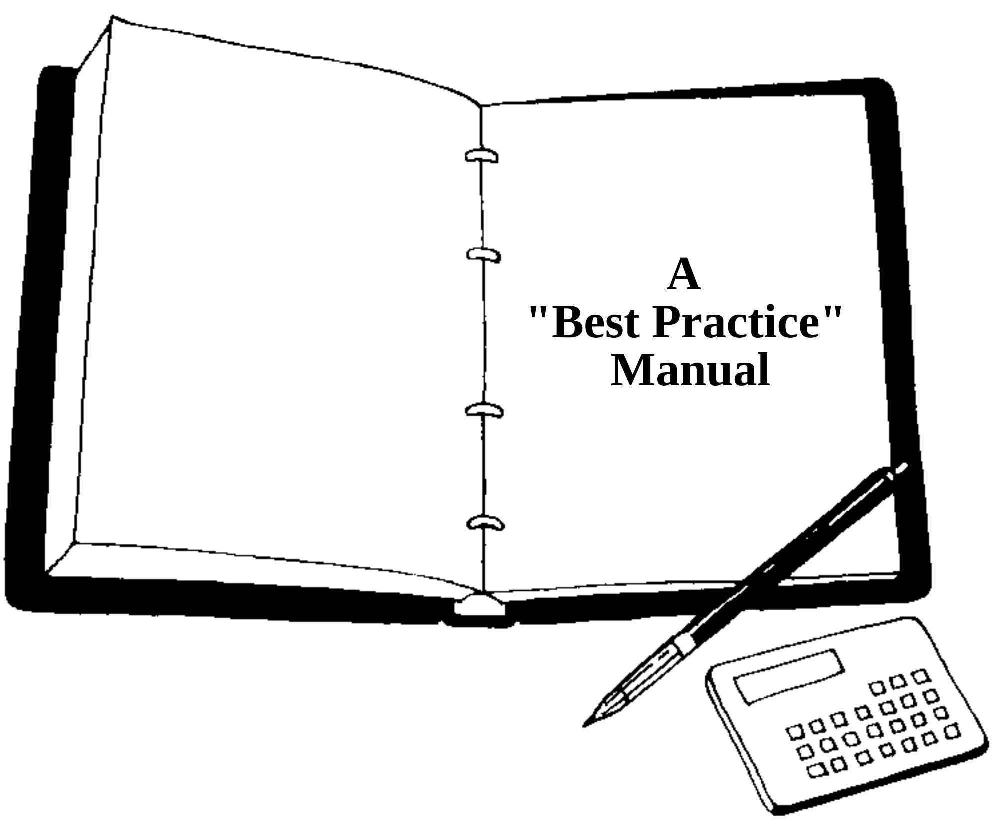
THE STATE UNIVERSITY OF NEW JERSEY
RUTGERS

Office of Industrial Productivity and Energy Assessment

A SELF-ASSESSMENT WORKBOOK*

For Small Manufacturers



*Support for this manual has come from the US Department of Energy, Office of Industrial Technology

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Acknowledgments

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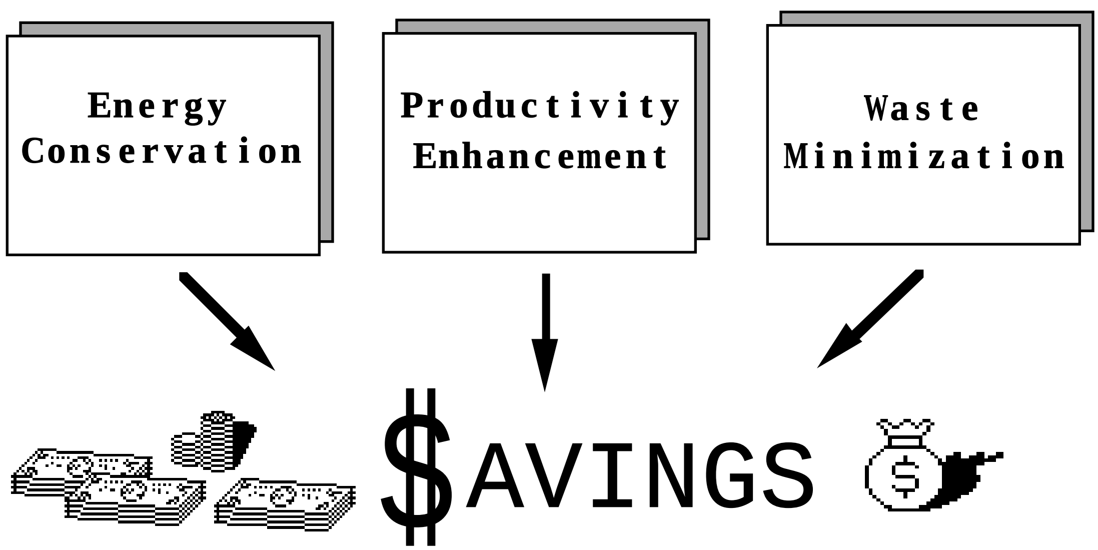
Introduction

The intention of this workbook is to provide the small manufacturer with a self assessment method of improving operations and reducing costs. In addition to presenting a general procedure for performing assessments of manufacturing plants, the reader is supplied with the information necessary to implement several specific cost savings projects which are common to most operations. These specific projects were identified from those recommended frequently through the Department of Energy's Energy Analysis and Diagnostic Center and the Industrial Assessment Center programs. The specific measures are recommendations in energy conservation, waste minimization, and manufacturing productivity designed to reduce production costs for small and medium-sized businesses.

The EADC/IAC Program



Recommendations by EADCs and IACs throughout the past eighteen years have allowed those participating manufacturers to cut down on waste costs and save energy. Both of these actions have permitted the manufacturers to be more competitive and profitable. Many of the ECOs came, in part, from a list presented in the Department of Commerce Guidebook

(EPIC)[1]. The recommendations for waste reduction came, in part, from a list assembled by Professor Richard J. Jendrucko of the University of Tennessee.

This workbook will permit the owner of a small manufacturing operation to perform a self assessment to identify and calculate energy savings, waste reduction opportunities, and production enhancements frequently available only to larger companies.

This self assessment workbook is organized using an expert system approach. The idea is to have the individual performing the task of analysis to go through the workbook once.

The workbook is arranged in a manner to lead the individual to those recommendations which specifically relate to that individual's manufacturing plant and process. For this reason the workbook cannot be totally comprehensive but is limited to those recommendations which will have the widest scope of applicability and be the most likely to be implemented by the manufacturers.

1 Energy Conservation Program Guide for Industry and Commerce; National Bureau of Standards Handbook 115; U.S. Government Printing Office, Washington: 1974

Workbook Organization

The self analysis workbook is intended for use by a small manufacturing entity. It is expected therefore that the chief operating officer and plant manager will frequently be the same individual or two people who are working in close contact. Communication and commitment to the aims of the program by different individuals thus should not be a problem. The workbook will be most effective if a single individual such as the plant manager carries out the self analysis. However, no energy conservation, production strategy, or waste minimization proposal will have any success unless all the people who carry it out understand its value to the manufacturing operation and believe their participation is appreciated and rewarded by some form of recognition on the part of plant management.

The workbook is broken up into a series of steps which can be followed sequentially or in parallel depending on the assessors time and manpower constraints. The first step is to quantify energy and utility unit costs. These are necessary inputs to the calculation of savings involved with the specific cost saving measures. The second step is to obtain a list of the major plant energy consuming equipment. This list can be obtained through maintenance records, purchase orders, or gathered during the tour of the manufacturing process and its subsystems (step 3a and step 3b). Such a list will be found extremely helpful when actual calculation of

Three Step Program

1) **Quantify unit costs for energy and utilities**

2) **Obtain a list of major plant energy consuming equipment**

3) **Identify and quantify savings opportunities in the Manufacturing Process**

dollar savings is begun. The third step (step 3) is to identify cost savings measures in the manufacturing process and gather the necessary information to perform subsequent analysis, i.e. to be able to quantify energy conservation, production enhancement, and waste minimization savings and implementation costs. In order to perform this step efficiently it is suggested that the assessor take the following approach. Follow the manufacturing process from the entrance of raw materials to the departure of the finished product observing the various subsystems (thermal, motor systems, boilers, etc.) as they are encountered. By breaking up the approach in this manner the assessor need only use those portions of the workbook which specifically apply to the particular manufacturing process under study. The attempt is made in the workbook to have the assessor gather the required data for those cost savings measures (for which examples are given in the Appendix A) during the tour of the plant. Some simple measuring devices should be bought or rented beforehand and carried with the assessor. The most useful of these is a temperature measuring device. Preferably, the device would be capable of measuring surface temperatures by contact, fluid temperatures by immersion, and air temperatures while held aloft. Even a simple mercury in glass thermometer would work well for the latter two measurements but would probable be inaccurate for surface temperatures. A tape measure for measuring sizes of openings and surface areas is useful. If the plant has combustion systems, then a device capable of measuring exhaust gas temperature and oxygen content is advisable.

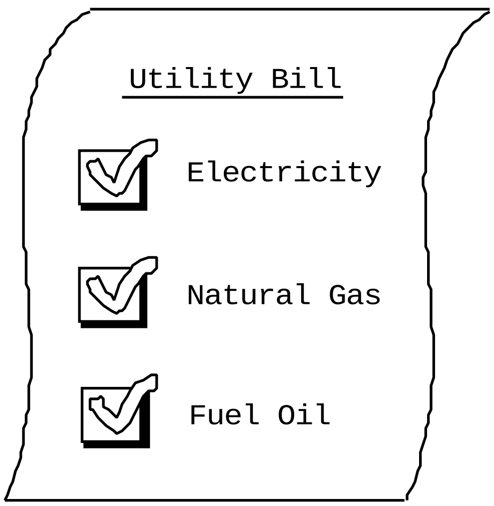
Equipment Required

- Thermocouple or thermometer for:
  (a) Temperature of Liquids
  (b) Air Temperature
  (c) Surface Temperatures of machines, furnaces, steam lines, etc.
- Combustion Analyzer
  (Simple Variety) capable of measuring O_2 (oxygen) levels in flue gases and their temperature.
- Light meter
  To measure lighting levels in different areas of plant.
- Vibration meter
- Tape Measure
- Tachometer
- Gloves
- Flashlights
- Wire brushes
- Disposable suits
- Ropes for hauling

The fourth and final step is the calculation of cost savings and implementation costs for each of the most common cost saving measures identified by the assessor. Sample illustrations are provided to lead the assessor through the calculation procedure. Once all of the paybacks and dollar savings are in known the manufacturer will be in a position to make intelligent decisions on the implementation of these cost saving measures.

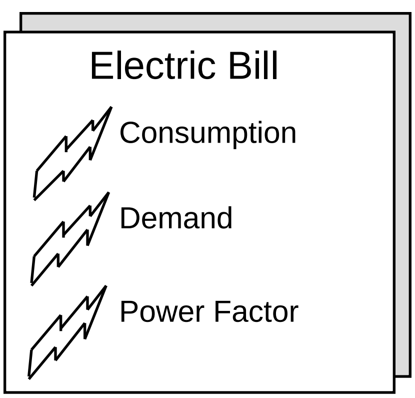
Step 1. Quantify Cost of Energy and Utilities

The energy bills for electricity, natural gas, and fuel oil should be obtained for a period of at least one year. Samples of data taken from a typical plant which used all three common sources of energy follow on the next few pages. Obtaining unit costs of energy is a necessary step in determining the savings involved when switching from one energy source to another or decreasing the use of a particular energy. In addition the cost of other utilities such as water and sewer should be quantified if they form a significant part of the manufacturing costs.



Electricity must be treated in a different manner from fuel oil and natural gas. The cost of electricity is charged to the manufacturer using two different cost components and sometimes a third. The first two are consumption and demand and the third is power factor (so called reactive charge).

The cost of electrical consumption is similar to that for natural gas and fuel oil, i.e. all three are charges for units consumed. The usual unit of electrical consumption is the kilowatt-hour or kWH. This is measured by the watt-hour meter and appears on the bill as kWH consumed each month and has an associated cost. Even this charge may be broken down into a charge for consumption on peak (usually 8AM-8PM) and off peak (the rest of the day).



The second cost component, demand, is based on the highest rate of consumption during the billing period. It is usually obtained by the electric utility by measurement of energy consumed in sequential fifteen minute periods throughout the month. The fifteen minute period with the maximum consumption is then converted to an average rate of consumption in units of kilowatts or kW. This maximum kW value is then multiplied by a demand cost factor which can vary considerably depending on whether one is talking about demand during the on-peak (daytime hours) or off-peak (night time hours). This demand charge is then added on to your consumption costs to yield the monthly electric cost. Demand costs can often make up 50% or more of the total electric bill. Since electricity frequently is the largest monthly energy cost it is important to understand how it is billed and what effect certain strategies will provide in terms of cost savings. Stated another way, it is often possible to decrease the monthly electric bill by fifteen to twenty percent by decreasing the demand cost while continuing to consume the same amount of electricity.

The third component of the bill, power factor (reactive charge), is significant only if five percent or more of the bill is a penalty charge for having a low power factor. It most often is significant when the great majority of the electric consumption is taking place in electric motors. The power factor can be corrected by installing banks of capacitors within the plant or providing a matched capacitor to each motor to offset their reactive effect.

The discussion above indicates how important it is to be familiar with the rate structure which the electric utility is imposing on the manufacturer. The recent changes in electric utility regulation are such that the utility should be more than glad to assist any manufacturer in getting the best rate structure for the plant because competition between electric utilities is expected to increase significantly in the next few years. The informed consumer is best prepared to take actions which can decrease costs.

In addition, where natural gas costs are concerned, it is also important to discuss the rate structure with the utility supplying the manufacturing plant. Natural gas savings may be possible by change to a bulk supply rate or signing up for an interruptible rate schedule. The latter may only be possible if an alternate fuel source (fuel oil or propane) is already available on site available as a suitable replacement.

Some examples of data compiled from electricity, natural gas, and fuel oil bills follows on the next few pages.

EXAMPLE OF PLANT ENERGY CONSUMPTION

ELECTRICITY

DATE	CONSUMPTION - kWH	COST ($)	PEAK DEMAND - kW	COST($)
January 1991	198,800	$12,975	948	$8,759
February 1991	331,200	$20,374	912	$8,427
March 1991	245,000	$13,951	710	$6,560
April 1991	305,600	$18,902	948	$8,759
May 1991	368,000	$22,621	1,222	$11,290
June 1991	318,400	$19,651	888	$8,205
July 1991	289,200	$18,855	890	$8,223
August 1991	335,600	$21,720	964	$8,907
September 1991	367,600	$23,638	952	$8,796
October 1991	387,200	$25,384	1,144	$10,570
November 1991	350,000	$22,583	824	$7,613
December 1991	374,400	$24,701	1,105	$10,210
TOTALS	3,871,000	$245,355	11,507	$106,319

Average unit energy cost = $0.0634 per kWH

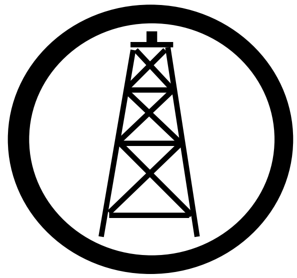
Average demand cost each month = $9.24 per kW per month of peak demand

NATURAL GAS

DATE	NATURAL GAS (THERM)	COST ($)
January 1991	8,877	$5,722
February 1991	7,618	$4,852
March 1991	4,232	$2,689
April 1991	3,761	$2,457
May 1991	3,410	$2,220
June 1991	3,212	$2,088
July 1991	3,050	$1,983
August 1991	3,123	$2,036
September 1991	3,157	$2,055
October 1991	3,348	$2,177
November 1991	4,722	$3,069
December 1991	8,277	$5,245
TOTALS	56,787	$36,593

Average unit energy cost = $0.644 /Therm

#2 Fuel Oil



DATE	CONSUMPTION (Gallons)	COST ($)
December 1990	499	$450
January 1991	3,014	$3,536
February 1991	1,120	$1,264
March 1991	2,683	$2,512
April 1991	1,070	$1,116
May 1991	469	$418
June 1991	0	$0
July 1991	0	$0
August 1991	141	$118
September 1991	0	$0
October 1991	522	$444
November 1991	821	$742
TOTALS	10,339	$10,601

Average unit energy cost = $1.03 /Gallon

Step 2. Obtain a list of the major plant energy consuming equipment

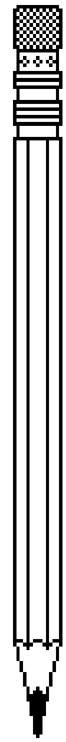
This list can be compiled during the manufacturing process survey or from the maintenance files. Either way it should result in some sort of list similar to the example which follows on the next page.

Major Plant Energy Consuming Equipment

<u>Electricity</u>

☒. **Air Compressors**

1-60 HP Screw Type Air Compressor



☒. **Heating/Cooling/Ventilating Equipment**

1-Roof mounted Air Conditioners
1-Roof mounted Heat Pump

☒ **Production Equipment**

Roll Forming Machines:
5-5 HP lines(v-belt)
1-5 HP line(direct drive)
3-7.5 HP lines(v-belt)
5-10 HP lines(direct drives)
5-10 HP lines(v-belt)
1-15 HP line(v-belt)
2-20 HP lines(v-belt)
1-63 HP Slitter(40 HP v-belt)
2-10 HP Winding Machines(v-belt)

<u>Natural Gas</u>

☒ **Heating/Cooling/Ventilating Equipment**
]

5-Gas Fired Infrared Heaters
15-Gas Fired IR Heaters
1-Hot Water Heater
1-300 Boiler HP (also used in production)

☒ **Production Equipment**

1-300 Boiler HP boiler

<u>#2 Fuel Oil</u>

☒ **Heating/Cooling/Ventilating Equipment**

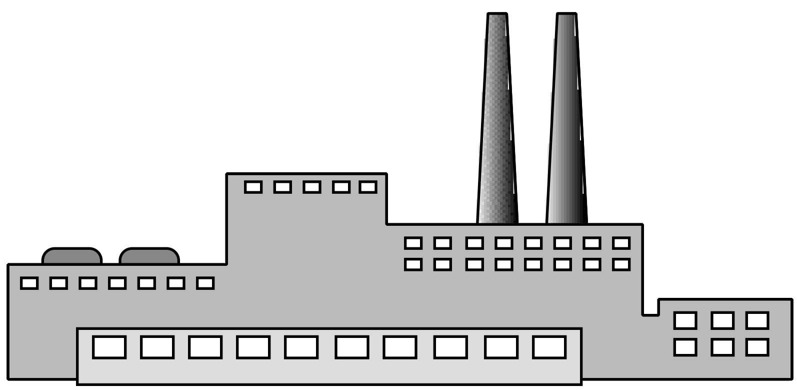
1-250 Boiler HP Fuel Oil fired boiler

Step 3a. Self Analysis of the Manufacturing Process

The identification of the energy, waste minimization, and productivity enhancements which are available within a manufacturing plant and its operation will usually require the assessor to follow the manufacturing process from that point at which the raw material enters the plant to the point of departure for the finished product with side trips to the roof and any internal subsystems which supply energy and supplies to the process. Not every manufacturing process has the same steps in production. This means the process must be analyzed anew by every assessor. There are, however, general guidelines which when followed will yield a significant return.

The self analysis most logically starts at this point. Questions which the assessor might answer are posed and notes should be taken. The boxes provided allow the assessor to check off those areas completed.

The Manufacturing Process

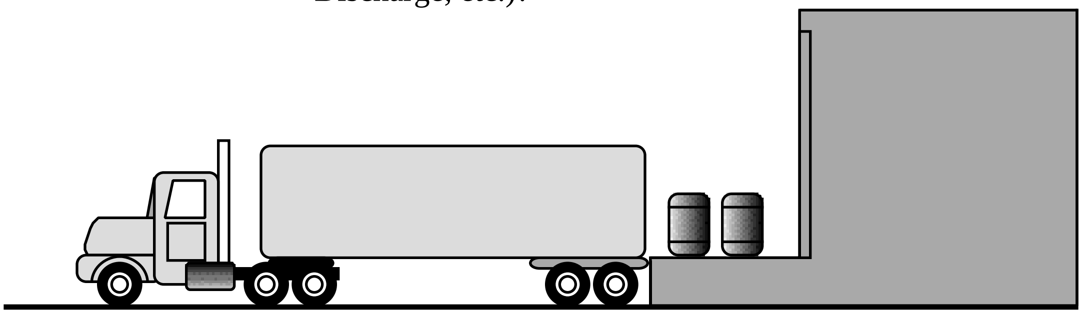


A. Raw Materials

1. How do they enter the plant?

- ❐ Are air seals used around truck loading doors? Are loading doors closed when not in use?
- ❐ Are radiant heaters installed in dock area? Are the radiant heaters exposed to wind/convection currents which will significantly reduce their effectiveness?
- ❐ Are people being used efficiently at the dock area?

- ❒ What light levels are maintained in the area? What type of lighting is employed(energy efficient fluorescent, High Intensity Discharge, etc.)?



2. How are the materials distributed to the manufacturing operation?

- ❒ Are fork lift trucks battery operated or propane driven? If battery operated are they being recharged during off peak hours (at night)?
- ❒ Are the raw materials taking up excessive space, can they be received on an as-needed basis?
- ❒ Can water-based adhesives be substituted?
- ❒ Can heavy metal reagents be replaced with non-hazardous reagents?
- ❒ Can raw materials be altered to reduce air emissions?

B. The Manufacturing Process.

1. What preprocessing is done to the raw material?

- ❒ Is there a mixer?
- ❒ Is there a cutting operation?
- ❒ Does the raw material flow through this process without problems?

2. What are the energy interactions with the raw material. (grinding, cutting, heating, cooling, pumping, etc.)?

- ❒ Is there a heating operation?
- ❒ Is an oven/furnace involved? Does it have a stack damper? What is the fuel source? If the oven is electric can a fossil fuel

device be used instead? Where does the air for combustion come from (inside or outside the building)? What is the surface temperature and surface area of the apparatus? Is the oven furnace flue gas used or just exhausted? Are heated process fluids (or steam) used? Are lines properly insulated? Are steam traps installed and working properly? Is steam being supplied at the lowest acceptable pressure? How are other process fluids (besides steam) heated?

- ❐ Are there uncovered tanks of process fluids which are evaporating?

- ❐ Is compressed air used? What is the minimum pressure for operation of each of the machines using compressed air? What is the line pressure in the machinery area? Is the compressed air used for cooling product, cooling equipment, or agitating liquids?

- ❐ Are compressed air leaks present? Is there a maintenance program in place to eliminate compressed air leaks?

- ❐ What is the light level in the manufacturing area? Adequate? Too much? What type of lighting is employed? Fluorescent, High Intensity Discharge, incandescent, Halogen, etc.?

- ❐ Are skylights used? Are they dirty?

- ❐ Are windows broken, cracks around doors, sashes, etc.?

- ❐ Are machines left running when not in operation?

- ❐ Do the motor systems employ direct drives, cog belts, v-belts, etc.
- ❐ Are energy efficient motors used? Are motors sized with load? Do the motor systems use variable speed drive control?

- ❐ Is there hydraulic equipment (pumps) involved?

- ❐ What sort of ventilation is used in the area? Is the plant under negative or positive pressure from either too much exhaust air being drawn out of or too much supply air being blown into the plant? Are exhaust/supply fans shut down during non-working hours?

- ❐ What is the temperature of the work space? Is it air-conditioned? What are the ceiling heights in the work area? Are destratification fans used? Are set back timers used to control space temperature during non-working hours?

3. **What are the waste streams involved with the manufacturing process (water, packaging materials, lubricants, heat, vapors, solvents, inks, etc.)?**

- ❐ Are containers of solvent, resin, or ink uncovered?
- ❐ Is rinse water reused?
- ❐ What is the source of water (well, city water, recycled via cooling tower)?
- ❐ Is counter current rinsing used to reduce waste water? Are there leaks present?
- ❐ Look in the dumpsters. Are there wastes that can be reduced or eliminated?
- ❐ Can color changes be minimized? Are light color jobs scheduled before dark?
- ❐ Are spent solvents segregated (by color) for reuse in washing? Are spent oils and acid baths reprocessed on site for reuse? Are waste metals recovered and recycled?
- ❐ Are rags recycled and use minimized through worker training?

C. Finished Product.

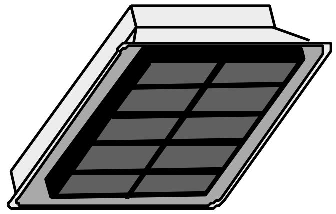
1. **What energy interactions are involved with packaging, warehousing, shipping, of the final product.**

- ❐ What light levels are maintained in the warehouse? What type of lighting is employed? Are motion sensors or timers used to turn off lights when no one is present?
- ❐ What insulation is present on the walls of the warehouse?
- ❐ What is the temperature at which the warehouse must be maintained? Is maintained? Can a dry sprinkler system be employed to eliminate need of warehouse heating?

2. **What waste streams are associated with the departure of the finished product?**

- ❐ Is there a lot of waste to the packaging process?

3. **What operational changes might be employed to reduce costs (decrease warehousing, loading dock operation, etc.)?**



Radiant Heater

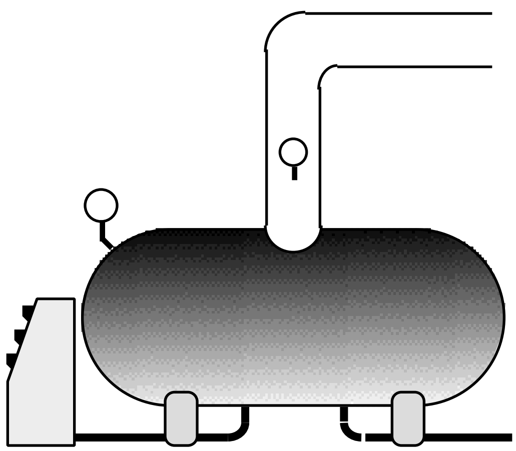
- ❐ Same questions about loading docks, radiant heaters, and efficient use of people which applied to raw materials entering the plant.

Step 3b. Self Analysis of the Manufacturing Subsystems

Having finished the walk through the manufacturing plant, the assessor's attention must now be directed to the many associated subsystems in the plant.

Manufacturing Subsystems

A. Boilers



1. **Operation.**

- ❐ Does boiler operate at high fire during most operational time?
- ❐ Is a program to analyze flue gas for proper air/fuel ratio active? What is the measured 0_2 content and temperature of the flue gas of the boiler?

- ❒ Is a feedwater treatment program active?
- ❒ Are the steam lines insulated?
- ❒ Is condensate returned from process areas? Is condensate tank insulated?
- ❒ Are there steam leaks?
- ❒ Is flue gas heat energy used for any purpose?

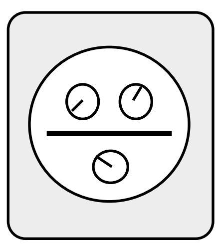
B. Chillers

1. Operation.

- ❒ Can cooling tower water be used instead of refrigeration during any part of the year?
- ❒ Is chilled water produced at the highest acceptable temperature?
- ❒ Is frost forming on the evaporators?
- ❒ Can outside air be used in a drying process and instead of conditioned air?

C. Electric Power & Billing

1. Meters



- ❒ What kind of meter, i.e. what does it record?
- ❒ Is more than one meter employed in the plant (see electric bills)?
- ❒ Have discussions with electric utility billing agents taken place in last two years to determine appropriateness of rate scale used? (Utilities are in a new competitive environment and will be much more receptive to such discussion today than they were several years ago.)

2. Demand Management

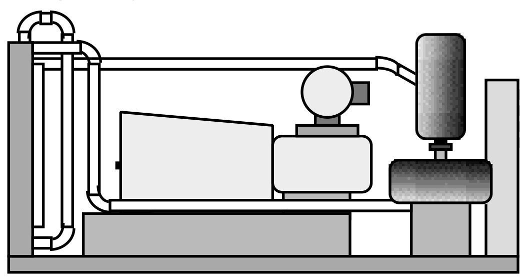
❐ Does the rate schedule of the plant show a demand charge? If there is a demand charge on the bill, is there information on what time of day or part of the month demand maximum occurs? If not, get a printout of the hourly variation of the demand for an average month where production is fairly uniform. With this information: (a) Is the demand maximum significantly greater at one time of day each day? (b) Is the maximum demand significantly greater than the average demand during each day? (c) Is the monthly maximum demand significantly greater on one day than any other?

3. Power Factor

❐ Does the bill show a power factor penalty?

❐ What is the average power factor value? If bill doesn't report the power factor it can be obtained if the bill reports either KVAH (kilovolt-ampere-hours) or KVARH (kilovolt-ampere-reactive-hours). (The computation appears in the discussion of the power factor cost saving analysis.)

D. Air Compressors



1. Operation

❐ Is the air-compressor system operated at the lowest acceptable line pressure for machinery using compressed air?

❐ Is the intake of the air located either outdoors or at the coolest possible location? Is the cooling air for the compressor discharged outdoors in the summer and into areas requiring heat in the winter?

❐ With more than one compressor operating, are the compressors sequenced so that rather than operating several at part load, each operating compressor is operating at or near its maximum?

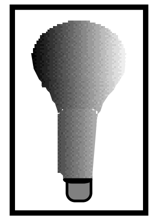
❐ If screw compressors and reciprocating compressors are used in parallel, is the screw compressor operated as close to its rated capacity as possible? Is the screw compressor shut down when only small amounts of compressed air are in demand (weekends, nights, etc.)?

2. Maintenance

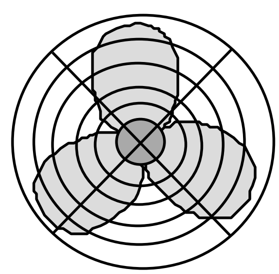
- ❐ Is the compressor lubricated with a synthetic lubricant?
- ❐ Is there an aggressive program to detect and eliminate leaks ?
- ❐ Are filters (air and oil) changed on a regular schedule?

E. Building and Grounds

1. Lighting



- ❐ Are lighting levels at or below those recommended for each task? Can lighting hours be reduced?
- ❐ Are employees trained/encouraged to turn off unnecessary lights?
- ❐ Can delamping be employed?
- ❐ Can motion sensor lighting controls be employed in warehouses, storage areas, etc., where personnel entry is intermittent?
- ❐ Are all fluorescent bulbs installed of an energy efficient design? Is a program to replace old ballasts with an energy efficient type in place? (This is especially important if power factor costs are high.)
- ❐ Are ceilings at least 15-20 feet high? If so, Metal Halide or Sodium lamps may be substituted for fluorescent or mercury vapor lamps.
- ❐ Is very fine color rendition required? If so energy efficient fluorescent lights should be used.
- ❐ Reduce exterior lighting to minimum safe level. Use timers or photocells to turn off exterior lights when daylight permits.



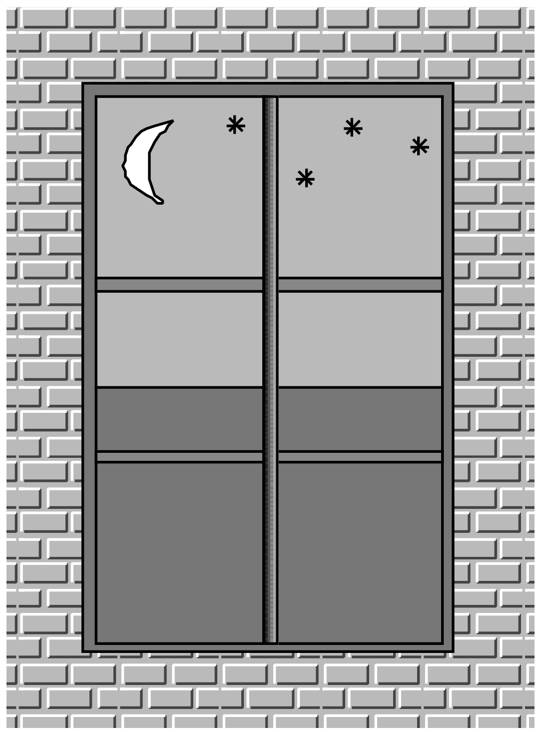
2. Ventilation

- ❐ Use minimum acceptable ventilation. Minimize building exhausts.

3. Building Envelope

☐ Go up onto roof. Is the roof flat? If so, is the exterior painted white over spaces which must be air-conditioned? Are air-conditioners, unit heaters, etc. located on the roof? Inspect them for proper maintenance. Are the fan belts notched or standard v-belts? Are excessive steam plumes coming from outlets on the roof? Are stacks emitting smoke? What are the temperatures of the flue gases passing through outlets on the roof? Are roof exhaust fans using notched belts? Are filters on roof air intakes clean?

☐ Is proper thickness of insulation used on walls, ceilings, roofs, and doors? Are loose-fitting doors and windows weather stripped? Repair broken windows, sashes, doors, etc.



Step 4. Calculate Industrial Opportunities For Savings

Using the information from Step 3a and 3b calculate the savings involved in the energy conservation, waste minimization, and productivity enhancements identified. The many sample calculation examples which follow allow the manufacturer to quantify savings and implementation costs so intelligent decisions can be made on measures, and operational upgrades can be found in Appendix A.

Appendix A contains many specific examples of Energy Conservation and Waste Minimization Recommendations which are chosen for their perceived generality. It is believed they will find the most widespread use throughout plant manufacturing practice. Each has sample calculation of simple payback which may be applied to recommendations unique to any other manufacturing plant. It is hoped that they will permit calculation by any plant manager or assistant plant manager.

Appendix A

Example Calculations of Cost Saving Measures

In the recommendations which follow the cost of electricity, natural gas, and fuel oil obtained in the sample plant energy data given earlier was used as well as the example Major Plant Energy Consuming Equipment.

Recommendation No. 1

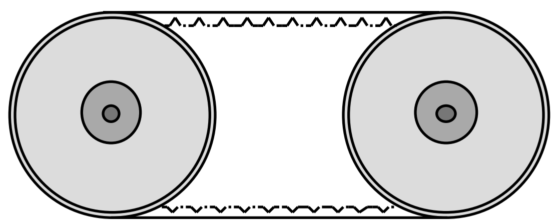
REPLACE DRIVE BELTS ON LARGE MOTORS WITH HIGH TORQUE DRIVE BELTS OR ENERGY EFFICIENT COG BELTS

Current Practice and Observations

Currently, many of the forming lines use standard V-belts to transmit power resulting in an unnecessary loss of energy. Sixteen of the twenty-two forming lines use these belts employing a total of 152.5 horsepower. The slitter and its take-up motors are driven through V-belts for an additional 80 HP.

Recommended Action

Replace standard wrapped V-belts with high torque drive belts (HTD) or energy efficient cog belts.



In addition to internal inefficiencies in electric motors, which cause energy loss, the power available at the drive shaft of the motor cannot be transmitted to a machine through a belt without some additional energy losses. These losses come in the form of slippage, energy used to flex the belt as it goes around pulleys, and stretching and compression of the belt. A recent study[2] has shown that standard V-belts have a maximum efficiency of about 94%. This means 94% of the energy transferred to the drive shaft of the electric motor is transferred to the machinery performing the useful industrial task. There are two readily available means to reduce the losses. One is to replace the belts with energy efficient cog belts. These belts slip less and can bend more easily than standard V-belts. The other method is to use belts with teeth and also replace the pulleys with ones that have sprocketed grooves (essentially installing a "timing chain") which is referred to in the industry as a high torque drive belt (HTD). In both cases, the belt can bend with less loss of energy and need not be stretched as tightly as the standard V-belt which in turn prolongs belt life. The cog belts also reduce slippage and the HTD's eliminate it.

Anticipated Savings

2 "High Torque Drive Belts Reduce Energy Losses," Michael Brown, Industrial Energy Conserver, Vol. 7, No. 3, March 1986.

Many studies in the literature have shown that a typical well maintained industrial V-belt is about 92% efficient. Field tests of cog belts for both large and small drives show gains in efficiency from 2.0% to 8.4%. For our calculations, we will use the conservative value of 2.0%. If HTD's are installed, the gain in efficiency should be approximately 6%. We can calculate the yearly electric consumption savings using the following formulae:

$$PS = \frac{HP}{\eta} \times LF \times S$$

$$ES = PS \times H$$

where:

PS	=	the anticipated reduction in electric power in kW.
ES	=	the anticipated energy savings (kWH/yr)
HP	=	the total horsepower for the large motors using standard V-belts in the plant. This is estimated to be 232.5 HP based on the equipment list contained in the plant background section.
η	=	average efficiencies of the motors (0.85)
LF	=	average load factor (75%).
H	=	annual operating time (8 hrs/day x 5 days/wk x 52 wks/yr)
	=	2,080 hrs/yr
S	=	estimated energy savings (taken here as either 2% for cog belts or 6% for HTD's)

Therefore for cog belts the reduction in power consumption rate is:

PS = (232.5 HP/0.85) x (0.7459 kW/HP) x 0.75 x 0.02 = 3.06 kW
ES = 3.06 kW x 2,080 hrs/yr = 6,365 kWH/yr

and the cost savings would be (see Electricity Consumption Table, page 8):

Consumption Savings = ($0.0634/kWH) x (6,365 kWH/yr) = $404/yr

$$\text{Demand Savings} = \frac{\$9.24}{\text{kW-month}} \times 3.06\text{ kW} \times 12\text{ months/yr} = \$339/\text{yr}$$

Total Annual Savings = $743

while if HTDs are installed:

PS = (232.5 HP/0.85) x (0.7459 kW/HP) x 0.75 x 0.06 = 9.18 kW
ES = 9.18 kW x 2,080 hrs/yr = 19,094 kWH/yr

and the cost savings would be:

Consumption Savings = ($0.0634/kWH) x (19,094 kWH/yr) = $1,211/yr

$$\text{Demand Savings} = \frac{\$9.24}{\text{kW-month}} \times 9.18\text{ kW} \times 12\text{ months/yr} = \$1{,}018/\text{yr}$$

Total Annual Savings = $2,229

Implementation

Cog Belts

There is a premium cost associated with cog belts. However, this premium has been shown by many vendors to be offset by a longer lifetime of the belt (up to 55% longer). Since the premium is on the order of 30%-35% there should be an equivalent increase in belt cost, but replacing belts more infrequently will not increase the overall expenditures.

Therefore, the payback period is immediate if the belts are replaced with cog belts as needed.

HTDs

The installation of new pulleys could be carried out by maintenance personnel. The capital cost required would be about $200 per drive. There are approximately nineteen belt drives which could be changed. Therefore the total implementation cost would be:

(19 motors) x ($200 per motor) = $3,800

Based on the above implementation cost and energy cost savings, the simple payback period for this recommendation is:

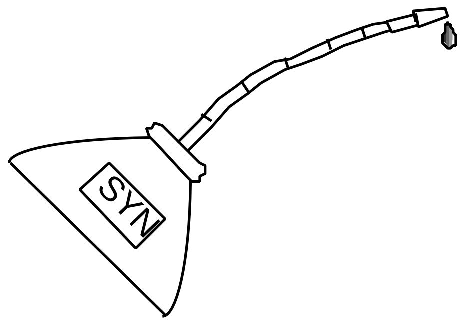
($3,800 implementation cost)/($2,229/yr) = 1.7 years

Simple Payback = 1.7 years

Because of their inherent safety it is recommended that you install cog belts rather than HTD's.

Recommendation No. 2

USE SYNTHETIC LUBRICANTS



Current Practice and Observations

Currently, all of the electric motors used in the plant are lubricated with petroleum based lubricants resulting in an unnecessary loss of energy.

Recommended Action

Begin a practice of using synthetic lubricants on the air compressors and other large motors.

> *Please note: There are several classes of synthetic lubricants which differ in their chemical and physical properties and lubricating ability (including compatibility with hydrocarbon lubricants). We strongly recommend consulting with manufacturer representatives as well as seeking advice from an expert for proper lubricant selection. Several recent review articles*[3] *are available which can also provide information on acceptable lubricants.*

Anticipated Savings

Manufacturers of synthetic lubricants claim from actual field experience an energy savings of 10 to 20 percent of the energy normally lost in the operation of electric motors, gearboxes, etc. with the use of their products. These claims are based on information showing that the synthetic oils, which run at a relatively constant viscosity over an extended temperature range, possess better lubricating properties and are more resistant to oxidation than petroleum based lubricants.

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3 See, for example, Nolden, C. (1985). "A Guide to Synthetic Lubricants," Plant Engineering, **39**, no. 9, pp. 30-41.

The potential savings in energy of changing to synthetic lubricants can be calculated using the following formula:

$$PS = HP \times (1-\eta) \times LF \times S$$
$$ES = PS \times H$$

where:

PS	=	the anticipated reduction in electric power in kW.
ES	=	the anticipated energy savings (kWH/yr)
HP	=	the total horsepower for the compressors and other large motors (347.5 HP from the major plant energy consuming equipment)
η	=	average efficiency of the motors (estimated here to be 85 %)
LF	=	average load factor (estimated to be 0.75)
H	=	annual operating time (5 dys/wk x 52 wks/yr x 8 hrs/dy = 2,080 hrs/yr)
S	=	estimated reduction of energy losses through lubrication. (taken here as 10%)

Therefore:

$$PS = (347.5 \text{ HP}) \times (1-0.85) \times (0.7459 \text{kW/HP}) \times 0.75 \times 0.1 = 2.92 \text{ kW}$$
$$ES = (2.92 \text{ kW}) \times (2{,}080 \text{ hrs/yr}) = 6{,}074 \text{ kWH/yr}$$

and the cost savings would be (see Electricity Consumption Table, page 8):

$$\text{Consumption Savings} = (\$0.0634/\text{kWH}) \times (6{,}074 \text{ kWH/yr}) = \$385/\text{yr}$$
$$\text{Demand Savings} = \frac{\$9.24}{\text{kW-month}} \times 2.92 \text{ kW} \times 12 \text{ months/yr} = \$324/\text{yr}$$

Total Annual Savings = $709

Implementation

There are no direct costs of implementation concerning this recommendation. However we suggest the hiring of a lubrication consultant to help select lubricants and maintenance strategies. There will also be an increased operating cost associated with the more expensive synthetic lubricants. However, the extended life of these products offsets the increased cost. Therefore the total implementation cost would be:

(8 consultant hrs) x ($100/hr) = $800

Based on the above implementation cost and energy cost savings, the simple payback period for this recommendation is:

($800 implementation cost)/($709/yr) = 1.1 year payback

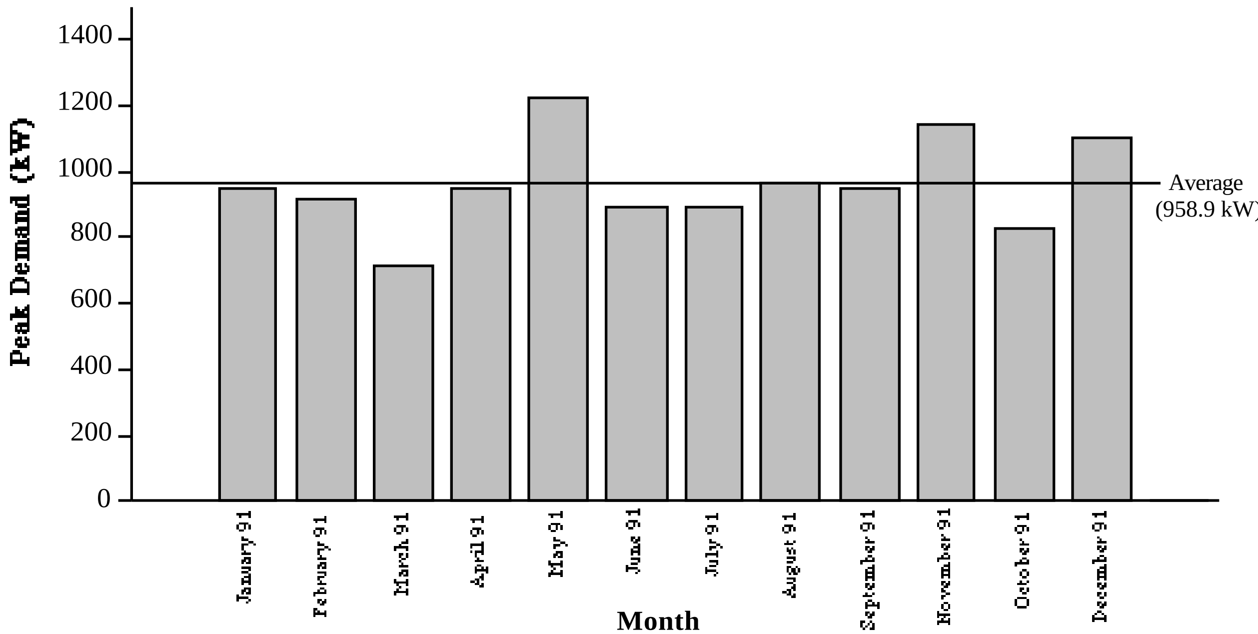
Simple Payback = 1.1 years

Recommendation No. 3

BEGIN A PRACTICE OF MONITORING ELECTRICAL DEMAND

Current Practice and Observations

The energy bills revealed that the monthly kilowatt demand was excessively high and variable throughout the year. At present the average billed demand is 959 kW. Measurement of the demand during the highest productivity portion of the day will usually show a rate of electric consumption well below the peak demand recorded by the electric utility for the month. With proper management nearly any manufacturing plant could reduce the excess demand costs by about 15%.



Recommended Action

Begin a practice of monitoring and minimizing electrical demand.

> *Power companies charge their customers for the peak kW demand during each month. This is done to encourage their customers to reduce the power spikes in their operations. By law, power companies must maintain a "spinning reserve" to account for spikes in user demand. However, it is costly for the power companies to maintain these reserves at high levels. The power companies customarily measure demand in the plant by measuring the consumption of electric power over consecutive 15 or 30 minute intervals throughout the month. The peak demand is then selected as that interval with the largest kWH consumption and converted to a kW rate. The power company will then charge a substantial amount of money per kW for on peak demand (usually daytime hours).*

Peaks in demand are caused by a number of different factors. The two most important of these are the starting of large motors and the starting of many motors of any size in a single 15 minute period. Electric motors can draw between 5 and 7 times their full load currents during start ups. These current spikes will last until the motor has reached nearly full operating speed. For fully loaded motors this is typically between 30 seconds and 2 minutes. The demand spike due to starting a fully loaded motor is approximated by the following equation:

$$DS = \frac{(N \times f \times \Delta T) + (N \times Tr)}{T}$$

where:

DS	=	The demand spike in kW.
N	=	The size of the motor in kW
f	=	Increase in current during start up (Taken to be 6 times)
ΔT	=	Time that the increased current is drawn (Taken to be 1.5 minutes)
T	=	Time period over which the power company measures demand (usually 15 or 30 minute intervals)
Tr	=	The time remaining in the measurement period (T - ΔT)

If the time the power company uses to measure demand is assumed to be 15 minutes the above equation reduces to DS = 1.5 x N. That is to say that starting a motor will cause a demand spike that is 150% of the rated power of the motor being started.

Demand spikes from electric motors can be reduced in a number of way. In general it is suggested that the starting of small motors be staggered and that of large motors be electronically controlled. Some startup problems have a hardware solution such as the placement of sequencers on air conditioning systems and soft start devices on large motors. Placing sequencers on an air conditioning system will prevent more than one air conditioner from coming on at once. The sequencer will cycle through the units allowing 15 minutes for each unit to cool its respective area. Slow, or soft, start devices will control spikes in demand by limiting the amount of current that a large motor can draw. They will slowly increase, or ramp, the current to its operating level. The reduction in the demand spike from the implementation of the soft start devices is nearly 100%. The estimated savings are therefore:

Savings = DS - N
or, from the above equation:
Savings = 0.5 x N

Some of the problems with demand can be solved through procedural changes rather than the installation of hardware. For instance having the first shift start before 8:00 AM will move the demand spike to off peak hours. Also, staggering the times for breaks and lunches will keep all of the workers from returning to work at once. This will prevent a power spike from various production machines being returned to use at the same time.

The determination of when a demand spike occurs is typically a very difficult job. It is suggested that a demand meter be installed. Such a meter can be obtained from the power company. Some meters come with a printout. This would enable plant personnel to examine the demand. A determination of when peak demand occurs could then be made. Once the time of peak demand is found, it is usually easy to determine what is causing it and what must be changed to reduce it.

Anticipated Savings

It is anticipated that with careful control of demand, the average demand could be reduced by 15%. This will save no electricity, since we are considering only the billing policies of your utility company, but it will save a considerable amount of money per year. Noting that your average demand was 959 kW and your average charge for each kW of on peak demand was $9.24 , the cost savings are:

$$0.15 \times \frac{\$9.24}{\text{kW-month}} \times (959 \text{ kW}) = \$1{,}329/\text{month}$$

Then the yearly total is:

$$(12 \text{ months/year}) \times (\$1{,}329/\text{month}) = \$15{,}948/\text{year}$$

Total Annual Savings = $15,948

Implementation

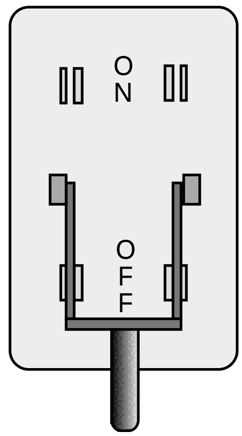
It is suggested that a demand meter with a printout be installed. This would provide a simple means to analyze monthly demand. The installation and cost of a demand meter with a printout is about $2,500. With this installation cost and the above yearly savings, the simple payback period is:

$$(\$2{,}500) / (\$15{,}948/\text{year}) = 0.2 \text{ years}$$

Simple Payback = 0.2 years

Recommendation No. 4

TURN OFF EQUIPMENT WHEN NOT IN USE



Current Practice and Observations

During the audit it was noticed that about seventy percent of the roll forming machines were left on when they were not in use. Each motor left on, no matter how small, results in a large amount of wasted energy when considered over a year.

Recommended Action

Ensure that all machinery is shut down when not in use.

> *Demand spikes will have to be avoided on restarting as mentioned previously, but the consumption costs can be reduced. This can be done by instructing plant maintenance personnel to check all equipment at the beginning of breaks and throughout the day to make sure that they are not running without due purpose.*

Anticipated Savings

The energy savings realized by shutting off the hydraulic motors when not in use can be found by:

$$ES = \frac{HP \times CV}{\eta} \times HR \times IL$$

where:

ES	=	the realized energy savings (kWH/yr)
HP	=	the horsepower of motors left on during the day 0.7 x 207.5 HP = 145 HP
CV	=	the conversion factor (0.7459 kW/HP)

η	=	the average efficiency of the motors (85%)
HR	=	the annual hours of unnecessary idling (2 hrs/day x x 7 days/week x52 weeks/yr = 728 hours/yr)
IL	=	Idle load horsepower consumption of motor (10%)

Therefore,

$$ES = \frac{145 \text{ x } 0.7459}{0.85} \text{ x } 728 \text{ x } 0.10 = 9{,}263 \text{ kWH/yr}$$

It is assumed there is no savings in peak demand involved with this recommendation as staggered startups will be employed.

The annual cost savings (CS) are:

$$CS = ES \text{ x } EC$$

where EC is the electricity cost per kilowatt-hour (kWH), thus:

CS = (9,263 kWH/yr) x ($0.0634/kWH) = $587/yr

Total Annual Savings = $587

Implementation

This recommendation requires instructing plant maintenance personnel to check all equipment at the beginning of breaks and throughout the day to make sure that they are not running without due purpose. Therefore, there is no implementation cost of this recommendation. And the payback is immediate.

Simple Payback = Immediate

Recommendation No. 5

INSTALL SET BACK TIMERS ON THERMOSTATS CONTROLLING SPACE HEATING

Current Practice and Observations

Currently, space heating is provided by two boilers .

> *Each area of the plant has its own thermostat, but there is no procedure for setting temperatures back during non-working hours on nights and weekends resulting in an unnecessary loss of energy.*

Recommended Action

Purchase and install 7-day set back timers to lower thermostat settings in the plant during nights and weekends.

Anticipated Savings

An estimate of the savings which could be realized through the installation of the setback timers can be made by using the following approach. The percent of time during a week when the plant is not operating is:

$$P_o = \frac{(168\text{-}40)\text{hrs not operating/wk}}{168 \text{ hrs/wk}} \times (100\%) = 76\%$$

where P_o is the percent of time during the week when the plant is not operating.

The average temperature difference between the plant and the outdoors during the winter months can be determined by:

$$\Delta T = T_p - \{65 - \frac{DDY}{HD}\}$$

where ΔT = the average temperature difference
T_p = the temperature maintained in the plant (assumed here to be 70^oF)
DDY = the heating degree days for the year (5,674) for the plant location which can be obtained from local newspaper or weather bureau data.
HD = the number of days per year when the average temperature drops significantly below 65^oF. Weather data shows this to be about 190 days for this area.

Therefore the average temperature difference during the winter months is:

$$\Delta T = 70 - \{65 - \frac{5674}{190}\} = 35\ ^oF$$

The energy loss from the building is proportional to the temperature difference between the inside and outside. If the temperature in the building is lowered 15^{o}F during non-working hours, the energy savings which will result can be calculated with the following formula:

$$ES = \frac{RT}{\Delta T} \times P_o \times YU$$

where	ES	=	the energy savings in units consumed
	P_o	=	Percent of week plant is not operating (76%)
	RT	=	the reduction in temperature during the off hours (15 ^{o}F)
	ΔT	=	average temperature difference between inside and outside during winter months.
	YU	=	the yearly usage for heating

The portion of the natural gas used for heating may be approximated by assuming that the amount used in the production process remains nearly constant throughout the year and is the same as can be found by averaging the amount of natural gas consumed in the months from May through September. The natural gas bills yield an average of 3,190 therms for those months. The annual use of natural gas in production is then:

12 month/yr x 3,190 therms/month = 38, 280 therms/yr

Examination of the plant's energy bills shows all of the #2 fuel oil was used for heating, but only a portion of the natural gas.

The amount of natural gas for heating (YU) is then the annual usage minus the amount for production or:

YU = 56,787 therms/yr - 38,280 therms/yr = 18,507 therms/yr

Therefore for natural gas:

$$ES_{ng} = \frac{15\ ^oF}{35\ ^oF} \times (.76) \times (18{,}507 \text{ therms/yr}) = 6{,}028 \text{ therms/yr}$$

and for #2 fuel oil, YU = 10,339 gallons/yr and:

$$ES_{fo} = \frac{15\ ^oF}{35\ ^oF} \times (.76) \times (10{,}339 \text{ gallons/yr}) = 3{,}368 \text{ gallons/yr}$$

and the annual cost savings would be:

Annual Savings = ($0.644/therm) x (6,028 therms/yr) + ($1.03/gal) x (3,368 gal/yr)

Annual Savings = $3,882/yr + 3,469/yr = $7,351/yr

Implementation

The purchase and installation of 7-day programmable timers is suggested. There are several producers of such products and many types to choose from. Analog single circuit timers sell at retail for about $100. We suggest the purchase of digital seven day set back timers which would sell for about $185. Some vendors are: Lumenite Electronics Co. in Illinois, Tork Inc. in New York, Square D Co. in Wisconsin or Electric Counters and Controls Inc. in Illinois. Installation of the units should be done by professional electricians and installation time is estimated to be 2 hours at $27/hr. Therefore a typical price for one unit including installation is about $239. Based on the size of the plant and the number of thermostats, the installation of 10 separate setups is suggested. Therefore the implementation cost would be:

(10 setback timers) x ($239 per timer) = $2,390

Based on the above implementation cost and energy cost savings, the simple payback period for this recommendation is:

($2,390 implementation cost)/($7,351/yr) = 4 months

Simple Payback = 4 months

Recommendation No. 6

IMPLEMENT PERIODIC INSPECTION AND ADJUSTMENT OF COMBUSTION IN A NATURAL GAS FIRED BOILER

Current Practice and Observations

During the audit, the exhaust from the boilers was analyzed. This analysis revealed excess oxygen levels which result in unnecessary energy consumption.

Recommended Action

Many factors including environmental considerations, cleanliness, quality of fuel, etc. contribute to the efficient combustion of fuels in boilers. It is therefore necessary to carefully monitor the performance of boilers and tune the air/fuel ratio quite often. Best performance is obtained by the installation of an automatic oxygen trim system which will automatically adjust the combustion to changing conditions. With the relatively modest amounts spent last year on fuel for these boilers, the expense of a trim system on each boiler could not be justified. However, it is recommended that the portable flue gas analyzer be used in a rigorous program of weekly boiler inspection and adjustment for the two boilers used in this plant.

Anticipated Savings

The optimum amount of O_2 in the flue gas of a gas fired boiler is 2.0%, which corresponds to 10% excess air. Measurements taken from the stack on the 300 HP boiler gave a temperature of 400 ^{o}F and a percentage of oxygen at 6.2%. By controlling combustion the lean mixture could be brought to 10% excess air or an excess O_2 level of 2%. This could provide a possible fuel savings of 3%.

The 300 HP natural gas boiler is used both for production and heating. It is estimated that 100% of the natural gas is consumed in the boiler.

Therefore the total savings would be:

Savings in Fuel (therms/yr):	=	(% burned in boilers) x (annual therms per year) x (percent possible fuel savings)
	=	(1.0 x (56,787 therms/yr) x (0.02)
	=	1,136 therms/yr
Savings in Dollars ($/yr):	=	(therms Saved/yr) x (cost/therm)
	=	1,136 therms/yr x $0.644/therm
	=	$732/yr

Implementation

It is recommended that you purchase a portable flue gas analyzer and institute a program of monthly boiler inspection and adjustment of the boilers used in the plant. The cost of such an analyzer is about $500 and the inspection and burner adjustment could be done by the current maintenance personnel. The simple payback is:

$500 cost / $732 = 8.2 months

Simple Payback = 8.2 months

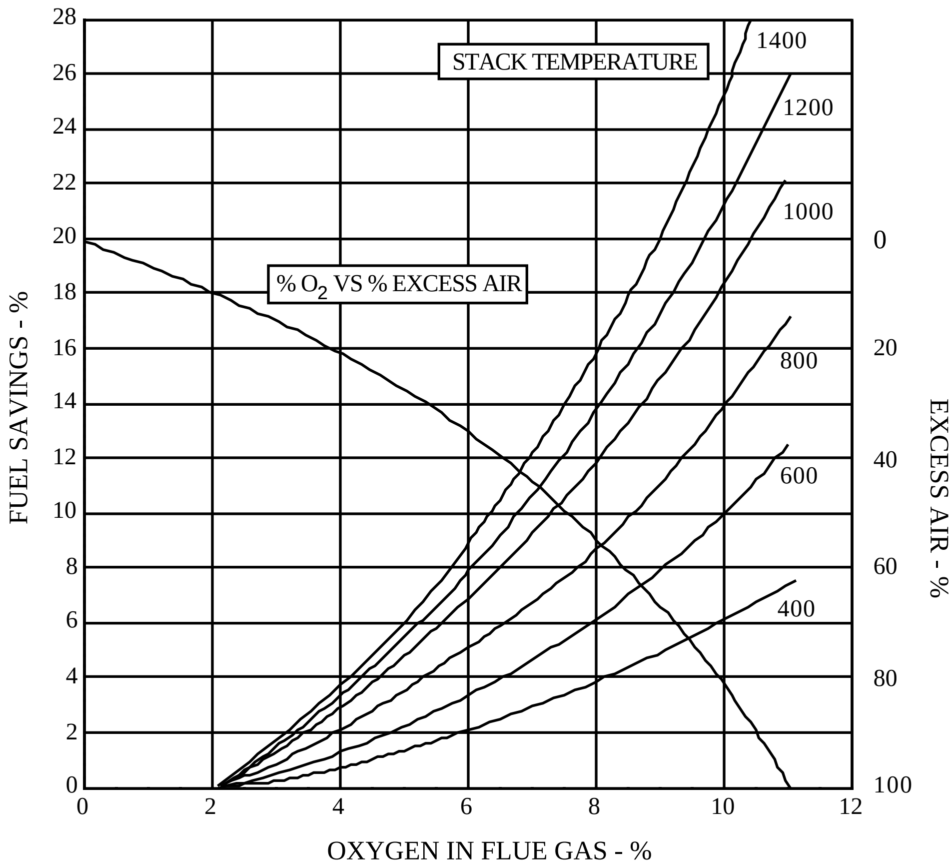


Figure 1. Natural Gas Fuel Savings Available by Reducing Excess Air to 10%[4].

Note: Fuel savings determined by these curves reflect the following approximation: The improvement in efficiency of radiant and combination radiant and convective heaters or boilers without air pre-heaters that can be realized by reducing excess air is 1.5 times the apparent efficiency improvement from air reduction alone due to the accompanying decrease in flue gas temperature.

As an example, for a stack temperature of 600 ^{o}F and O_2 in flue gas of 6%, the fuel savings would be 3%. If desired, excess air may be determined as being 36%.

4 *Energy Conservation Program Guide for Industry and Commerce*, National Bureau of Standards Handbook 114, September 1974, p.3-48.

Recommendation No. 7

IMPLEMENT PERIODIC INSPECTION AND ADJUSTMENT OF COMBUSTION IN AN OIL FIRED BOILER

Current Practice and Observations

During the audit, flue gas samples were taken from the boiler . The boiler was operating with too much excess air resulting in unnecessary fuel consumption.

Recommended Action

- SEE recommendation No. 6

Anticipated Savings

The optimum amount of O_2 in the flue gas of an oil fired boiler is 3.7%, which corresponds to 20% excess air. The boiler we measured had an O_2 level of 8.5 % and a stack temperature of 400 ^{o}F. From the Figure 1, using the measured stack temperature and excess oxygen for the boiler indicates a possible fuel saving of nearly 4.0% for the oil fired boiler.

It is assumed that the boiler consumes all of the fuel oil consumed during the year. The possible savings is then the sum of the products of amount used and percent saved.

ES = (10,339 gallons/yr) x (0.04 savings.) = 414 gallons/yr

Therefore the total cost savings would be:

Cost Savings = (414 gallons/yr) x ($1.03/gallon) = $426/yr

Total Annual Savings = $426

Implementation

It is recommended that you purchase a portable flue gas analyzer and institute a program of monthly boiler inspection and adjustment of the boilers used in the plant. The cost of such an analyzer is about $500 and the inspection and burner adjustment could be done by the current maintenance personnel. The simple payback period will then be:

$500 implementation cost / $426 savings = 1.2 years

Simple Payback = 1.2 years

Note: The payback is improved if recommendation #6 is also implemented.

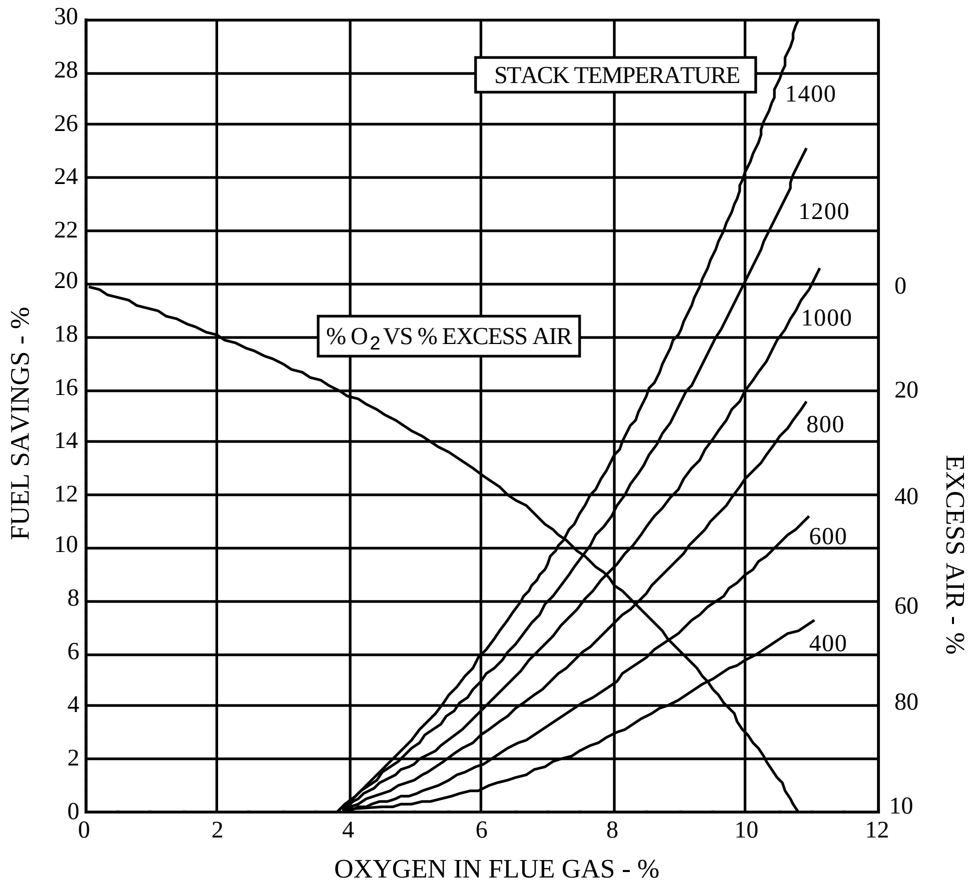


Figure 2. Liquid Petroleum Fuel Savings Available by Reducing Excess Air to 20%[5].

Note: Fuel savings determined by these curves reflect the following approximation: The improvement in efficiency of radiant and combination radiant and convective heaters or boilers without air pre-heaters that can be realized by reducing excess air is 1.5 times the apparent efficiency improvement from air reduction. This is due to the decrease in flue gas temperature which must follow increased air input.

As an example, for a stack temperature of 800 ^{o}F and O_2 in flue gas of 6%, the fuel savings would be 3%. If desired, excess air may be determined as being 36%.

5 *Energy Conservation Program Guide For Industry and Commerce*, National Bureau of Standards Handbook 115, September 1974, p.3-48.

Boiler Efficiency Tips

① Conduct a boiler flue gas analysis once a week, unless an automatic systems is operating the controls. Recommended percentages of O_2, CO_2, and excess air in the exhaust gases are:

Fuel	*O_2*	*CO_2*	*Excess Air*
Natural Gas	*2*	*0*	*10*
Liquid Petroleum	*4*	*2.5*	*20*
Coal	*4*	*5*	*25*
Wood	*5*	*5.5*	*30*

The air-fuel ratio should be adjusted to the recommended optimum value. However, a boiler with a wide operating range may require a control system to adjust the air-fuel ratio continuously, in order to maintain efficient combustion.

② A high flue gas temperature may reflect the existence of deposits and fouling on the fire and water side of the boiler. The resulting loss in boiler efficiency can be approximated by estimating that 1% efficiency loss occurs with every 40 ^{o}F increase in stack temperature from these conditions.

It is suggested that the stack gas temperature be recorded immediately after boiler servicing and that this value be used as the preferred reading. Stack gas temperature readings should be taken on a regular basis and compared with the established reading at the same firing rate. A major variation in the stack gas temperature indicates a drop in efficiency and the need for either air-fuel ratio adjustment or boiler tube cleaning. In the absence of any reference temperature, it is normally expected that the stack temperature will be about 150 ^{o}F to 200 ^{o}F above the saturated steam temperature at a high firing rate in a saturated steam boiler (not applicable to a boiler with an economizer and air preheater).

③ After an overhaul of the boiler, start up the boiler and re-examine the tubes for cleanliness after thirty days of operation. The accumulated amount of dirt will establish the necessary frequency of the boiler tube cleaning.

④ Check the burner head and orifice once a week and clean if necessary.

⑤ Check all controls frequently and keep them clean and dry.

⑥ For water tube boilers burning coal or oil, blow out the soot once a day. The Bureau of Standards indicators that 8 days of operation can result in an efficiency reduction of 8%, caused solely by sooting of the boiler tubes.

⑦ For frequency and amount of blowdown depends upon the amount and condition of the feed water. Check the operation of the blowdown system and make sure that excessive blowdown does not occur.

Recommendation No. 8

PREHEAT BOILER COMBUSTION AIR WITH STACK WASTE HEAT

Current Practice and Observations

Combustion air is drawn into the 300 HP natural gas boiler from the outside. The intake air is thus at ambient outdoor temperature throughout the year which results in unnecessary fuel consumption to heat the combustion air .

Recommended Action

Install recuperative preheater on the air intake of the boiler to preheat the combustion air using heat which is exhausted along with the products of combustion from the boiler.

Anticipated Savings

The energy bills over the year show an annual natural gas consumption of 56,787 therms. The boiler efficiency was measured at 82%.

A high quality recuperator could recover up to 60% of this waste heat.

Therefore the potential savings from the installation of a recuperator on the process boiler is:

For natural gas:

$$ES = EC \times (1 - \eta) \times (RC)$$

Where:

EC	=	Energy Consumed
η	=	The efficiency of the boiler
RC	=	Percent of energy recoverable by recuperator

$$ES = (56{,}787 \text{ therms}) \times (1 - 0.82) \times (0.6) = 6{,}133 \text{ therms/yr}$$

with a cost saving of:

$$\text{Cost Saving} = (6{,}133 \text{ therms/yr}) \times (\$0.644/\text{therm}) = \$3{,}950/\text{yr}$$

Total Annual Savings = $3,950

Implementation

Many boiler companies such as Eclipse Combustion of West Trenton, NJ, sell off-the shelf boiler recuperators of various sizes and efficiencies. The cost of a recuperator capable of handling the exhaust flow rate of the boiler as well as having an efficiency greater than 70% would be about $9,000 and the anticipated installations costs would run to about $4,500. The simple payback period is thus:

($13,500 cost)/($3,950/yr) = 3.4 years

Simple Payback = 3.4 years

This payback time would be greatly reduced if the boiler operating time were to increase, e.g., by adding more shifts.

Recommendation No. 9

INSULATE CONDENSATE RETURN TANK

Current Practice and Observations

> *It was observed that the condensate return tank for the 300 HP boiler is very hot and uninsulated. The heat loss from the condensate return tank must be made up by the boilers and therefore the lack of insulation makes for unnecessary energy loss.*

Recommended Action

Insulate the surface area of the condensate return tank to reduce the heat loss.

Anticipated Savings

The heat loss rate from the condensate return tank can be estimated from the expression:

$$Q = h \times A \times (\Delta T) \times H$$

where:

Q	=	the heat loss rate (in BTU/yr)
h	=	a combined convective and radiative heat transfer coefficient (estimated to be 2.4 BTU/hr-ft^2-^{o}F; from National Bureau of Standards Handbook #121, Table 7.1)
A	=	the estimated surface area (57 sq.ft.)
ΔT	=	the average temperature difference between the tank surface and ambient air (estimated to be 152 ^{o}F- 77 ^{o}F = 75 ^{o}F)
H	=	Hours per year operation (8 hrs/day x 5 dys/wk x 51 wks/yr = 2,080 hrs/yr)

thus:

$$Q = (2.4 \text{ BTU/hr-ft}^2\text{-}^oF)(57 \text{ ft}^2)(75^oF)(2{,}080 \text{ hrs/yr}) = 21.3 \times 10^6 \text{ BTU/yr}$$

One can assume that sufficient insulation will achieve an efficiency of 90% and accounting for the efficiency of the boiler (approximately 82%), the energy loss reduction will be:

$$\frac{0.90 \times 21.3 \times 10^6 \text{ BTU/yr}}{0.82} = 23.4 \times 10^6 \text{ BTU /yr}$$

or

$$\frac{23.4 \times 10^6 \text{ BTU/yr}}{0.1 \times 10^6 \text{ BTU/therm}} = 234 \text{ therms/yr}$$

Therefore, the total cost savings would be:

Savings = ($0.644/therm) x (234 therms/yr) = $151/yr

Total Annual Savings: $151

Implementation

To obtain permanent insulation on the condensate return tank, custom fiberglass board insulation jackets should be applied. Products are available which would provide sufficient insulation using a 2" thick fiberglass™ elevated temperature board with an eight ounce canvas cover.

Materials:		
(60 sq. ft. of insulation)($1.25/sq. ft.)	=	$75
Labor:		
(8 man-hour)($12/hour)	=	$96
Total Estimated Implementation Cost	=	$171

Based on the above implementation cost and energy cost savings, the simple payback period for this recommendation is:

($171 implementation cost)/($151/yr) = 1.1 year payback

Simple Payback = 1.1 years

Recommendation No. 10

INSULATE PLANT ROOF

Current Practice and Observations

Currently, the machine shop is not insulated and this permits a large heat loss during the cold weather.

Recommended Action

Insulate the machine shop roof to keep heat inside the building in winter time.

Anticipated Savings

For this roof (no suspended ceiling and no insulation) the average overall thermal conductance is approximately 0.25 BTU/hr-ft^2-^{o}F.[6] The installation of R-11 fiberglass insulation to the underside will decrease the coefficient by 73% to 0.067 BTU/hr-ft^2-^{o}F. The heating degree days were found to be 5,674 degree-days/year at this location. The amount of energy saved is found from the following equation (with an assumed average heating day of 24 hours/day, 7 days/week throughout the winter):

$$ES = A \times (U_{old} - U_{new}) \times HDD \times \frac{H}{\eta}$$

where:

ES	=	Energy Saved (BTU/yr)
A	=	Area of roof (5,600 ft^2)
U_{old}	=	Uninsulated overall heat transfer coefficient
U_{new}	=	Insulated value of overall heat transfer coefficient
HDD	=	Annual heating degree days
H	=	Heating hours per day during heating season (24 hrs/day)
η	=	Overall efficiency of steam space heaters and boilers which supply the steam (80%)

$$ES = (5{,}600\ ft^2) \times (0.25 - 0.067\ BTU/hr\text{-}ft^2\text{-}^oF)(5{,}674\ F\text{-}day/yr) \times \frac{24\ hrs/day}{0.80}$$
$$= 174 \times 10^6\ BTU/yr$$

All of the heating of the machine shop is accomplished with steam supplied from the #2 fuel oil fired boiler. The annual cost savings is given by:

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6 *1989 ASHRAE Handbook Fundamentals I-P Edition,* American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc., 1989, pp. 22.2-22.3

$$CS = \frac{ES}{CV} \times CF$$

where:

CS	=	the anticipated cost savings ($/yr)
ES	=	the energy saved in the form of #2 fuel oil per year
CV	=	conversion factor for #2 fuel oil (140,000 BTU/gal)
CF	=	Cost of #2 fuel oil ($1.03/gallon)

thus:

$$CS = \frac{174 \times 10^6 \text{ BTU/yr}}{0.14 \times 10^6 \text{ BTU/gal}} \times \$1.03\text{/gallon} = \$1,280\text{/yr}$$

Total Annual Savings = $1,280

Implementation

The estimated cost of paper-backed fiberglass insulation is $0.49/ft^2 and the labor cost to install it is estimated at $0.35/ft^2. The total implementation cost is:

$$IC = (5,600 \text{ ft}^2) \times (\$0.49\text{/ft}^2 + \$0.26\text{/ft}^2) = \$4,200$$

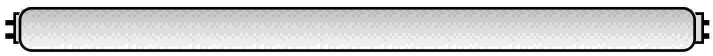
Based on the above implementation cost and energy cost savings, the simple payback period for this recommendation is:

($4,200 implementation cost)/($1,280/yr) = 3.3 years payback

Simple Payback = 3.3 years

Recommendation No. 11

REPLACE STANDARD FLUORESCENT LIGHTING WITH ENERGY EFFICIENT TUBES



Current Practice and Observations

A survey of the lighting in the plant revealed that a major source of lighting consists of 8 ft. fluorescent fixtures loaded with standard 75 watt fluorescent tubes resulting in unnecessary energy loss.

Recommended Action

Replace all standard fluorescent tubes with high efficiency tubes.

Anticipated Savings

The present lighting in the office and the plant consists of 956 of the 75 Watt-8 ft standard lamps. Assuming a ballast factor of 1.1 and noting that the lighting is on an average 8 hrs/day for 5 days per week for the fifty-two weeks during which the plant operates each year. The resulting total operating time is thus:

$$8 \text{ hrs/day} \times 5 \text{ days/week} \times 52 \text{ wks/yr} = 2{,}080 \text{ hrs/yr}$$

The power consumption (PC) and energy consumed (EC) by the 8 ft. tubes is:

$$PC = (956 \text{ lamps} \times 0.075 \text{ kW/lamp}) \times 1.1 = 78.9 \text{ kW}$$
$$EC = 78.9 \text{ kW} \times 2{,}080 \text{ hrs/yr} = 164{,}112 \text{ kWH/yr}$$

With an average kWH cost of \$0.0634/kWH and a demand charge of $\frac{\$9.24}{\text{kW-month}}$ (see table on page 8) this amounts to a yearly cost of:

$$\text{Consumption Cost} = (\$0.0634/\text{kWH}) \times (164{,}112 \text{ kWH/yr}) = \$10{,}405/\text{yr}$$
$$\text{Demand Cost} = 78.9 \text{ kW} \times \frac{\$9.24}{\text{kW-month}} \times 12 \text{ mths/yr} = \$8{,}748/\text{yr}$$

$$\text{Total Annual Cost} = \$19{,}153/\text{yr}$$

Using a higher efficiency tube, less wattage is needed to provide essentially the same amount of light. We suggest that the 8 ft long 75 watt tubes be changed to high efficiency 60 watt tubes. Manufacturers of energy efficient lamps[7] claim a saving of 15 watts per lamp for the 60 watt high efficiency type :

Demand Saving = 956 lamps x .015 kW/lamp = 14.3 kW
Consumption Saving = 14.3 kW x 2,080 hrs/yr = 29,744 kWH/yr

Implementation of the efficient tubes would then provide an estimated cost savings of:

Consumption Cost Savings = 29,744 kWH/yr x $0.0634/kWH = $1,886/yr

$$\text{Demand Cost Savings} = 14.3 \text{ kW} \times \frac{\$9.24}{\text{kW-month}} \times 12 \text{ months/yr} = \$1{,}586/\text{yr}$$

Total Annual Savings = $3,472/yr

Implementation

Typical prices for industrial lighting are as follows:

Standard 75-Watt-8 ft. fluorescent lamps	$5.69 each
High-efficiency 75-Watt-8 ft. fluorescent lamps.	$6.67 each

We consider two possible types of implementation: 1) an immediate implementation where all of the standard tubes are replaced at once and 2) an incremental implementation where tubes are replaced as they burn out.

Immediate Implementation

The estimated cost of implementation of this recommendation is:

Materials:

New Tubes: (956 x $6.67)	=	$6,377

Labor:

Can be replaced by maintenance personnel	=	$0
Total Estimated Implementation Cost	=	$6,377

Based on the above implementation cost and energy cost savings, the simple payback period for this recommendation is:

($6,377 implementation cost)/($3,472/yr) = 1.8 year payback

7 Phillips model #F96T12/VHO/CW & model #F96T12/VHO/EW; and GTE Sylvania model #F40/RS/SS as per data from the GTE Lighting Center, Danvers, Massachusetts 01923

Incremental Implementation

If the recommendation is implemented incrementally, and if the standard lamps are replaced by the high-efficiency lamps only at burnout, not all will be replaced in the first year. The average rated life of an 8 ft. fluorescent light is about 12,000 hours , therefore the amount of savings per year is estimated as follows:

Average 8 ft lamp lifespan = (12,000 hrs)/(2,080 hrs/yr) = 5.77 yrs

If the tubes burn out randomly, the percentage of tubes which will burn out each year is:

Percent of tube burnout/yr = 1/(Average lamp lifespan) x 100

For the 8 ft tubes:

Percent burnout/yr = 1/(5.77) x 100 = 17.3%

Therefore:

First year savings = total savings x % tube burnout per yr/100

For the 8 ft tubes:

First year savings = $3,472 x 17.3/100 = $601/yr
Second year savings=$3,472 x 17.3/100 x 2=$1,201/yr
Third year savings = $1,802/yr

The full annual savings for these bulbs is attained after only six years.

The incremental implementation cost will consist only of the increased expense of purchasing high efficiency tubes and will be constant each year.

Incremental cost (IC) for the high-efficiency 60 Watt-8 ft. fluorescent lamps:

IC = (17.3/100 x 956) lamps burned out/yr x ($6.67-$5.69) cost difference = $162/yr

The simple payback for incremental implementation is:

For the 8 ft high efficiency fluorescent lamps:

First year = ($162 implementation cost)/($601 savings/yr) = 3 months
Second year =($162 implementation cost)/($1,201 savings/yr) = 1.6 months

Succeeding years are calculated in same manner up to the sixth year when savings are complete.

Recommendation No. 12

LOWER LIGHTING LEVELS

Current Practice and Observations

It was observed that lighting levels in the manufacturing area were much higher than needed for the tasks being performed. Based on the lighting needs of the tasks performed a delamping of up to twenty-five percent of the total plant lighting could be implemented.

Recommended Action

Remove 25% of all fluorescent lights from areas containing excess lighting levels.

Anticipated Savings

The plant contains 600 eight foot fluorescent lights in the manufacturing areas which don't require the high level of lighting level measured. The removal of 150 lamps in this area would result in the desired 25% reduction. We can calculate the yearly consumption cost savings for the delamping by using the following formula:

$$CS = n \times H \times W \times CF$$

CS	=	the anticipated consumption cost savings ($/yr)
n	=	the number of eight foot lamps not operated (150 lamps)
H	=	annual operating time (2,080 hrs/yr), (see recommendation #1).
W	=	lamp wattage (75 Watts)
CF	=	Consumption Cost Factor

Therefore:

$$CS = (150 \text{ lamps}) \times (.075 \text{ kW/lamp}) \times (2{,}080 \text{ hr/yr}) \times (\$0.0634/\text{kWH}) = \$1{,}484/\text{yr}$$

In addition, the demand cost savings would be:

$$DS = n \times W \times DF$$

DS	=	the anticipated demand cost savings ($/yr)
n	=	the number of eight foot lamps not operated (150 lamps)
W	=	lamp wattage (75 Watts)
DF	=	Consumption Cost Factor, $\left(\frac{\$9.24}{\text{kW-month}}\right)$

$$DS = 150 \times 0.075 \text{ kW} \times \frac{\$9.24}{\text{kW-month}} \times 12 \text{ months/yr} = \$1{,}247/\text{yr}$$

and the total cost savings would be:

Total Annual Savings = DS + CS = $1,484/yr + $1,247/yr = $2,731/yr

Implementation

Since this recommendation requires only a change in procedure there is no implementation cost and the payback is immediate.

Simple Payback = immediate

Recommendation No. 13

REDIRECT AIR COMPRESSOR INTAKE TO USE OUTSIDE AIR

Current Practice and Observations

Currently, there is one 60 HP air compressor installed. That compressor draws air from the indoor room in which it is located. The room temperature was measured and found to be 90 ^{o}F. By drawing this warm intake air the compressor is working more to compress it resulting in lost energy.

Recommended Action

Install insulated pipes from the intake to outside air.

Anticipated Savings

Whenever feasible, the intake for an air compressor should be run to the outside of the building, preferably on the north or coolest side. Since the average outdoor temperature is usually well below that in the compressor room, it normally pays to take in cool air from outdoors. The energy savings potential in lowering the air intake temperature results from the fact that colder air is more dense, and therefore a given pressure increase may be obtained with less reduction of volume of the air. This in turn means that the compressor does not need to work as hard to obtain the desired pressure.

The reduction in compressor work resulting from a change in inlet air temperature can be calculated using the following formula:

$$WR = \frac{(WI - WO)}{WI} = \frac{(TI - TO)}{(TI + 460)}$$

where:

WR	=	fractional reduction of compressor work
WI	=	compressor work with indoor inlet
WO	=	compressor work with outdoor inlet
TI	=	annual average indoor temperature (^{o}F)
TO	=	annual average outdoor temperature (^{o}F)

Assuming an average indoor intake temperature of 90 ^{o}F and determining that the average outdoor temperature was 51 ^{o}F, the reduction of compressor work can be evaluated as:

$$WR = (90 - 51)/(90+ 460) = 7.1\%$$

The Cost Savings from using the cooler intake can now be calculated as:

$$CS = HP \times \frac{1}{\eta} \times LF \times H \times WHP \times CF \times WR$$

where:	CS	=	the anticipated cost savings ($/yr)
	HP	=	the horsepower for the operating compressor (60 HP)
	η	=	the efficiency of the compressor motor (85%)
	LF	=	average partial load factor (estimated here to be 0.6)
	H	=	annual operating time (8 hrs/day)(5 days/wk)(52 wks/yr) = 2,080 hrs/yr
	WHP	=	Conversion factor (.7459 kW/HP)
	CF	=	Consumption cost Factor ($.0634/kWH)

Therefore:

$$CS = \frac{60\ HP}{0.85} x(0.6)x(2{,}080\ hr/yr)x(0.7459\ kW/HP)x(\$.0634/kWH)x(.071) = \$296/yr$$

Total Annual Savings = $296

No demand savings are anticipated from this recommendation.

Implementation

Connect the intake of the compressor to the outside air by running an insulated section of PVC schedule 40 piping. While standard pipe insulation is usually formed from rigid material an inexpensive and adequate method would be to purchase a roll of fiberglass™ insulation. The estimated implementation cost for this recommendation is found as follows:

Materials:		
	Two eight foot sections of 3 inch PVC diameter pipe	$40
	2 rolls of 6 inch by 25 foot fiberglass™ insulation @ $3.99/roll	$10
Labor:		
	(8 man-hours)($25/hour)	$200
	Total Estimated Implementation Cost	$250

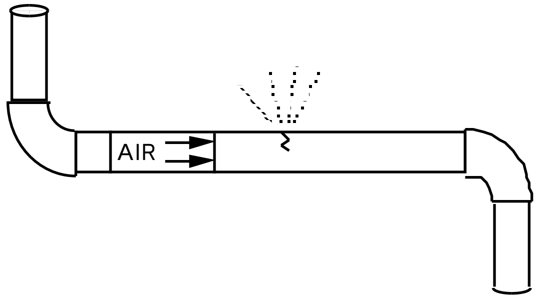
Based on the above implementation cost and energy cost savings, the simple payback period for this recommendation is:

($250 implementation cost) / ($296/yr saving) = 10 months

Simple Payback = 10 months

Recommendation No. 14

REPAIR COMPRESSED AIR LEAKS



Current Practice and Observations

It was noticed that air leaks were present in the compressed air system, resulting in unnecessary energy loss during the operation of the air compressor. One significant air leak was noted during the inspection of the plant and three very small ones were observed.

Recommended Action

Repair leaks as soon as possible.

In some situations, there may be a need to wait for a scheduled plant shutdown. Temporary repair can often be made by placing a clamp over a leak.

A program of routine inspection should be implemented. Air leaks can easily go unnoticed since they are odorless and invisible and their hissing sound can be hidden by other plant noise. Therefore it is advisable to inspect pipelines, air hoses, valves and fittings at regular intervals to detect leaks. A common way of detecting leaks in air pipelines is by swabbing soapy water around the joints. Even very small leaks will make their presence known by blowing bubbles. Also there are instruments available that detect air leaks by sound.

Maintenance personnel can easily be trained to monitor the compressed air system for leaks during periods when the manufacturing activity is shut down such as weekends or after hours. Using their own ears will usually work well during such periods.

Anticipated Savings

The cost of leaks in a compressed air system can be calculated using standard relations. The mass flow out of a hole can be calculated using Fliegner's formula as:

$$m = 1915.2 \times k \times A \times P \times (T + 460)^{-0.5}$$

where:

m	=	mass flow rate [lbm/hr]
k	=	nozzle coefficient (taken here as 0.65)
A	=	area of the hole [in^2]
P	=	pressure in the line at the hole [psia]
T	=	temperature of the air in the line [^{o}F]

If the large hole is estimated to be approximately 1/4" in diameter and the small ones are estimated as 1/32" in diameter, with a line pressure of 110 psi and a line temperature estimated at 75¤F, the mass flow from a single hole is:

$$m_{1/4} = 1915.2 \times 0.65 \times (0.04909 \text{ in}^2) \times (114.7 \text{ psia}) \times (75 + 460)^{-0.5} = 303 \text{ lbm/hr}$$

$$m_{1/32} = 1915.2 \times 0.65 \times (0.00077 \text{ in}^2) \times (114.7 \text{ psia}) \times (75 + 460)^{-0.5} = 4.75 \text{ lbm/hr}$$

The one large leak and three small air leaks observed during the audit bring the total lost air to 317.25 lbm/hr.

The intake for the compressors was in the compressor room. It will be assumed to average 95 ^{o}F .

A simplified equation for determining the amount of energy needed to compress this wasted air (based on an isothermal compression process) is:

$$PR = 0.0687 \times \left(\frac{1}{\eta}\right) \times (T_1 + 460) \times \ln\left(\frac{p_2}{p_1}\right)$$

where:

PR	=	power required to pressurize the air [BTU/lbm]
η	=	compressor efficiency (65%)
T_1	=	inlet temperature [90 + 460]
ln	=	natural logarithm
p_1	=	inlet pressure [14.7 psia]
p_2	=	outlet pressure from compressor [110 +14.7]psia

$$PR = 0.0687 \times \left(\frac{1}{0.65}\right) \times (550) \times \ln\left(\frac{124.7}{14.7}\right) = 124.3 \text{ BTU/lbm}$$

or, changing the units,

$$PR = (124.3 \text{ BTU/lbm}) \times (0.0002931 \text{ kWH/BTU}) = 0.03643 \text{ kWH/lbm}$$

The cost savings would be:

$$CS = P \times L \times HR \times LF \times CF$$

CS = Cost Savings in $/yr
P = Energy required to raise air to pressure (0.03643 kWH/lbm)
L = total leak rate (317.25 lbm/hr)
HR = yearly operating time of the compressed air system (2,080 hrs/yr)
LF = average partial load factor (estimated here to be 0.6)
CF = Cost of electric consumption ($0.0634/kWH)

CS = (0.03643 kWH/lbm) x (317.25 lbm/hr) x (2,080 hrs/yr) x .6 x ($0.0634/kWH) = $914/yr

Total Annual Cost = $914

Implementation

It is estimated that it will take one man-hour to find and repair the air leaks mentioned in this recommendation. This labor cost and the material cost of valves, piping, hoses, etc. results in an approximate implementation cost of $30.

Based on the implementation cost and energy cost savings, the simple payback period for this recommendation is:

($30 implementation cost)/($914/yr savings) = 0.4 months

Simple Payback = 0.4 months

This recommendation is based on the four air leaks that were found. Chances are good that there are more air leaks, but it is also probable the dollar loss due to the one large hole is overestimated. This is due to the fact that large holes in the tubing allow the line pressure to drop and the actual pressure drop across the large hole will be somewhat smaller than 110 psi. But such a large hole is too expensive to allow it to go unrepaired for long.

Recommendation No. 15

LOWER AIR PRESSURE IN COMPRESSORS

Current Practice and Observations

Presently, the 60 HP compressor is operated at 110 psi.

Recommended Action

The maximum pressure required from any process machinery in the plant is 90 psi. It is recommended that the plant operating pressure be reduced from 110 psi to 95 psi in order to realize an energy savings.

Anticipated Savings

Reduction of operating pressure of a compressor reduces its load and operating horsepower (brake horse power). The chart contained in the following figure indicates that by lowering the discharge pressure from 110 to 95 psi, the horsepower output of the compressor will be reduced 7.5%.

We can calculate the yearly cost savings using the following formula:

$$CS = \frac{HP}{\eta} \text{ x } LF \text{ x } H \text{ x } S \text{ x } WHP \text{ x } CF$$

where:

CS	=	the anticipated cost savings for the compressors ($/yr)
HP	=	the horsepower for the compressor (60 HP)
η	=	Efficiency of electric motor driving compressor
S	=	estimated power reduction (taken here as 7.5%)
H	=	annual operating time (2,080 hr/yr).
LF	=	average partial load factor (estimated here to be 0.6)
WHP	=	Conversion factor (.7459 kW/HP)
CF	=	Consumption cost Factor ($.0634/kWH)

Therefore:

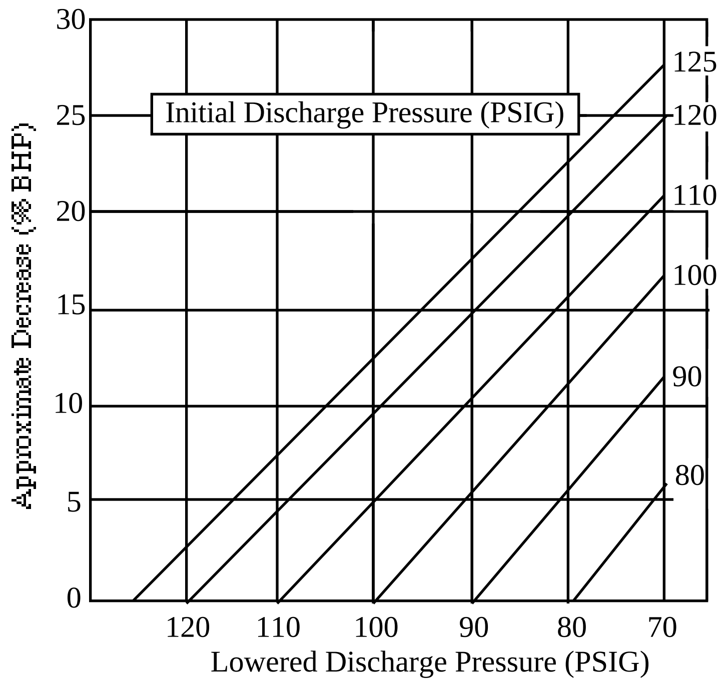
$$CS = \frac{60 \text{ HP}}{0.85} \text{ x } (0.6) \text{ x } (2{,}080 \text{ hr/yr}) \text{ x } (.075) \text{ x } (0.7459 \text{ kW/HP}) \text{ x } (\$.0634/\text{kWH})$$

$$CS = \$316/\text{yr}$$

Total Annual Savings = $316

Implementation

In order to lower the discharge pressure on the compressor, a simple adjustment of the pressure control may be all that is necessary. However, the manufacturer should be consulted in case any additional modifications need to be made or to inform you of any particular limitations inherent in your model.

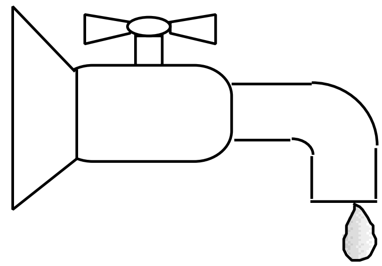


The cost for this implementation is zero making the payback period of the recommendation immediate.

Simple Payback = immediate

Recommendation No. 16

MINIMIZE WASTE OF TAP WATER



Current Practice and Observations

It was noted that tap water was being used to cool the 60 horsepower air compressor by letting it flow freely through the compressor cooling coils. The temperature rise of the cooling water at inlet was 65 ^{o}F and the exit water temperature was 85 ^{o}F. The unrestricted flow results in significant waste water. The compressor oil temperature was also found to be 90 ^{o}F.

Recommended Action

Reduce flow of cooling tap water by installing a gate valve and/or recirculate water through a small cooling tower.

The air compressor specifications indicate that the operating temperature of the oil should be maintained at approximately 150 ^{o}F. The free flow of tap water through the cooling passages is wasting water and overcooling the compressor oil.

- *A gate valve (with a hole drilled in the gate of the correct cross section to limit the flow to rate to the minimum acceptable to the manufacturer of the compressor) should be installed.*
- *The hole will guarantee that the cooling water will not be accidentally shut off*
- *The use of a valve rather than a flow restrictor will permit adjustment of the flow rate in the event of line fouling and permit periodic flushing of the line to eliminate scale.*

Additional water savings would be possible by installing a small cooling tower to reject heat from the compressor cooling water and then recirculate it through the compressor cooling lines.

Anticipated Savings

At full load (60 HP) approximately 20% of the energy delivered to the compressor is removed by the cooling water. The flow rate in gallons per hour for a 20 ^{o}F temperature rise is given by:

$$GPH = \frac{(f \times HP \times CF \times GPP)}{(CP \times \Delta T)}$$

where:

GPH = Gallons of water per hour through the compressor.
HP = full load horsepower of the compressor
f = the fraction of compressor power lost to cooling water (0.2)
CF = the conversion factor (2,545 BTU/HP-hr)
GPP = Gallons of water per pound mass (0.12 gallons/lbm)
CP = specific heat of water (1 BTU/lbm-^{o}F)
ΔT = Temperature rise of water through the compressor (20 ^{o}F)

$$GPH = \frac{(0.2 \times 60\ HP \times 2{,}545\ BTU/HP\text{-}hr \times 0.12\ gal/lbm)}{(1\ BTU/lbm\text{-}^{o}F \times 20\ ^{o}F)} = 183\ GPH$$

It is assumed that allowing the exit water temperature to rise to 145 ^{o}F will maintain the compressor oil at 150 ^{o}F. The flow rate can be reduced by $\frac{(85\ ^{o}F - 65\ ^{o}F)}{(145\ ^{o}F - 65\ ^{o}F)}$ yielding the flow rate as:

$$\frac{(85\ ^{o}F - 65\ ^{o}F)}{(145\ ^{o}F - 65\ ^{o}F)} \times 183\ GPH = 46\ GPH$$

and the cost savings as:

$$CS = L \times HR \times CF$$

CS = Cost Savings in $/yr
L = total water flow reduction rate (183 GPH - 46 GPH = 137 GPH)
HR = yearly operating time of the compressed air system ((8 hours/day) x (5 days/ week) x (52 weeks/yr) = 2,080 hours/yr
CF = Cost of tap water consumption ($18/1000 gallons)

Thus with gate valve flow restrictor:

CS = (137 gal/hr) x (2,080 hrs/yr) x ($0.018/gallon) = $5,129/yr

Cooling tower makeup water is estimated to be no more than 10 gallons per hour for this size unit, thus the cost savings with an installed cooling tower would be:

CS = (183 GPH - 10 GPH x (2,080 hrs/yr) x ($0.018/gallon) = $6,477/yr

Total Annual Savings = $6,477

Implementation

It is estimated the cost of a flow good gate valve will be approximately $20 and it can be installed and drilled by maintenance personnel.

In any case, a gate valve with a drilled hole in the gate or a small water bypass line should be installed in the compressor cooling water line. Another approach is to use a fail safe temperature controller at the cooling water outlet from the compressor. This will prevent accidental shutting off cooling water to the compressor.

Based on the implementation cost and reduction in cost of wasted tap water, the simple payback period for this recommendation is:

($20 implementation cost)/($5,129/yr savings) = 1.4 days

The implementation cost with a cooling tower is considerably greater. It is estimated to be $7,500 for a five ton packaged unit which would be adequate for this application.

Based on this implementation cost and reduction in cost of wasted tap water, the simple payback period for this recommendation is:

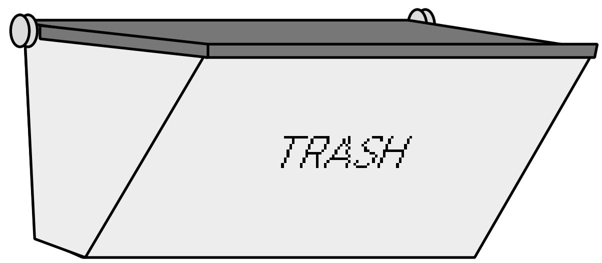
($7,500 implementation cost)/($6,477/yr savings) = 1.2 years.

Simple Payback = 1.2 years

The relatively long payback and complexity involved with the cooling tower may make this approach undesirable. If some other requirement within the plant makes a cooling tower purchase likely this solution should be considered.

Recommendation No. 17

IMPLEMENT CORRUGATED CARDBOARD RECYCLING PROGRAM



Current Practice and Observations

A substantial amount of corrugated cardboard is generated by packaging of incoming raw-materials, supplies, and other parts used in the manufacturing process. Cardboard waste is not currently being segregated and recycled. It is disposed with other solid waste and hauled to the municipal landfill. The estimated amount of cardboard generated at this facility is 15% of the total solid trash volume. This estimate is based on observation of the dumpsters. The annual volume of trash hauled to the landfill is about 4,000 cubic yards per year as determined from the trash bills. The bills also indicate a unit disposal cost of $2 per cubic yard.

Recommended Action

A recycling program for corrugated cardboard should be implemented. Segregate the cardboard into a separate dumpster and deliver it to a recycling center.

Anticipated Savings

The annual solid waste volume reduction and the estimated annual solid waste savings are calculated as follows:

$$SWRV = PC \times CTV$$
$$SWS = SWRV \times UCD$$

where:

SWS	=	Solid waste savings, \$/yr
PC	=	percent of solid waste which is cardboard, 15% (estimated)
CTV	=	Current annual solid waste volume, 4,000 yd^3/yr
UCD	=	Unit cost of solid waste disposal, 2 \$/yd^3.
SWRV	=	Solid Waste Volume Reduction, yd^3/yr

$$SWRV = 0.15 \times 4{,}000\ yd^3/yr = 600\ yd^3/yr$$
$$SWS = 600\ yd^3/yr \times 2\ \$/yd^3 = \$1{,}200/yr$$

Implementation

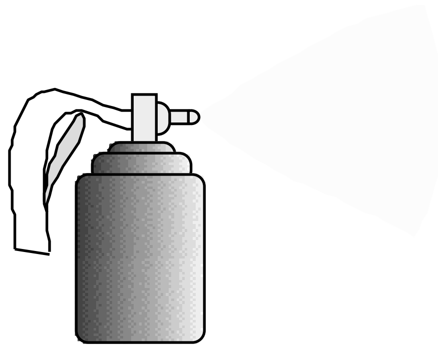
The cost of recycling the cardboard is based on discussions with a waste management company. The cost to haul one 30 cubic yard dumpster to a recycling center, dump it, and return the dumpster is estimated as $165 per trip. The recycling center pays about $55 per ton of cardboard and a 30 cubic yard dumpster holds about 3 tons of cardboard if the boxes are broken down flat. The cost of hauling is thus equal to the recycle credit. The only other requirement is that plant personnel responsible for solid waste removal to the dumpster must be trained to separate out the cardboard and break down the boxes.

There is thus no associated implementation cost and the payback is immediate.

Simple Payback = immediate

Recommendation No. 18

REPLACE CONVENTIONAL PAINT SPRAY GUN



Current Practice and Observations

Currently, the paint guns used in the paint booth are the high pressure airspray variety. These conventional guns have a low transfer efficiency compared to the newer high volume low pressure (HVLP) paint guns. Transfer efficiency is the percentage of paint sprayed that lands on the part being painted. Increasing the transfer efficiency will reduce solvent emissions and reduce solids which bounce off or miss the object being painted. This latter problem is usually called overspray. The high overspray of the conventional paint guns results in high raw material use and costs as well as high waste disposal costs. The amount of waste is greater than the paint sludge (oversprayed solids) as it includes filters, booths or water (in case of a water curtain-booth). Using bills obtained from accounting, current paint consumption was found to be 340 gallons/year with a cost of $20 per gallon. Waste disposal costs were $140 per 55 gallon drum

Recommended Action

Replace the two conventional paint guns with HVLP guns.

Note: An HVLP gun has an average transfer efficiency of 55% compared to 40% for conventional guns.

This action will reduce the amount of paint used.

Anticipated Savings

The amount of paint that will be saved due to switching to an HVLP gun can be estimated as follows

$$PRS = TE_c \times CPU$$

$$FPU = \frac{PRS}{TE_p}$$

$$PS = CPU - FPU$$

$$PCS = PS \times CPG$$

where:

PCS	=	Paint cost savings, $/yr
PS	=	Paint saved, gallons/yr
PRS	=	Paint reaching surface
CPU	=	Current paint usage, 340 gal/yr
FPU	=	Paint usage with HVLP gun
TE_c	=	Transfer efficiency of conventional gun, 40%.
TE_p	=	Transfer efficiency of HVLP gun, 55%.
CPG	=	Cost per gallon of paint, $20/gallon

$$PRS = .40 \times 340 \text{ gal/yr} = 136 \text{ gal/yr}$$

$$FPU = \frac{136 \text{ gal/yr}}{0.55} = 247 \text{ gal/yr}$$

$$PS = 340 \text{ gal/yr} - 247 \text{ gal/yr} = 93 \text{ gal/yr}$$

$$PCS = 93 \text{ gal/yr} \times \$20\text{/gal} = \$1{,}860\text{/yr}$$

The amount of solids in the paint is estimated to be 32% by volume and it is assumed that the waste to be disposed will be approximately five times the amount of oversprayed solids. This is to account for waste generated by filters and booth materials necessary to remove the oversprayed solids from the manufacturing plant.

The amount of waste reduction and waste costs saved due to switching to an HVLP gun can be estimated as follows:

$$SWG_c = 5 \times (CPU - PRS)$$

$$SWG_p = 5 \times (FPU - PRS)$$

$$SWD_c = SWG_c \times UDC$$

$$SWD_p = SWG_c \times UDC$$

$$SWR = SWG_c - SWG_p$$

$$WCS = SWD_c - SWD_p$$

where:

WCS	=	Waste cost savings, \$/yr
SWR	=	Solid waste reduction, gal/yr
SWG_c	=	Solid waste generated per year with conventional spray gun, gal/yr (5 x solids oversprayed)
SWG_p	=	Solid waste generated per year with HVLP spray gun, gal/yr (5 x solids oversprayed)
UDC	=	Unit disposal cost of solids, \$140 per 55 gallon drum
SWD_c	=	Solid waste disposal cost with conventional spray gun, \$/yr
SWD_p	=	Solid waste disposal cost with HVLP spray gun, \$/yr

therefore:

$$OSS_c = 340 \text{ gal/yr} - 136 \text{ gal/yr} = 204 \text{ gal/yr}$$
$$OSS_p = 247 \text{ gal/yr} - 136 \text{ gal/yr} = 111 \text{ gal/yr}$$
$$SWG_c = 5 \times 204 \text{ gal/yr} = 1{,}020 \text{ gal/yr}$$
$$SWG_p = 5 \times 111 \text{ gal/yr} = 555 \text{ gal/yr}$$
$$SWD_c = 1{,}020 \text{ gal/yr} \times \frac{\$140}{55 \text{ gal}} = \$2{,}596/\text{yr}$$
$$SWD_p = 555 \text{ gal/yr} \times \frac{\$140}{55 \text{ gal}} = \$1{,}413/\text{yr}$$
$$SWR = 1{,}020 \text{ gal/yr} - 555 \text{ gal/yr} = 465 \text{ gal/yr}$$
$$WCS = \$2{,}596/\text{yr} - \$1{,}413/\text{yr} = \$1{,}183/\text{yr}$$

The total annual waste savings is thus:

Total Annual Savings = PCS + WCS = \$1,860/yr + \$1,183/yr = \$3,043/yr

The amount of solvent emitted into the air will also be reduced. Although no cost savings can be attributed directly at this time. The increased pressure to reduce solvent emissions may make this reduction very cost effective in the near future. Solvent emission for the particular paint used is 2.83 lbm/gal (from manufacturer's data). The Solvent Air Emission Reduction (SAER) is thus:

$$SAER = PS \times 2.83 \text{ lbm/gal} = 93 \text{ gal/yr} \times 2.83 \text{ lbm/gal} = 263 \text{ lbm/yr}$$

Implementation

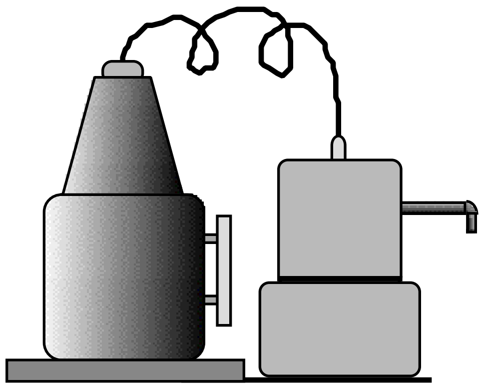
The cost of an HVLP gun is approximately \$500. The replacement of two guns is thus about \$1000 and the cost saving is \$3,043 per year. The simple payback period is thus:

$$\text{Payback} = \frac{IC}{CS} = \frac{\$1000}{\$3043/\text{yr}} = 0.33 \text{ years} = 4 \text{ months}$$

Simple Payback = 4 months

Recommendation No. 19

USE A SOLVENT RECOVERY UNIT



Current Practice and Observations

The cleanup of parts in preparation for painting results in the waste of approximately 600 gallons per year of MEK (Methyl Ethyl Ketones). These solvents are expensive both in their purchase and disposal because of their hazardous nature. The cost of MEK is approximately $3.20 per gallon and the disposal costs are estimated to be $3.65 per gallon. This is based on a review of purchase orders and waste disposal charges during the past year.

Recommended Action

Purchase solvent distillation unit which will recover a large fraction of the spent MEK for reuse in the cleaning process.

Anticipated Savings

The savings will come from two sources. There will be a significant decrease in purchase of MEK and in addition a large reduction in the disposal costs of spent MEK. The recovery factor for a 15 gallon commercially available distillation unit is 75% (EFF).

The current waste generation costs may be calculated as follows:

$$WGC = VOL \times (DC + PC)$$

where: WGC = Waste generation cost of MEK.
VOL = Volume of Waste MEK generated per year.(600 gal/yr)
DC = Disposal Cost of waste MEK ($3.65/gal)
PC = Purchase Cost of waste MEK ($3.20/gal)

$$WGC = (600 \text{ gal/yr}) \times (\$3.65/\text{gal} + \$3.20/\text{gal}) = \$4{,}110/\text{yr}$$

The projected annual operating costs of the solvent recovery unit are estimated as follows:

First determine the number of batches which will be passed through the recovery unit. This is found by dividing the current volume of spent MEK by the batch size of the unit or :

$$NB = \frac{VOL}{GB}$$

NB	=	Annual Number of Batches
GB	=	Size of the unit in (Gallons/Batch).

$$NB = \frac{600 \text{ gal/yr}}{15 \text{ gal/batch}} = 40 \text{ batches/yr.}$$

Using the manufacturers data one can then estimate the electricity, labor, and cooling water costs per batch and then obtain the annual operating cost of the unit.

$$AOC = NB \times (CW \times WC + LC + EC) + LNC + SBDC \times UNR \times VOL$$

AOC	=	Annual Operating Costs in $/yr
CW	=	Cooling Water Required 120 gal/batch
WC	=	Cost of water ($0.0021/gal)
LC	=	$12.50 per batch
EC	=	$0.90 per batch
LNC	=	Boiler Liner Cost Maintenance ($135/yr)
SBDC	=	Still Bottom Disposal Cost per gallon ($2.95/gallon)
EFF	=	Efficiency of the still. (75%)
UNR	=	(1-EFF) 25% (75% recovered and 25% is unrecovered)

$$AOC = 40 \text{ batches/yr} (120 \text{ gal/batch} \times \$.0021/\text{gal} + \$12.5/\text{batch} + \$0.90/\text{batch}) + \$135 + \$2.95/\text{gal} \times 0.25 \times 600 \text{ gal/yr} = \$1{,}124/\text{yr}$$

The annual savings will be the difference between the current annual cost and the projected annual operating cost above:

$$AS = EFF \times WGC - AOC = 0.75 \times \$4{,}110/\text{yr} - \$1{,}124/\text{yr} = \$1{,}958/\text{yr}$$

Total Annual Savings = $1,958/year

Implementation

The purchase cost of the unit is approximately $6,700. The installation cost is estimated to be $200 and the cost of analysis of still bottom waste is $300.

Implementation total cost is thus estimated to be:

IC = $6,700 + $200 + $300 = $7,200

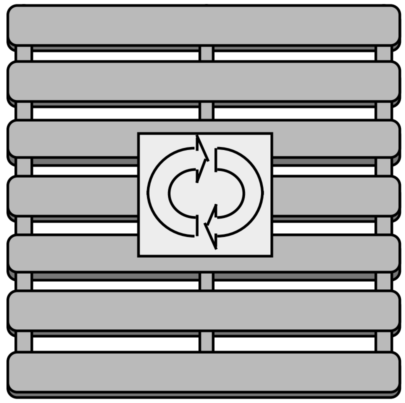
Based on this implementation cost and reduction in cost of wasted tap water, the simple payback period for this recommendation is:

$$\frac{\$7200 \text{ implementation cost}}{\$1958/\text{yr savings}} = 3.7 \text{ years.}$$

Simple Payback = 3.7 years

Recommendation No. 20

RECYCLE WOODEN PALLETS



Current Practice and Observations

Presently, the excess pallets generated at the facility are being disposed of in the general waste stream. Recently the value of pallets has created a market for used pallets. There are now pallet recycling companies available to remove and in many cases pay for the waste pallets. The industry standard pallet is the 40 " x "48" GMA pallet. These pallets are in high demand and can have a value as much as $2.00 per pallet. The number of waste pallets per year is estimated from the number of new ones purchased each year. The purchasing records indicate this amount to be 2,500 pallets.

Recommended Action

A recycling program for wooden pallets should be implemented. Segregate the pallets into a separate dumpster for pickup by a recycling company.

Anticipated Savings

The current conservative industry charge for trash disposal at the facility is approximately $50/ton. If the pallets are stored until a "pick up" quantity is generated (typically 100 pallets), the recycling company can be contracted to remove them on a routine schedule. The estimated weight per pallet is 30 pounds.

It was noted during discussions with site personnel that the disposed pallets are of various sizes. To be conservative we are assume that 70% of the waste pallets are GMA type and the client will receive a lower payment of approximately $1.50 per GMA pallet. It is further estimated that 20% of the pallets that are GMA type, will be severely damaged and therefore, will not result in a payment. The expected yearly amount of savings is estimated as follows:

Annual Savings = Recycling Payment + Annual Solid Waste Savings Annual Savings = RP + ASWS

where:

$$RP = NP \times (0.7) \times (0.8) \times (\$1.50/\text{pallet})$$

$$ASWS = \frac{NP \times WPP \times CPT}{2000 \text{ pounds/ton}}$$

where:

ASWS = Annual Solid waste savings; $/yr
RP = Recycling Payment
NP = Number of Pallets per Year; 2,500/yr
WPP = Weight per Pallet; 30 lbs/pallet
CPT = Unit cost of solid waste disposal; $50/ton.

$$RP = 2{,}500 \text{ pallets/yr} \times (0.7) \times (0.8) \times (\$1.50/\text{pallet}) = \$2{,}100/\text{yr}$$

$$ASWS = \frac{2500 \text{ pallets/yr} \times 30 \text{ lbs/pallet} \times \$50/\text{ton}}{2000 \text{ lbs/ton}} = \$1{,}875/\text{yr}$$

Annual Savings = $2,100/yr + $1,875/yr = $3,975/yr

Total Annual Savings = $3,975/year

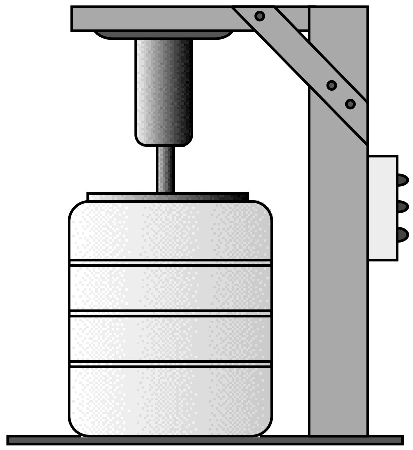
Implementation

There would be no implementation cost involved with this recommendation. However, a space would be required for the storage of pallets.

Simple Payback = Immediate

Recommendation No. 21

COMPACT TRASH TO REDUCE WASTE DISPOSAL FEES



Current Practice and Observations

I. Municipal Trash

Municipal trash is generated through the plant. As stated in the earlier example, it is estimated the amount of cardboard generated at this facility is 15% of the total solid trash volume disposed and hauled to the municipal landfill. That estimate is based on observation of the dumpsters. The annual volume of trash hauled to the landfill is about 4,000 cubic yards per year as determined from the trash bills. The bills also indicate a unit disposal cost of $2 per cubic yard which includes the cost of renting three dumpster. Whether or not the cardboard is segregated the remaining 85% of the trash is currently thrown loosely into dumpsters and can be reduced in volume by compacting thus significantly reducing the annual charge for disposal.

II. Paper Cleaning Towels

The company has recently shifted to paper towels for cleanup of solvents and inks which must be disposed in an environmentally correct manner. Under this system the company spends $180 per month for paper towels plus another $575 per barrel to dispose of the towels. The company generates two barrels of towels per month.

Recommended Action

Purchase two trash compactors and compress trash and paper towels before they are shipped. The company is charged for both types of disposal on a volume rather than a weight basis thus significant savings can be expected.

Anticipated Savings

I. Municipal Trash

It is conservatively estimated that approximately 50% of the municipal waste volume at the time of disposal consists of air voids. Use of a compactor should effectively reduce the air void volume to about 10%. Thus a 40% reduction in landfill waste volume and associated costs can be expected annually. The plant currently has a contract with the local trash company that includes the rental of three 8 cubic yard dumpsters. The compactor recommended to be installed will include a dumpster in the purchase cost thus eliminating the need for the rented dumpsters and further increasing annual cost savings. The annual cost savings are estimated to be 70% of the present rental and removal costs since no dumpsters will be rented and the volume of hauling will be reduced by 40%.

Annual Savings = 0.7 x $2/cubic yard x 4,000 cubic yards/yr = $5,600/yr

Total Annual Savings (Municipal Trash) = $5,600/year

II. Paper Cleaning Towels

A household trash compactor can be used to compress the paper towels to occupy 75% of their current volume before they are shipped.

ACS = FRV x VOL x DIS

where

ACS	=	Annual Cost Savings
FVR	=	Fraction of Original by which volume is reduced;0.75
VOL	=	Current Annual Volume shipped; 24 barrels
DIS	=	Disposal Cost per barrel; $575

ACS = 0.75 x 24 barrels/yr x $575/barrel = $10,350/yr

Total Annual Savings (Paper Cleaning Towels) = $10,350/year

Implementation

I. Municipal Waste

Implementation will require the purchase and installation of one 30 cubic yard trash compactor/dumpster. After the installation of this unit the plant should arrange with the local trash removal company to make less frequent pick-ups and remove the three presently utilized eight cubic yard dumpster. Included in the new arrangement should be a pickup from the new compactor dumpster. The total implementation cost is estimated to be:

New 30 cubic yard compactor/dumpster	=	$12,000
Installation Labor	=	$1,600
Total Implementation Cost	=	$13,600

The simple payback of I. Municipal Waste is:

$$\frac{\$13600 \text{ implementation cost}}{\$5600/\text{yr cost savings}} = 2.4 \text{ years payback}$$

Simple Payback (Municipal Waste) = 2.4 years

II. Paper Cleaning Towels

Implementation of this part requires the purchase and installation of a household trash compactor from any household appliance distributor.

New Household Trash Compactor	=	$350
Installation Labor	=	$35
Total Implementation Cost	=	$385

The simple payback of II. Paper Cleaning Towels is:

$$\frac{\$385 \text{ implementation cost}}{\$10350/\text{yr cost savings}} = 2 \text{ weeks (nearly immediate!)}$$

Simple Payback (Paper Cleaning Towels) = 2 weeks

Appendix B

Useful Conversion Factors

ENERGY UNIT	ENERGY EQUIVALENT		
1 kWH	3,412 BTU		
1 BTU	0.0002931 kWH		
1 Therm	100,000 BTU	or	29.31 kWH
1 Cu. Ft. of Natural Gas	1,000 BTU*	or	0.2931 kWH
1 gallon #2 Oil	140,000 BTU*	or	41.03 kWH
1 gallon #4 Oil	144,000 BTU*	or	42.20 kWH
1 gallon #6 Oil	152,000 BTU*	or	44.55 kWH
1 gallon propane	91,600 BTU*	or	26.85 kWH
1 ton coal	28,000,000 BTU*	or	8,206 kWH
1 boiler horsepower	33,480 BTU/hour	or	9.812 kW
1 mechanical horsepower	2,545 BTU/hour	or	0.7459 kW

*Varies slightly with supplier