CascadeEnergy®

Reducing Energy Consumption in Non-Refrigeration Systems

BEST PRACTICES GUIDE

Best Practices for Non-Refrigeration Systems

Cascade Energy's *Industrial Refrigeration Best Practices Guide* identifies approaches for making industrial refrigeration systems both energy efficient and productive. But, of course, opportunities for energy efficiency aren't limited to refrigeration systems. There are many other common industrial systems that offer energy-saving opportunities as well.

For example, cold storage warehouses consume significant amounts of power through lighting, fork truck battery chargers, and office HVAC. Food processing plants with refrigeration systems typically run large, non-refrigeration systems as well, including boilers, compressed air, pumps, etc.

There are some basic approaches to successful energy management that apply to virtually any industrial system. Some of these fairly straightforward measures include:

- Turning the system or components off
- Using your best part-load option
- Minimizing loads
- Eliminating leaks
- Processing goods once, not twice
- Maintaining cleanliness
- Minimizing pressure drops
- Using speed control where appropriate
- Running your most efficient equipment first
- Calibrating instrumentation and controls
- Establishing standards and best practices

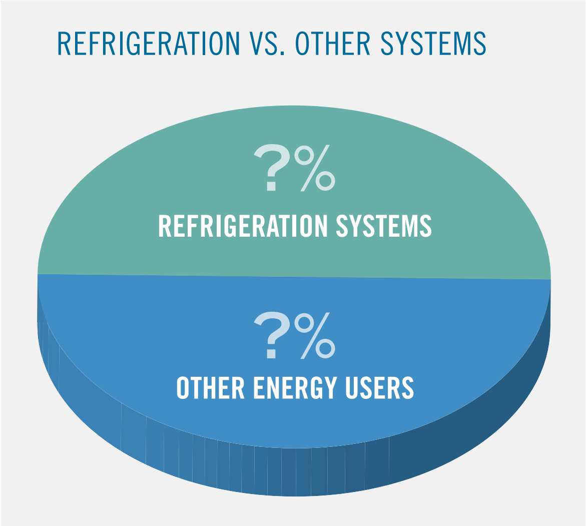

FIGURE 1. How is the energy pie sliced at your facility? How large are the systems at your facility? How much energy do they consume?

In the following discussion we'll focus on some of the more common industrial systems from boilers and compressed air systems, to pumps, fans, and lighting. We'll outline specific actions or upgrades you can make to reduce consumption and costs while increasing energy efficiency at your facility.

Energy Efficiency for Boilers

BASIC PRINCIPLES FOR BOILERS

- Gain a one percent increase in boiler efficiency when you decrease excess air by 15%.
- An excess air level of 10% is commonly attainable (1.9% excess O_2).
- On average, over 20% of steam traps fail in facilities without trap maintenance.
- A single failed steam trap can cost your facility over $1,000 per year, and sometimes as much as $10,000 per year.
- Recommended steam-trap testing intervals:
  - High pressure (150 psig and above): weekly to monthly
  - Medium pressure (30 to 150 psig): monthly to quarterly
  - Low pressure (below 30 psig): annually
- Blowdown typically accounts for four-to-eight percent of total makeup water.

OPERATIONS AND MAINTENANCE OPPORTUNITIES FOR BOILERS

Conduct annual boiler tuning and minimize excess air. Have a boiler service provider tune the air/fuel mixture across the operating range.

Ensure proper blowdown control. Blowdown is necessary to keep dissolved solid levels under control and to prevent scaling in boiler tubes. Most often, blowdown is automatically controlled by a conductivity meter; so it's important to make sure the meter is set and functioning properly.

Repair steam leaks in piping and traps. Steam traps should only pass liquid condensate, but if they fail they can pass live steam.

Maintain water treatment. Good water quality keeps boiler tube surfaces clean and heat transfer high.

Stage boilers effectively. Generally operate your most efficient boilers first, such as units with stack heat recovery or recently rebuilt tubes. Then trim with a less efficient unit, ideally one that's outfitted with a VFD controlled fan.

Use correct steam pressure. Some systems may provide an opportunity to reduce steam pressure, but there are tradeoffs to this which should be discussed with a steam expert.

CAPITAL OPPORTUNITIES FOR BOILERS

Trim O_2 controls. Trim O_2 controls measure oxygen content in the waste gas and continuously adjust the air/fuel mixture to achieve peak boiler efficiency. Trim O_2 control upgrades are frequently combined with combustion fan VFDs.

VFD pumps and fans. If the boiler's feedwater pressure is significantly higher than the steam pressure, VFD control of the pumps can reduce discharge pressure and pump power. Boilers operating at part load will benefit greatly from VFD control of the combustion air fan.

Condensate return. Condensate is warm, treated water. Returning it to the system whenever possible instead of sending it down the drain reduces fuel, makeup water, and water treatment costs.

Automated blowdown control. Blowdown and water treatment should be automated.

Stack heat recovery. Use the heat from stack gasses to preheat boiler makeup water or process water.

Blowdown heat recovery (for large systems). Similar to condensate return, heat from blowdown water can be used to pre-heat makeup water, or to provide other process heat.

Insulation. Failed pipe insulation results in continuous energy drain.

Energy Efficiency for Compressed Air

BASIC PRINCIPLES FOR COMPRESSED AIR

- Because compressed air accomplishes less than 15 hp of work per 100 hp of compressor power, it's best to avoid using compressed air if possible.
- You get one-half percent power savings per one psi pressure reduction for screw compressors.
- Leaks commonly contribute to about 30% of total load if you don't have an active leak-reduction program.
- Depending on your system and your electric rates, one cubic foot per minute (CFM) of continuous compressed air flow can cost $100 to $250 per year.
- The most cost effective and efficient "sweet spot" for compressed air is about five gallons of receiver storage per one CFM of load/unload trim compressor capacity (oil injected screws).
- Dryers: For every 20°F you decrease the dew point temperature, you remove half of the remaining water.

OPERATIONS AND MAINTENANCE OPPORTUNITIES FOR COMPRESSED AIR

Reduce compressed air pressure. Lower air pressure settings reduce compressor power and flow to unregulated leaks and users. Gradually reduce pressure settings and find your limiting user. Upgrade if economical, and keep reducing pressure settings.

Compressor sequencing and part load. Fully loaded compressors are most efficient. Make sure only one compressor at a time operates at part load. Keep your best trim compressor in trim mode. Load/unload control is efficient for oil free screws, and for oil injected screws if there is enough receiver volume present and the trim compressor can unload to low power.

Night/weekend shut down or setback. Shut down your compressed air system whenever practical by hand, or by using a timer. Some plants need a lower pressure on weekends, and pressure settings can be reduced by hand or automatically.

Leak management. If not regularly addressed, system leaks can contribute to 30% and higher of air demand. A regular program to tag and repair leaks helps to avoid wasted power, and compressor purchases. It also reduces maintenance costs, as well as piping pressure losses.

Avoid inappropriate use of compressed air. Open blowing is rarely an appropriate use of compressed air. Install mechanical wipes or guides and use engineered nozzles instead of pinched tubing where blowing is unavoidable.

Upsize critical end-use FRL. Filter, Regulator, and Lubricator units are sometimes the ultimate bottleneck preventing the reduction of plant air pressure. These are inexpensive and easy to upgrade.

Zero loss drains. This type of drain uses no compressed air, saving it for end users and reducing compressor power.

Dryer control. Most regenerative desiccant dryers should have energy-saving controls installed to reduce regeneration energy (mostly purge air use). Refrigerated dryers with dual modes (cycling and non-cycling) should be kept in the cycling mode.

CAPITAL OPPORTUNITIES FOR COMPRESSED AIR

Replace inappropriate air users. Some open blowing can be replaced with electric fan systems. Pneumatic pumps or vibrators that have a high run fraction can be upgraded to electrically driven systems.

VFD trim compressor. When considering a future purchase of oil injected screw compressors, consider a variable speed compressor. These typically have the best part-load efficiency available. Oil free compressors are offered with VFD control, but the energy savings potential is significantly lower due to the efficient load/unload operation of oil free screws.

Upgrade desiccant to refrigerated dryer. If the piping is indoors and the plant doesn't need -40°F dewpoint air, consider replacing a desiccant dryer with a refrigerated dryer which will produce about 38°F dewpoint air. Refrigerated dryers use substantially less energy. Purchase a cycling refrigerated dryer for trim use. Small, point-of-use desiccant dryers can be installed wherever piping goes outside, is used in a cooler, or is used for special applications.

Isolate end users. Install automatic valves to isolate end users when they are off. Good candidates are packaging lines and processing equipment. Connect the equipment controls to the valve controls to eliminate leaks when the equipment is down, without relying on operators to shut off the air.

THE RELATIVE COST OF LEAKS IN COMPRESSED AIR SYSTEMS AT $0.06 PER KWH

●	1/16"	= 6.5 CFM, at least $650/yr
●	1/8"	= 26 CFM, at least $2,500/yr
●	1/4"	= 104 CFM, at least $10,000/yr

Point-of-use storage. Some users such as baghouses take air in large gulps, and draw down the pressure near them substantially when they cycle, disrupting other users and forcing a higher plant air pressure. A dedicated storage tank can be set up to smooth out the flow to these users.

Reduce pressure losses. If bad actors are found restricting air flow and imposing a large pressure drop (filters, old undersized piping, long small hoses, cheap FRLs, etc.) upgrade them to remove the bottleneck. Reduce compressor system pressure settings.

Waste-heat recovery. Air compressors turn 85% or more of their input energy into waste heat. This can be used for nearby space heating in the winter, or to heat process water year round.

Use outside air for air compressor intake. Drawing cooler intake air from outside will increase compressor capacity and efficiency.

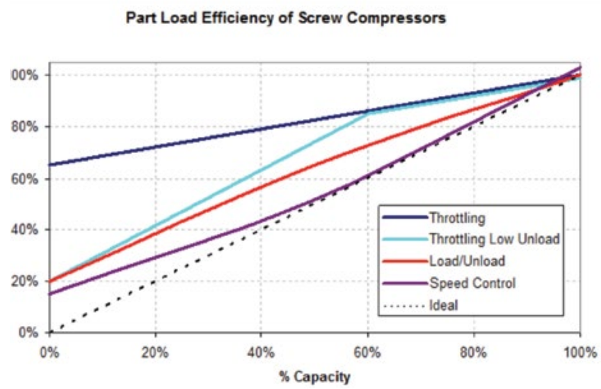

FIGURE 2. Sample part-load performance of oil injected screw air compressors

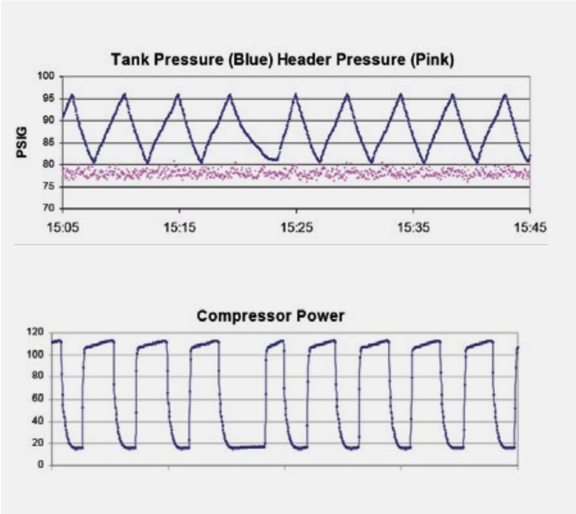

FIGURE 3. Load/unload cycle pressure and power

LOAD/UNLOAD TRIM COMPRESSOR

Stages in an Oil Lubricated Screw Compressor Load/Unload Cycle:

- The compressor operates at 100% capacity until the unload pressure is reached.
- When the unload pressure is reached, the inlet valve closes and the sump blowdown valve opens.
- The sump pressure and compressor power fall during blowdown.
- When blowdown completes, the compressor reaches a fully unloaded power, typically 20% to 50% of full load power.
- Air in the storage tanks supplies the system as the pressure falls to the load pressure. The compressor loads (closes the sump blowdown valve, opens inlet valve) and operates at 100% capacity until it has driven the pressure up to the unload pressure.

Failure of the load/unload trim compressor to fully unload may be due to insufficient storage volume in the system, leading to short cycling. Some compressor designs don't allow the power to fall very far or very fast. Sometimes unloaded power is high due to a failed part or misadjusted sump pressure.

CENTRIFUGAL PART LOAD

Centrifugal compressors use inlet guide vanes (or butterfly valves) to reduce flow. They can't reduce flow too much without surging, with a typical maximum turndown of 25% to 35%. If less air is needed, it must be produced by the compressor and then "blown off" or wasted.

Some compressors allow a more efficient "Auto-Dual" mode that is analogous to load/unload control on screw compressors, but it is seldom used.

Smart control systems can modulate all centrifugal compressors at the same time and reduce blow off. Extra compressors are turned off to keep the operating compressors in the efficient throttle range.

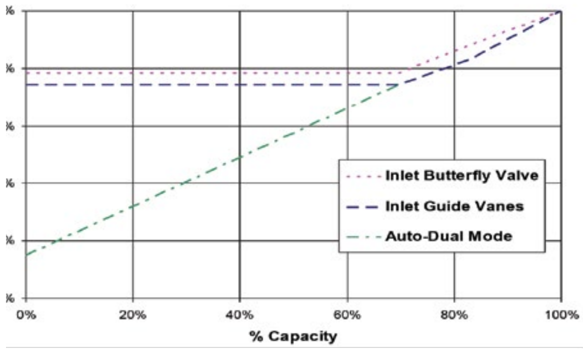

FIGURE 4. Part load control methods of centrifugal compressors

AIR DRYING

Compressed air moisture content is expressed as the dew point temperature of the air. Refrigerated dryers typically produce dewpoints near 38°F. Cycling refrigerated dryers match their energy use more closely with air flow than non-cycling refrigerated dryers which have a near constant energy use regardless of flow. Desiccant dryers can produce air at -40°F and even at -100°F dewpoint.

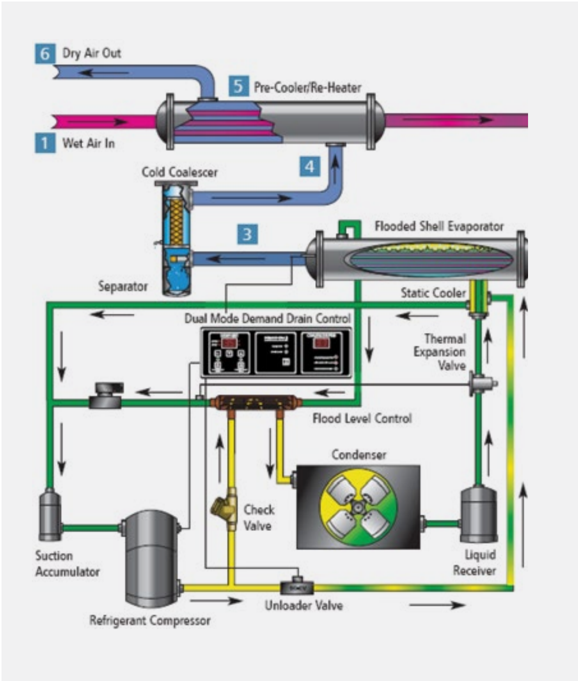

FIGURE 5. Refrigerated dryer flow path

REFRIGERATED DRYERS

Refrigerated dryers cool air through a refrigeration cycle, then remove liquid condensate and re-heat the outgoing air. There is no purge air flow, and the power of the refrigeration system is very small compared to the power required to operate a desiccant dryer.

REGENERATIVE DESICCANT DRYERS

Desiccant dryers are filled with alumina beads that water molecules stick to. Typically one vessel dries air while the other vessel is regenerated as water is removed from the beads. With good controls, the regenerated vessel will stand by and wait until the online vessel is "full" of water. Regeneration typically uses some dry compressed air, which increases the air that the compressors must produce.

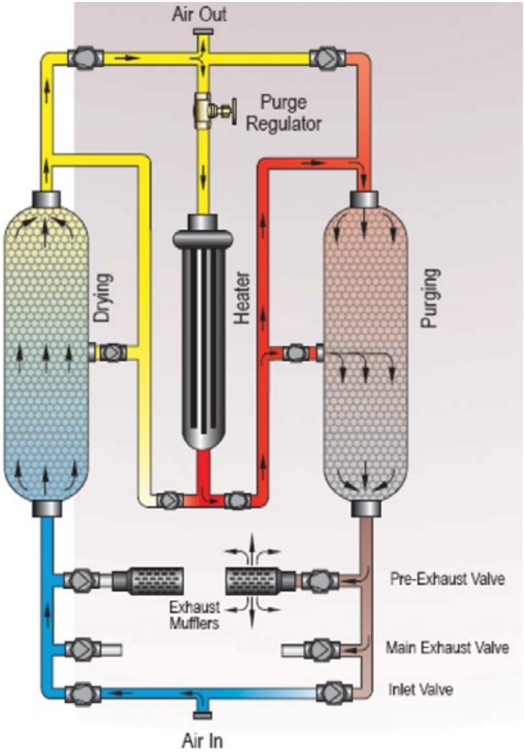

FIGURE 6. Externally heated desiccant dryer flow path

DESICCANT DRYER REGENERATION METHODS:

- **Heatless** – uses 12% to 15% of rated flow to dry (regenerate) the desiccant.
- **Heated** – uses electric heating and about 7% of rated flow in purge air.
- **Heated blower purge** – uses blowers in lieu of compressed air to supply some or all of the regeneration air.
- **Heat of compression** – passes hot discharge air, before the aftercooler, through the regenerating bed, then through the aftercooler, and then through the drying bed. This is a very efficient setup that is applied to oil-free systems only. There is little or no purge air use, and no heater power.

Energy Efficiency for Pumps

OPERATIONS AND MAINTENANCE OPPORTUNITIES FOR PUMPS

Shut down pumps when not needed.
Automated controls are best.

Conduct a facility-wide pump survey.
A review of pump systems often reveals inefficiencies.

Here are some things to look for:

- Permanent throttling
- Bypassed flow
- Automatic control valves operating at low percent when open
- Cavitation noise, growling
- Gather pump curves, check if pumps are near their best efficiency point

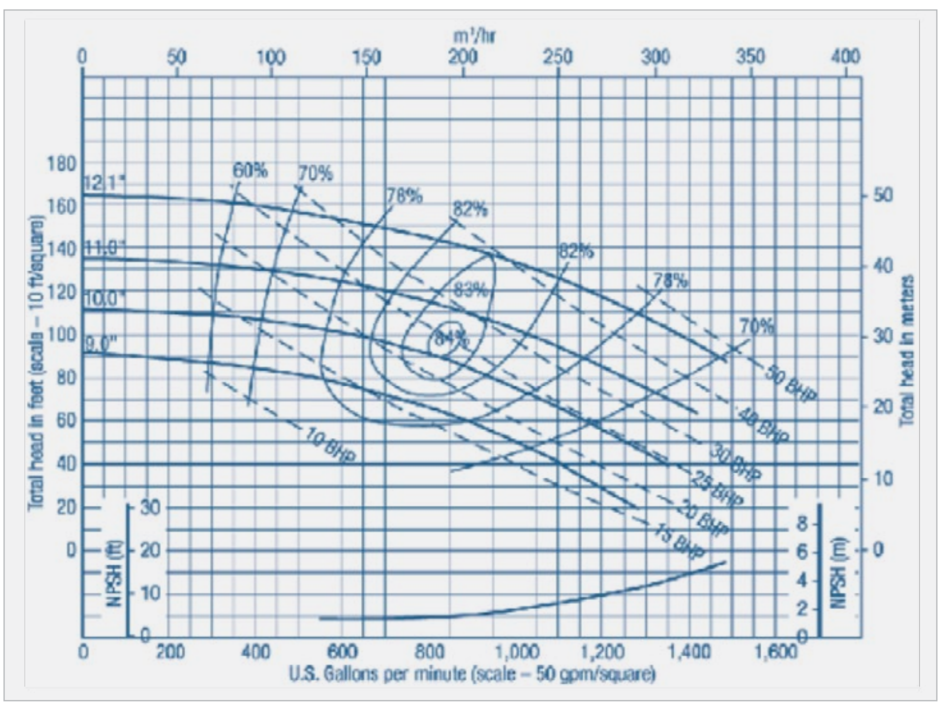

FIGURE 7. Industrial pumps, and a sample pump curve

CAPITAL OPPORTUNITIES FOR PUMPS

Impeller Trim. For permanently throttled pumps, the impeller can be trimmed to match the required flow and head.

Replace pump. Some pumps are just wrong for the job, and operate at an inefficient point on the pump curve. These should be replaced.

VFD Controls. For pumps with varying flow rates, install a VFD to control flow directly or maintain a pressure setpoint.

Remove pressure drops. Upgrade undersized piping or components.

Add flow straighteners to inlet piping.
Poor inlet piping to a pump will rob performance. Flow straighteners can get it back onto the pump curve.

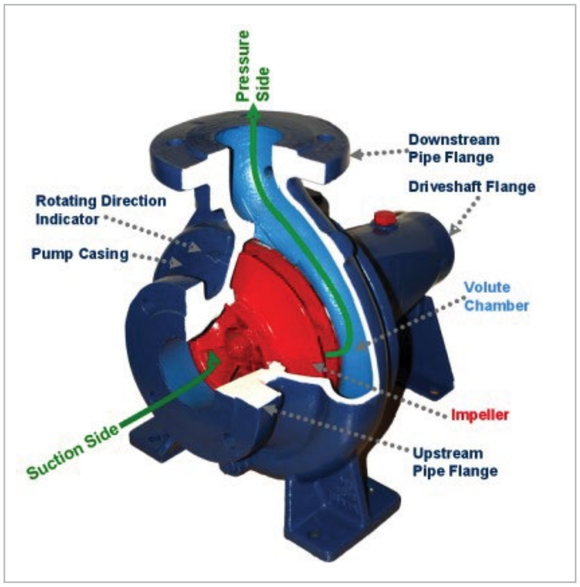

FIGURE 8. Typical end-suction centrifugal pump

PUMP POWER

Pump power is heavily impacted by flow, head, and pump efficiency. Pump power is calculated using the following equation:

$$BHP = \frac{sg \cdot Q \cdot H}{3960 \cdot \eta}$$

sg = Specific Gravity (1 for water)
Q = Capacity (GPM)
H = Total Head (ft)
BHP = Brake Horsepower (BHP)
η = Hydraulic Efficiency (%)

Energy Efficiency for Fans

OPERATIONS AND MAINTENANCE OPPORTUNITIES FOR FANS

Filter maintenance. Baghouse pulsing should employ differential pressure controls to manage the filter cleaning process. This reduces compressed air use and prolongs filter life. Filters should be replaced regularly as part of a preventative maintenance program.

Belt maintenance. Slipping belts rob system performance.

Leak reduction. Leaks force the fan to produce more flow, increasing fan power and reducing system efficiency.

Efficiency survey. Conducting a facility-wide fan survey can often identify inefficient operations. You can start by gathering fan curves and checking to see if your fans are operation near design conditions.

Then, check for:

- Manual dampers set partially closed
- Automatic dampers with significant run time are at low percent open
- High noise or vibration levels

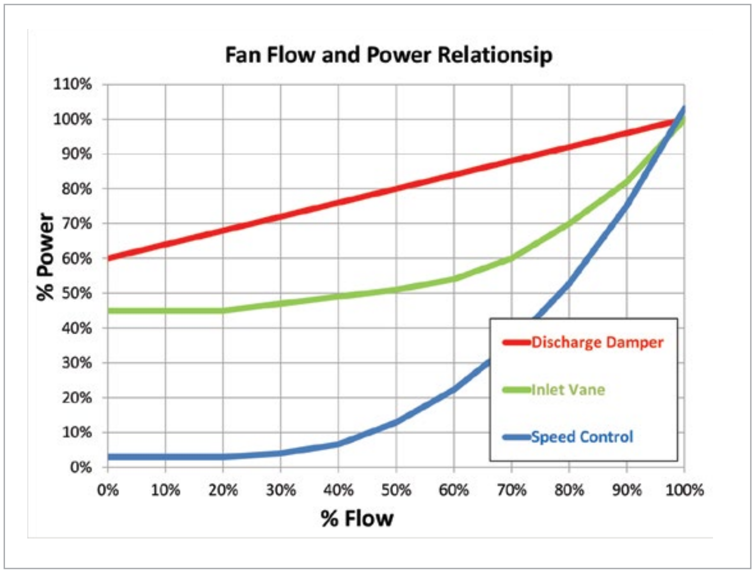

FIGURE 9. Sample part-load performance of various fan control methods

CAPITAL OPPORTUNITIES FOR FANS

Change sheave ratio. If the fan is belt driven, the sheave sizes can be changed to adjust fan speed. This is a low cost way to save energy for permanently throttled fans.

Install VFD controls. For fans with varying flow rates, install a VFD to control flow directly or maintain a pressure setpoint.

Remove pressure drops. Poor ducting increases fan power and potentially diminishes performance. Examples include badly designed turns right before or after a fan and undersized distribution ducting.

Upgrade fan type. There are a variety of centrifugal impeller designs that provide varying degrees of efficiency. Consider upgrading fans with high run hours and/or poor design.

FAN POWER

Fan power is heavily impacted by flow, pressure, and efficiency. Fan power is calculated using the following equation:

$$BHP = \frac{Q \cdot P \cdot K_p}{6362 \cdot \eta}$$

Q = Flow required (cfm)

P = Pressure required (in WC)

K_p = Compressibility Factor (1-for non compressible)

η = Fan Efficiency

CENTRIFUGAL/AXIAL FAN AFFINITY LAWS AND THE BENEFITS OF SPEED CONTROL

Fans follow the affinity laws, which in most systems, allows for significant energy savings when used with speed controls. For example, at 50% speed, a fan produces 50% flow. But due to the affinity laws, the fan only uses $50\%^3$ power (.5 x .5 x .5), or 12.5% power in theory. Actual results are closer to 15% power, but this is a dramatic power reduction. Many fan systems that operate at variable flow rates or use on/off controls can benefit greatly from speed control.

FAN TYPE	PEAK EFFICIENCY
Radial Blade	60%
Radial Tip	76%
Forward Curved	65%
Backward Inclined	75%
Backward Curved	76%
Airfoil	83%

FIGURE 10. Centrifugal fans and their potential efficiencies

Energy Efficiency for Lighting Systems

Turn interior lights off. When it comes to turning lights off, automatic controls are more reliable than humans. Basic timers can be used to shut off lighting circuits on nights and weekends. Occupancy sensors on fixtures turn lights on when someone enters an area, and off after a period of inactivity.

Turn exterior lights off. Periodically audit your outside lighting. Do you know when it comes on and when it turns off? Are there some lights that seem to have a "mind of their own" and go off or on randomly? Exterior lights should be controlled by a timer or photo cells, or both. Astronomical clocks will adjust for sunrise and sunset changes over the year, and are better than simple timers. Photo cells tend to get dirty, which can force lights on earlier, and keep them on longer. At industrial facilities, exterior lighting should come on late and shut off early.

Delamping. Some areas have more light than necessary. "Delamping" is the process of removing unnecessary fixtures. Sometimes these changes require moving the remaining fixtures so that the light is in the right place. Delamping should not be used everywhere, but in some cases it can provide quick, inexpensive savings.

Replace old lights with new. Older fixtures include High Intensity Discharge (HID) such as Metal Halide and High Pressure Sodium, T-12 fluorescent, and some early T-8 fluorescent fixtures. New fixtures are typically T-8 and T-5 fluorescent, with some LED fixtures entering the marketplace.

Adjust occupancy sensors. Some facility occupancy sensors don't work as effectively as they could, particularly if they are overridden or if the delays are set too long. In some production areas, occupancy sensors are not appropriate. But they are appropriate in warehouse, dock, storage, office, conference rooms, and similar spaces. Typical fluorescent fixture occupancy sensors should shut lights off after 10 –15 minutes without activity. Occupancy sensors can be used successfully in maintenance shops and compressor rooms when they have a wide field of view, and high sensitivity settings with longer delays of about 30 minutes.

Notes

INDUSTRIAL STRENGTH ENERGY EFFICIENCY

Cascade Energy provides corporations and utilities with the industrial strength expertise needed to realize their energy efficiency potential. With a full complement of services and engineering know-how based on 20 years of hands-on experience, Cascade has a proven track record of reducing industrial energy consumption and costs.

20 YEARS

Deep, hands-on technical expertise over a 20-year span.

2,000 PROJECTS

Analyzed and implemented more than 2,000 energy efficiency projects.

350 SITES

Monitor energy performance at over 350 industrial sites.

250 FACILITIES

On-site tune-up and retro-commissioning at over 250 industrial facilities.

INDUSTRY EXPERTISE

- Refrigerated storage
- Food processing and distribution
- Pulp and paper
- Oil and gas
- Steel and heavy industry
- High technology
- Water and wastewater
- Chemicals
- Manufacturing
- Agriculture

SYSTEM EXPERTISE

- Refrigeration
- Compressed air
- Fans, pumps, blowers
- Manufacturing processes
- Controls and VFDs
- Chillers
- Cooling towers
- HVAC systems
- Thermal systems
- Lighting

TALK TO CASCADE ENERGY TODAY! 866.321.4573

cascadeenergy.com energysensei.com info@cascadeenergy.com

CascadeEnergy®

123 NE 3rd Ave, Suite 400
Portland, OR 97232
503.287.8488 *main*
503.287.8788 *fax*

CE-EBOOK-007-1-print-REV 28-OCT-2013