Toolbox Talk Cards

Advanced Energy Systems

Employee Energy Awareness Program

version 1.2

neea.org

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Continuous Energy Improvement

Continuous Energy Improvement (CEI) (energyimprovement.org) is an energy management process that helps you:

- Manage energy as a controllable expense
- Get everyone on your team working together to reduce energy use
- Improve energy productivity
- Increase payback on energy-related capital improvements
- Reduce O&M expenses
- Complement your company's existing continuous improvement programs
- Obtain a competitive cost advantage at the point of production

Each card contains a tip or piece of advice to keep energy top of mind among your team so you can manage energy as a controllable expense at the point of production.

How to use these cards

AUDIENCE: Production, maintenance and purchasing staff and technicians

PURPOSE: "Toolbox Talks on Energy Efficiency." These cards provide key learning points and discussion topics on energy efficiency to engage your team in discussions on energy use in industrial facilities.

USE: Use this card set during a weekly or daily shift meeting to initiate energy efficiency talks with your team. These cards are designed to start the conversation, but be creative and encourage discussion. Participation is the best way to reinforce energy efficiency practices for key industrial systems in your facility.

REVIEW: This card set includes "20/20 Review" cards, which allow you to check in with participants and ask about actions that resulted from ideas or suggestions from previous "Toolbox Talks."

RECORD: At the end of this set you'll find log sheets. Use this log to record your team's "Toolbox Talks" and gauge your contributions to achieving your company's energy goals. It's also an easy way to track and share your progress with management.

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Question:

What is the most significant cost when purchasing a motor?

Answer:

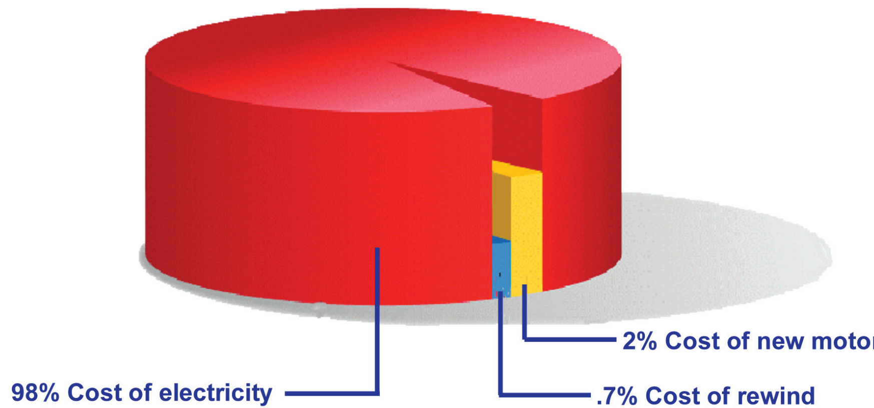
Electricity. It's 98% of the motor's 8-year cost.

Learning Objective:

"Penny wise but pound foolish" couldn't be more relevant. Too often, first purchase cost is the determining factor. However, a motor's "life cycle costs," which include price per kWh, driven load requirement, efficiency, and hours of operation, often tower over its purchase price.

Discussion Questions:

- What are the normal cost considerations you use to purchase a new motor?
- What are the additional life cycle costs to consider when making equipment-purchasing decisions?



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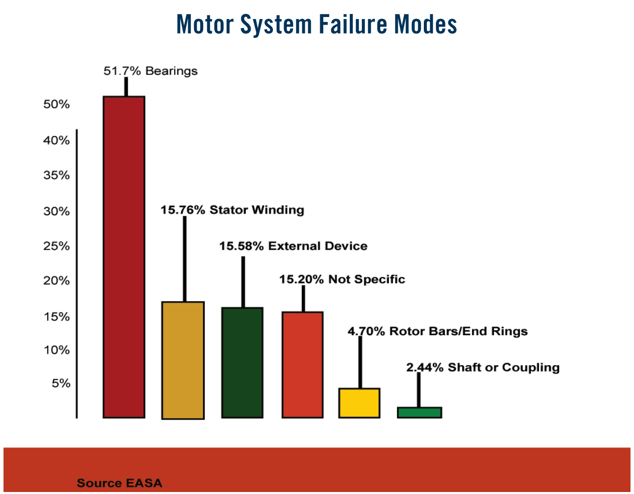
Question:

If a motor is in storage, how often should the shaft be turned?



Answer:

When in storage, a motor shaft needs to be rotated every 30 days. The motor shaft needs to be rotated in order to supply sufficient grease to the bearings' surfaces, because any vibration, metal-to-metal, will cause premature failure of the motor. 52% of all motor failures are bearing related.

Discussion Questions:

At the facility level, we may not be able to affect the purchase decision or all of the life cycle costs, but we can influence the driven load and hours operated. What two driven system elements have the biggest impact on life cycle costs?

1. **Hours of Operation:**
   If a motor is **running needlessly,** report it (or tag it) to ensure the hours of operation are reduced without harm to the motor or process.
2. **Load:**
   If **less mechanical force** is needed to operate a motor driven system, report it (or tag it). This can reduce the driven load requirement and electricity used.

Question:

Have we investigated which motors are appropriate to turn off when they are not in use?

Discussion Questions:

- How many motors did you find that could be turned off or put on standby?
- What can we gain by turning off motors when they are not in use?
- Did you know that 98% of the cost of owning a motor is contained in our electric bill? The purchase price and maintenance of the motor accounts for only 2%.

Question:

What is meant by electric motor efficiency?

Answer:

It's the percentage of electrical power that is converted to mechanical power
(Note: methods of measuring efficiency vary)

Learning Objective:

Consider a typical, fully-loaded, 5 horsepower electric motor:

- 100% of the electricity goes in, but only 85% is converted to mechanical power and is available at the motor's output shaft.
- The remaining 15% is lost due to resistance, stray currents, bearing friction, and motor cooling.
- Most of the 15% motor inefficiency is manifested as heat and will directly contribute to a shorter motor life.

Discussion Question:

What are the benefits of a more efficient motor or motor-driven system?

POSSIBLE ANSWERS:

- Higher efficiency means less electricity used, which means lower operational costs and higher production
- Higher efficiency means a longer motor life
- Higher efficiency means a more reliable motor

Energy Losses

	Stator Res.	Rotor Res.	Iron Core	Friction	Stray Losses	Total
Percent of Losses	40%	25%	20%	5%	10%	100%
Percent of Input	6.2%	3.6%	3.1%	0.7%	1.4%	15%

Typical 5 hp, 4 Pole, 3 Phase 85% Efficient Motor

Question:

Do all electric motors have about the same efficiency?

Answer:

No. Motor efficiencies and efficiency trends have varied for decades.

Learning Objective 1:

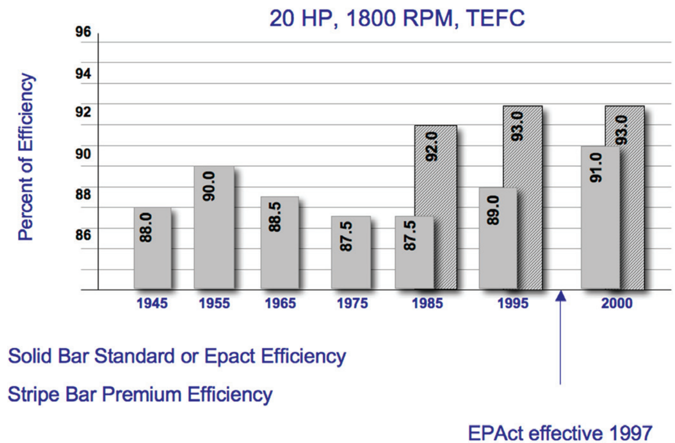
Motors are not created equal, and motor efficiency is difficult to define with general rules of thumb. Generally, the larger the motor, the more efficient. A national standard exists which qualifies motor efficiency, called NEMA (National Electrical Manufacturers Association).

Learning Objective 2:

The Energy Independence Act of 2007 raised minimum efficiency levels of motors between 1 and 500 hp to NEMA MG-1 standards, effective December 2010. The NEMA PremiumTM label indicates a “high performance” motor that runs at a slightly faster RPM, is more tolerant to Variable Frequency Drive (VFD) application, and meets or exceeds efficiency standards.

Discussion Questions:

- How are motors labeled in our facility?
- What are the life cycle pros of purchasing a NEMA Premium® motor?



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Question:

Have we checked with the engineering/maintenance and purchasing departments to learn about using NEMA Premium® efficient motors in our plant?

Discussion Questions:

- Are there areas in this plant where it would be beneficial to upgrade to a NEMA Premium® motor?
- Do you have ideas for ways in which we could save more motor energy?
- Have you learned anything about energy efficiency that you thought was interesting, or that the rest of us should know about?

Question:

When a motor driven system component failure occurs, how should it be handled?

Answer:

Refer to and follow a motor driven system pre-failure action plan.

Learning Objective:

When a motor driven system component fails and must be removed for repair or replacement, the situation becomes ideal to advance efficiency and reliability. An action plan should be preared and in place for each significant motor driven system component. This plan should be designed to improve Key Performance Indicators (KPIs) and give direction for the best course of action.

Discussion Topic & Question:

Here's the situation: A process line stops and it is important to get it back up and running as fast as possible. Unfortunately, haste-based decisions that don't consider electrical costs, reliability, and system impacts are very often the norm in a crisis situation. Referring to a pre-prepared action plan will not only quickly return motor function, but also ensure the greatest system advantage by improving KPIs.

What are the possible KPIs of our motor management system?

- The ratio of motor energy (kWh) to product produced (e.g. tons, units).
- The mean time between failure (MTBF) of the motor systems.
- The percentage of available time consumed by motor-related failures.

Question:

How long does the average motor last?

Answer:

It depends upon the amount of load, environment, and duty cycle required of the motor. However, if properly applied, the average motor life is approximately seven to eight years.

Learning Objective:

It's a given that all motors will eventually fail. Put time on your side by consistently taking advantage of each opportunity to develop and improve a motor failure action plan in advance to help you prepare ahead and make upgrades to improve efficiency.

Discussion Topic & Questions:

If energy and system reliability impacts are advanced each time a motor fails, then the majority of the facility's systems will have improved significantly within a short time and with limited expense.

Use your action plans to consistently make the best possible decisions and enhance motor system key performance indicators. In a short period of time, you'll see positive results in facility-wide motor driven systems efficiency and reliability advancement.

Consider these issues for your motor systems:

- When a motor is exchanged in a fixed speed application, is consideration given to rpm reduction (e.g. 1800 rpm to 1200 rpm)? In a centrifugal device application, savings can be significant.
- Are we looking beyond the motor to maximize possible efficiencies throughout the system?
- Have we taken startup and steady state amperage readings and confirmed the right size motor is in place?

Question:

How much money does it cost to run a fully-loaded, 20 horsepower motor twenty-four/seven for a year, if electricity is only $.05 per kWh?

Answer:

For the extra $100 investment in a NEMA Premium® motor, the return over its 8-year life = **$1,280 in electrical savings**

	New Motor Costs	Annual Electrical Costs	Annual Savings	8 Year Life Electrical Savings
Standard Motor	$721	$7,160	$0	$0
NEMA Premium®	$828	$7,000	$160	$1280

Discussion Question:

Even a small motor is expensive to operate. To find the cost of a 100 horsepower motor, multiply the previous operational cost by five. This equals $35,030. For a 200 horsepower motor, multiply by 10. This equals $70,060. (Note: larger motors are slightly more efficient.)

Based on these numbers, to what can you compare these motor driven systems' electrical costs in your facility?

POSSIBLE ANSWERS:

payroll, benefits for X-number of employees

Question:

Should a motor be turned off at lunch or when it's not being used?

Answer:

Maybe.

Learning Objective:

A loaded, unused motor is inarguably a very inefficient motor. Generally speaking, turning off a motor for one hour a day is the equivalent of upgrading from a standard efficient motor to a NEMA Premium®.

Discussion Topic & Question:

Motors are only designed to start a few times in an hour period of time, influenced by speed and inertia. Too many starts per hour could result in a premature failure.

- Can you identify any opportunities in this facility for turning off unused motors?
- Have you discussed these opportunities with your supervisor, or asked engineering to review them?

Question:

Can motor over-lubrication cause loss of efficiency?

Answer:

Yes.

Learning Objective 1:

Many motor manufacturers have changed to a lubricant called Polyurea, which is incompatible to most grease. Improperly applying incompatible greases may almost certainly cause bearings to fail.

Learning Objective 2:

Proper lubrication and correct motor maintenance procedures are important, not only for maintaining reduced energy consumption, but for extending motor life.

Discussion Topic:

Too much lubrication or the wrong lubrication is more likely to cause motor failure than under-lubrication. Improper application practices and over-lubrication often results in motor windings becoming packed with grease and therefore unable to dissipate heat.

What happens if grease comes in contact with motor magnetic-wire due to over-lubrication?

ANSWERS:

- Decay of insulation materials and premature electrical failure
- Dust and fine particles will enter raceways and damage both rotating and static bearing surfaces
- Additional friction
- Collapsed bearing shields, and seals (causing a significant loss of efficiency and higher operational costs)

Incompatible
Borderline
Compatible

	Aluminum complex	Barium	Calcium	Calcium 12-hydroxy	Calcium complex	Clay	Lithium	Lithium 12-hydroxy	Lithium complex	Polyurea	Sodium
Aluminum complex		Incompatible	Incompatible	Compatible	Incompatible	Incompatible	Incompatible	Incompatible	Compatible	Incompatible	Incompatible
Barium	Incompatible		Incompatible	Compatible	Incompatible	Incompatible	Incompatible	Incompatible	Incompatible	Incompatible	Incompatible
Calcium	Incompatible	Incompatible		Compatible	Incompatible	Compatible	Compatible	Borderline	Compatible	Incompatible	Incompatible
Calcium 12-hydroxy	Compatible	Compatible	Compatible		Borderline	Compatible	Compatible	Compatible	Compatible	Incompatible	Incompatible
Calcium complex	Incompatible	Incompatible	Incompatible	Borderline		Incompatible	Incompatible	Incompatible	Compatible	Compatible	Incompatible
Clay	Incompatible	Incompatible	Compatible	Compatible	Incompatible		Incompatible	Incompatible	Incompatible	Incompatible	Incompatible
Lithium	Incompatible	Incompatible	Compatible	Compatible	Incompatible	Incompatible		Compatible	Compatible	Incompatible	Borderline
Lithium 12-hydroxy	Incompatible	Incompatible	Borderline	Compatible	Incompatible	Incompatible	Compatible		Compatible	Incompatible	Borderline
Lithium complex	Compatible	Incompatible	Compatible	Compatible	Compatible	Incompatible	Compatible	Compatible		Incompatible	Borderline
Polyurea	Incompatible	Incompatible	Incompatible	Incompatible	Compatible	Incompatible	Incompatible	Incompatible	Incompatible		Incompatible
Sodium	Incompatible	Incompatible	Incompatible	Incompatible	Incompatible	Incompatible	Borderline	Borderline	Borderline	Incompatible	

Question:

Does a motor lose efficiency when it's rewound?

Answer:

Maybe not.

Learning Objective:

If the failure event which caused the need for a motor rewind didn't inflict catastrophic damage to the core, and the motor service center follows Green Motors Practices' shop procedures, the motor should retain or slightly improve efficiency.

Discussion Topic & Question:

Two questions fit the task of rewinding motors very well: "Do you want it done fast or done well? Do you want it done cheaply or done right?" A qualified motor service center understands efficiency is just as important as reliability and can rewind motors to sustain efficiency. Efficiency will improve, provided the failure didn't destroy the motor core, a prior rewind was done well, and the service center is given adequate time to do the work. An occasional visit with a motor service center, stressing the importance of efficiency over price, is an important activity two to four times a year.

Would it be useful for our facility's motor system team to work with a motor service center to improve efficiency?

Question:

What is the most significant cost of running a compressed air system?

Answer:

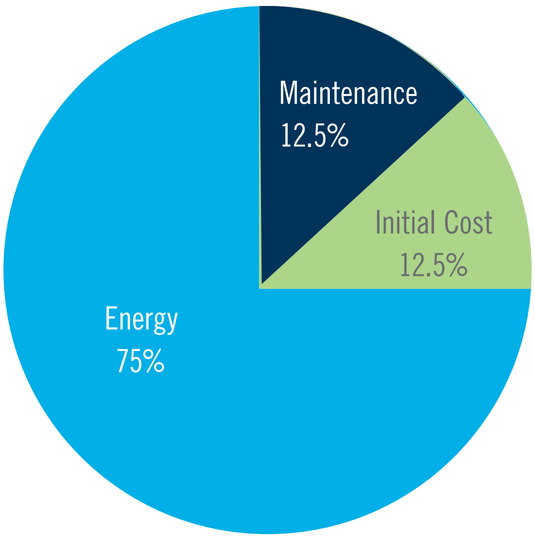
Energy

Learning Objective: 1

Compressed air is an extremely inefficient work method. For every 100 hp of energy required to operate the equipment, only 9 hp of work is delivered.

Learning Objective 1:

Electrical energy is 75% of the monetary cost of a compressed air system over its 10-year life.



Discussion Question:

Are we using compressed air in our facility for an application that could be performed with a less expensive method?

(Potential high cost applications)

- Cleaning
- Drying
- Vibration
- Open Blowing
- Cooling
- Diaphragm pumps
- Air motors (i.e. for stirring)

Question:

Have we noticed any compressed air leaks in our plant? If so, have they been reported to the appropriate maintenance personnel? Recall that compressed air is not free!

Discussion Questions:

- What energy saving actions have you taken lately?
- Do you have any ideas for ways in which we could save more energy?
- Have you learned anything about energy efficiency that you thought was particularly interesting, or about which the rest of us should know?

➲ **ENERGY CHAMPION** – *Have your Tool Box card presenter write down energy saving actions and ideas and pass them along to you.*

Question:

What inefficient uses of compressed air are most common in manufacturing plants?

Answer:

1. **Personal cooling -** comfort cooling with air
2. **Open hand-held blow guns or lances -** any unregulated hand-held blowing
3. **Diaphragm pumps -** commonly installed without regulators and speed control valves
4. **Cabin cooling -** cooling electrical panels with open tools

Learning Objective:

A facility can take various action steps to eliminate or reduce inefficient uses of compressed air. Here are a few examples from a food processing plant. Peak flow is identified in cubic feet per minute (cfm):

Discussion Question:

What inefficient uses of compressed air are present in our facility?

(**SUGGESTION:** Offer an incentive or recognition for the person/team who identifies the most inappropriate uses of compressed air.)

Operation	Original Peak Flow (cfm)	Number of Hours	Action Taken	Revised Peak Flow (cfm)	Peak Flow Reduction (cfm)
Open hand-held blow guns	200	6,500	Installed nozzles	50	150
Vacuum generator	1,000	5,000	Motor-driven vacuum pump	0	1,000
Personal Cooling	800	3,500	Used fans	0	800
Pneumatic actuators	750	3,500	Replaced with electric actuators	0	750
Total CFM reduction					**2,700**
Annual Savings (18kW/100cfm at $.05/kWh)	**$102,600**				

Question:

Where are leaks most likely to occur and reappear in a compressed air system?

Answer:

Leaks are most likely to occur between the main line and end use and in the equipment itself.

Learning Objective:

Leaks normally occur in the compressed air piping system where there are valves, regulators, quick disconnects and flexible hoses with joints and o-ring seals that harden and crack. This area is known as the “dirty thirty” because it’s usually within 30 feet of the end-usage point. Also, the machinery has many small hoses and tubing that eventually develop leaks. These areas are hard to reach, but still require constant attention.

Discussion Question:

Where do you think leaks commonly occur in this facility’s compressed air system?

(Identify possible locations and ask your compressed air champion/leak team to check and then report back to you.)

Question:

Is the compressed air pressure kept as low as possible without having a negative effect on production? If it is having a negative effect, should we discuss this with engineering staff?

Discussion Questions:

- What is meant when we talk about “negative effects” on production?
- Is keeping the compressed air at a low pressure always OK?
- What energy saving actions have you taken lately?
- Do you have any ideas for ways in which we could save more energy?

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Question:

What does it mean to establish a baseline measurement (called “baselining”) for a compressed air system?

Answer:

Baselining involves taking measurements that determine the effectiveness of your compressed air system in meeting load efficiency. Measurements of power, energy, pressure, leak load, flow and temperature are needed to establish the baseline measurement.

Learning Objective:

Establishing a baseline helps you:

- Better understand the dynamics of your system
- Calculate the cost at which you are currently operating
- Establish a benchmark against which future progress will be measured
- Identify action steps to improve compressed air performance (e.g. adjust controls)

Discussion Question:

What factors could give us an incorrect baseline measurement?

POTENTIAL ANSWERS:

- Not using proper instruments
- Instruments out of calibration
- Not taking repeated baseline measurements over time
- Not taking baseline measurements after changes to the system

Question:

How is the total amount of leaks calculated in a typical compressed air system?

Answer:

During a down production period, log how much compressed air it takes to maintain the system. Compare this to data during production, and the difference is leaks.

Learning Objective:

In a well-maintained system, leaks are less than 10% of the system capacity. Is this facility above or below 10% leaks?

Discussion Question:

How do I calculate my leak load?

If the machines are load/unload, then time the load duration versus the unload duration over a specific time frame, say 10 minutes. This should also be performed when production has stopped and all open-blowing applications are valved off. Use the following equation to calculate your leak load:

Leakage (%) = (Loaded time x 100)/ (Loaded time + Unloaded time)

Alternative method: Some compressors have percentage capacity gauges that display the percentage of the total output of the compressor. Shut down all machinery and close all open-blowing applications. Check to see what the percentage capacity gauges read and then make adjustments for total percentage if more than one machine is running. This constitutes the total leaks in the system.

Question:

Has anyone identified inefficient uses of compressed air in our plant, such as air jets to dry cans or for personal cooling?

Discussion Questions:

- How much money is spent each year on compressed air in our plant?
- What are some other ways that air can be wasted?
- What should we do when we see a wasteful use of compressed air?

Question:

What percentage of total compressed air produced constitutes leaks?

Answer:

Up to 50%

Learning Objective:

The accepted national average for leaks in a compressed air system is 20-30% of the total compressor output. Nevertheless, in certain industries, such as wood products, where there is an excessive amount of vibration, the leak total can reach 50% of the total compressor output. Thus, leaks are a significant component of waste in a compressed air system and for that reason they deserve constant maintenance.

Discussion Question:

What could you do to significantly reduce leaks in our compressed air system?

POTENTIAL ACTION POINTS:

- Institute regular leak detection and leak maintenance into regular maintenance procedures.
- Notify our Compressed Air Champion weekly of maintenance concerns and potential leaks.
- Invest in an ultrasonic leak detector and use the tool on a regular basis to locate and prioritize leak repair.
- Purchase high quality quick disconnects and purchase large diameter hoses.
- Install solenoid or ball valves that are closed when the machinery is unused.

Question:

How much does it cost per year to have a 1/4 inch diameter hole in a compressed air line?

Answer:

Approximately $10,000 per year.

Learning Objective:

Compressed air generation is one of the most expensive systems equipment in an industrial facility. The average U.S. manufacturing plant leaks 20-30% of the compressed air generated. This chart shows the average costs of leaks per year.

Hole Diameter (inches)	Average Cost Per Year
1/32	$160
1/16	$628
1/8	$2,514
1/4	$10,059

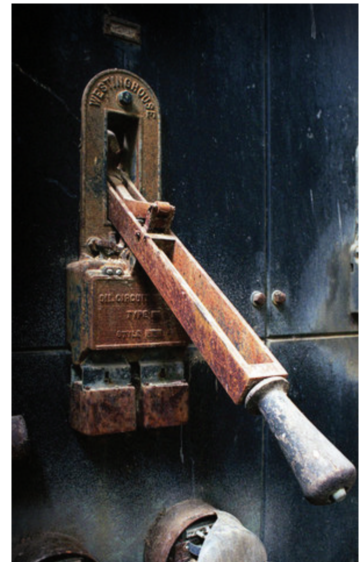
**calculated costs assume 100 psig and a $0.06/kWh electricty rate*

Discussion Questions:

- How much product (use standard unit, e.g. case or pound) do you think we have to sell to pay for this amount of lost air (if our plant leaks 20-30%, as the national average)?
- Can you imagine all that product and the work it took to create it being thrown out and wasted? That's what being lost when compressed air leaks go unchecked here.

Question:

Is process equipment turned on as close to the start of production as possible? And is it shut off as soon as production is complete?



Discussion Questions:

- How much energy is saved by only running the equipment when it's needed?
- Does it always make sense to start and stop our machinery throughout the day?
- Have you noticed any machinery that is being used in a way that is wasting energy?

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Question:

What is one of the most inefficient, part-load control methods for an air compressor?

Answer:

Inlet throttling or modulation.

Learning Objective:

Compressors are most efficient at full load. However, it's extremely rare that a plant requires the full capacity of a compressor. Therefore, part-loading is necessary. More efficient part-load methods are:

- Load/unload
- Start/stop
- Variable displacement
- Variable speed

Discussion Questions:

- Are there throttled compressors in your compressor room?
- What possible methods could you use to improve part-load performance and efficiency for these compressors?

Question:

If you're operating your compressor system at 10 psi higher than what is needed, how much additional energy is being used at how much greater cost (percentage)?

Answer:

Approximately 5% more energy and 5% more money.

Learning Objective:

For every 1 psi of additional pressure, it costs .5% more. Another consequence of elevated pressure is increased air consumption by leaks and end-uses.

Discussion Questions:

- Which end-use (or department) complains first when pressure drops?
- What is the minimum pressure at which our facility's compressed air system can operate?
- At what pressure is our system currently operating?

Develop a KPI that relates cost to value of product and operates the system at minimum pressure.

Question:

What percentage of lighting power in a cold storage facility ends up as heat load on the refrigeration system?

Answer:

100%

Learning Objective:

Would you run an electric baseboard heater in a cold storage facility? Each light is no different than a baseboard heater. The energy it takes to run lights ends up as heat that the refrigeration system must handle. Turning off lights saves energy and reduces energy used in your refrigeration system.

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Discussion Question:

How can you reduce light energy in our plant?

POSSIBLE ANSWERS:

- Reduce motion sensor occupancy time
- Establish light quality standards for areas and periodically inspect them
- Turn off lights when areas are unoccupied
- Install bi-level high bay, high intensity discharge (HID) lighting, light-emitting diodes (LED) or on/off fluorescent lighting with motion sensors
- Disconnect fixtures in over-lit areas (a de-lamped fixture still draws energy)

Full Power (Left) and Dimmed (Right) High Bay Lighting

Shift Talk on Energy Efficiency for Refrigeration

QUESTION 1: How much do we spend on electricity per year?
ANSWER 1: (Questioner to provide answer)

QUESTION 2: Approximately what percentage of total facility electrical energy use goes towards refrigeration?
ANSWER 2: (The group comes up with an agreed upon answer)

QUESTION 3: How much does it cost per year to operate our refrigeration system?
ANSWER 3: (Multiply Answer 1 by Answer 2 for answer)

Learning Objective:

Any effort to save refrigeration energy use can save considerable money. The energy use of most refrigeration systems can be reduced by 10% with little or no investment in capital equipment.

Discussion Question:

What are some ways you could reduce refrigeration system energy use?

POTENTIAL ANSWERS:/ACTION STEPS

- Raise suction pressure
- Lower condensing pressure
- Turn off compressors whenever possible
- Close doors and turn off lights
- Fine-tune defrost
- Implement evaporator fan cycling

Question:

Are temperatures in refrigerated areas kept as high as possible without negatively affecting what's supposed to be kept cool?

Discussion Questions:

- What energy saving actions have you taken lately?
- Do you have any ideas for ways in which we could save more refrigeration energy?

Question:

How much does it cost to leave open a 10 x 12 ft door to a 0°F freezer on an 80°F day? How about to a 32°F cooler?

Answer:

- $140/day or $4,200/month for the 0°F freezer (at $0.05 kWh)
- $50/day or $1,500/month for the 32°F cooler (at $0.05 kWh)

Learning Objective:

Leaving cold storage doors open is expensive and makes it more difficult to maintain space and product temperature. Open doors also lead to frosting of the floor and walls which can be a safety hazard.

Discussion Question:

How can you reduce unnecessary loads on the refrigeration system?

POTENTIAL ANSWERS/ACTION STEPS:

- Turn off lights in refrigerated area
- Minimize defrosts
- Maintain the highest room temperature possible
- Avoid damaging insulation and door seals
- Maintain strip curtains

Question:

At what percentage of full load capacity does an evaporative condenser operate with only the pump running (fan is off)?

Answer:

10%

Question:

At what percentage of full load capacity does an evaporative condenser operate when running dry (pump is off)?

Answer:

10-30%, depending on ambient temperature

Learning Objective:

The most efficient mode of operation for evaporative condensers is with the pumps and fans running.

Discussion Question:

Why might you operate our condenser with the pump or fan only?

- Concerns about shutting pumps down causing coil scaling
- Cold weather could cause freezing
- Poor controls
- Tradition
- Liquid refrigerant hanging in the condensers

Question:

Are the doors to refrigerated spaces kept closed as much as possible? Leaving doors open causes unnecessary energy use and can be very expensive for the plant.

Discussion Questions:

- What are some other common causes of infiltration of refrigerated space in our facility?
- What energy saving actions have you taken lately?
- Do you have any ideas for ways in which we could save more energy?

Question:

What percentage of total plant refrigeration load is related to heat gain through insulated walls and the ceiling?

Answer:

Less than 5%

Learning Objective:

The majority of the refrigeration load on the plant is from freezing product. The next largest refrigeration loads come from gaps in doors, opening doors, evaporator fans and lights. Heat gain through insulated walls and the roof is just a small fraction of the total refrigeration load.

Discussion Question:

What are the loads on this facility's refrigeration system?

POSSIBLE ANSWERS:

- Freezing product
- Cold storage lighting
- Evaporator fans
- Under floor heating
- Conduction through walls and the roof
- Opening doors
- Gaps in doors
- Door heating
- Defrosts
- Forklifts
- People
- Product respiration (e.g., apples)

Question:

What percentage of full-load power does an unloaded screw compressor with slide valve capacity control draw?

Answer:

40%

Learning Objective:

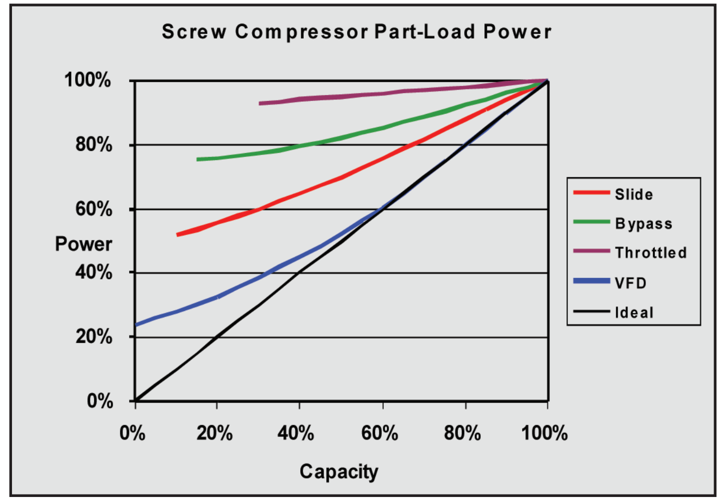
Screw compressors with slide valve capacity control are very inefficient at part load. Strive to operate only one compressor at part load per suction system. Utilize a compressor that is efficient at part load, such as a VFD screw, reciprocating, or the smallest screw compressor you can get away with.

Discussion Question:

It is critical to match refrigeration supply (compressors) with demand (load). What are some variables that will vary refrigeration loads and necessitate a change in the operating compressors?

POSSIBLE ANSWERS:

- Change in product that is processed
- Change in tunnels that are utilized
- Change in outdoor temperatures
- Defrosts



Screw Compressor Part Load Performance

Question:

Increasing suction pressure causes compressor capacity to increase or decrease?

Answer:

Increase

Question:

Increasing suction pressure causes compressor efficiency to increase or decrease?

Answer:

Increase

Learning Objective:

Increasing suction pressure causes an increase in compressor capacity (tons of refrigeration – TR) as well as power (horsepower – BHP). The net effect is an improvement in compressor efficiency (BHP/TR). In general, an increase in suction temperature of 1°F leads to a 2% improvement in compressor efficiency.

Discussion Question:

How can you increase suction pressure in our facility?

(develop list of possible action steps)

Condensing Temperature	Suction temperature								
	-40°F			0°F			+40°F		
	BHP	TR	BHP/TR	BHP	TR	BHP/TR	BHP	TR	BHP/TR
75°F	269	108	2.49	347	317	1.09	350	773	0.45
85°F	301	103	2.92	389	308	1.26	419	751	0.56
95°F	336	99	3.39	436	296	1.47	496	729	0.68
105°F	374	94	3.98	486	290	1.68	582	705	0.83

Sample Compressor Ratings

Question:

Increasing suction pressure causes the compressor capacity, power and efficiency to increase or decrease?

Answer:

Increase

Learning Objective:

A 1°F increase in suction temperature leads to a 2% improvement in compressor efficiency.

Discussion Question:

What are some ways to increase suction pressure?

POTENTIAL ANSWERS:

- Raise set point
- Reduce pressure drops and other bottlenecks
- Reduce evaporator approach (temperature of room minus temperature of refrigerant)
- Have screw compressors provide tighter control

Question:

What percentage of full load power does a condenser fan draw at 50% speed?

Answer:

Approximately 15%

Learning Objective:

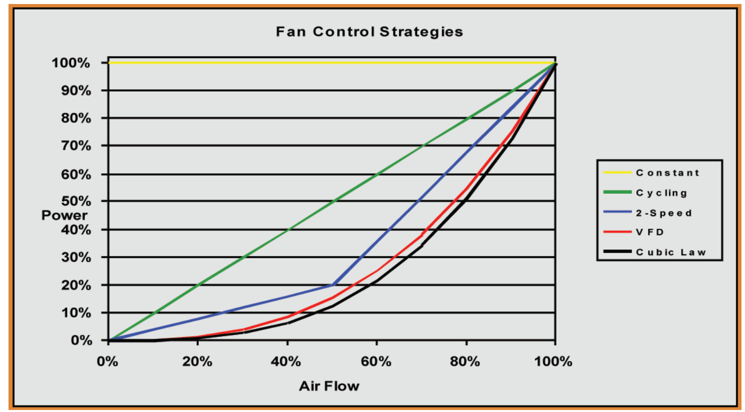
Power varies with the cube of speed for fans and other centrifugal devices, such as pumps. A fan at 50% speed thus draws about 20% of full load power after you account for motor and drive losses.

Discussion Question:

What are some applications where you could operate fans and pumps at reduced speeds?

POTENTIAL ANSWERS:

- Condenser fans
- Evaporator fans
- Wastewater pumps
- High pressure cleanup pumps



Fan Part Load Efficiency

Shift Talk on Energy Efficiency for Refrigeration

Question:

What percentage of condenser capacity is lost when there is 1/16 inch of scale on the condenser coil?

Answer:

50%

Learning Objective:

Optimizing your condenser is critical to reduce condensing temperature. A 2°F reduction in average condensing temperature reduces refrigeration compressor energy use by 3%.

Discussion Question:

How can you ensure that our facility achieves full capacity with our condensers?

POTENTIAL ACTION ITEMS

- Keep good maintenance records
- Tighten fan belts
- Make sure that the water blow-down system is working correctly
- Periodically inspect and clean condenser coils and nozzles
- Clean condenser grills and drift eliminators
- Install high performance spray nozzles
- Ensure new condensers are passivated

Badly Scaled Condenser

Question:

Are plant lights left on when they are unneeded?

Are lights illuminating areas that do not require light (e.g. at the top of racks?).

Discussion Questions:

- Are there any lighting circuits in our facility that would benefit from occupancy sensors or timers?
- What lighting technology is least efficient (potential answers: incandescent, mercury vapor)?
- What lighting technologies are more efficient (potential answers: metal halide, high-pressure sodium, fluorescent, and LED)?

Question:

What is the relationship between pump maintenance and pump energy efficiency?

Answer:

There is a direct correlation. Pumps with significant maintenance and reliability problems are also extremely inefficient and costly to run.

Learning Objective 1:

Pumps with maintenance problems are an ideal opportunity to save energy.

Learning Objective 2:

Pumps that are throttled way back, or are running over capacity, cost much more to operate (energy) and maintain (labor cost).

Discussion Questions:

- Are there pumps in our facility that are throttled back or running over capacity?
- Are these pumps less reliable and more costly to operate?

Question:

How many bypass loops and throttling valves are throughout your facility, and what could be a more efficient way to control flow?

Answer:

More efficient ways to control flow include putting in a smaller pump and motor and installing a Variable Speed Drive (VSD).

Learning Objective:

Bypass loops and throttling valves are the least efficient and most costly way to control flow. Bypass loops and throttling valves increase energy usage and maintenance costs and decrease reliability.

Discussion Topic & Question:

Throttled valves produce significant pressure drops and are a major contributor to pump efficiency loss. A Variable Speed Drive that reduces the speed an average of 10% on a continuously running 100 hp pump can save about $10,000 per year in energy costs alone.

Variable Frequency Drives (VFDs) can eliminate the need for valves, starters and bypass systems because they adjust pump speed automatically, according to demand. They also protect against process upsets and pressure spikes, and some have soft-starting capabilities. A 20% reduction in speed can reduce power consumption by 50% (close to $20,000 per year for the previous example).

Are there pump systems in our facility that would improve efficiencies with a Variable Frequency Drive?

Variable frequency drives (VFD) are a category of variable speed drive (VSD) that adjusts the speed of the motor by manipulating the frequency of the power supplied to the motor.

Question:

Is process equipment turned on as close to the start of production as possible? And is it shut off as soon as production is complete?

Discussion Questions:

- How much energy is saved by only running the equipment when it's needed?
- Does it always make sense to start and stop our machinery throughout the day?
- Have you noticed any machinery that is being used in a way that is wasting energy?

➲ **ENERGY CHAMPION** – *Have your Tool Box card presenter write down energy saving actions and ideas and pass them along to you.*

Question:

What are the organizational elements necessary to continuously improve our pump systems?

Answer:

- Pump System Champion
- KPIs
- A comprehensive assessment
- Training for all staff
- Engaging vendors in the improvement process

Learning Objective:

Strategic energy management can be used to:

- Assign a Energy System Champion for your pump systems
- Identify and track progress towards KPIs
- Conduct a comprehensive energy assessment
- Train and educate staff on energy management strategies and activities

Discussion Questions:

- Who has been assigned the responsibility to improve this facility’s pump systems?
- What data is collected to track the system efficiencies over time?
- Who has taken a comprehensive look at the opportunities to improve the systems?
- Has our staff been trained on the proper operation of pump systems?

Question:

What percentage of the life cycle cost of a pumping system is devoted to energy and maintenance?

Answer:

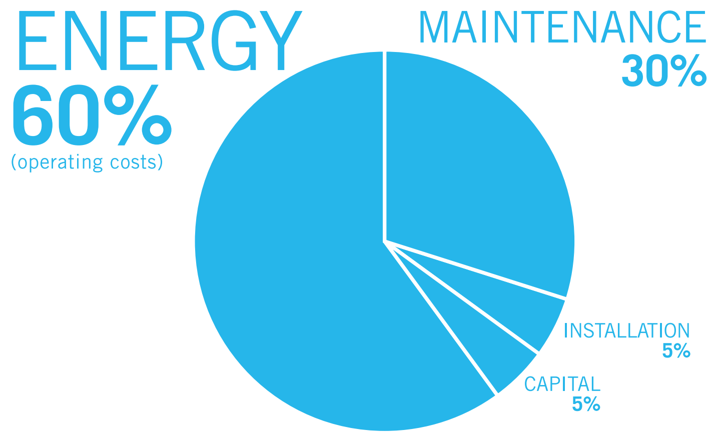
70-80%

Learning Objective:

Energy and maintenance costs are usually the largest expenses for pumping systems. There is a direct correlation between pump system operation and maintenance costs.

Discussion Topic:

Please draw a larger version of this pie chart on a flipchart. The two smallest slices in the pie chart represent the initial cost of the pump system and installation costs. The second largest slice represents maintenance costs. The largest slice, which represents energy costs, is over 60% of the total cost of operation—and often overlooked when making purchasing decisions.



LCC/TCO typical 75 hp pump $750,000 over 20 years

Question:

Are plant lights left on when they are unneeded?

Are lights illuminating areas that do not require light (e.g. at the top of racks?).

Discussion Questions:

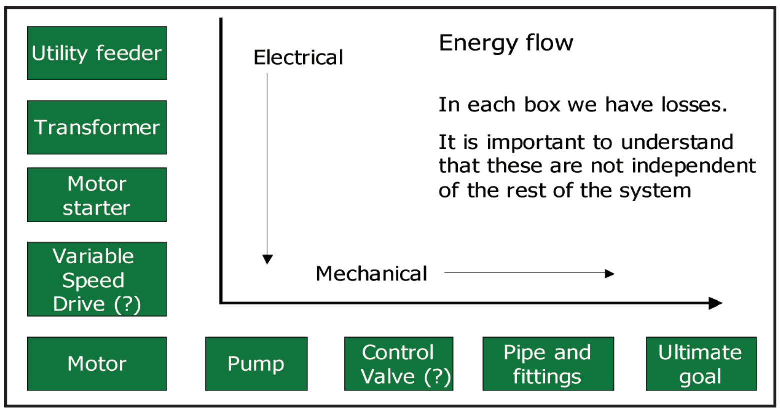
- How much energy is wasted by leaving the lights on?
- What kinds of lights waste the most power?
- Are there any areas in our plant that would benefit from energy-saving compact fluorescent light bulbs?

Question:

What are the elements of a pumping system?

Answer:

The motor, pump, piping, valves, friction losses, leaks and work performance. (Draw and discuss the graphic below.)



Learning Objective:

A pump system needs to be considered as a whole. Inefficiencies occur at each step, and matching supply to demand can have a multiplying effect in terms of savings back to your meter.

Discussion Question:

The motor system for a pump includes everything from the electricity entering the facility to the end-use application for the pumped fluid. There are systems losses at each step through the process.

What are the potential system losses for this facility's pump system?

Question:

What are the "symptoms" of an unreliable and inefficient pump system?

Answer:

- Throttled valves (over 25% of design flow)
- Normally open bypass lines
- Multiple parallel pumps running continuously
- Pumps running continuously with significant variations in system requirements
- Systems that are cavitating
- Frequent cycling pumps in batch operation
- Pumps with high maintanence costs. Toolbox Talk on Energy Efficiency for Pumps

Learning Objective:

Identify pump systems that show symptoms of being unreliable and inefficient, and conduct an assessment. There is a strong correlation between inefficient pump systems and “bad actors,” high maintenance costs and less reliability.

Discussion Questions:

Symptoms of unreliable and inefficient pump operation also indicate that the company is wasting money on energy, maintenance costs and possibly, productivity.

- Can you think of a particular system that has these symptoms?
- Who is the Champion or owner of that system?
- Is our electric utility available to help evaluate alternatives to improve the system?

Question:

What are some of the opportunities to improve a pump system?

Answer:

It is important to size and operate the motor and/or pump according to process requirements. Following are a few techniques. However, before beginning these tasks, it is important to conduct a detailed analysis to determine which of these activities is most appropriate for our system.

- Trim pump impeller
- Install a variable speed drive
- Install parallel pumps where a single oversized pump is currently used
- Modify the fluid system – such as increased pipe diameter, removing bends and valves
- Turn off pumps that are unneeded
- Examine the system to determine if function and requirements have changed over time Toolbox Talk on Energy Efficiency for Pumps

Learning Objective:

System improvements can be as simple as turning a pump off and as complicated as "re-sizing" or "re-piping" the system based on current design conditions.

Discussion Topic:

Can you identify any systems that are currently operating that may be oversized, and that could be turned off or improved by matching the system to current production requirements?

(For a list of some of the symptoms refer to Card #95)

Question:

How much does it cost to operate our pump system?

Answer:

The cost depends on the operating conditions (not on the size of the motor). If the power requirement of a pump is 100 hp, then use the following table to estimate electrical costs:

Table 1. Pumping Energy Costs for Pump Driven by 100-hp Motor (assuming a 90% motor efficiency)

Operating Time	Energy Costs for Various Electricity Costs				
	2 cents per kWh	4 cents per kWh	6 cents per kWh	8 cents per kWh	10 cents per kWh
1 hour	$1.60	$3.30	$4.90	$6.60	$8.20
24 hours	$39	$79	$119	$159	$198
1 month	$1,208	$2,416	$3,625	$4,833	$6,042
1 year	$14,500	$29,000	$43,600	$58,000	$72,600

(Does not include demand charges)

neea

Learning Objective:

The energy cost for operating a pumping system is significant – and warrants the effort to improve the efficiency of these systems. Energy cost depends on the load.

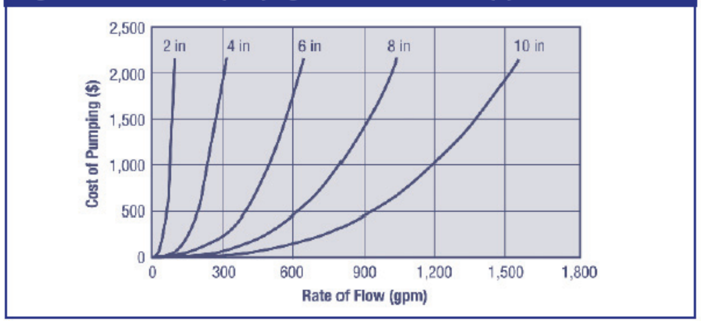
Discussion Questions:

- How many "100 hp equivalent" pump systems do we have in our facility?
- What is our electrical rate in terms of $/kWh?
- What do we spend on electricity for the pumping system in our facility?
- What is our demand charge?

Question:

How much does it cost to operate our pump system?

Figure 1. Annual water pumping cost for 1,000 feet of pipe of different sizes



Based on 1,000 ft. for clean iron and steel pipes (schedule 40) for pumping 70°F water. Electricity rate—0.05 $/kWh and 8,760 operating hours annually. Combined pump and motor efficiency—70%.

Answer:

Large diameter piping will be significantly more efficient. For example, for a pump operating at 600 gpm (in figure below), the annual cost for each pipe size is:

- 6-inch pipe = $1750
- 8-inch pipe = $500
- 10-inch pipe = $200

Learning Objective:

The frictional component of pumping losses is significant, and larger size pipes will reduce energy costs dramatically.

Discussion Question:

What can you do to reduce the frictional component of your pumping system?

POTENTIAL ANSWERS:

- Lower the flow rate
- In systems dominated by friction head, evaluate pumping costs for at least two pipe sizes and try to accommodate pipe size with the lowest life-cycle cost.
- Look for ways to reduce friction factor. If application permits, epoxy-coated steel or plastic pipes can reduce friction factor by more than 40%, proportionately reducing pumping costs.
- Compute the annual and life-cycle cost for systems before making an engineering design decision.

Question:

What are the recommended methods for monitoring a pumping system?

Answer:

Recommended methods include vibration monitoring, power monitoring, flow rate or pressure monitoring and temperature monitoring.

Learning Objective:

A pumping system must be well monitored to track its operational performance. Also, tracking KPIs will help keep the system running in an optimal way, leading, potentially, to significant electricity and maintenance savings. Wireless monitoring systems can be cheaper to install than wired systems.

Discussion Questions:

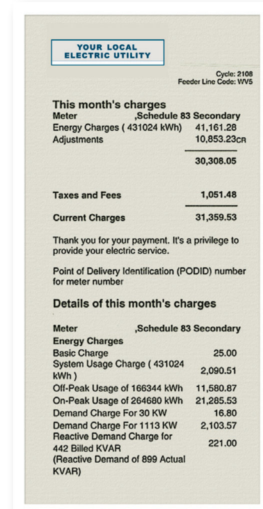
- Do you use some of the pump system monitoring methods in your facility?
- Which parameters do you track? Is the information used to improve the operation of the system?
- Can you easily measure power divided by flow? (This is like measuring miles per gallon for a car. It will show when the pump is worn, for example.)
- Can we use wireless monitoring?
- Would it be cheaper?

Question:

What types of charges show up on the typical utility bill?

Answer:

- Basic charge
- Energy charge (kWh), demand charge (kW), power factor charge (kVAR), local taxes, and franchise charges and adjustments.



YOUR LOCAL ELECTRIC UTILITY

Cycle: 2108
Feeder Line Code: WV5

This month's charges

Meter	**,Schedule 83 Secondary**
Energy Charges (431024 kWh)	41,161.28
Adjustments	10,853.23CR
	30,308.05
Taxes and Fees	**1,051.48**
Current Charges	**31,359.53**

Thank you for your payment. It's a privilege to provide your electric service.

Point of Delivery Identification (PODID) number for meter number

Details of this month's charges

Meter	**,Schedule 83 Secondary**
Energy Charges	
Basic Charge	25.00
System Usage Charge (431024 kWh)	2,090.51
Off-Peak Usage of 166344 kWh	11,580.87
On-Peak Usage of 264680 kWh	21,285.53
Demand Charge For 30 KW	16.80
Demand Charge For 1113 KW	2,103.57
Reactive Demand Charge for 442 Billed KVAR	221.00
(Reactive Demand of 899 Actual KVAR)	

Discussion Questions:

- Why do utilities break out the separate charges?
- How much energy in kWh did our facility use last month?
- How much demand in kW?

What We Learned:

Utilities recover costs associated with providing electric service to the customer. A utility bill reflects costs incurred by the utility for: metering/billing; customer service; purchased and generated power; substations; distribution lines and poles; transformers; and system and dispatch control.

Question:

What information does a typical meter record?

Answer:

Energy (kWh), demand (kW) and reactive power (kVAR).

Discussion Questions:

- How often are your meters read (billing cycle)?
- Where are your meters located?

What We Learned:

Modern electronic meters record "pulses" with each pulse equal to an amount of energy kWh. The meter is read by the meter reader (or in some cases, remotely) and the demand reset. The information is then used to calculate your monthly bill. In some cases, your meter records "on-peak" and "off-peak" energy and demand. Typical on-peak times are 6 a.m. to 10 p.m., Monday through Saturday.

Question:

What is your cost for electricity?

Answer:

It depends on many factors, including:

1. How much energy you use (kWh)
2. How much you need at any one period (kW)
3. Your power factor (kVAR) and
4. Your rate schedule

Details of this month's charges

Meter	**,Schedule 83 Secondary**
Energy Charges	
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(Reactive Demand of 899 Actual KVAR)	

Discussion Questions:

- How much do you pay for electricity each month?
- How does that change over the year?

What We Learned:

There are many factors that go into determining what rate you pay for electricity, but a general range for the Northwest is between four and six cents/kWh, demand is between $4 and $5 per kW, with kVAR being $0.50.

Question:

What costs the most on your monthly electric bill?

Answer:

Energy use, measured in kilowatt hours (kWh). This answer applies to the Pacific Northwest. In other regions, peak demand can be a more significant portion of the total cost.

Discussion Questions:

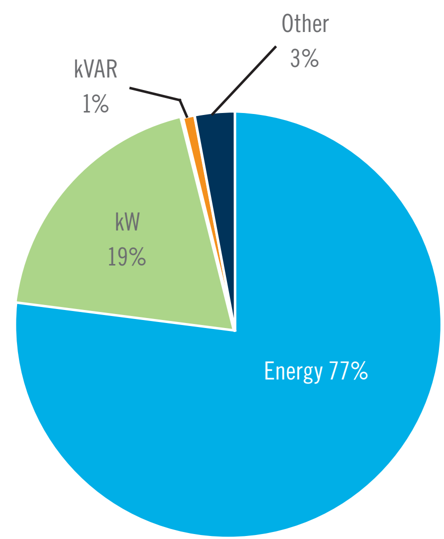
- What can you do to reduce energy consumption in this facility?
- Have you presented your ideas to your supervisor?

What We Learned

Depending on your rate schedule and how you use energy, the typical monthly bill *might* look something like this:

- 77% energy
- 19% kW
- 3% other
- 1% kVAR

The greatest opportunity to lower your monthly bill is to reduce your energy use through improved energy management and energy efficiency projects.



Typical Monthly Bill

Question:

Why do utilities have different rate schedules?

Answer:

Costs vary when serving different groups of customers.

Discussion Questions:

- Under what conditions would it make sense for a customer to be served at a higher voltage?
- What voltage is this facility served under?
- Where is our utility point-of-delivery?
- Who owns the transformers?
- How many electric accounts do we have?

What We Learned

Utilities attempt to allocate the costs among different customer groups. Non-residential rates are typically grouped by the voltage served:

- Secondary voltage is normally 480 volts or less
- Primary voltage (or feeder voltage) is 12,470 volts
- Transmission voltage (also called sub-transmission) voltage is 57,500 volts or above

** For more information on your rate schedules, talk to your utility representative.*

Question:

How do we know how much energy the equipment is using?

Answer:

For a precise answer, energy must be directly measured or calculated.

Discussion Questions:

- How much energy does a 50 hp motor use?
- Which piece of equipment in this facility uses the most energy?

What We Learned:

Monitoring power (kW) is more than measuring amps with an ammeter. Energy consumption is power (kW) used over time (hr) producing kWh.

Calculating energy use can be done using the following formula for 3-phase power:

kW = (volts) X (amps) X (power factor) X 1.732/1000.

Energy can also be determined by manufacturer's data, pump and equipment performance curves, and industry databases such as lighting.

Question:

How is demand determined by the electric meter?

Answer:

Demand is internally calculated and recorded based on the highest average energy consumption over the utility monitoring interval in a billing cycle (typically 15-30 minutes). Demand is typically measured in kW.

Discussion Questions:

- At what time of day or on which day of the month is the highest amount of energy used by this facility?
- Is there anything that can be done to reduce demand? Is it practical?

What We Learned

Demand is one of the most misunderstood metering topics. Demand is NOT:

- An instantaneous number
- Affected by the number of motors started at once or by motors starting at all

Demand is an AVERAGE number relating to how much energy is consumed during a metering interval. The meter records the energy consumed (kWh) and divides it by the time interval (hr). Demand is highest when the most amount of energy-consuming equipment is operating concurrently over the metering interval.

Question:

What is power factor?

Answer:

Power factor is the ratio between the real power (kW) and the apparent power (kVA). In other words, power factor is the ratio of the amount of working power flowing to the load to the total power in the circuit.

Discussion Questions:

- How much does the utility charge for your facility's power factor, if any?
- What percentage of the entire bill is the power factor?
- What is the largest motor in this facility that is unloaded at least part of the time?

What We Learned:

Power factor is of concern to utilities and electricians because they must size their power lines and equipment based on the potential power delivered. In other words, it means investing a large sum of money in larger components (wires and transformers) to serve the same useful work (power).

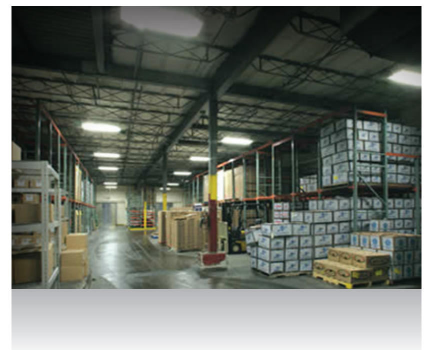
The primary culprit of a low power factor is large, unloaded motors. A typical facility with motors like this are sawmills and rock crushers. Typically, the best way to correct a low power factor is with capacitors.

Question:

Why should we consider saving energy?

Answer:

It will likely lower our monthly bill!



Discussion Questions:

- What systems in this facility could be improved to save energy?
- How can we determine the energy savings?
- What other procedures or technologies can we use to save energy?

What We Learned

There are often ways to do the same thing for less power. For example, there are many energy efficient lighting sources, including fluorescent, light-emitting diodes and high intensity discharge, that use less energy than incandescent lights.

Other systems where energy savings can typically be found:

- Compressed air
- Refrigeration
- Electric motors
- Pumps
- Fans

The equipment *being driven* by a motor is usually the best place to look for energy improvements.

Question:

How can I get more detail about my electric use than what is provided by the numbers on the monthly bill?

Answer:

Some meters can provide the pulses gathered during each monitoring interval and will transmit them to a local data collector, or you can ask your utility if it provides this service separately.

Discussion Questions:

- Does your facility have access to interval metering? If so, what can it tell you about how you use energy? Are there any surprises looking at the data?
- Have you compared the energy used during non-production or non-occupied times? What should it be? Can it be lowered?

What We Learned:

Electronic meters have the capability to store energy information for each monitoring interval programmed into the meter. Use this information to provide insight into how your facility is using energy. Energy used during non-occupied or non-production hours can help you make decisions about shutting down equipment that is unneeded. Or, you might discover that equipment is not starting or stopping as it should.

Toolbox Talk Log Sheet

System & Card Number	Date Completed	Dept. or Shift Number