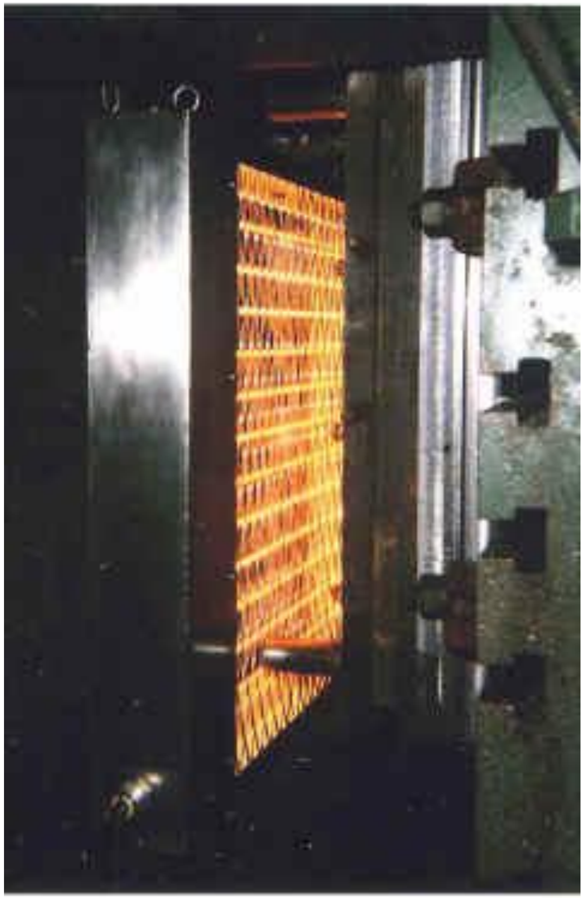
Electric Impulse Drying Using Induction

PAPRICAN – Pulp and Paper Research Institute of Canada

Infrared Heating

- Wavelength range 0.76 – 10 microns
- Line-of-sight technology
- Suited for surface heating applications





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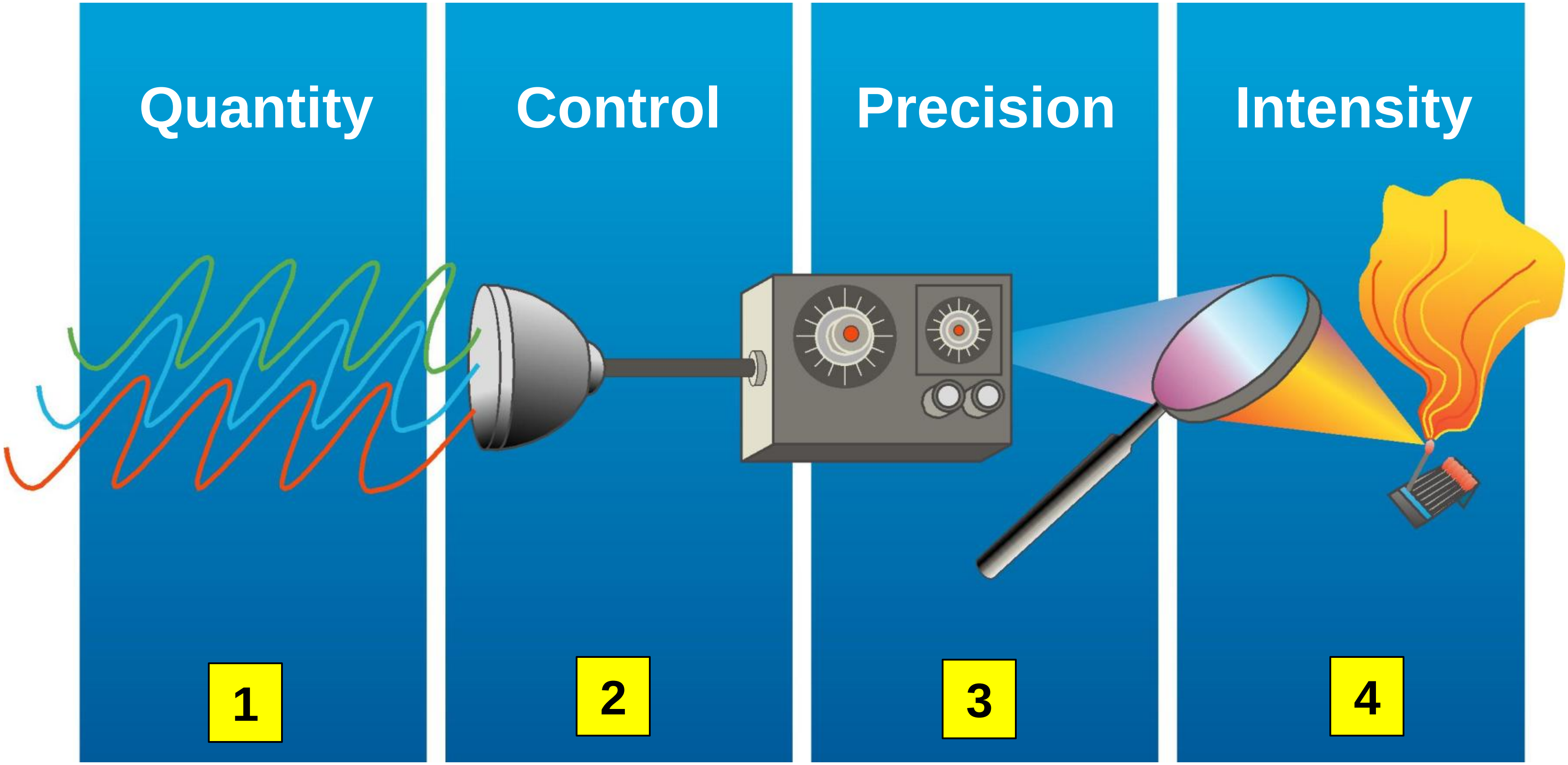
Electric IR – Characteristics



Infrared Benefits

- Immediate turn on/off
- Full output obtained within seconds
- Reduced environmental concerns (no point emissions)
- Energy efficiency > 90%

Electric IR Tunnel Oven for Powder Coat Curing

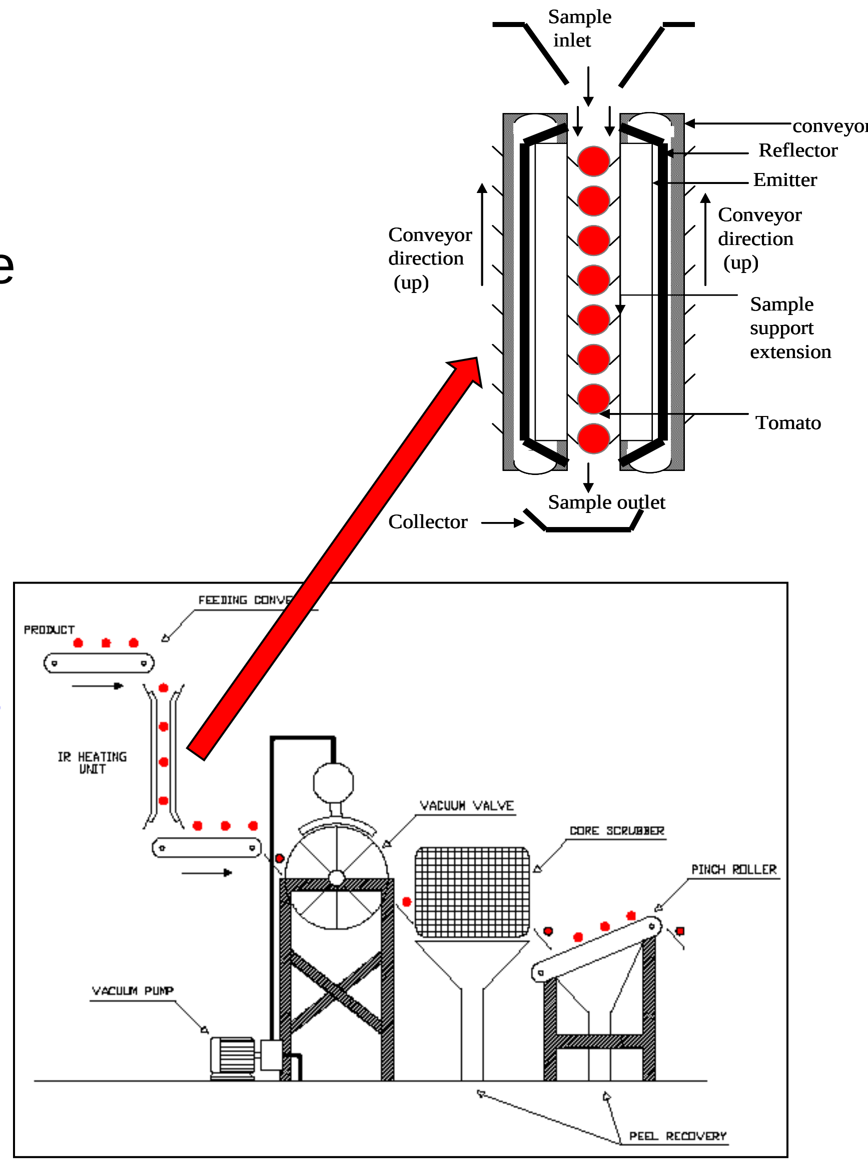
Electric IR System to Pre-Heat Aluminum Billets

Infrared: Applications

- Textile and Paper industry for drying
- Latex and adhesive drying
- Annealing and curing of rubber
- Powder coating of metal (automobile industry)
- Preheating cast aluminum wheels
- Heating aluminum strips prior to bending
- Ink curing
- Drying of parts
- Fine soldering
- Silk screening
- Molding plastics by blowing, vacuuming, squeezing the plastic between calendar rolls

Example of Infrared Application – Food Industry: Tomato Peeling

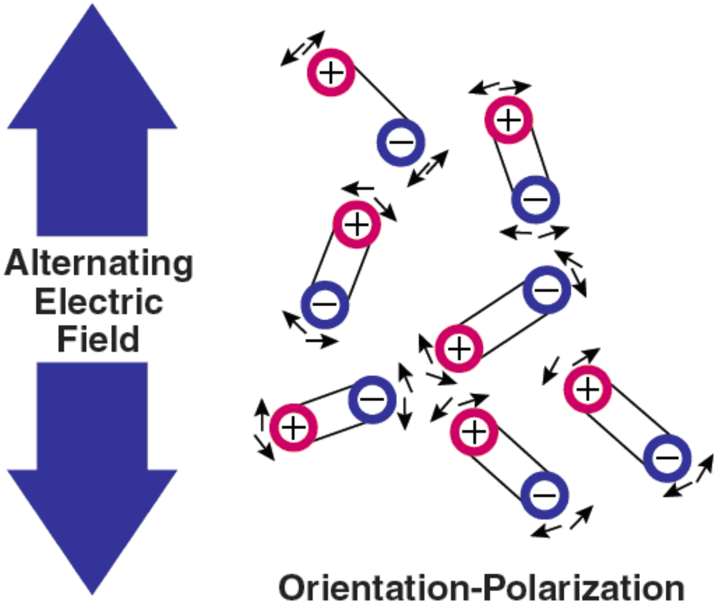
- Tomatoes are fed through conveyors
- IR heating heats the surface skin of the tomatoes
- Heated tomatoes pass through vacuum valve and a core scrubber to peel the skin
- Better than lye peeling
- Reduces waste water and peeling loss



UC Davis and USDA Research

Microwave Heating

- Suited for drying applications of polar molecules (i.e. water)
- Industrial microwave frequencies
  - 915 MHz
  - 2.45 GHz (typically used)
  - 5.8 GHz
  - 24.125 GHz
- Recent advances in solid state amplifier devices make improvements to magnetrons more economically attractive



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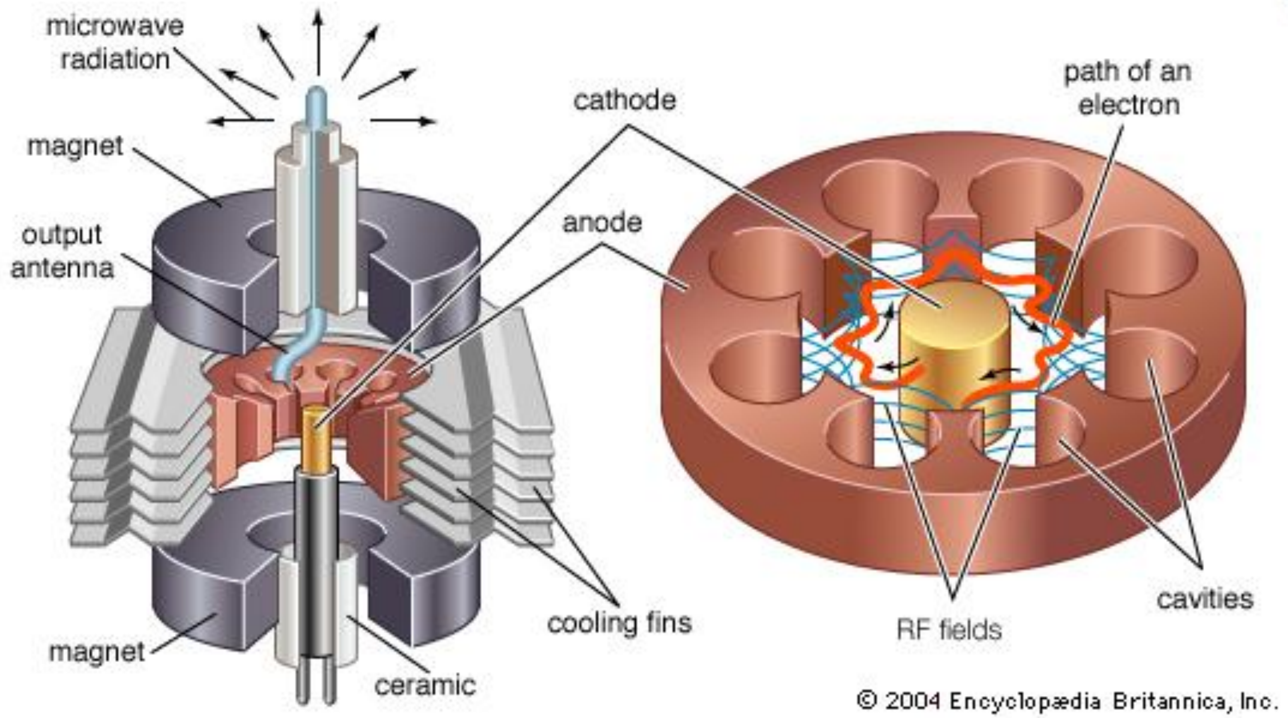
The Magnetron

The device in microwave ovens that generates microwaves



Microwave Heating Applications

Chemicals

- Applications ranging from curing adhesives to preheating resins before extrusion

Food Processing

- Applications for food processes that require a heat cycle including drying, pasteurizing and sterilization

Textiles and Nonwovens

- Fabrics that require drying benefit from pre-drying, post drying or total drying

Other Applications

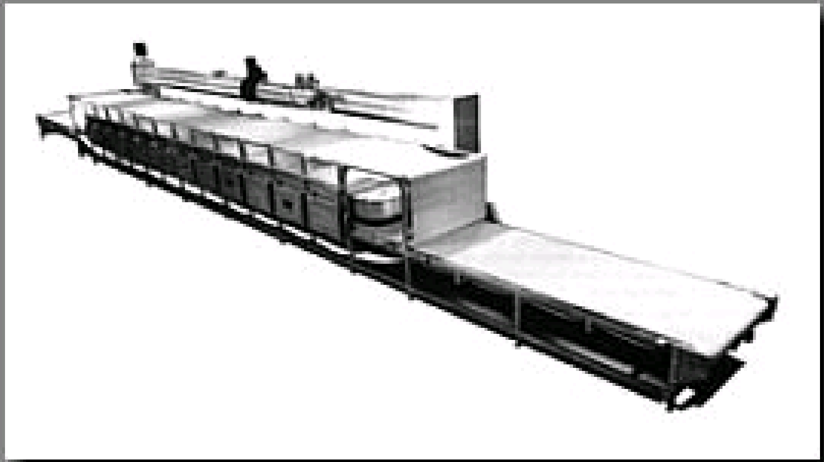
- Ceramics, pharmaceuticals, electronics
- Waste treatment

Microwave Heating Advantages

- Quick heat penetration
- Selective heating:
  - Different materials absorb microwave energy at different rates; a product with many components can be heated selectively.
- Increased flexibility:
  - Complex shapes heat more uniformly with microwave energy because heat is not generated directly on the surface.
- Combination with conventional methods:
  - Because microwave units are more compact, they may be added before, after, or inside conventional heating or drying units.
  - This can decrease processing times by as much as 75%.

Example of Microwave Application - Food Industry: Bacon Cooking

- MW cooking systems operate at 400 to 500 KW
- Operating frequency: 915MHz
- Throughput: 50,000 to 60,000 slices of bacon per hour.
- Finished bacon is packed and frozen for distribution.
- Approximately 150 to 200 million kilograms of raw bacon processed in USA per year



Source: http://www.microdry.com/btd.htm

Radio Frequency Heating

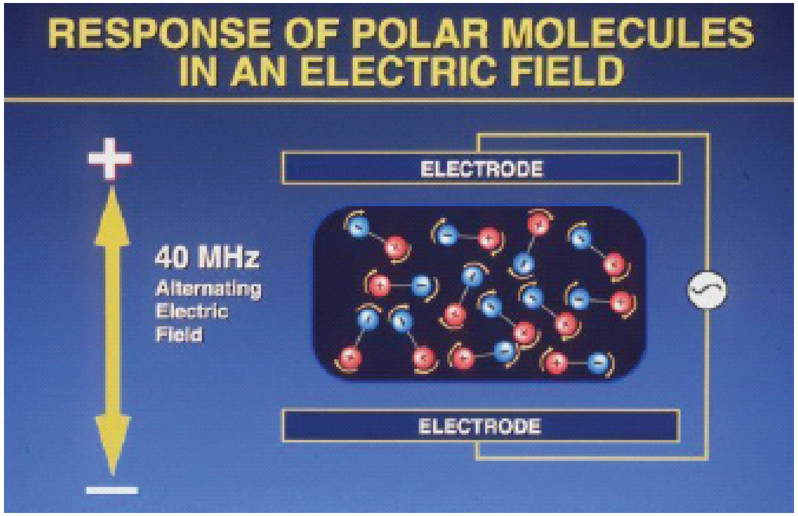
1,500+ RF units installed since 1977

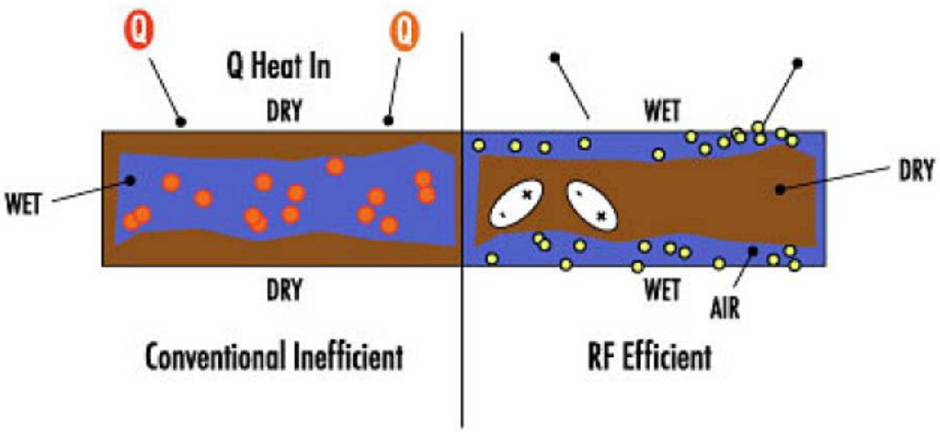
Similar to microwaves

Longer wavelength = less energy

Suitable for more "delicate" applications

Better suited for larger surface area than microwaves





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RF Heating Advantages

- Quick heating: 2 to 20 times quicker than by conventional methods.
- Uniform heating: Heating is more uniform throughout the cross section
- Selective heating/drying: Similar to microwave heating
- Improved product quality: Heat sensitive materials are not exposed to high temperatures for long times, improving product strength and quality.
- High energy efficiency: The efficiency, defined as the energy put into the material divided by the power supplied to the equipment, is typically 50 to 70% for RF and microwave heating.

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Industrial Energy Efficiency Case Studies

Company Alpha

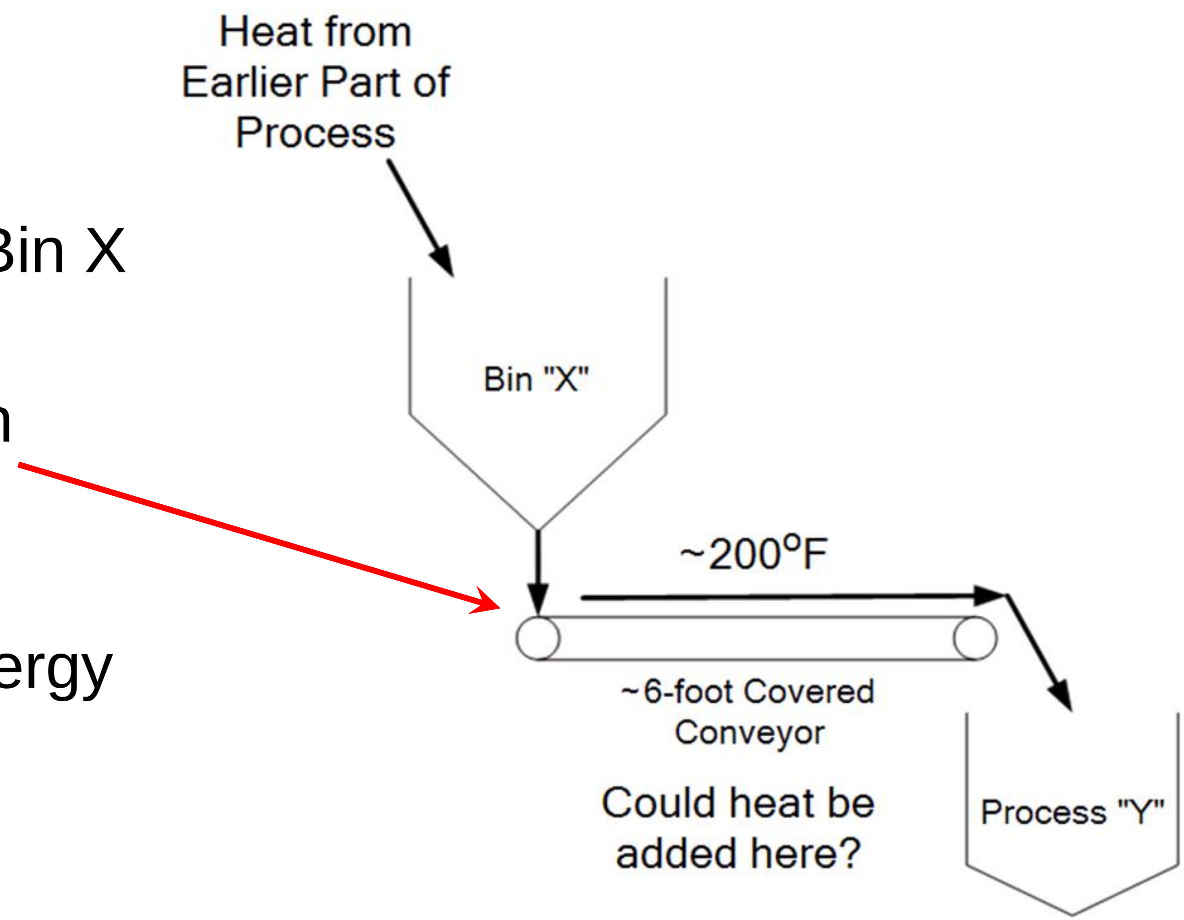
- Manufactures materials used for construction
- Uses rock crushers and drying kilns
- Identified savings
  - From $51,000 to $67,000 with
    - associated costs of around $72,000 to $81,000.
  - Simple payback from 1.2 to 1.4 years on average
    - Shortest: immediate
    - Longest: ~7 years

Company Alpha Considerations

- "Static Load" of between 300 to 500 kW
  - Equipment operating regardless of production
    - $162,500 per year at $0.065/kWh
    - 14.5% to 17% of electrical usage per year
    - Should identify, turn off if possible
- Weather and humidity affect energy usage
  - Northern climate
  - Raw material stored outside
- Main energy use is natural gas
  - Electrification opportunity?

Alpha Electrification Opportunity

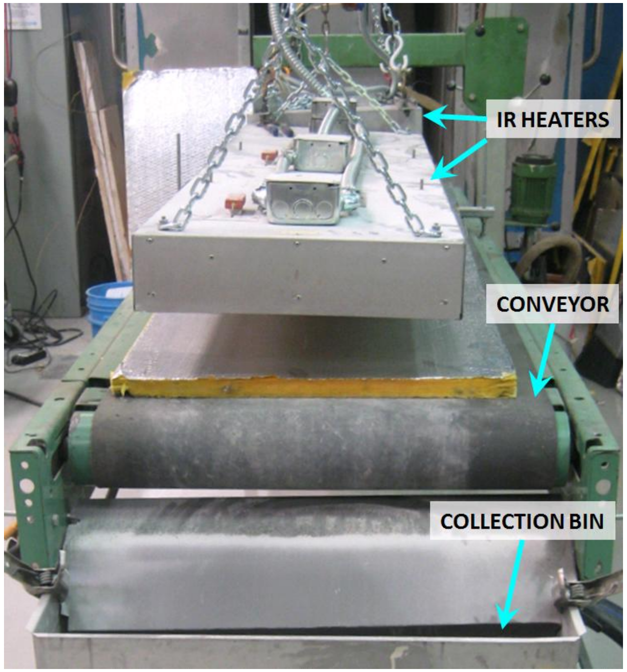
- Existing process
  - Input temp allows ~200°F between Bin X and Bin Y
- One possible point in conveyor system for heating
  - May save total energy
    - Infrared
    - Induction

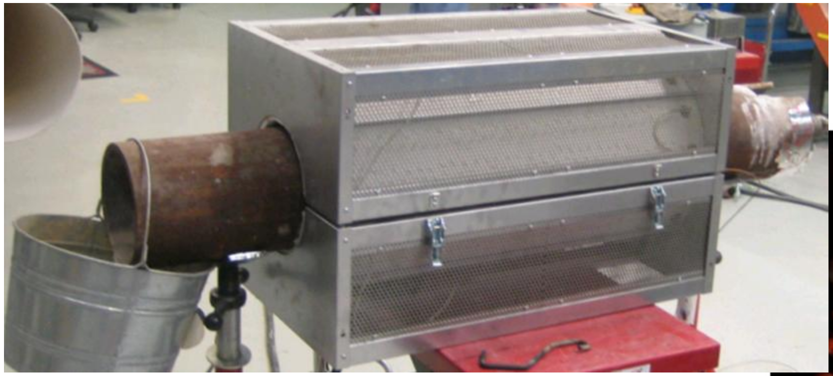


Experiment: Infrared vs. Induction

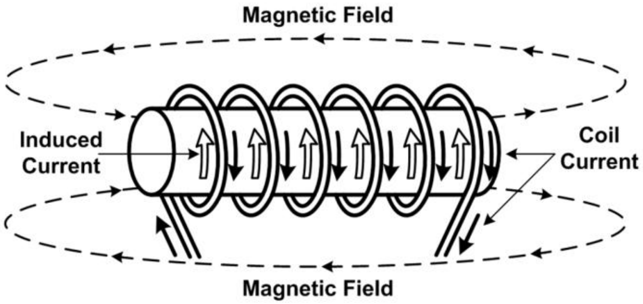
- TAC Center in Alabama
  - Will material be heated effectively and in what time frame?
  - Testing proved both could work
- Alpha test project would verify whether or not electrification would be preferable

Infrared





Induction



Gas vs. Electricity

- Gas ovens can be less efficient and cost more to operate
- Alpha kiln more efficient than this

(Source: TAC, Birmingham, AL)

	FACTOR	ORIGINAL	REPLACEMENT
Case 1	Equipment	Gas-fired oven addition	Infrared preheat
	Equipment rating	1.97 Million BTU	133 kW
	Equipment Efficiency	15%	65% (Short Wave)
	Load Factor	55%	45%
	Energy Consumption/yr	9491 Million BTU	524286 kW Hrs
	FACTOR	**ORIGINAL**	**REPLACEMENT**
Case 2	Equipment	Steam oven	Infrared heating
	Equipment rating	2.1 Million BTU/Hr.	144 kW
	Equipment Efficiency	15%	65% (short wave)
	Load Factor	51.40%	45.60%
	Energy Consumption/yr	9450 Million BTU	576000 kW Hrs.
	FACTOR	**ALTERNATE**	**REPLACEMENT**
Case 3	Equipment	Gas-fired oven	Infrared heating
	Equipment rating	15.6 Million BTU/Hr.	940 kW
	Equipment Efficiency	10%	65% (short wave)
	Diversity Factor	75%	75%
	Load Factor	51.40%	45.60%
	Energy Consumption/yr	52650 Million BTU	2.82 Million kW Hrs.

Case 1			
Gas		9,491,000	Cubic ft. Natural Gas
	$	56,946.00	per year
Electricity		524,286	kWh
	$	34,078.59	per year
Case 2			
Gas		9,450,000	Cubic ft. Natural Gas
	$	56,700.00	per year
Electricity		576,000	kWh
	$	37,440.00	per year
Case 3			
		52,650,000	Cubic ft. Natural Gas
Gas	$	315,900.00	per year
		2,820,000	kWh
Electricity	$	183,300.00	per year

Estimated Rotary Kiln Dryer Efficiency

Production Rate	255	Tons/Hr
Specific Heat of Product Granules	0.193	BTU/lb Farenheit
Process Input Tempature	45	Average Annual Temp
Process Output Temperature Requirement	200	Deg. F
Temperature Difference Requirement	155	Delta T
Gas Energy Input	25,000,000	BTU/hr (max = 50MMBTU, Typical 20-30MM BTU)
Electric Energy Input	164.9	kW (based on 95% Efficient Motors)
Estimated Energy Input (Gas + Electric)	25,562,657	BTU/hr
Process Heating Requirement (BTUs/Hr)	15,256,650	BTUs/Hr
Estimated Rotary Kiln Efficiency	60%	Energy Input

- Electricity calculated to be $149/hr
- Gas-$42/hr

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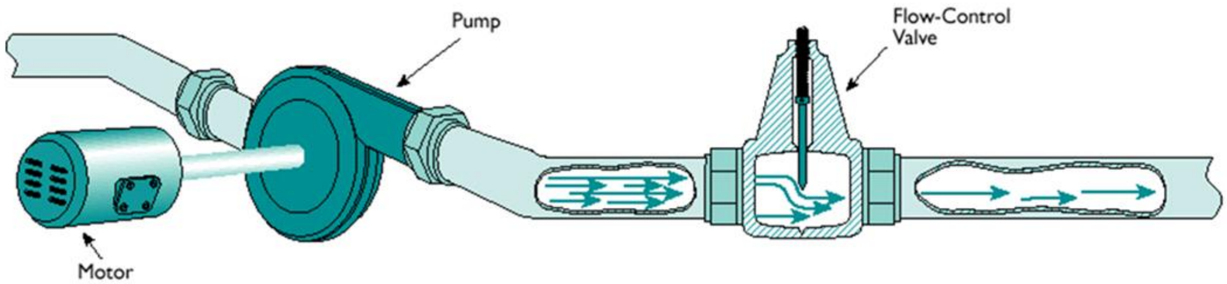
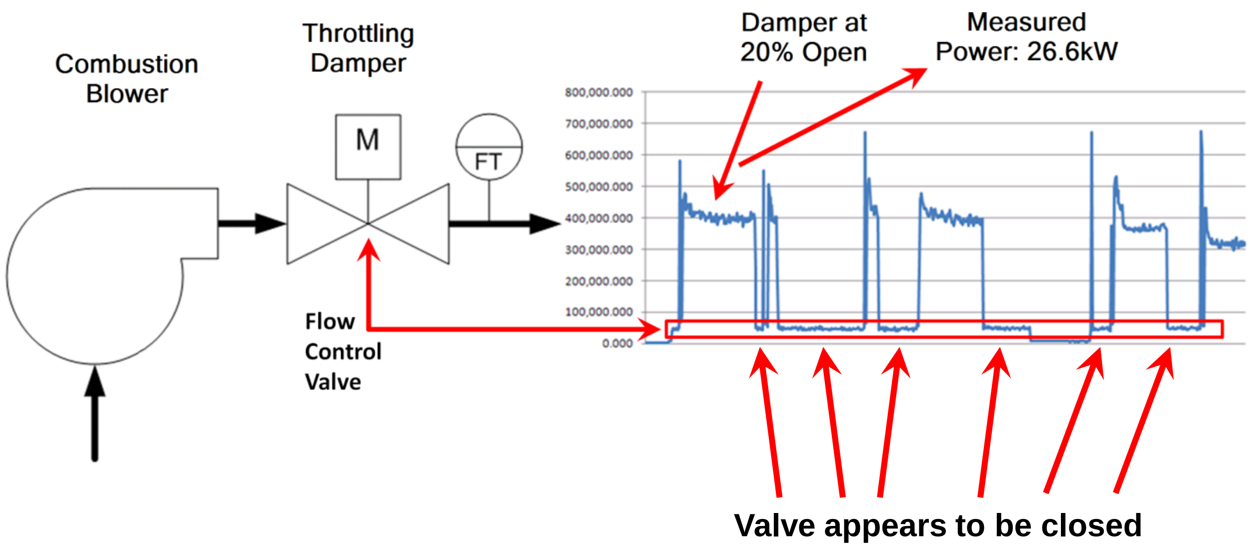
Alpha – Valve vs. ASD

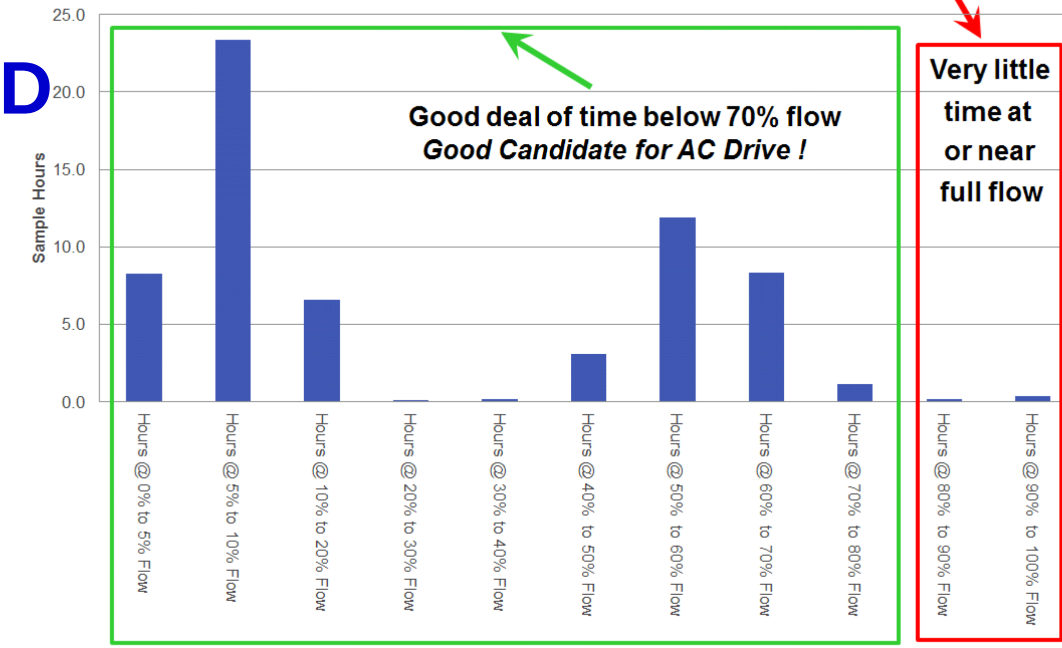
- Valve normally around 20% open
- At times, blower “dead heads”

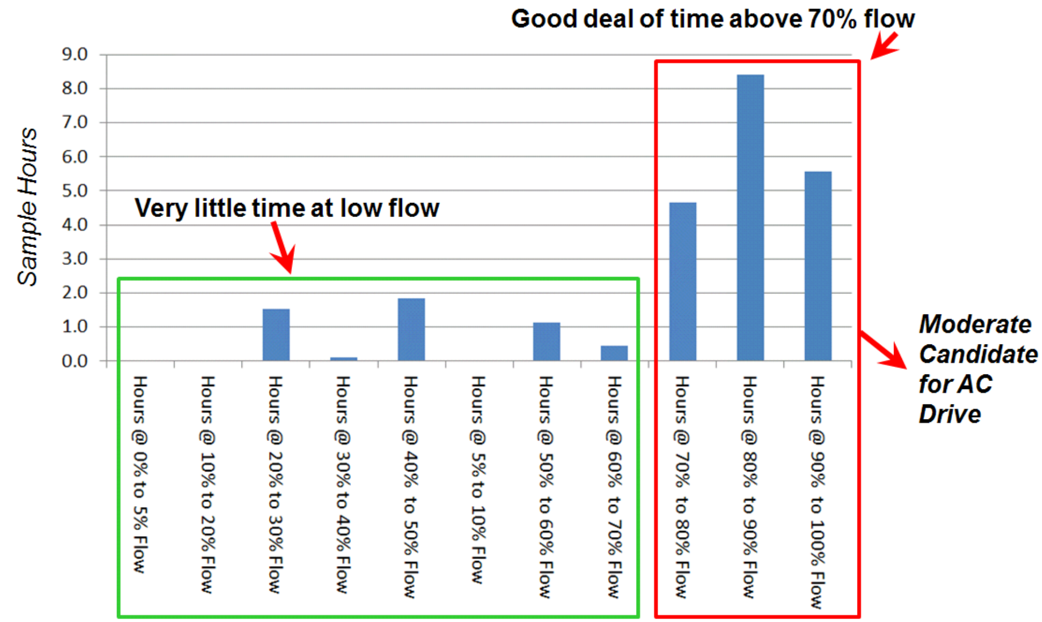




Alpha – Valve vs. ASD

- Blower 1:
  - ASD may save significant energy
- Blower 2:
  - ASD may save some energy





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Alpha – ASD Application

- May install drives to save energy in the long term
- May also turn off blower when valve is closed for immediate savings.

ECM	Savings/ yr	Cost	Simple Payback	
Use AC Drives for 60 hp combustion air blowers to replace throttling damper scheme. (typical 5 places)	Best Case: $14,960 Worst Case: $10,495	$36,390	Best Case: 2.43 years Worst Case: 3.47 years	Cost includes estimated labor of $1500 per installation. Best and Worst estimates based on analysis of two Dryers
Optional or interim solution to implementing above ECM: Turn combustion blower motors off when dampers are closed (typical 5 places)	$25,600	$0	immediate	May be a best-case estimate—based on review of the manual control operation on 1st dryer blower. Simple PLC code change to turn blower motor starter off required.

Alpha Motor Considerations

- Alpha chooses replacement motors of higher efficiency rather than rewiring failed motors

Alpha Belt Drives

- V-belt replacement
  - Standard
  - Cogged
  - Synchronous
- Could save money by replacing standard v-belts

ECM - Replace V-Belt with Cogged or Synchronous Belt			
Cost/kWh		0.065	Average kWh Costs
Operating Hrs/yr		6240	
V-Belt Efficiency		0.93	Typical Value over lifetime
Cogged-Belt Efficiency		0.95	Typical Value over lifetime
Synchronous Belt Efficiency		0.98	Typical Value over lifetime
Total Motor HP		1475	Total HP from Both Sites
Number of Fans		16	
Motor Efficiency		0.95	Percent
Motor Power Usage		1158	kW
Motor Diversity		100%	% of time Motor is running
Load Diversity		75%	Average Load
Net Hours Base Loaded		4680	
Power Savings Cogged Belt		24.4	kW
Power Savings Synchronous Belt		59.1	kW
Yearly Energy Use with V-belt		5,420,672	kWh
Energy Savings Cogged Belt		114,119	kWh
Energy Savings Synchronous Belt		276,565	kWh
Estimated Yearly Savings Cogged Belt	$	7,418	
Estimated Yearly Savings Synchronous Belt	$	17,977	
Estimated Cost/Cogged Belt	$	500	Site & App specific
Total Estimated Cost/Cogged Belts	$	8,000	
Estimated Cost/Synchronous Belt and Sprockets	$	1,000	Site & App specific
Total Estimated Cost/Synchronous Belts & Sprockets	$	16,000	
Estimated Payback Cogged Belt		12.94	Months
Estimated Payback Synchronous Belt		11	Months

Alpha Lighting

- Existing Metal Halide - ~460W per fixture

Fixture & lamp #	Cost of Fixture plus 20% labor	% of energy 460W Metal Halide	Payback 24/7	Payback 24/5	Payback 12/7	Mean lumens
T5, 2-lamp	$ 330.0	23%	1.6	2.3	3.3	9K-10K
T5, 3-lamp	$ 408.0	35%	2.4	3.4	4.8	13K-15K
T5, 4-lamp	$ 618.0	47%	4.4	6.2	8.9	18K-20K
T5, 6-lamp	$ 480.0	78%	8.4	11.8	16.9	28K-30K
T8, 2-lamp	$ 144.0	12%	0.6	0.9	1.3	5.1K-6.2K
T8, 3-lamp	$ 156.0	18%	0.7	1.0	1.5	7.7K-9.3K
T8, 4-lamp	$ 240.0	25%	1.2	1.7	2.4	10.3K-12.4K
T8, 6-lamp	$ 336.0	42%	2.2	3.1	4.4	15K-18.6K
Metal Halide 460W		na	na	na	na	29K

Comparable light output

Based on $0.065/kWh

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Alpha Lighting

- Simple payback averages 3.2 years
  - 1.7 to 7 years
  - LED replacements based on $800 per fixture
    - Price is decreasing

ECM	Savings/yr	Cost	Simple Payback
Compressed air shop 1: replace six 460W metal halide fixtures with T8, 6-lamp units	$912	$2,016	2.2 years
Compressed air shop 2: replace five 250W metal halide fixtures with T8, 3-lamp units	$473	$780	1.7 years
Compressed air shop outside lighting: Replace 14 outside 458W metal halide fixtures with LED fixtures	$1,602	$11,200	6.99 years
Warehouse 2: replace six 250W metal halide fixtures with T8, 3-lamp units	$936	$567	1.7 years
Waste Oil Storage Building: replace four 250W metal halide fixtures with T8, 3-lamp units	$378	$624	1.7 years
Maintenance building: replace eighteen 460W metal halide fixtures with T8, 6-lamp units	$2,737	$6,048	2.2 years
Maintenance building: replace six 460W metal halide fixtures with LED	$686	$4,800	6.99 years
Crusher building: replace six 460W metal halide fixtures with T8, 6-lamp units	$912	$2,016	2.2 years

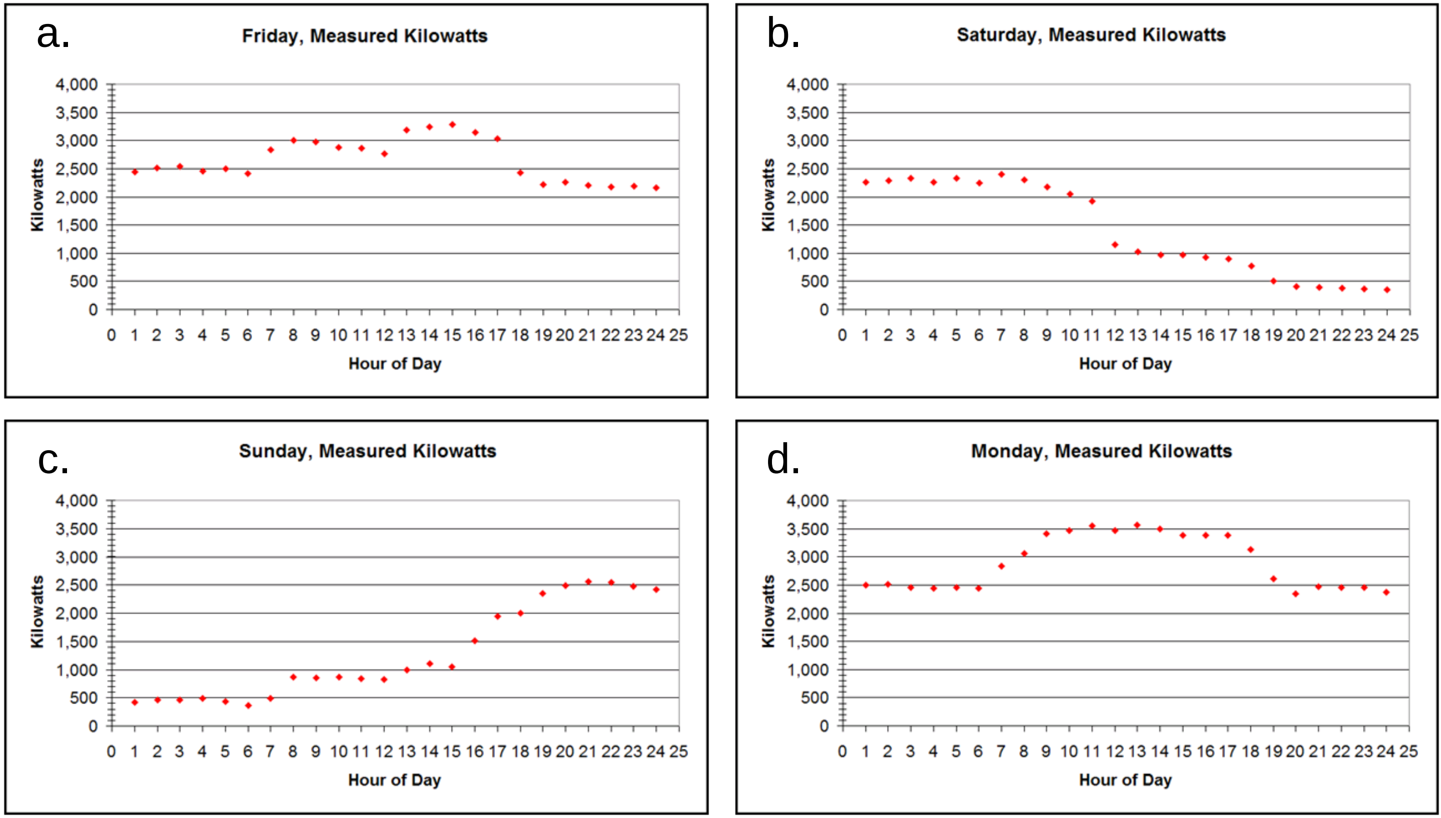
Beta Company

- Manufactures cleaning equipment
  - Brooms, mops, etc.
- Identified ~$89,000 per year in energy cost savings
- Costs totaled around $138,000
- Simple payback averaged 1.6 years
  - Ranged from immediate to 11.5 years

ECM	Savings/yr	Cost	Simple Payback	
Delayed Machine by 2 hours on Sundays	$3,016	$0	Immediate	Operational procedures should be reviewed.
Turn off Injection Molding Conveyors when not in use	$1,844	$9,200	4.88 years	Use simple interlocking with machine run contactor. Utility incentives may lower payback.
Follow Heater Shutdown Procedures	$43,602	$0	Immediate	The plant load is 2MW to 2.5MW for 12 hours between shifts. More thorough machine shutdown between shifts could lead to significant savings.
Insulate Heater Barrels on Machines	$21,149	$38,064	1.8 years	EPRI estimates are more conservative than blanket supplier estimate.
Install additional efficient lighting for (163) T8 fixtures	$1,423	$16,300	11.5 years	Utility incentive not included in payback
Install additional efficient lighting for (95) T12 fixtures	$2,352	$9,500	4 years	Utility incentive not included in payback
Replace 21 Metal Halide Fixtures with 6 Lamp T-5s	$878	$5,280	6 years	Utility incentive not included in payback
Replace remaining Outdoor Metal Halides with LEDs	*$6,724*	$60,000	9 years	Utility incentive not included in payback
Consider Lowering Compressed Air Pressure by 10 PSIG	*$3,571*	$0	Immediate	Every 2 psi equates to a 1% decrease in energy costs.
Utilize mechanical spring or stop instead of compressed air to hold open boiler damper	*$4,500*	$0	Immediate	Inappropriate use of compressed air.
Utilize MotorMaster+ and MotorMaster+ International to purchase replacement motors	*$0*	$0	Immediate	See examples in report regarding potential savings for select motor types.

Beta Company Energy Profile – 2 year data

- Weekdays resembled “a.” and “d.” below
- Weekends (“b.” and “c.”) may fall to 500 kW but may remain at or above 1,000 kW
- At end of profile period, energy use on weekends fell to well-below 500 kW
  - May have realized energy being wasted



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Beta Extrusion Processes

- Do extruder heater barrels continue to heat without production?
  - Require 2-hour warm-up
    - Can this be delayed?
    - ~$3,000 savings per year possible with no capital costs

ECM - Delayed Load Start Up		
Cost/kWh	0.058	Average kWh Costs
Cold Start-up Occurances/Year	52	
Delayed Load Startup	2	Hours
Delayed Startup Load Amount	500	kW
Estimated kWH Savings	52000	
Estimated Yearly Savings	$ 3,016	
EstimatedPayback	Immediate	

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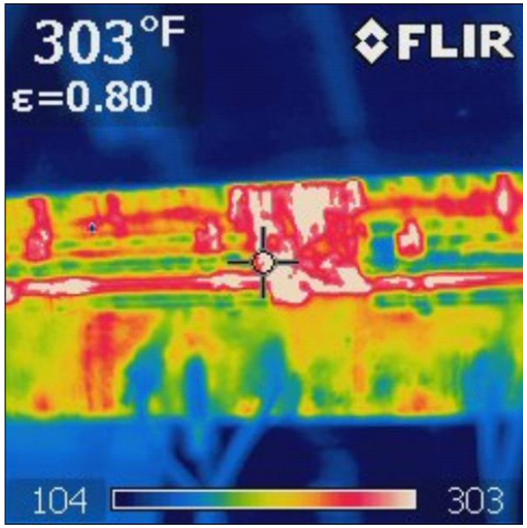
Beta Extrusion Process Conveyors

- Some conveyors appeared to run whether or not production also occurred
- Install interlock or implement effective procedure modification
  - Procedure payback immediate
  - Interlock payback ~59 months
    - Utility incentives possible

ECM - Turn off Motors When not in Use		
Cost/kWh	0.058	Average kWh Costs
Operating Hrs/yr	6240	
Motor Size	0.33	Typical HP
Motor Efficiency	0.82	For small motors, low efficiency
Motor Power Usage	0.40	kW
Motor Diversity	100%	% of time Motor is on Normally
Load Diversity	75%	% of time at or near full load
Net Hours Base Loaded	4680	
Est. Percent of Time Left On when not in use	15%	This is a guess that would need to be verified.
Estimated Hour Reduction if Turned Off	702	
kWh/yr saved	283	
Number of Motors	115	Based on average of 2.5 conveyor motors per machine
Total kWh/yr saved	32,489	
Estimated Yearly Savings	$ 1,884	
Estimated cost	$ 200	Estimated Cost to implement per machine, simple contact interlocking
Number of Machines	46	Injection Molding Machine Count
Total Estimated Cost	$ 9,200	
Utility Incentives	$ -	Note if applicable
Net Estimated Cost	$ 9,200	Total cost minus any incentives
EstimatedPayback	4.88	Years
	59	Months

Beta Extruder Barrels

- Two-hour warm-up, often left idle.
  - Not insulated
- If turned off during idle periods
  - $43,602 potential savings



ECM : Heaters off in Idle State (Non Insulated Heater Barrels)

Cost/kWH $ 0.058

Machine	No. Units	hours/Year in Idle State	Estimated KW Uninsulated Per Machine	Estimated Total kW Used in Idle	Total kWh/Yr Savings if Heaters Turned Off	Estimated yearly Savings	
EC55	2	3120	1	2.0	6,240	$	361.92
EC65n	1	3120	1	1.0	3,120	$	180.96
EC110	2	3120	1.5	3.0	9,360	$	542.88
EC180	2	3120	2	4.0	12,480	$	723.84
EC200 SX	3	3120	2	6.0	18,720	$	1,085.76
Ec240n	1	3120	2.5	2.5	7,800	$	452.40
EC310N	6	3120	3	18.0	56,160	$	3,257.28
EC500	2	3120	7.65	15.3	47,736	$	2,768.69
EG500 NII	6	3120	7.65	45.9	143,208	$	8,306.06
ISGS 500	5	3120	7.65	38.3	119,340	$	6,921.72
EC610	5	3120	7.65	38.3	119,340	$	6,921.72
Isf 610 sii	1	3120	7.65	7.7	23,868	$	1,384.34
ISG610	4	3120	7.65	30.6	95,472	$	5,537.38
EC720 NII	1	3120	8.5	8.5	26,520	$	1,538.16
Main Extruders	2	3120	10	20.0	62,400	$	3,619.20
					Totals	$	43,602

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Insulate Extruder Barrels

- Estimated energy cost with insulated extruder barrels
  - $10,574
- Estimated savings per year
  - ~$30,000

ECM : Heaters off in Idle State (Insulated Heater Barrels)							
Cost/kWH	$ 0.058						
Machine	No. Units	hours/Year in Idle State	Estimated KW insulated Per Machine	Estimated Total kW Used in Idle	Total kWh/Yr Savings if Heaters Turned Off	Estimated yearly Savings	
EC55	2	3120	0.7	1.3	4,118	$	238.87
EC65n	1	3120	0.7	0.7	2,059	$	119.43
EC110	2	3120	1.0	2.0	6,178	$	358.30
EC180	2	3120	0.8	1.6	4,992	$	289.54
EC200 SX	3	3120	0.8	2.4	7,488	$	434.30
Ec240n	1	3120	1.0	1.0	3,120	$	180.96
EC310N	6	3120	0.9	5.4	16,848	$	977.18
EC500	2	3120	1.6	3.2	10,025	$	581.42
EG500 NII	6	3120	1.6	9.6	30,074	$	1,744.27
ISGS 500	5	3120	1.6	8.0	25,061	$	1,453.56
EC610	5	3120	1.6	8.0	25,061	$	1,453.56
Isf 610 sii	1	3120	1.6	1.6	5,012	$	290.71
ISG610	4	3120	1.6	6.4	20,049	$	1,162.85
EC720 NII	1	3120	2.1	2.1	6,630	$	384.54
Main Extruders	2	3120	2.5	5.0	15,600	$	904.80
					Totals	$	10,574

Beta Lighting

- Company replaced many of its metal halide fixtures (460W) before audit
  - 420 T5 6-lamp fixtures at 320W per fixture
  - Small difference in watts; therefore small savings possible
    - Calculated to be 270,000 kWh
    - Utility reported 240,000 kWh saved, or $12,000 at $0.056 per kWh
  - Additional metal halide remained with plans to replace them
  - Outdoor metal halide fixtures replaced with LED fixtures:

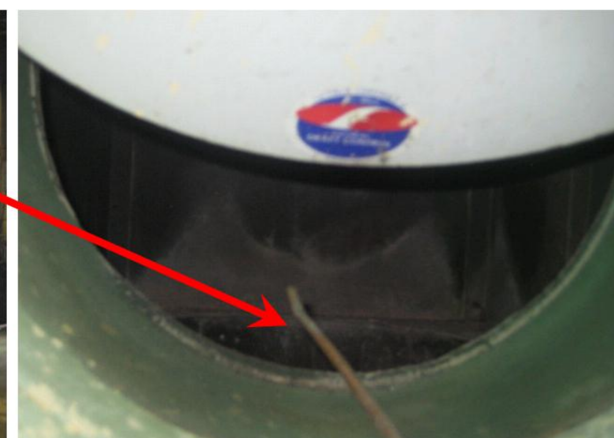
Technology	Cost/Fixture	Total Fixtures	kW/Fixture	Hrs/Year	KW Total	kWH Total	Cost/kWH	Cost/Year	
Metal Halide	$216	1	0.458	4380	0.458	2006.04	0.05	$100.30	
LED	$800	1	0.056	4380	0.056	245.28	0.05	$ 12.26	
							Savings	$ 88.04	
							Costs	$800	
							Payback	*9.04*	*Years*

Beta Compressors

- Compressed air is costly and between 10% and 15% efficient
- Rule of Thumb for cost: increases around 1% for every 2 pounds per square inch at 100 psi
- Should not be used to hold open a flue damper
  - Estimated cost at $4,500 per year
- Leak study recently done
  - EPRI audit did not identify any leaks

Header Pressure	Energy Cost Increase	Cost/Year
100	0%	$ 53,296
102	1%	$ 53,829
104	2%	$ 54,373
106	3%	$ 54,927
108	4%	$ 55,493
110	5%	$ 56,071
112	6%	$ 56,660
114	7%	$ 57,262
116	8%	$ 57,877
118	9%	$ 58,505
120	10%	$ 59,147

Based on 8760 hours of operation at 0.07343 $/kWh and 90% efficiency


Beta Compressor Air Pressure

- 113 psi at time of audit
- At 103 psi, savings could be realized
  - no material cost
  - Simply adjust pressure
- $3,570 cost savings/yr

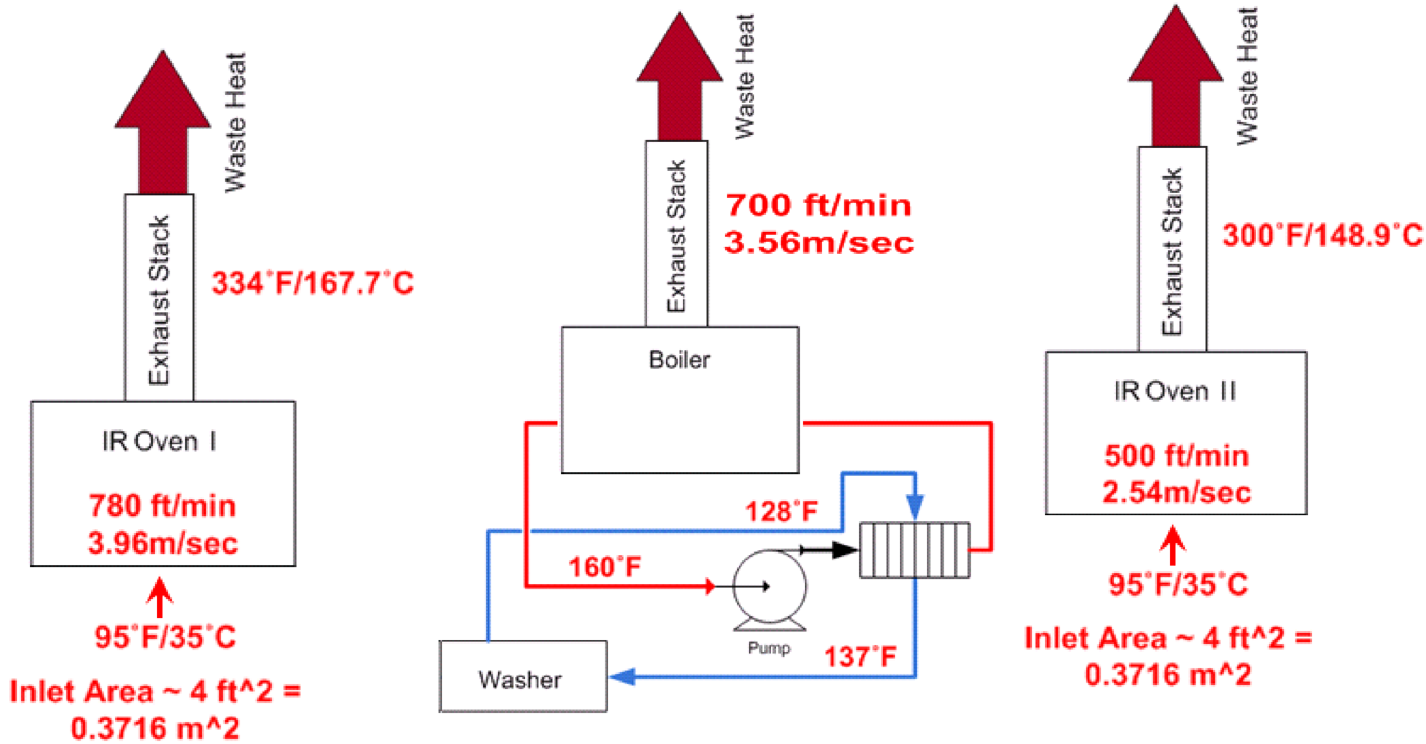
ECM Lower Compressed Air Pressure		
Cost/kWh	0.058	Average kWh Costs
Operating Hrs/yr	6240	
Air Compressor Size	250	Total HP
Motor Efficiency	0.945	Percent
Compressor Power Usage	197	kW
Compressor Diversity	100%	% of time compressor is on
Load Diversity	100%	% of time at or near full load
Net Hours Base Loaded	6240	
Current Header Pressure	113	psig
Reduced Air Pressure	103	psig
Reduction Factor	5.0%	
Estimated Electricity Consumption Decrease	9.9	kW
kWh/yr saved	61,575	
Estimated Yearly Savings	$ 3,571	
Estimated Payback	Immediate	

Extruders: Hydraulic vs. Electric

- 8 injection molding machines were hydraulic—will be replaced
- Hydraulic extruders may be slower but capable of greater force
  - Good for metal casting
  - May not be necessary for plastic extrusion
- Electric-powered machines may reduce energy costs by 30% to 60% compared to hydraulic
  - May process plastic molds faster

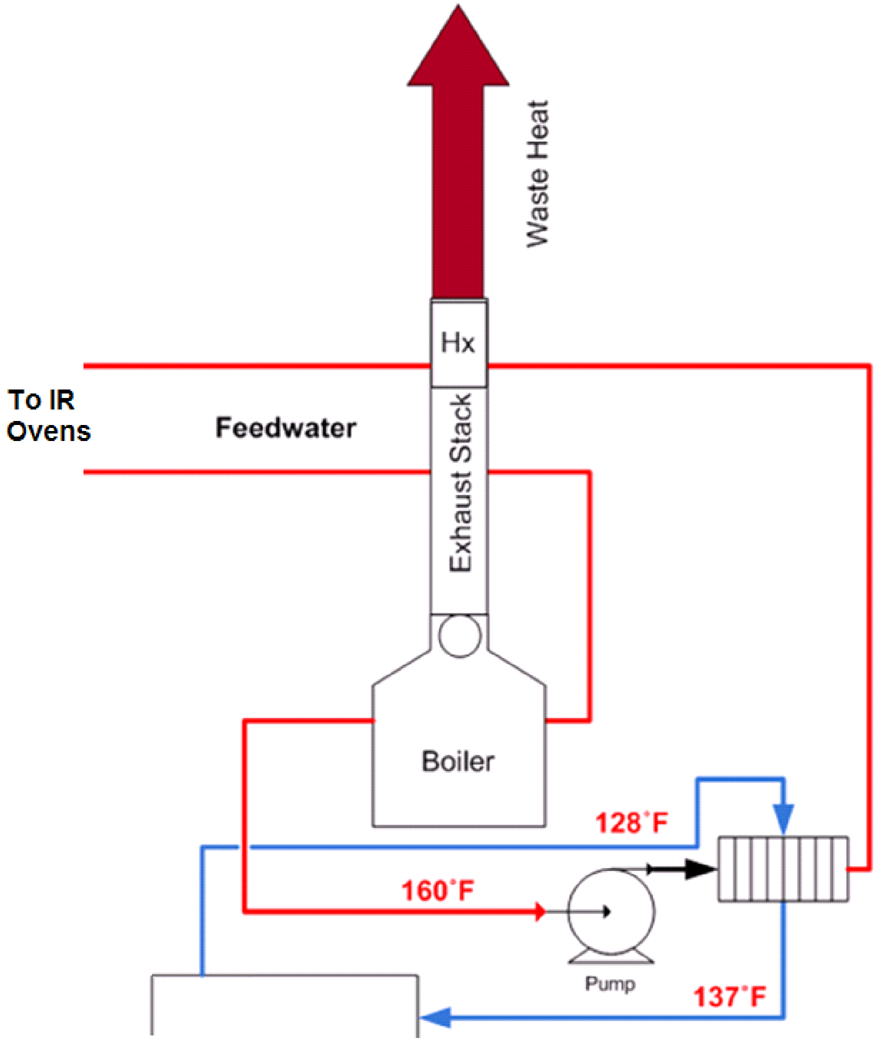
Beta Company Waste Heat Recovery

- Two IR Furnaces and one natural gas boiler
  - Waste heat from ovens: 1,272,676 BTU per hour
  - Could be used to preheat boiler water



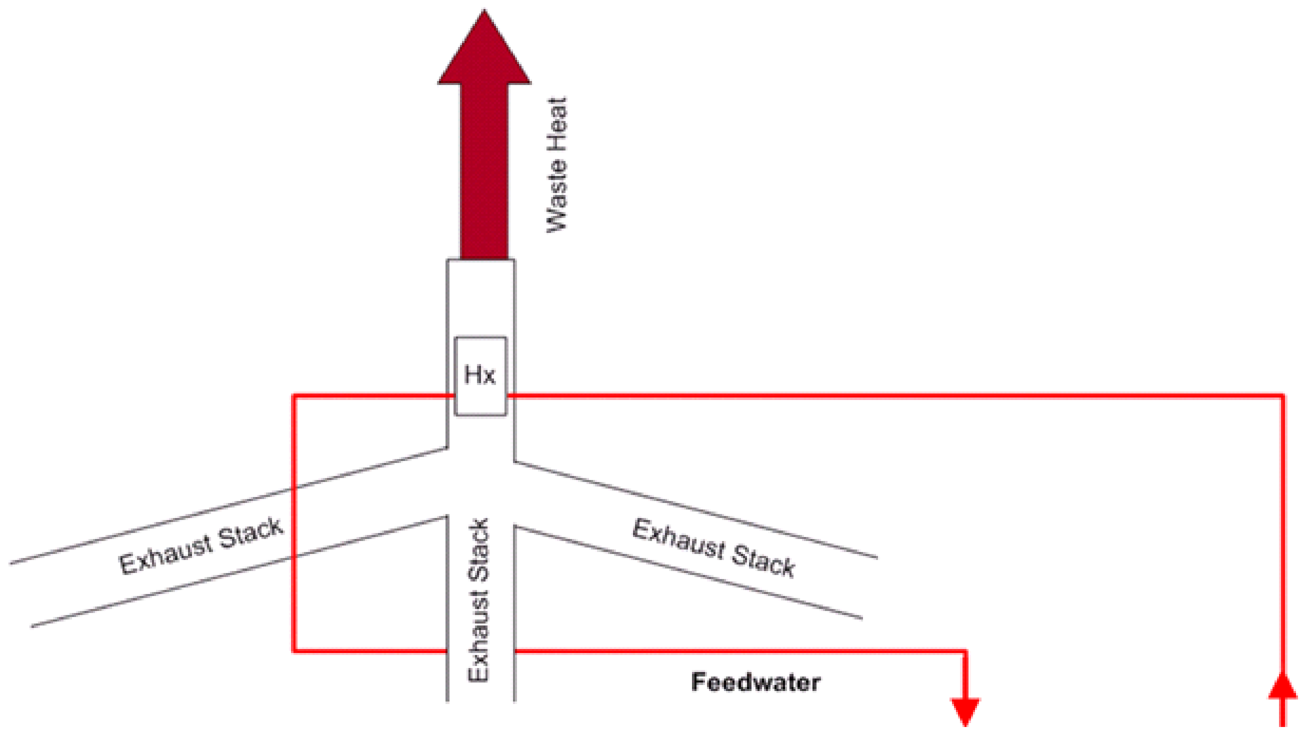
Beta Company Waste Heat Recovery

- Three separate heat exchangers
  - Two ovens
  - One boiler



Beta Company Waste Heat Recovery

- One large heat exchanger
- Significant ductwork



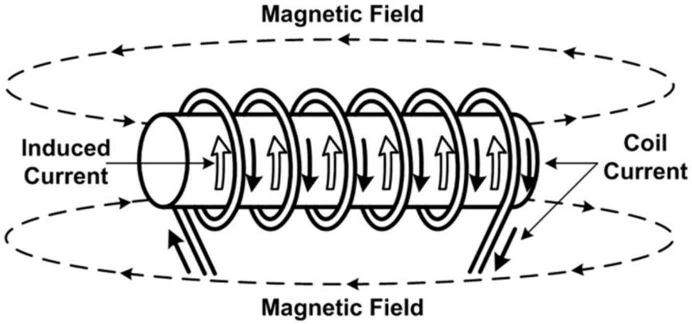
Mastering Motors

- EISA 2007 standards for new motors
  - mandatory from December 2010
  - all general purpose motors—NEMA Premium Efficiency, 85.6 to 96.2%—
  - larger motors from 201HP up to 500HP—96.2%—as well as Type II motors
- EPRI team identified 1HP motors with efficiency rating of 77%
  - Replace with 84.6% effic. motor, payback in 4 months*
- Replace 10HP 87.5% effic. with 91.6%
  - Payback in ~2.5 years*
- Replace 250HP 94.5% effic. with 95.8%
  - Payback in ~6.4 years*

*Using DOE's ITP Motormaster + software

Alternate Heating Method

- Process heat for metal components for products came from infrared ovens
- Heat could come from Magnetic Induction instead
  - Heats quickly to required temperature
  - Only heats material (steel)



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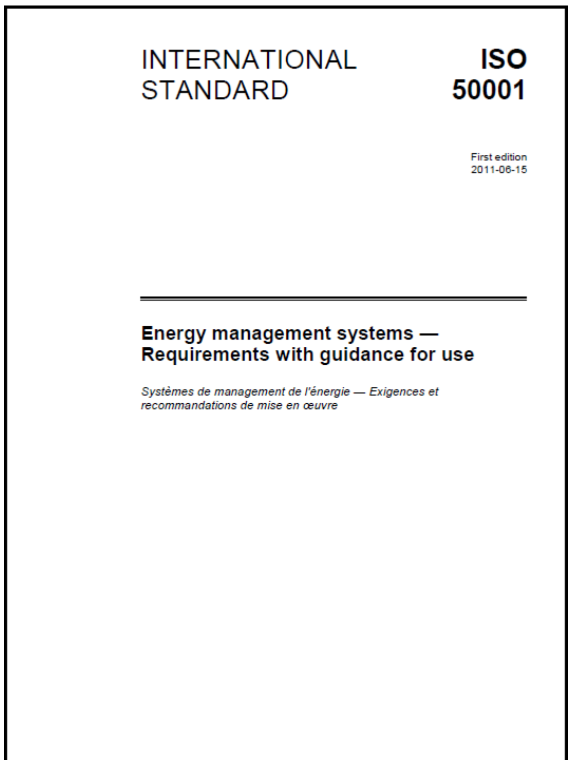
ISO 50001 and Superior Energy Performance

Mark Stephens, PE, CEM
EPRI | Senior Project Manager
Industrial PQ & Energy Efficiency

PQ and SD 2012
June 7, 2012

Related Standards Documents

- ISO 50001 – Energy Management Systems Requirements with Guidance for use
- ANSI 50021 – Additional Requirements for Energy Management Systems
- Superior Energy Performance Certification Protocol

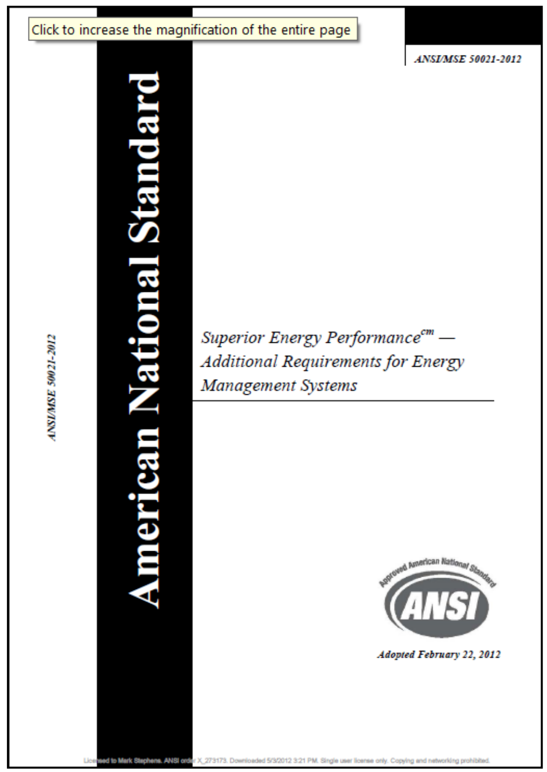

INTERNATIONAL STANDARD

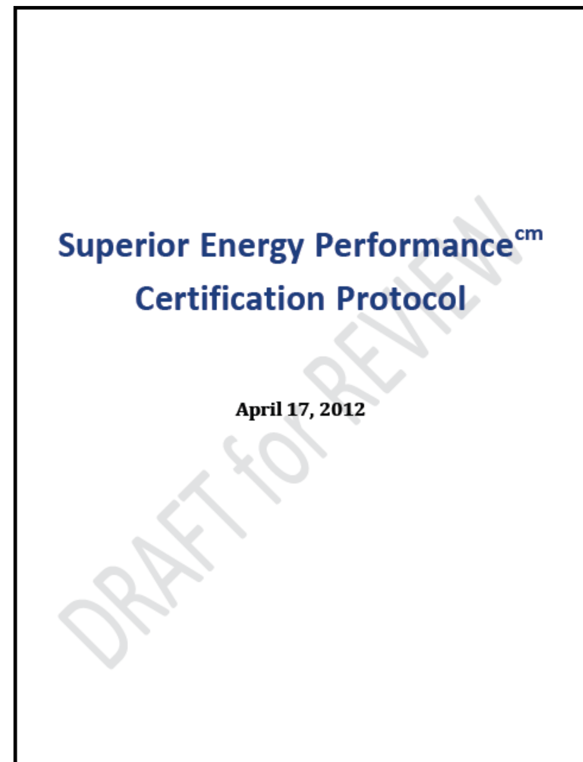
ISO 50001

First edition
2011-06-15

Energy management systems — Requirements with guidance for use

Systèmes de management de l'énergie — Exigences et recommandations de mise en œuvre





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ISO 50001

ISO 50001 – What is it?

ISO 50001:2011, *Energy management systems – Requirements with guidance for use*, is a voluntary International Standard developed by ISO (International Organization for Standardization).

ISO 50001 gives organizations the requirements for energy management systems (EnMS).

ISO 50001 provides benefits for organizations large and small, in both public and private sectors, in manufacturing and services, in all regions of the world.

ISO 50001 will establish a framework for industrial plants; commercial, institutional, and governmental facilities; and entire organizations to manage energy. Targeting broad applicability across national economic sectors, it is estimated that the standard could influence up to 60% of the world's energy use.*

Ref: DOE ISO 50001 Brochure:
http://www1.eere.energy.gov/energymanagement/index.html

What is Superior Energy Performance (SEP)

- Superior Energy Performance^{cm} is a certification program that provides industrial facilities with a roadmap for achieving continual improvement in energy efficiency while maintaining competitiveness.
- The program will provide a transparent, globally accepted system for verifying energy performance improvements and management practices.
- A central element of Superior Energy Performance is implementation of the global energy management standard, ISO 50001, with additional requirements to achieve and document energy performance improvements

		Level		
Pathway	Requirements	Silver	Gold	Platinum
Energy Performance	Minimum % improvement	5%	10%	15%
	Maximum years to achieve*	3	3	3
Mature Energy	Minimum % Improvement	15%	15%	15%
	Maximum years to achieve*	10	10	10
	Minimum Best Practice Scorecard points	35	61	81

Ref: http://www.superiorenergyperformance.net/

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ISO 50001

Ref: DOE ISO 50001 Brochure:
http://www1.eere.energy.gov/energymanagement/index.html

ISO 50001 — Why is it important?

Energy is critical to organizational operations and can be a major cost to organizations, whatever their activities. An idea can be gained by considering the use of energy through the supply chain of a business, from raw materials through to recycling.

In addition to the economic costs of energy to an organization, energy can impose environmental and societal costs by depleting resources and contributing to problems such as climate change.

The development and deployment of technologies for new energy sources and renewable sources can take time.

Individual organizations cannot control energy prices, government policies or the global economy, but they can improve the way they manage energy in the here and now. Improved energy performance can provide rapid benefits for an organization by maximizing the use of its energy sources and energy-related assets, thus reducing both energy cost and consumption. The organization will also make positive contributions toward reducing depletion of energy resources and mitigating worldwide effects of energy use, such as global warming.

ISO 50001 is based on the management system model that is already understood and implemented by organizations worldwide. It can make a positive difference for organizations of all types in the very near future, while supporting longer term efforts for improved energy technologies.

ISO 50001

Ref: DOE ISO 50001 Brochure:
http://www1.eere.energy.gov/energymanagement/index.html

ISO 50001 — What will it do?

ISO 50001 will provide public and private sector organizations with management strategies to increase energy efficiency, reduce costs and improve energy performance.

The standard is intended to provide organizations with a recognized framework for integrating energy performance into their management practices. Multinational organizations will have access to a single, harmonized standard for implementation across the organization with a logical and consistent methodology for identifying and implementing improvements.

The standard is intended to accomplish the following:

- Assist organizations in making better use of their existing energy-consuming assets
- Create transparency and facilitate communication on the management of energy resources
- Promote energy management best practices and reinforce good energy management behaviours
- Assist facilities in evaluating and prioritizing the implementation of new energy-efficient technologies
- Provide a framework for promoting energy efficiency throughout the supply chain
- Facilitate energy management improvements for greenhouse gas emission reduction projects
- Allow integration with other organizational management systems such as environmental, and health and safety.

ISO 50001

ISO 50001 — How does it work?

ISO 50001 is based on the ISO management system model familiar to more than a million organizations worldwide who implement standards such as ISO 9001 (quality management), ISO 14001 (environmental management), ISO 22000 (food safety), ISO/IEC 27001 (information security).

In particular, ISO 50001 follows the Plan-Do-Check-Act process for continual improvement of the energy management system.

These characteristics enable organizations to integrate energy management now with their overall efforts to improve quality, environmental management and other challenges addressed by their management systems.

ISO 50001 provides a framework of requirements enabling organizations to:

- Develop a policy for more efficient use of energy
- Fix targets and objectives to meet the policy
- Use data to better understand and make decisions concerning energy use and consumption
- Measure the results
- Review the effectiveness of the policy
- Continually improve energy management.

ISO 50001 can be implemented individually or integrated with other management system standards.

Ref: DOE ISO 50001 Brochure:
http://www1.eere.energy.gov/energymanagement/index.html

ISO 50001

ISO 50001 — Who can it benefit?

Like all ISO management system standards, ISO 50001 has been designed for implementation by any organization, whatever its size or activities, whether in public or private sectors, regardless of its geographical location.

ISO 50001 does not fix targets for improving energy performance. This is up to the user organization, or to regulatory authorities. This means than any organization, regardless of its current mastery of energy management, can implement ISO 50001 to establish a baseline and then improve on this at a rhythm appropriate to its context and capacities.

ISO 50001 — To certify or not?

Like all ISO management system standards, ISO 50001 can be implemented solely for the internal and external benefits it provides the user organizations and the latter's stakeholders and customers. Certification by an independent auditor of conformity of the user's energy management system to ISO 50001 is not a requirement of the standard itself. To certify or not is a decision to be taken by the ISO 50001 user, unless imposed by regulation.

Alternatives to independent (third party) certification are to invite the organization's customers to verify its implementation of ISO 50001 in conformity with the standard (second party verification), or to self-declare its conformity.

Ref: DOE ISO 50001 Brochure:
http://www1.eere.energy.gov/energymanagement/index.html

ISO 50001

ISO 50001 — What's in the standard ?

The content of ISO 50001 is structured as follows :

Foreword

Introduction (extract from ISO 50001)

"The purpose of this International Standard is to enable organizations to establish the systems and processes necessary to improve energy performance, including energy efficiency, use, and consumption. Implementation of this standard is intended to lead to reductions in greenhouse gas emissions, energy cost, and other related environmental impacts, through systematic management of energy. This International Standard is applicable to all types and sizes of organizations irrespective of geographical, cultural or social conditions. Successful implementation depends on commitment from all levels and functions of the organization, and especially from top management.

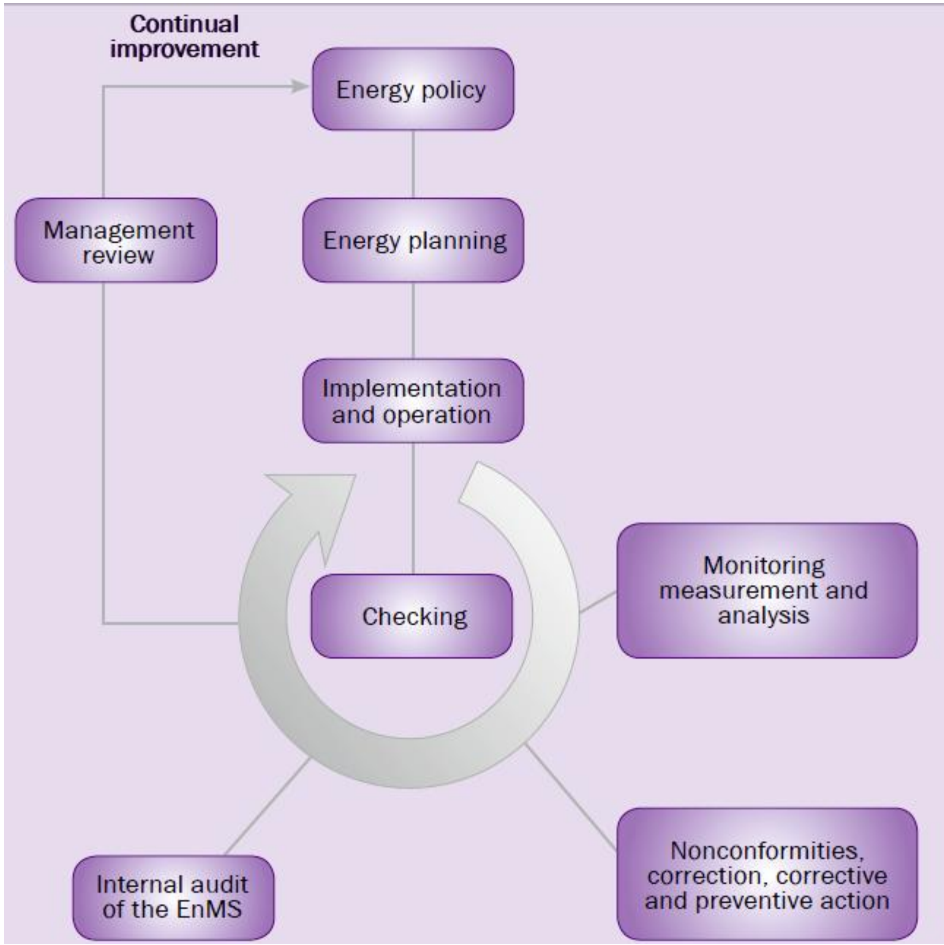
"This International Standard specifies requirements of an energy management system (EnMS) for an organization to develop and implement an energy policy, establish objectives, targets, and action plans, which take into account legal requirements and information related to significant energy use. An EnMS enables an organization to achieve its policy commitments, take action as needed to improve its energy performance and demonstrate the conformity of the system to the requirements of this International Standard. Application of this International Standard can be tailored to fit the requirements of an organization – including the complexity of the system, degree of documentation, and resources – and applies to the activities under the control of the organization.

"This International Standard is based on the Plan-Do-Check-Act continual improvement framework and incorporates energy management into everyday organizational practices.

Ref: DOE ISO 50001 Brochure:
http://www1.eere.energy.gov/energymanagement/index.html

ISO 50001 – Plan, Do, Check, Act

- **Plan:** *conduct the energy review and establish the baseline, energy performance indicators (EnPIs), objectives, targets and action plans necessary to deliver results in accordance with opportunities to improve energy performance and the organization's energy policy.*
- **Do:** *implement the energy management action plans.*
- **Check:** *monitor and measure processes and the key characteristics of its operations that determine energy performance against the energy policy and objectives and report the results.*
- **Act:** *take actions to continually improve energy performance and the EnMS.*



Ref: DOE ISO 50001 Brochure:
http://www1.eere.energy.gov/energymanagement/index.html

E-guide Offers Guidance to Standard Implementation

Ref: DOE E-Guide for ISO 50001:
https://save-energy-now.org/EM/SPM/Pages/Home.aspx

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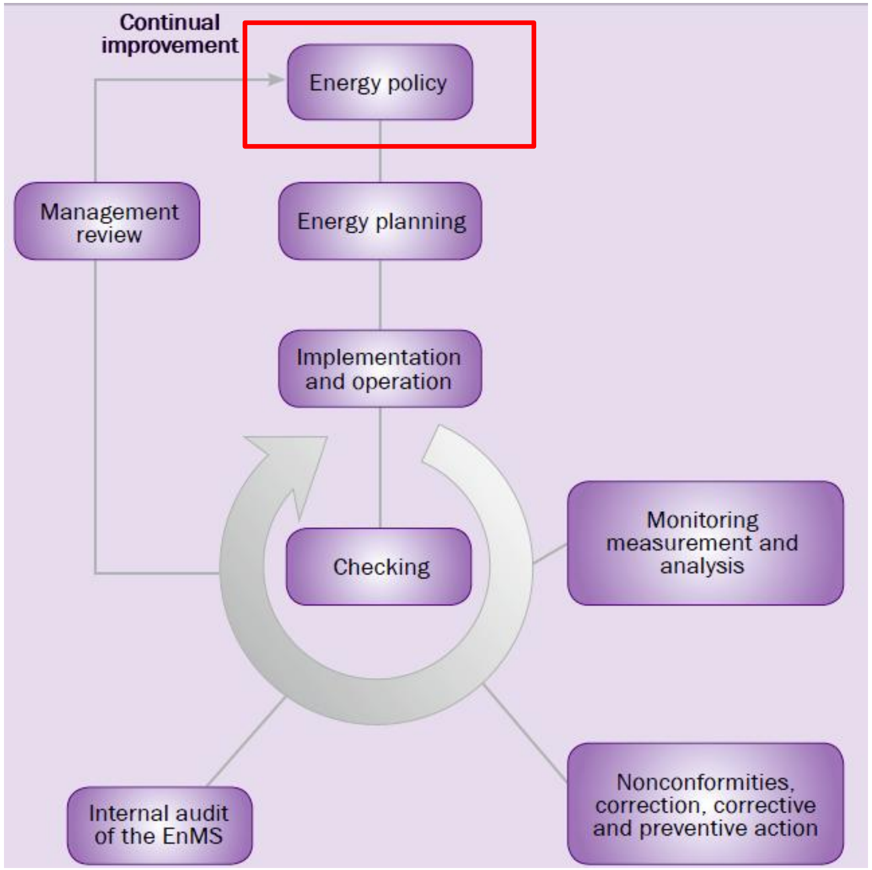
Step 1 – Getting Started with ISO 50001

Step 1.1 Make the business case
- Step 1.1.1 Identify key internal influencers
- Step 1.1.2 Understand your business drivers
- Step 1.1.3 Prepare sales pitch
- Step 1.1.4 Brief top management

Step 1.2 Secure top management commitment
- Step 1.2.1 Establish the scope and boundaries
- Step 1.2.2 Appoint a management representative
- Step 1.2.3 Assign the members of the energy team
- Step 1.2.4 Define the energy policy
- Step 1.2.5 Create organizational awareness
- Step 1.2.6 Ensure continual awareness

Step 1.3 Establish the structure for EnMS implementation
- Step 1.3.1 Set the timeframe for implementation
- Step 1.3.2 Develop the implementation plan
- Step 1.3.3 Establish communication channels
- Step 1.3.4 Celebrate success often

Step 1.4 Understand the role of documents and records



Ref: DOE E-Guide for ISO 50001:
https://save-energy-now.org/EM/SPM/Pages/Home.aspx

Step 2 - Profile Your Energy Situation

Step 2.1 Identify, evaluate and track legal and other requirements

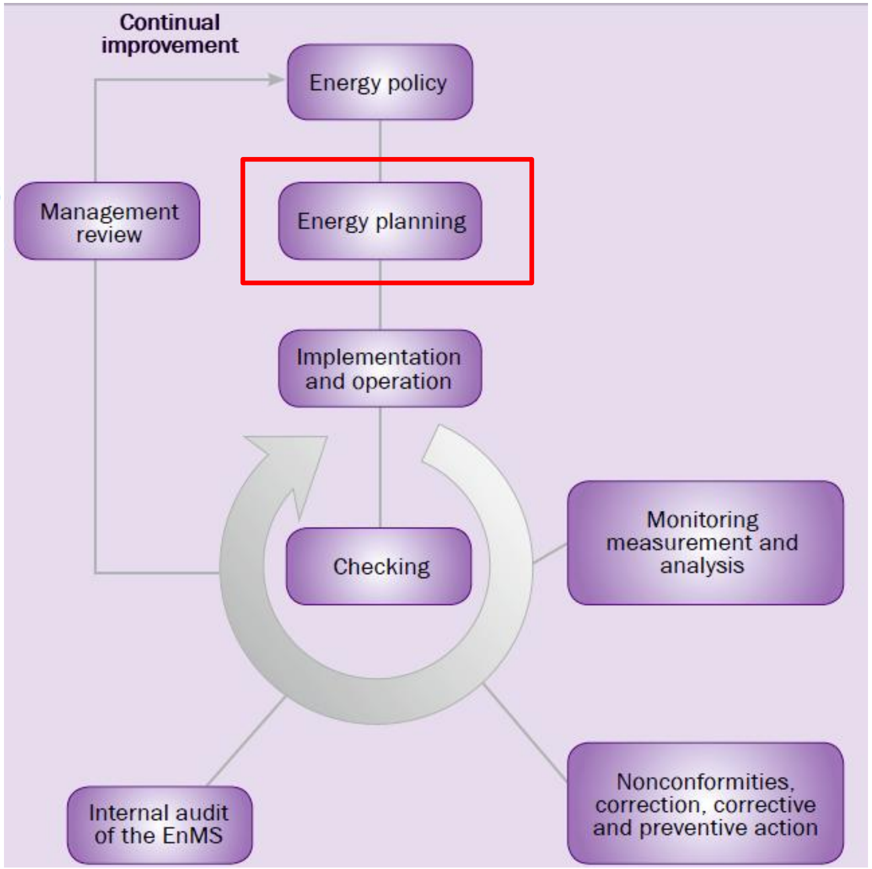
- Step 2.1.1 Identify and access legal requirements
- Step 2.1.2 Identify and access other requirements
- Step 2.1.3 Establish a process for evaluating and updating requirements
- Step 2.1.4 Plan for evaluating compliance with legal and other requirements

Step 2.2 Acquire, analyze and track energy data

- Step 2.2.1 Identify data needs
- Step 2.2.2 Determine availability of data
- Step 2.2.3 Formulate a process for acquiring and recording data
- Step 2.2.4 Investigate tools for analyzing and tracking energy data
- Step 2.2.5 Choose and implement an energy data management tool

Step 2.3 Determine significant energy uses

- Step 2.3.1 Prepare a list of your energy systems
- Step 2.3.2 Develop an energy balance
- Step 2.3.3 Determine criteria for significance
- Step 2.3.4 Record significant energy uses and the method used
- Step 2.3.5 Analyze and track significant energy uses



Ref: DOE E-Guide for ISO 50001:
https://save-energy-now.org/EM/SPM/Pages/Home.aspx

Step 2 - Profile Your Energy Situation

Step 2.4 Identify energy opportunities

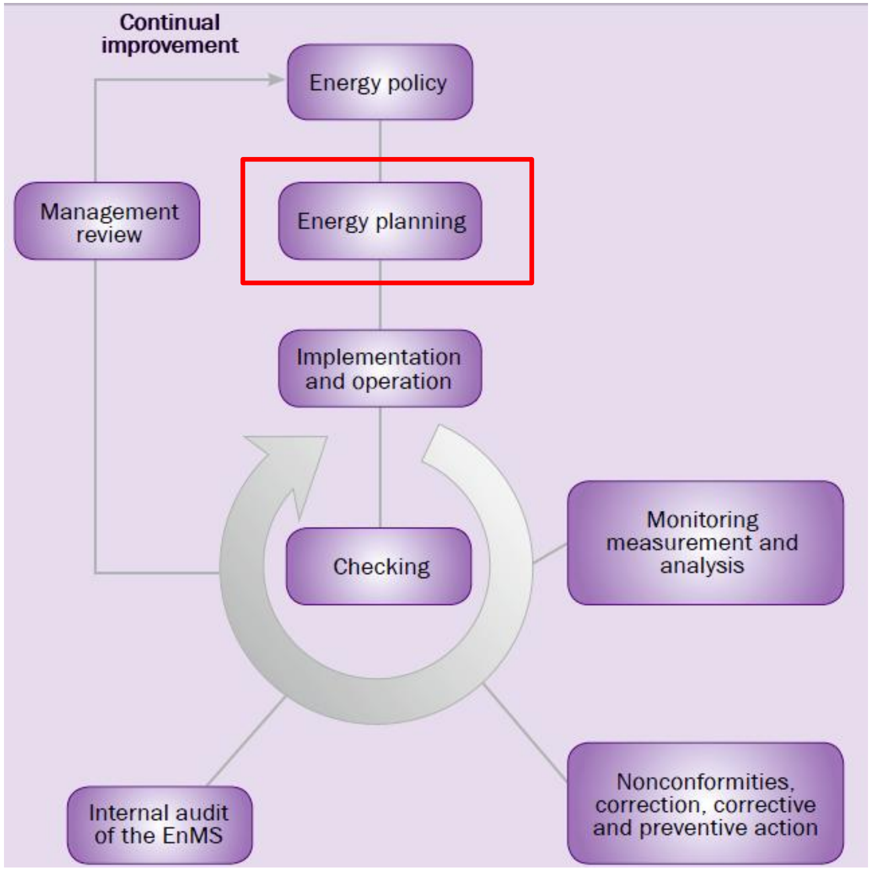
- Step 2.4.1 Use energy assessments
- Step 2.4.2 Utilize other methods

Step 2.5 Prioritize energy opportunities

- Step 2.5.1 Get the right people together
- Step 2.5.2 Review relevant organizational information
- Step 2.5.3 Determine criteria
- Step 2.5.4 Develop tools or techniques for applying criteria
- Step 2.5.5 Apply criteria to prioritize opportunities

Step 2.6 Establish a baseline and determine energy performance indicators (EnPIs)

- Step 2.6.1 Get stakeholder requirements for measuring performance
- Step 2.6.2 Establish a baseline
- Step 2.6.3 Develop a list of possible EnPIs
- Step 2.6.4 Determine factors that affect EnPIs
- Step 2.6.5 Select and test EnPIs
- Step 2.6.6 Analyze EnPIs to determine performance



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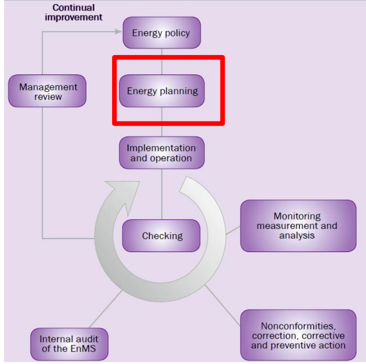
Example Energy Balance (Eguide 2.3.2)



Enterprise Annual Energy Usage

Source	Usage	Units
Natural gas	7,770	MMBtu
Electricity	2,119,800	kWh
Combined Btu	15,003	MMBtu

Step 2.3.2-2 Example Energy Balance

Energy Balance: Small Food Processing Plant

Description	Size	Units	Oper hr	Load	kWh	MMBtu	% total
Electrical Usage							
VSD screw	125	HP	8760	0.5	439,177	1,498	10.0%
Recip backup	50	HP	500	0.7	14,506	49	0.3%
Chiller	100	tons	8760	0.5	350,400	1,196	8.0%
Air handlers	20	HP	8760	0.75	108,916	372	2.5%
Cooling tower	15	HP	8760	0.45	49,012	167	1.1%
Refrigeration	3	tons	8760	0.5	10,512	36	0.2%
Process pumps	50	HP	6600	0.6	164,120	560	3.7%
Votator	20	HP	3300	0.4	21,883	75	0.5%
Homogenizer	40	HP	3300	0.4	43,765	149	1.0%
Plant lights	69	kW	6600	1	455,400	1,554	10.4%
Process motors	50	HP	6600	0.4	109,413	373	2.5%
Misc electrical use					352,695	1,203	8.0%
Natural Gas Usage							
Boiler	25	bHP	6600	0.35		6,909	46.1%
Water heater	300000	Btuh	8760	0.2		526	3.5%
Misc gas use						335	2.2%
Plant total						15,003	100.0%

Ref: DOE E-Guide for ISO 50001:
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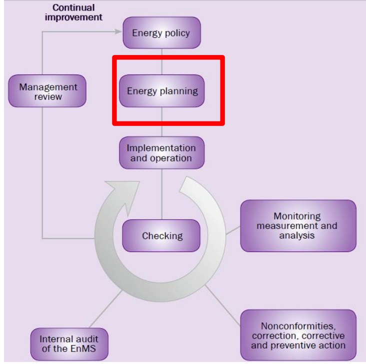
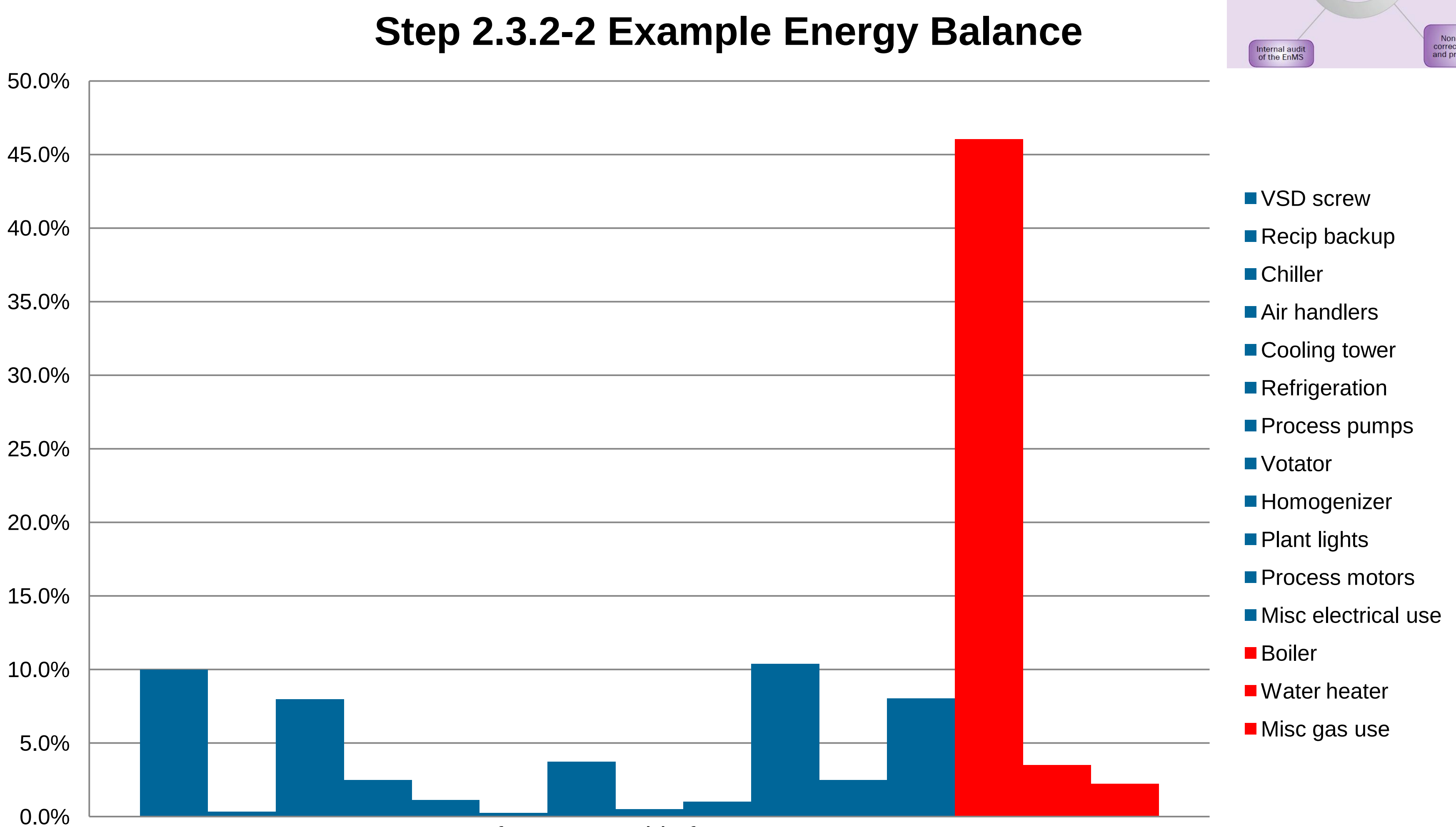
Example Energy Balance (Eguide 2.3.2)





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Example Cost Factor for Significant Energy Use Selection

Description	kW	%	Annual $
Melter	9,634	53.4%	$2,959,879
Hi Press Air Compressor	2,330	12.9%	$715,852
Med Press Air Compressor	780	4.3%	$239,641
Med Freq.	545	3.0%	$167,442
Forming Fans	494	2.7%	$151,773
Oven Scrubber	450	2.5%	$138,255
Scrubber	414	2.3%	$127,194
Cooling Water	407	2.3%	$125,044
Filtered Air	373	0.0%	$114,598
Fans	336	1.9%	$103,230
Med Freq	320	1.8%	$98,314
East Scrubber	255	1.4%	$78,344
Forming Fans	150	0.8%	$46,085
F. Fans West 4,5	122	0.7%	$37,482
Line Drive	69	0.4%	$21,199
Other loads and misc.	1,241	6.9%	$381,276
100% Load Factor kW	**18,042**	**100.0%**	**$5,543,090**

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Example EnPI Tracking (Eguide Step 2.3.5-2)

STEP 2.3.5-2 Example EnPI Tracking
Induction
Furnace
Tracking of EnPI for melt furnace personnel on 2 shifts
Daily data collected-shift steel production and furnace power input

Date	Shift 1			Shift 2		
	Tons melted	kWh in	1st shift EnPI-kWh/ton	Tons melted	kWh in	2nd shift EnPI-kWh/ton
15-Sep-10	624	255,840	410.00	610.00	245,758	402.88
16-Sep-10	624	255,712	409.80	610.00	245,630	402.67
17-Sep-10	624	255,559	409.55	610.00	245,483	402.43
18-Sep-10	624	255,533	409.51	610.00	245,451	402.38
19-Sep-10	624	255,508	409.47	610.00	245,426	402.34
20-Sep-10	624	255,278	409.10	610.00	245,196	401.96
21-Sep-10	624	255,175	408.94	610.00	245,048	401.72
22-Sep-10	624	255,150	408.89	610.00	245,068	401.75
23-Sep-10	624	254,767	408.28	610.00	244,685	401.12
24-Sep-10	624	254,640	408.08	610.00	244,558	400.91
25-Sep-10	624	253,876	406.85	610.00	244,411	400.67
26-Sep-10	624	253,876	406.85	610.00	244,264	400.43
27-Sep-10	624	254,640	408.08	610.00	244,118	400.19
28-Sep-10	624	254,513	407.87	610.00	243,630	399.39
29-Sep-10	624	254,004	407.06	610.00	243,922	399.87
30-Sep-10	624	253,877	406.85	610.00	243,775	399.63
01-Oct-10	624	253,115	405.63	610.00	243,033	398.41
02-Oct-10	624	252,862	405.23	610.00	242,780	398.00
03-Oct-10	624	252,761	405.07	610.00	242,634	397.76
04-Oct-10	624	252,533	404.70	610.00	242,451	397.46
05-Oct-10	624	252,028	403.89	610.00	242,306	397.22

Ref: DOE E-Guide for ISO 50001:
https://save-energy-now.org/EM/SPM/Pages/Home.aspx

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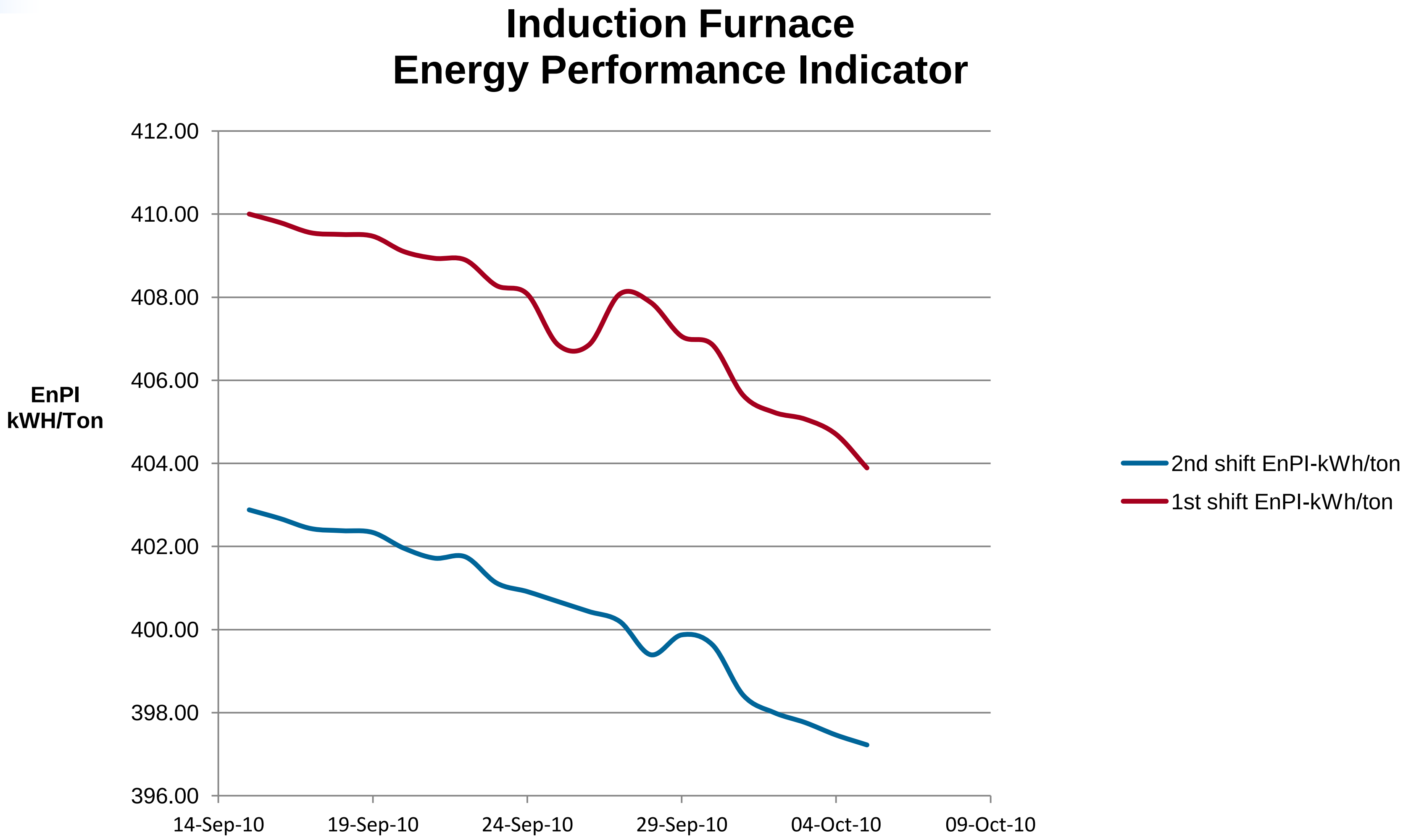
Example EnPI Tracking (Eguide Step 2.3.5-2)



Ref: DOE E-Guide for ISO 50001:
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Prioritizing Energy Opportunities (Eguide Step 2.5.4)

Step 2.5.4 Example Criteria and Ratings for Prioritizing Energy Opportunities (Weighted)

This table presents examples of criteria for prioritizing energy opportunities (also known as "energy projects"). Note that this example lists each criteria, uses a 4-point numerical rating scale, and defines each point on the rating scale for each criterion. A weight is also defined for each criterion.

Example

CRITERIA	RATING SCALE and DESCRIPTION				Weight
	1	2	3	4	(W)
1) Anticipated Annual Energy Cost Savings	Less than $10,000/year	$10,000-$25,000/year	$25,000-$100,000/year	Greater than $100,000/year	3
2) Expected time required for implementation	Greater than 12 months	6-12 months	Less than 6 months	Immediately	2
3) Simple Payback	Greater than 36	13-36 months	6-12 months	Less than 6 months	4
4) Environmental, Health or Safety Impact	Increased negative impact on environmental, health, and/or safety conditions	Minimal negative impact on environmental, health, and/or safety conditions	No change to environmental, health, and/or safety conditions	Improved environmental, health, and/or safety conditions	1

Example

Step 2.5.4 Example Worksheet for Prioritizing Energy Opportunities (Weighted)

This example includes a brief description of the opportunity (or project) in the left column. The weight for each criteria has been carried over from the table above and each opportunity has been rated against each of the criteria. The opportunity score is automatically calculated by formulas in the table. The opportunity score = [(criteria 1 rating X weight)(criteria 2 rating X weight)(criteria 3 rating X weight)(criteria 4 rating X weight)]. In this example, higher scores indicate higher priority.

Example

Opportunity	Opportunity Rating				Opportunity Score = Opportunity Rating x Weight
	Criteria #1 Cost Savings	Criteria #2 Time for Implementation	Criteria #3 Simple Payback	Criteria #4 EHS Impact	
WEIGHT (from above table)	3	2	4	1	
Insulate steam pipes	3	2	1	4	576
Replace fluorescent T-12 lighting with T-8 lighting	3	2	2	1	288
Repair compressed air leaks	3	4	3	2	1728

Example

Ref: DOE E-Guide for ISO 50001:
https://save-energy-now.org/EM/SPM/Pages/Home.aspx

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Using Regression to Predict Develop Energy Performance Model (Eguide Step 2.6.5)

STEP 2.6.5 Example Regression with Other Variables--Days Per Month Added to Model

Number of Data Points	17
Number of X's	2

	Y	X1	X2	X3	X4		
Period	Electricity (kWh)	Production	Days per month			Model	Electricity (kWh) / Model
1	582,888	2,919,395	31			588,862	0.99
2	538,692	2,905,952	28			545,879	0.99
3	613,903	3,367,991	31			601,081	1.02
4	561,483	2,982,647	30			576,379	0.97
5	579,790	2,616,006	31			580,599	1.00
6	569,556	2,438,080	30			561,547	1.01
7	563,476	2,137,521	31			567,566	0.99
8	562,696	2,470,007	31			576,622	0.98
9	552,665	1,805,674	30			544,322	1.02
10	576,319	2,190,076	31			568,998	1.01
11	557,430	2,099,662	30			552,329	1.01
12	537,889	2,167,349	31			568,379	0.95
13	582,888	2,944,682	31			589,551	0.99
14	538,692	2,472,728	28			534,079	1.01
15	613,903	2,601,276	31			580,198	1.06
16	561,483	2,393,034	30			560,320	1.00
17	579,790	2,477,697	31			576,832	1.01

	Y_1	X_1	X_2	X_3	X_4
m		0.03	14205.92	14205.92	
b		68963			
se		0.01	3697.51	3697.51	
r^2		0.6			
df		14.0			
T-stat		2.9	3.8	3.8	
P-value		0.0107	0.0018	0.0018	

y = (0.02724)*X14205.91967 + (0)*X3 + (0)*X4 + 68963

	X1	X2	X3	X4
Electricity (kWh)	Production	Days per month	0	0
P-Values	0.01073	0.00180		
r^2	0.62			
m	0.03	14205.92	0.00	0.00
b	68963			

Regression Model

y = (0.02724)*X1+ (14205.91967)*X2+ (0)*X3+ (0)*X4+ 68963

Round coefficients (m)	5
Round constant (b)	0

Ref: DOE E-Guide for ISO 50001:
https://save-energy-now.org/EM/SPM/Pages/Home.aspx

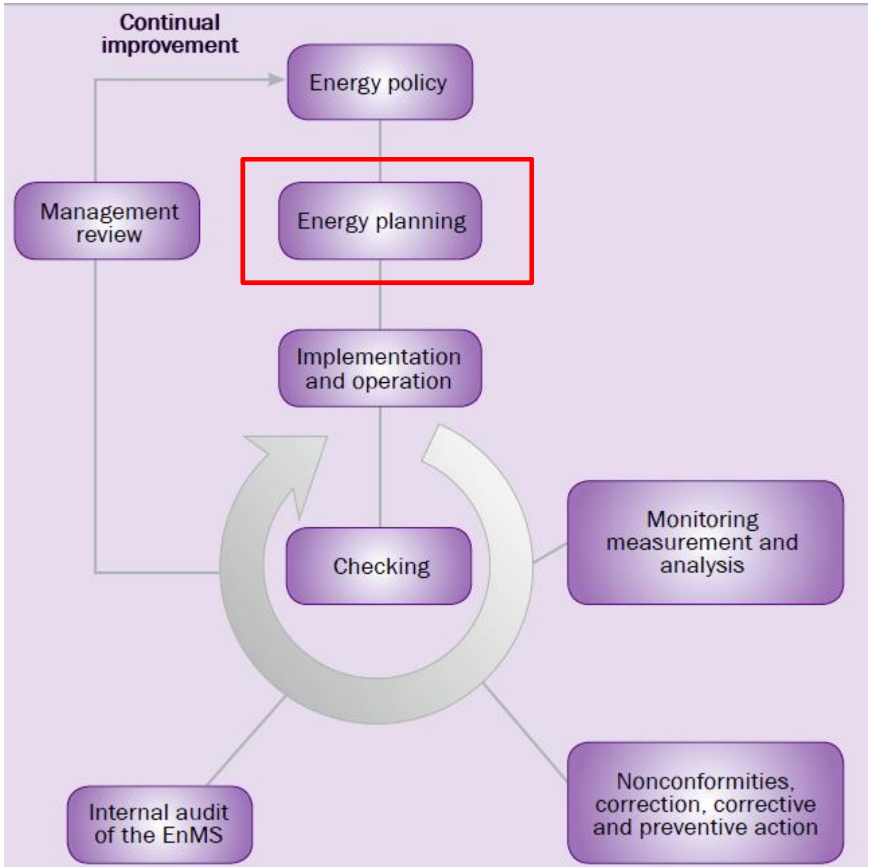
Step 3 - Develop Objectives, Targets and Action Plans

Step 3.1 Establish energy objectives and targets

- Step 3.1.1 Get the right people together
- Step 3.1.2 Provide appropriate inputs
- Step 3.1.3 Define and document objectives and targets
- Step 3.1.4 Obtain management approval
- Step 3.1.5 Communicate the energy objectives and targets

Step 3.2 Formulate energy management action plans

- Step 3.2.1 Select projects based on resources and other factors
- Step 3.2.2 List the actions needed
- Step 3.2.3 Develop the schedule
- Step 3.2.4 Assign roles and responsibilities
- Step 3.2.5 Document and regularly update the action plans



Ref: DOE E-Guide for ISO 50001:
https://save-energy-now.org/EM/SPM/Pages/Home.aspx

Step 4 Reality Check: Stop! Look! Can I Go?

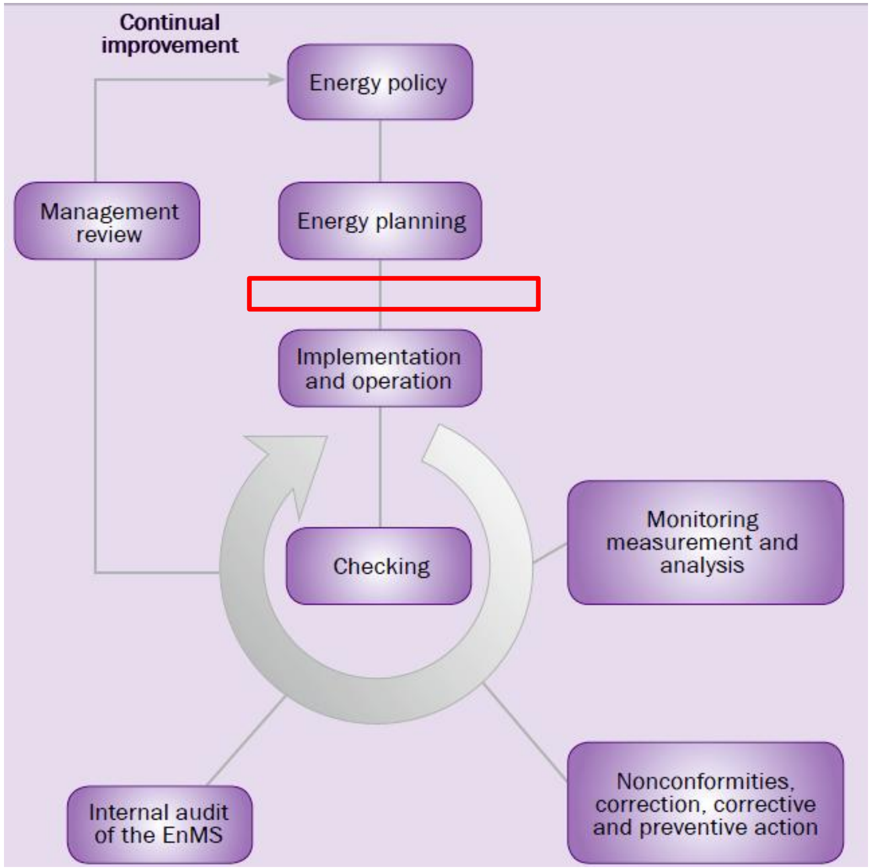
Step 4.1 Review the status of your efforts

Step 4.2 Perform a sanity check on resources

Step 4.3 Identify accomplishments and lessons learned

Step 4.4 Conduct a management review

Step 4.5 Communicate across the organization



Ref: DOE E-Guide for ISO 50001:
https://save-energy-now.org/EM/SPM/Pages/Home.aspx

Step 5 - Manage Current State and Improvements

Step 5.1 Manage and control information

Step 5.2 Determine operational controls
- Step 5.2.1 Determine and establish effective operating criteria
- Step 5.2.2 Operate according to established controls
- Step 5.2.3 Communicate operational controls

Step 5.3 Ensure competence of personnel
- Step 5.3.1 Define competencies
- Step 5.3.2 Assess personnel against competencies
- Step 5.3.3 Develop plan to address training needs

Step 5.4 Ensure awareness of personnel
- Step 5.4.1 Define awareness requirements
- Step 5.4.2 Plan and implement training

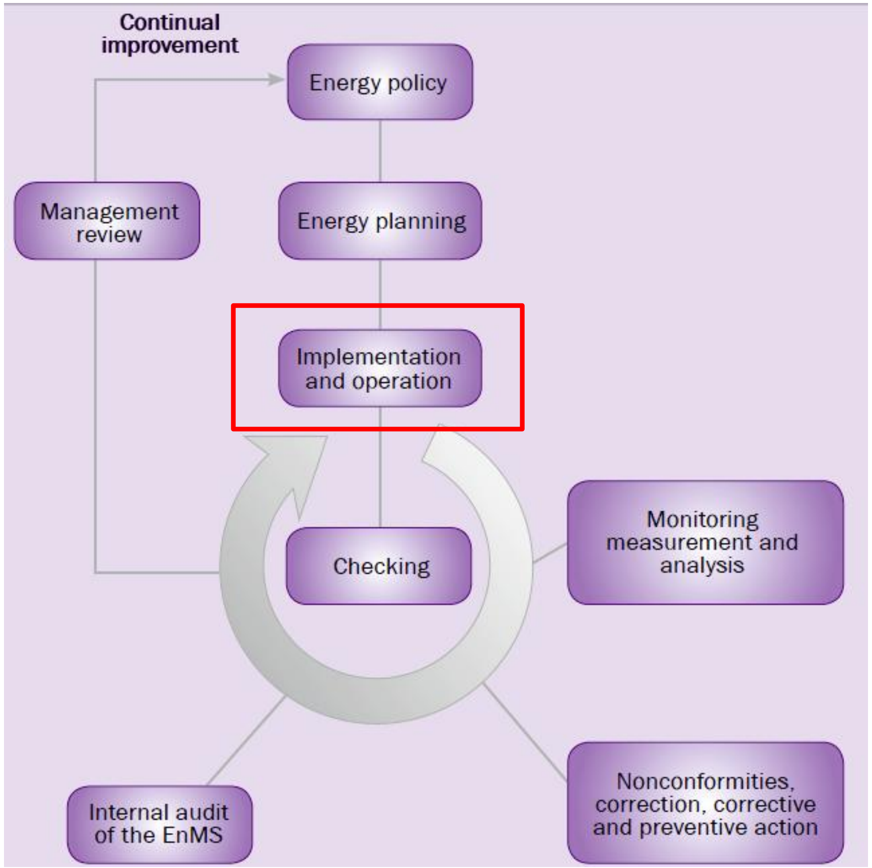
Step 5.5 Define purchasing specifications for energy supply

Step 5.6 Incorporate energy considerations in procurement

Step 5.7 Manage energy considerations in design

Step 5.8 Communicate internally

Step 5.9 Decide on external communications



Ref: DOE E-Guide for ISO 50001:
https://save-energy-now.org/EM/SPM/Pages/Home.aspx

Step 6 - Check the System

Step 6.1 Monitor, measure and analyze key characteristics

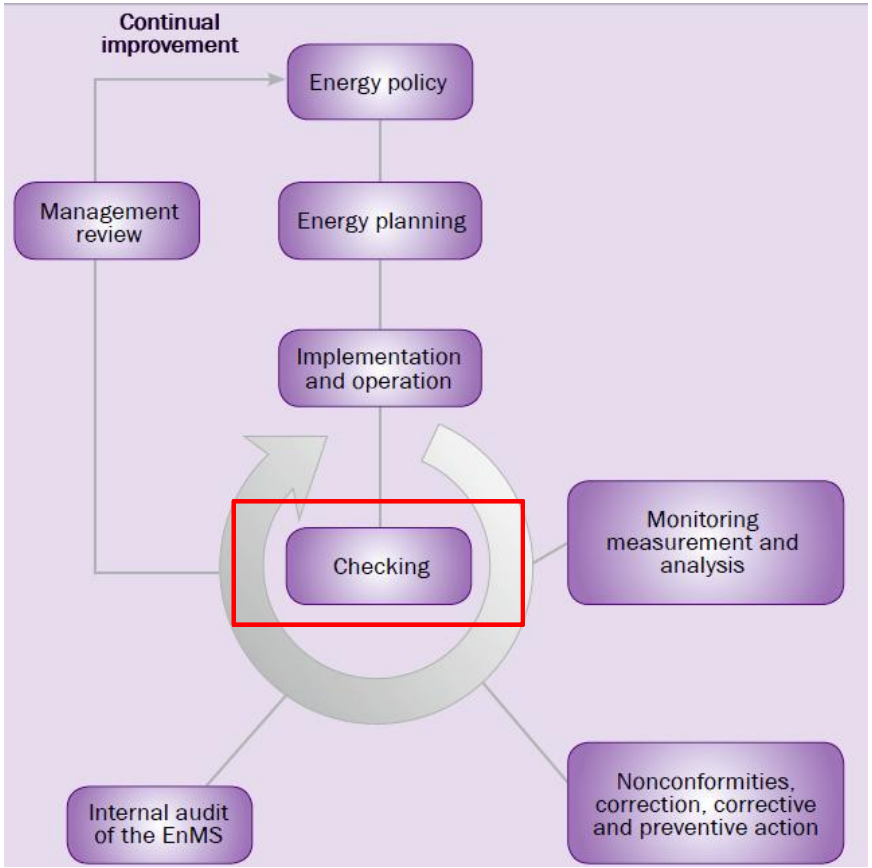
Step 6.2 Calibrate monitoring and measuring equipment

Step 6.3 Evaluate legal and other compliance

Step 6.4 Plan and conduct internal audits

Step 6.5 Take action to correct and prevent nonconformities

Step 6.6 Check and use the evidence



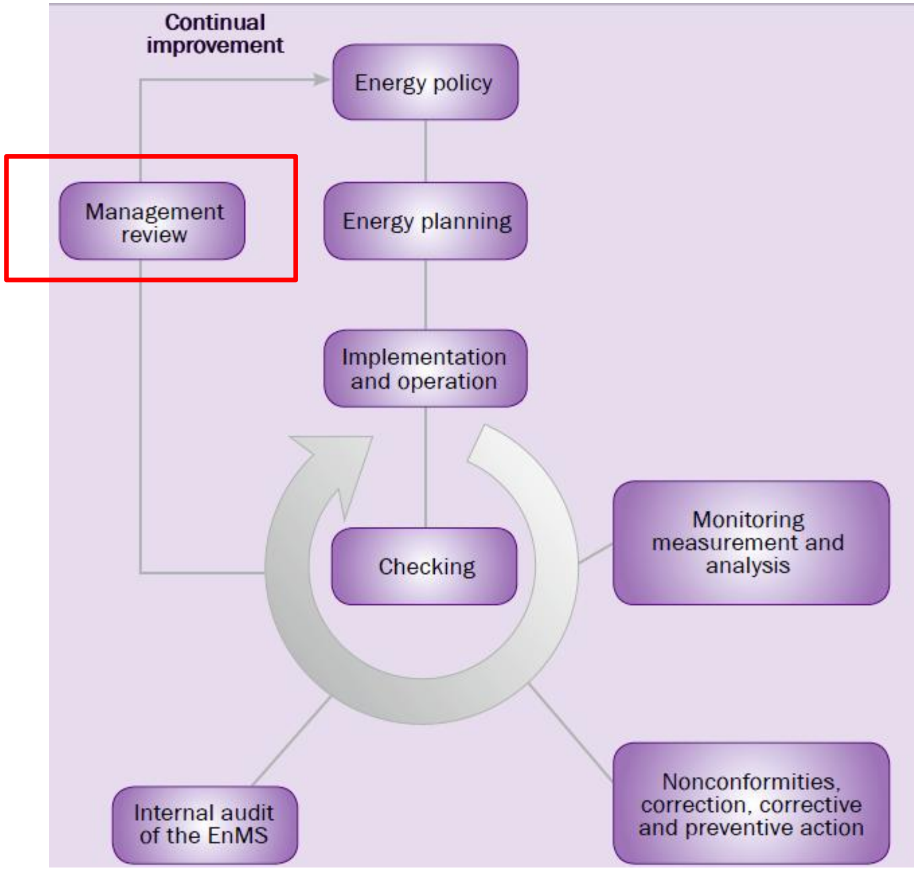
Ref: DOE E-Guide for ISO 50001:
https://save-energy-now.org/EM/SPM/Pages/Home.aspx

Step 7 - Sustain and Improve the System

Step 7.1 Collect information for management review

Step 7.2 Conduct management reviews

Step 7.3 Ensure continual improvement



Ref: DOE E-Guide for ISO 50001:
https://save-energy-now.org/EM/SPM/Pages/Home.aspx

EnPI Tool Helps with M&V Efforts

EnPI Tool v3.02

Released 6/6/11

Disclaimer

The EnPI Tool is being made available to assist companies with their evaluation of their energy performance improvement. The Georgia Tech Research Corporation (GTRC) and the Georgia Institute of Technology (GIT) Georgia Tech disclaim any and all promises, representation and warranties both expressed and implied with respect to the results generated using the EnPI Tool.

Note for SEP M&V Protocol Users: The EnPI tool is intended to assist companies in their efforts demonstrate energy performance improvement in compliance with the Superior Energy Performance Plant Measurement and Verification Protocol (SEP M&V Protocol). This tool is NOT intended to be a substitute for the end-user's thorough understanding of the SEP M&V Protocol, and use of this tool on its own does not represent conformance to SEP M&V Protocol.

EnPI Tool Step 1 – Energy Utilities

EnPI Tool v3.02, © 2011 Georgia Tech Research Corporation

Utilities	Units of Data Entered	MMBtu Conversion Factor	Generation / T&D Efficiency
Electricity	kWh	0.003412	33.3%
Natural Gas	MCF	1.03	100.0%
[None]	MMBtu	1	100.0%

EnPI Tool Step 2 – Data Entry

EnPI Tool v3.02, © 2011 Georgia Tech Research Corporation

1000 Data Points Max

		Utilities			Independent Variables				
	Date	Electricity (kWh)	Natural Gas (MCF)	[None] (MMBtu)	Production	Average Temp	HDD	CDD	Dry Tons
1	Jan-09	5,685,825	102,713		53,942	42	721	0	31,275
2	Feb-09	5,664,904	103,112		56,181	48	485	0	33,691
3	Mar-09	5,706,338	97,368		59,127	58	235	11	29,614
4	Apr-09	5,792,469	122,411		62,775	62	116	353	35,683
5	May-09	5,687,716	113,392		63,931	71	4	194	35,378
6	Jun-09	5,547,835	115,582		64,381	76	0	330	36,209
7	Jul-09	5,483,640	127,258		64,406	79	0	425	35,491
8	Aug-09	5,711,789	115,299		60,847	80	0	451	31,724
9	Sep-09	5,541,890	116,652		58,975	72	12	238	35,441
10	Oct-09	5,726,782	99,122		61,228	64	71	42	33,924
11	Nov-09	5,436,763	83,331		50,214	58	251	29	25,070
12	Dec-09	5,995,052	116,308		64,550	42	701	0	35,425
13	Jan-10	6,192,191	105,618		54,230	44	666	0	29,321
14	Feb-10	6,045,216	120,431		57,542	45	574	1	32,610
15	Mar-10	6,239,523	112,132		63,105	58	242	16	33,896
16	Apr-10	5,692,977	114,456		58,829	62	136	44	32,740
17	May-10	6,016,468	112,154		57,369	74	12	299	34,992
18	Jun-10	5,718,187	112,424		60,978	79	0	422	34,311
19	Jul-10	5,683,007	119,755		61,058	81	0	486	33,155
20	Aug-10	5,671,433	114,390		61,609	78	0	395	34,155
21	Sep-10	5,606,231	111,989		59,755	74	0	280	34,222
22	Oct-10	5,768,469	120,645		60,651	66	48	78	34,109
23	Nov-10	5,636,991	117,441		58,444	56	297	24	33,899
24	Dec-10	5,716,985	116,744		57,071	46	605	0	32,555
25	Jan-11	5,826,876	95,795		54,086	47	565	2	30,298
26	Feb-11	5,588,352	101,613		56,862	52	357	1	33,151
27	Mar-11	5,906,176	94,039		61,116	60	208	48	31,755
28	Apr-11	6,116,421	102,238		60,802	66	55	92	34,212
29	May-11	6,267,905	113,956		60,650	75	6	323	35,185
30	Jun-11	6,020,986	120,964		62,680	84	0	555	35,260

EnPI Tool Step 3 – Data Review

EnPI Tool v3.02, © 2011 Georgia Tech Research Corporation

Model Year First Row 01/05/09
Model Year Last Row 12/12/09

Set Range | Show All Data | Model OK

		Y1	Y2	Y3	X1	X2	X3	X4	X5	X6	X7	X8
	Date	Electricity (MMBtu)	Gas (MMBtu)	[None] (MMBtu)	Production	Average Temp	HDD	CDD	Dry Tons			
1	01/05/09	58,200	105,794	-	53,942	42	721	0	31,275			
2	02/05/09	57,986	106,205	-	56,181	48	485	0	33,691			
3	03/08/09	58,410	100,289	-	59,127	58	235	11	29,614			
4	04/08/09	59,292	126,083	-	62,775	62	116	353	35,683			
5	05/09/09	58,220	116,794	-	63,931	71	4	194	35,378			
6	06/09/09	56,788	119,049	-	64,381	76	0	330	36,209			
7	07/10/09	56,131	131,075	-	64,406	79	0	425	35,491			
8	08/10/09	58,466	118,758	-	60,847	80	0	451	31,724			
9	09/10/09	56,727	120,152	-	58,975	72	12	238	35,441			
10	10/11/09	58,619	102,096	-	61,228	64	71	42	33,924			
11	11/11/09	55,651	85,831	-	50,214	58	251	29	25,070			
12	12/12/09	61,365	119,797	-	64,550	42	701	0	35,425			

P-Values

	Production	Average Temp	HDD	CDD	Dry Tons			
Electricity (MMBtu)	0.21356	0.10216	0.11472	0.40805	0.32568	#VALUE!	#VALUE!	#VALUE!
Natural Gas (MMBtu)	0.00170	0.14803	0.33103	0.00620	0.00058	#VALUE!	#VALUE!	#VALUE!
[None] (MMBtu)	#NUM!	#NUM!	#NUM!	#NUM!	#NUM!	#VALUE!	#VALUE!	#VALUE!

R^2

	Production	Average Temp	HDD	CDD	Dry Tons			
Electricity (MMBtu)	0.15	0.24	0.23	0.07	0.10	#VALUE!	#VALUE!	#VALUE!
Natural Gas (MMBtu)	0.64	0.20	0.09	0.54	0.71	#VALUE!	#VALUE!	#VALUE!
[None] (MMBtu)	1.00	1.00	1.00	1.00	1.00	#VALUE!	#VALUE!	#VALUE!

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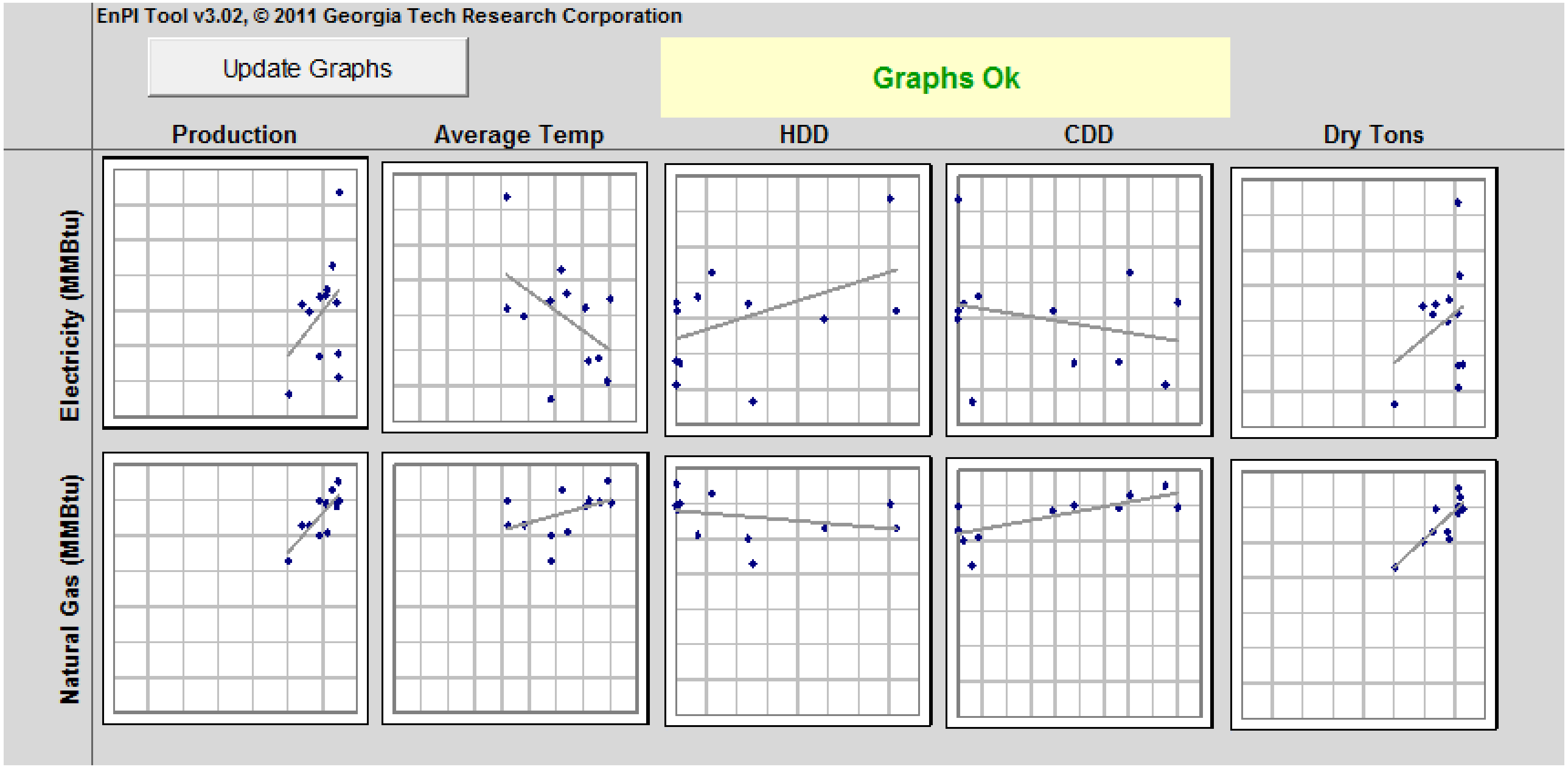
EnPI Tool Step 3 – Data Review Graph



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EnPI Tool Step 4 – Y1 Regression (Electricity Usage Model Check)

EnPI Tool v3.02, © 2011 Georgia Tech Research Corporation

Model Year First Row	01/05/09
Model Year Last Row	12/12/09

Model OK

Variables to be Included

Yes	Production	No	CDD
Yes	Average Temp	No	Dry Tons
No	HDD		

Evaluate Model | Show All Rows

		Y1	X1	X2	X3	X4		
	Date	Electricity (MMBtu)	Production	Average Temp			Model	Electricity (MMBtu) / Model
1	1/5/2009	58,200	53,942	42			58,396	1.00
2	2/5/2009	57,986	56,181	48			58,395	0.99
3	3/8/2009	58,410	59,127	58			58,196	1.00
4	4/8/2009	59,292	62,775	62			58,739	1.01
5	5/9/2009	58,220	63,931	71			58,182	1.00
6	6/9/2009	56,788	64,381	76			57,824	0.98
7	7/10/2009	56,131	64,406	79			57,548	0.98
8	8/10/2009	58,466	60,847	80			56,556	1.03
9	9/10/2009	56,727	58,975	72			56,838	1.00
10	10/11/2009	58,619	61,228	64			58,160	1.01
11	11/11/2009	55,651	50,214	58			55,948	0.99
12	12/12/2009	61,365	64,550	42			61,071	1.00

	X1	X2	X3	X4
Electricity (MMBtu)	Production	Average Temp		
P-Values	0.00466	0.00267		
F-Test	0.00419			
r^2	0.70			
m	0.25	-94.24	0.00	0.00
b	48751			

Regression Model

y = (0.252)*X1+ (-94.24)*X2+ (0)*X3+ (0)*X4+ 48751

Round coefficients (m)	3
Round constant (b)	0

EnPI Tool Step 4 – Y2 Regression (Natural Gas Usage Model Check)

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Model Year First Row	01/05/09
Model Year Last Row	12/12/09

Model OK

Variables to be Included

No	Production	Yes	CDD
No	Average Temp	Yes	Dry Tons
No	HDD		

Evaluate Model | Show All Rows

		Y2	X1	X2	X3	X4		
	Date	Natural Gas (MMBtu)	CDD	Dry Tons			Model	Natural Gas (MMBtu) / Model
1	1/5/2009	105,794	-	31,275			102,096	1.04
2	2/5/2009	106,205	-	33,691			108,109	0.98
3	3/8/2009	100,289	11	29,614			98,323	1.02
4	4/8/2009	126,083	353	35,683			124,641	1.01
5	5/9/2009	116,794	194	35,378			118,669	0.98
6	6/9/2009	119,049	330	36,209			125,196	0.95
7	7/10/2009	131,075	425	35,491			126,524	1.04
8	8/10/2009	118,758	451	31,724			118,001	1.01
9	9/10/2009	120,152	238	35,441			120,268	1.00
10	10/11/2009	102,096	42	33,924			110,066	0.93
11	11/11/2009	85,831	29	25,070			87,604	0.98
12	12/12/2009	119,797	-	35,425			112,425	1.07

	X1	X2	X3	X4
Natural Gas (MMBtu)	CDD	Dry Tons		
P-Values	0.00497	0.00060		
F-Test	0.00006			
r^2	0.88			
m	32.79	2.49	0.00	0.00
b	24260			

Regression Model

y = (32.789)*X1+ (2.489)*X2+ (0)*X3+ (0)*X4+ 24260	
Round coefficients (m)	3
Round constant (b)	0

EnPI Step 5 – Performance Improvement: (Forecast Example)

Pathway	Requirements	Level: Silver	Gold	Platinum
Energy Performance	Minimum % improvement	5%	10%	15%
	Maximum years to achieve*	3	3	3
Mature Energy	Minimum % Improvement	15%	15%	15%
	Maximum years to achieve*	10	10	10
	Minimum Best Practice Scorecard points	35	61	81

Example Usage Models:

Electricity = (0.25)(Tons Production)-(94.29)(Avg. Temp)+48751

NG=(33.39)(CDD)+(2.49)(Dry Tons)+24260

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Y1 Model OK
Y2 Model OK
Y3 Model Error
Forecast Data Valid

Confirm Modeled Period for Each Utility Are Same

Utility	Electricity	Gas	[None]
First Row	01/05/09	01/05/09	01/00/00
Last Row	12/12/09	12/12/09	01/00/00

Select Modeling Method: Forecast

Last Year of Evaluated Period, First Row: 01/19/11
Last Year of Evaluated Period, Last Row: 12/26/11

Performance Improvement (+) or Decline (-): 1.9%

Electricity

	Date	Y1	X1	X2	X3	X4	B	Electricity (MMBtu)	Model
			0.25	-94.24	0.00	0.00	48751		
		Electricity (kWh)	Production	Average Temp					
1	01/05/09	5,685,825	53,942	42	-	-		58,200	58,396
2	02/05/09	5,664,904	56,181	48	-	-		57,986	58,395
3	03/08/09	5,706,338	59,127	58	-	-		58,410	58,196
4	04/08/09	5,792,469	62,775	62	-	-		59,292	58,739
5	05/09/09	5,687,716	63,931	71	-	-		58,220	58,182
6	06/09/09	5,547,835	64,381	76	-	-		56,788	57,824
7	07/10/09	5,483,640	64,406	79	-	-		56,131	57,548
8	08/10/09	5,711,789	60,847	80	-	-		58,466	56,556
9	09/10/09	5,541,890	58,975	72	-	-		56,727	56,838
10	10/11/09	5,726,782	61,228	64	-	-		58,619	58,160
11	11/11/09	5,436,763	50,214	58	-	-		55,651	55,948
12	12/12/09	5,995,052	64,550	42	-	-		61,365	61,071
13	01/12/10	6,192,191	54,230	44	-	-		63,383	58,280

Natural Gas

	Y2	X1	X2	X3	X4	B	Natural Gas (MMBtu)	Model
		32.79	2.49	0.00	0.00	24260		
	Natural Gas (MCF)	CDD	Dry Tons					
1	102,713	-	31,275	-	-		105,794	102,096
2	103,112	-	33,691	-	-		106,205	108,109
3	97,368	11	29,614	-	-		100,289	98,323
4	122,411	353	35,683	-	-		126,083	124,641
5	113,392	194	35,378	-	-		116,794	118,669
6	115,582	330	36,209	-	-		119,049	125,196
7	127,258	425	35,491	-	-		131,075	126,524
8	115,299	451	31,724	-	-		118,758	118,001
9	116,652	238	35,441	-	-		120,152	120,268
10	99,122	42	33,924	-	-		102,096	110,066
11	83,331	29	25,070	-	-		85,831	87,604
12	116,308	-	35,425	-	-		119,797	112,425
13	105,618	-	29,321	-	-		108,786	97,233

EnPI Step 5 – Performance Improvement (Chaining Modeling Methods)

Pathway	Requirements	Level: Silver	Gold	Platinum
Energy Performance	Minimum % improvement	5%	10%	15%
	Maximum years to achieve*	3	3	3
Mature Energy	Minimum % Improvement	15%	15%	15%
	Maximum years to achieve*	10	10	10
	Minimum Best Practice Scorecard points	35	61	81

Example Usage Models:

Electricity = (5.09) (Tons Production)+20109

NG=(2.56)(Tons Production) + (211.52)(Avg Temp)+7323

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Y1 Model OK
Y2 Model OK
Y3 Model Error
Backcast Data Valid
Forecast Data Valid

Confirm Modeled Period for Each Utility Are Same

Utility	Electricity	Gas	[None]
First Row	01/01/08	01/01/08	01/00/00
Last Row	12/01/08	12/01/08	01/00/00

Select Modeling Method: Chaining

	Year Zero	Last Year
First Row	01/01/07	01/01/10
Last Row	12/01/07	12/01/10

Performance Improvement (+) or Decline (-): 12.1%

		Electricity								Natural Gas							
		Y1	X1	X2	X3	X4	B			Y2	X1	X2	X3	X4	B		
			5.09	0.00	0.00	0.00	20109				2.56	211.52	0.00	0.00	7323		
	Date	Electricity (kWh)	Production					Electricity (MMBtu)	Model	Natural Gas (Therms)	Production	Average Temp				Natural Gas (MMBtu)	Model
1	01/01/07	15,281,844	24,993	-	-	-		156,425	147,223	855,491	24,993	55	-	-		85,549	82,940
2	02/01/07	13,804,495	22,542	-	-	-		141,303	134,757	823,635	22,542	49	-	-		82,364	75,480
3	03/01/07	15,084,654	24,714	-	-	-		154,407	145,804	832,492	24,714	62	-	-		83,249	83,727
4	04/01/07	14,992,023	23,713	-	-	-		153,459	140,713	767,139	23,713	72	-	-		76,714	83,322
5	05/01/07	14,710,694	22,903	-	-	-		150,579	136,593	766,639	22,903	78	-	-		76,664	82,454
6	06/01/07	10,734,456	15,700	-	-	-		109,878	99,959	616,147	15,700	84	-	-		61,615	65,177
7	07/01/07	15,553,184	24,314	-	-	-		159,203	143,769	838,948	24,314	88	-	-		83,895	88,118
8	08/01/07	15,128,236	24,350	-	-	-		154,853	143,953	815,650	24,350	90	-	-		81,565	88,654
9	09/01/07	15,173,158	25,599	-	-	-		155,313	150,305	808,984	25,599	78	-	-		80,898	89,271
10	10/01/07	15,256,985	25,319	-	-	-		156,171	148,881	866,919	25,319	68	-	-		86,692	86,545
11	11/01/07	15,201,284	26,593	-	-	-		155,600	155,360	864,810	26,593	57	-	-		86,481	87,543
12	12/01/07	14,504,240	23,046	-	-	-		148,466	137,320	799,355	23,046	50	-	-		79,936	76,898
13	01/01/08	15,398,553	28,724	-	-	-		157,620	166,199	910,461	28,724	42	-	-		91,046	89,805
14	02/01/08	14,046,280	23,799	-	-	-		143,778	141,150	794,058	23,799	49	-	-		79,406	78,677
15	03/01/08	14,908,571	25,162	-	-	-		152,604	148,082	835,772	25,162	64	-	-		83,577	85,255
16	04/01/08	8,635,463	16,838	-	-	-		88,393	105,747	590,247	16,838	62	-	-		59,025	63,606
17	05/01/08	9,216,821	15,705	-	-	-		94,343	99,984	621,178	15,705	74	-	-		62,118	63,265
18	06/01/08	11,912,004	18,179	-	-	-		121,931	112,567	767,032	18,179	81	-	-		76,703	71,080
19	07/01/08	14,689,537	23,289	-	-	-		150,362	138,556	852,646	23,289	84	-	-		85,265	84,648
20	08/01/08	12,765,098	25,115	-	-	-		130,664	147,843	872,066	25,115	88	-	-		87,207	90,190
21	09/01/08	14,429,648	23,978	-	-	-		147,702	142,061	881,760	23,978	82	-	-		88,176	85,968
22	10/01/08	14,260,725	25,098	-	-	-		145,973	147,757	836,102	25,098	72	-	-		83,610	86,825
23	11/01/08	14,876,345	21,929	-	-	-		152,274	131,639	794,756	21,929	61	-	-		79,476	76,428
24	12/01/08	14,521,951	26,071	-	-	-		148,647	152,706	847,384	26,071	50	-	-		84,738	84,599
25	01/01/09	14,807,836	26,170	-	-	-		151,573	153,209	890,364	26,170	47	-	-		89,036	84,239
26	02/01/09	13,789,004	23,959	-	-	-		141,144	141,964	821,359	23,959	54	-	-		82,136	80,081

Step 3 - Data Review (Graph) / Step 4 - Y1 Regression / Step 4 - Y2 Regression / Step 4 - Y3 Regression / Step 5 - EnPI / Notes

EPRI ELECTRIC POWER RESEARCH INSTITUTE

FYI - Use of DOE ITP Tools

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Industrial Technologies Program

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Software Tools

PLANT-WIDE | MOTOR-DRIVEN | STEAM | PROCESS HEATING | DATA CENTERS

The Industrial Technologies Program (ITP) offers a collection of free software tools to help you identify and analyze energy system savings opportunities in your plant or industrial facility. Learn more and download the tools to assess the energy situation at your plant and improve the efficiency of your motor-driven, process heating, and steam systems, as well as data centers. View the interactive diagram of plant energy flow and related ITP assessment software tools.

Software Tool Updates
MotorMaster+ International Version 1.1.4 – August 2011

ITP also offers related training to help plant personnel increase their knowledge on energy management and take full advantage of opportunities identified in the software programs.

For assistance with software tools, contact the EERE Information Center or call 1-877-337-3463. Please see the notice before downloading any of these tools.

ITP tools include:

Plant-wide
- Industrial Facilities Scorecard
- Quick Plant Energy Profiler/Integrated Tool Suite (Quick PEP)

Motor-Driven
- AirMaster+
- Fan System Assessment Tool (FSAT)
- MotorMaster+
- MotorMaster+ International
- Chilled Water System Analysis Tool (CWSAT)
- Pumping System Assessment Tool (PSAT)

Steam
- Mechanical Insulation Assessment and Design Calculators
- Steam System Tool Suite (SSTS)

Process Heating
- Combined Heat and Power (CHP) Application Tool
- NOx and Energy Assessment Tool (NxEAT)
- Process Heating and Survey Assessment Tool (PHAST)

Data Centers
- Data Center Profiler Software Tool Suite (DC Pro)

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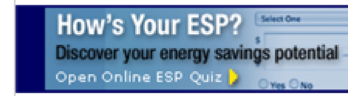

EPRI | ELECTRIC POWER RESEARCH INSTITUTE

Self-Assessment Software Tools

ITP's suite of analysis software tools identify energy savings opportunities and supply in-depth system-specific instruction.

First Step

Quick PEP *– diagnose overall energy use and identify savings opportunities*

- provides an overview of amount of energy purchased and generated
- identifies major industrial systems that consume the most energy
- describes savings potential
- points out specific resources and tools to realize savings

Self-Assessment Software Tools – Next Steps

- *AIRMaster+*
- *Chilled Water System Analysis Tool*
- *Combined Heat & Power Application Tool*
- *Fan System Assessment Tool*
- *MotorMaster+*
- MotorMaster+ International
- *Process Heating Assessment & Survey Tool*
- *Pumping System Assessment Tool*
- *Steam System Tool Suite*
  - Steam System Scoping Tool
  - Steam System Assessment Tool
  - 3E Plus®

These tools allow you to self-asses each system, model recommendations, and calculate impacts and cost savings

Self Assessment Software Tools

- **Motor Master +** Assists in energy-efficient motor selection and management. (International)
- **Pumping System Assessment Tool** Assesses the efficiency of pumping system operations.
- **Fan System Assessment Tool** quantifies potential benefits of a more optimally configured fan system
- **Chilled Water System Assessment Tool** Assesses the efficiency of a chilled water system.

- **Air Master+** Provides comprehensive information on assessing compressed air systems.
- **ASDMaster** Determines economic feasibility of an ASD application.

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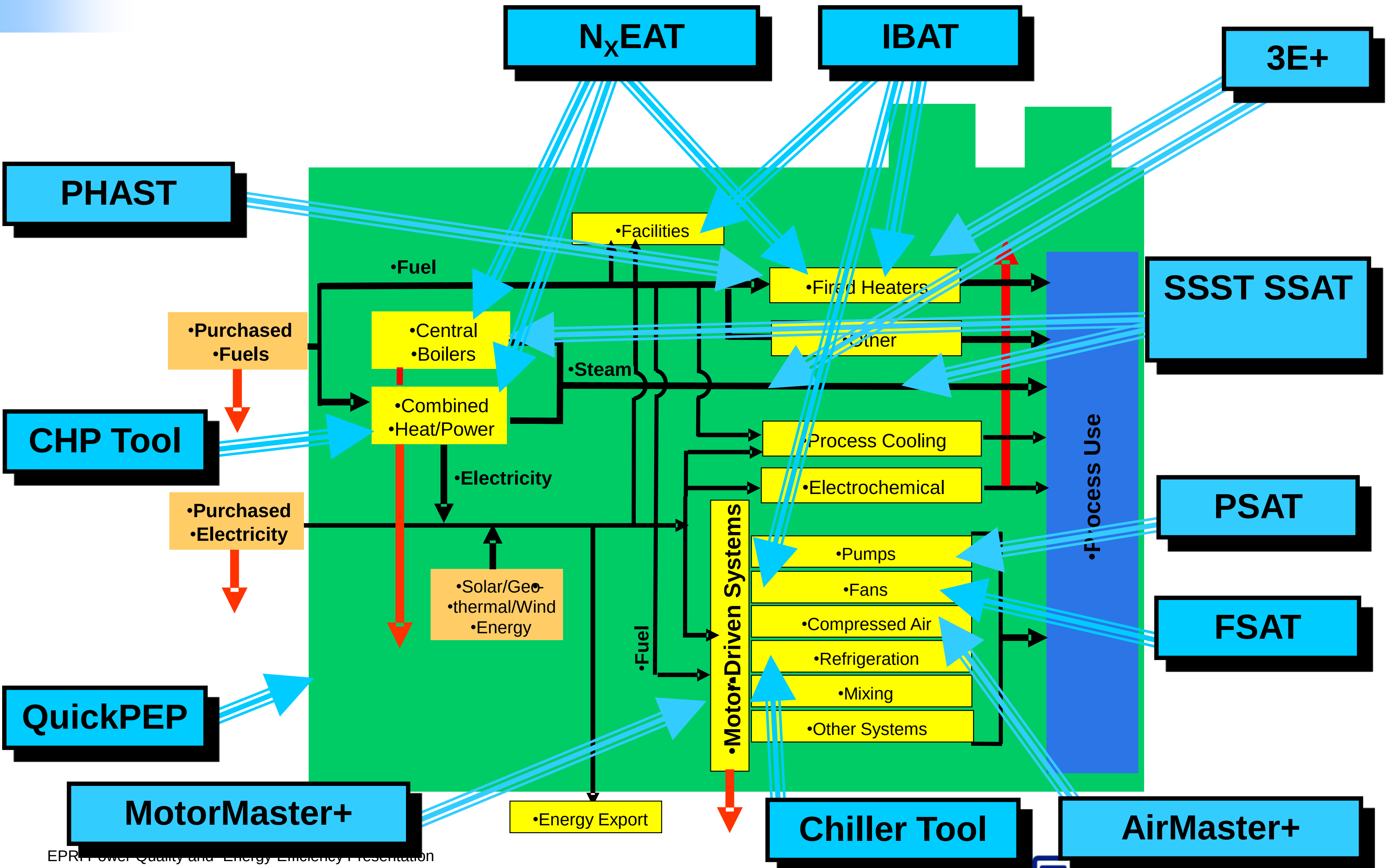
Self Assessment Software Tools

- **Steam System Scoping Tool** Profiles and grades large steam system operations/management.
- **Steam System Assessment Tool** Assesses potential benefits of specific steam-system improvements.
- **3EPlus Insulation Assessment Tool** Calculates most economical thickness of insulation for a variety of operating conditions.
- **Process Heating Assessment and Survey Tool** Assesses energy use in furnaces/ performance improvements
- **NOx and Energy Assessment Tool (NxEAT)** analyzes NOx emissions and energy efficiency improvements
- **Plant Energy Profiler** profiles plant energy supply along consumption streams and identifies energy savings opportunities

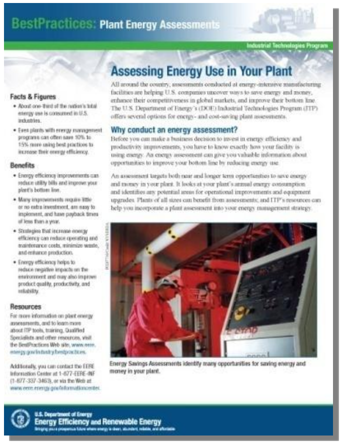
DOE ITP Tool Portfolio

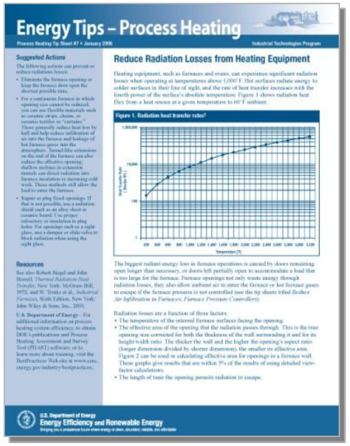


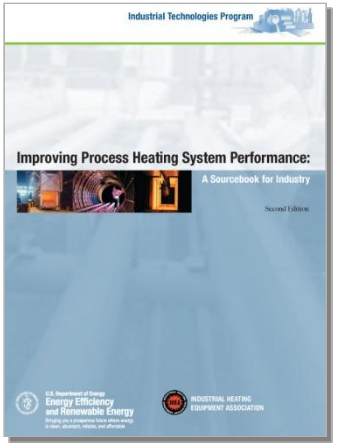
Technical Resources

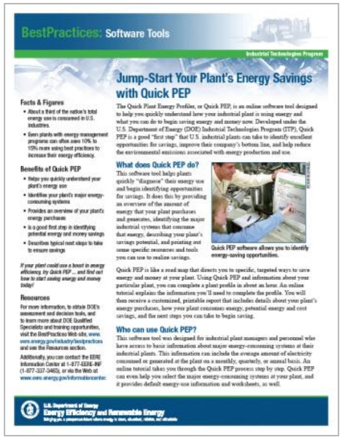
ITP's portfolio of technical information helps plant managers, engineers, and operators increase their knowledge on managing specific energy systems:

- ***Sourcebooks*** **–** essential references for analyzing and implementing energy efficiency and productivity improvements
- ***Tip Sheets & Fact Sheets*** – targeted, low-cost improvement recommendations
- ***Market Assessments*** – big picture energy efficiency opportunities









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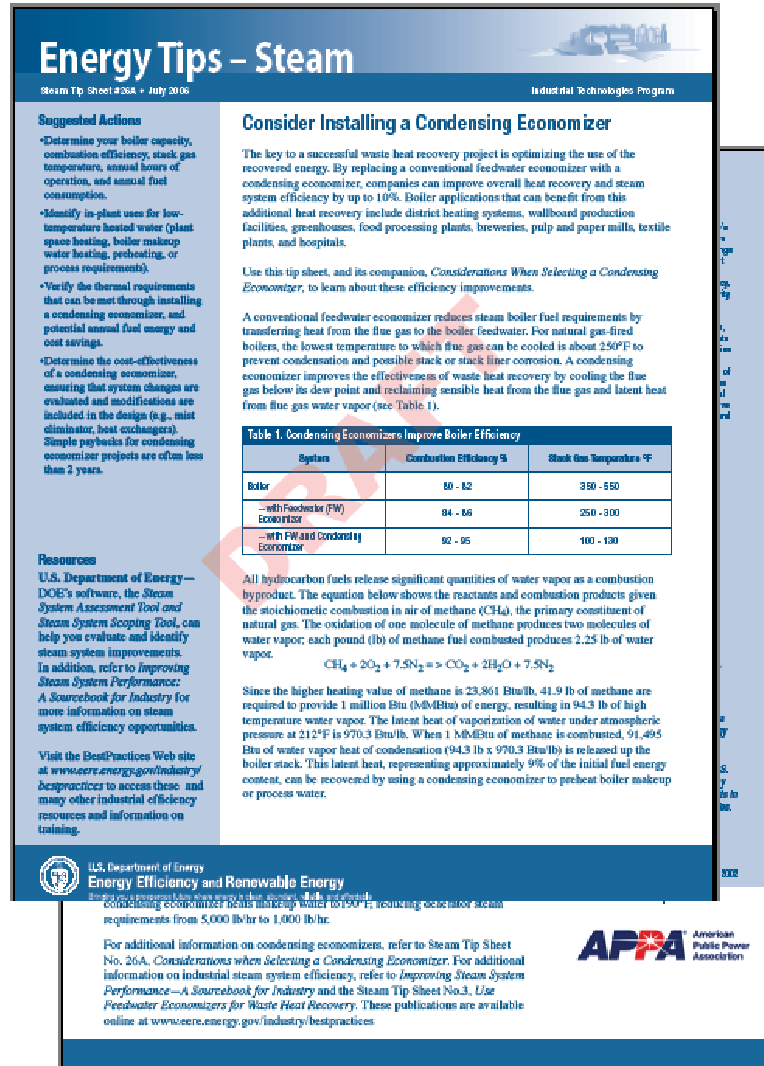
Tip Sheets

ITP provides dozens of Tip Sheets that are quick and to the point. They provide engineers, technicians, equipment operators, and others technical advice:

- to eliminate voltage unbalance
- reduce compressed air leaks
- inspect and repair steam traps
- benchmark the fuel cost of steam generation
- handle a host of other practical issues.


Energy Tips – Steam

Steam Tip Sheet #26A • July 2006

Industrial Technologies Program

Suggested Actions

•Determine your boiler capacity, combustion efficiency, stack gas temperature, annual hours of operation, and annual fuel consumption.

•Identify in-plant uses for low-temperature heated water (plant space heating, boiler makeup water heating, preheating, or process requirements).

•Verify the thermal requirements that can be met through installing a condensing economizer, and potential annual fuel energy and cost savings.

•Determine the cost-effectiveness of a condensing economizer, ensuring that system changes are evaluated and modifications are included in the design (e.g., mist eliminator, heat exchangers). Simple paybacks for condensing economizer projects are often less than 2 years.

Resources

U.S. Department of Energy—DOE's software, the *Steam System Assessment Tool and Steam System Scoping Tool*, can help you evaluate and identify steam system improvements. In addition, refer to *Improving Steam System Performance: A Sourcebook for Industry* for more information on steam system efficiency opportunities.

Visit the BestPractices Web site at *www.eere.energy.gov/industry/bestpractices* to access these and many other industrial efficiency resources and information on training.

Consider Installing a Condensing Economizer

The key to a successful waste heat recovery project is optimizing the use of the recovered energy. By replacing a conventional feedwater economizer with a condensing economizer, companies can improve overall heat recovery and steam system efficiency by up to 10%. Boiler applications that can benefit from this additional heat recovery include district heating systems, wallboard production facilities, greenhouses, food processing plants, breweries, pulp and paper mills, textile plants, and hospitals.

Use this tip sheet, and its companion, *Considerations When Selecting a Condensing Economizer*, to learn about these efficiency improvements.

A conventional feedwater economizer reduces steam boiler fuel requirements by transferring heat from the flue gas to the boiler feedwater. For natural gas-fired boilers, the lowest temperature to which flue gas can be cooled is about 250°F to prevent condensation and possible stack or stack liner corrosion. A condensing economizer improves the effectiveness of waste heat recovery by cooling the flue gas below its dew point and reclaiming sensible heat from the flue gas and latent heat from flue gas water vapor (see Table 1).

Table 1. Condensing Economizers Improve Boiler Efficiency

System	Combustion Efficiency %	Stack Gas Temperature °F
Boiler	80 - 82	350 - 550
—with Feedwater (FW) Economizer	84 - 86	250 - 300
—with FW and Condensing Economizer	92 - 95	100 - 130

DRAFT

All hydrocarbon fuels release significant quantities of water vapor as a combustion byproduct. The equation below shows the reactants and combustion products given the stoichiometric combustion in air of methane (CH_4), the primary constituent of natural gas. The oxidation of one molecule of methane produces two molecules of water vapor; each pound (lb) of methane fuel combusted produces 2.25 lb of water vapor.

$$CH_4 + 2O_2 + 7.5N_2 => CO_2 + 2H_2O + 7.5N_2$$

Since the higher heating value of methane is 23,861 Btu/lb, 41.9 lb of methane are required to provide 1 million Btu (MMBtu) of energy, resulting in 94.3 lb of high temperature water vapor. The latent heat of vaporization of water under atmospheric pressure at 212°F is 970.3 Btu/lb. When 1 MMBtu of methane is combusted, 91,495 Btu of water vapor heat of condensation (94.3 lb x 970.3 Btu/lb) is released up the boiler stack. This latent heat, representing approximately 9% of the initial fuel energy content, can be recovered by using a condensing economizer to preheat boiler makeup or process water.

U.S. Department of Energy
Energy Efficiency and Renewable Energy

requirements from 5,000 lb/hr to 1,000 lb/hr.

For additional information on condensing economizers, refer to Steam Tip Sheet No. 26A, *Considerations when Selecting a Condensing Economizer*. For additional information on industrial steam system efficiency, refer to *Improving Steam System Performance—A Sourcebook for Industry* and the Steam Tip Sheet No.3, *Use Feedwater Economizers for Waste Heat Recovery*. These publications are available online at www.eere.energy.gov/industry/bestpractices

APPA American Public Power Association

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