Self-Assessment Workbook

For Small Manufacturers

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Dr. Michael R. Muller
Kyriaki Papadaratsakis

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Disclaimer

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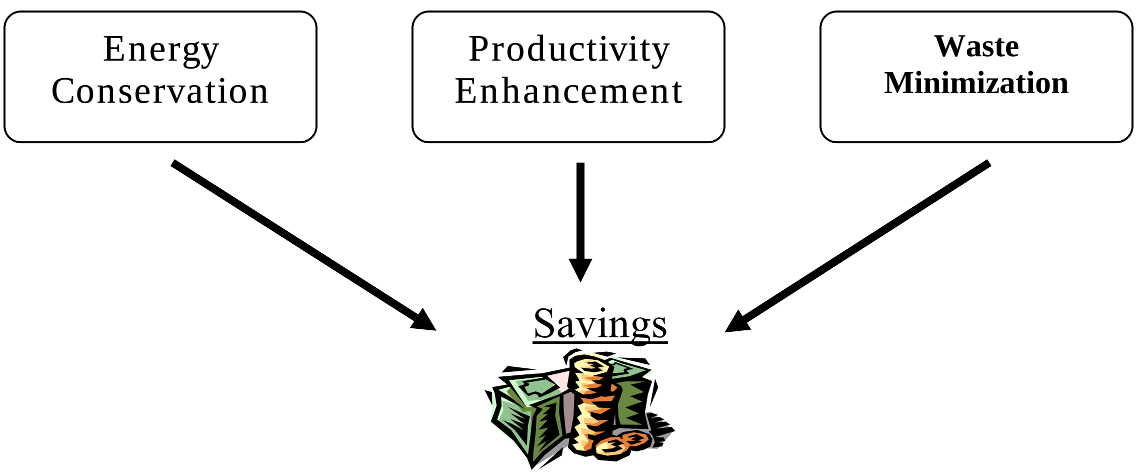
INTRODUCTION

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 Industrial Assessment Center program. 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 IAC Program

Industrial Assessment Centers provide energy, waste, and productivity assessments at no charge to small and mid-sized manufacturers. Assessments help plants maximize energy efficiency, reduce waste, and improve productivity. On average, recommended actions from an assessment result in annual cost savings of $55,000. The assessments are performed by teams of engineering faculty and students from over 26 participating universities across the country. The university-based IAC team conducts a one-day site visit and performs an assessment. Within 60 days, a report detailing the analysis, findings, and recommendations, is sent to the client. In six to nine months, follow-up phone calls are placed to the plant manager. Centers are funded through the Department of Energy, Industrial Technologies Program Office. For further information contact: The Doe Office of Energy Efficiency and Renewable Energy, Industrial Technologies Program Office, Phone: (303) 275-4857 and visit their website at www.eere.energy.gov or the IAC Field Manager at iac.rutgers.edu, phone # 732-445-5540.



Recommendations by 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 energy saving opportunities 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.

Workbook Organization& Equipment Required

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.

Four Step Program

1) Quantify unit costs for energy utilities
2) Obtain a list of major plant energy consuming equipment
3) Identify and quantify savings opportunities in the Manufacturing Process
4) Calculate ***YOUR*** energy and dollar savings!

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

The workbook is broken up into a series of steps which can be followed sequentially or in parallel depending on the assessor's 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. Such a list will be found extremely helpful when actual calculation of dollar savings is begun. The third step 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.

Equipment Required

- Thermocouple or thermometer for:
    - Temperature of liquids
    - Air Temperature
    - Surface Temperature of machines, furnaces, steam lines, etc.
- Combustion Analyzer
    - (Simple Variety) capable of measuring O (oxygen) levels in flue gases and their temperature.
- Light Meter
    - To measure lighting levels in different areas of plant.
- Vibration Meter
- Tape Measure
- Tachometer
    - To measure rotational speed in motors.
- Gloves
- Flashlights
- Wire Brushes
- Disposable Gloves
- Ropes for hauling
- Infrared Gun
- Ultrasonic Gun

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 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.

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 known, the manufacturer will be in a position to make intelligent decisions on the implementation of these cost saving measures.

Step 1 - Utility Analysis

1.1 <u>Energy Management</u>

To meet the challenge of the ever-changing energy marketplace, a successful company must have an energy conservation management program to consistently take advantage of every energy conservation opportunity. Several basic steps are required for effective energy management:

- Management Commitment
- Data Analysis
- Analysis of Conservation Opportunities
- Implementation of Conservation techniques
- Continued Feedback and Analysis

The Energy Management program must have the commitment of management for it to produce a long-term increase in energy efficiency. A brief, early show of support will only result in small, temporary improvements. Management must design the conservation program as a part of its regular, overall company management system. Also, energy costs and consequences of future energy shortages should be communicated throughout the plant to create overall energy awareness.

Accounting for energy and its cost is an essential component of an energy management program. Keeping up-to-date bar graphs of energy consumption and associated costs on a monthly basis can best do it. When the utility bills are received each month it is recommended that the energy can be plotted immediately on the bar graphs. A graph will be required for each type of energy used.

Data analysis will be greatly aided if the records use a standard format for all the company's divisions and if the different energy units are converted to common energy units such as the BTU (British thermal unit). One BTU is the amount of energy needed to raise the temperature of one pound of water one degree Fahrenheit. By comparing the cost of various fuels on the basis of cost per million BTU's, the true cost of each fuel can be determined. The conversion factors required are:

ENERGY UNIT	ENERGY EQUIVALENT
1 kWh	3,412 BTU
1 Therm	100,000 BTU
1 Cu. Ft. of Natural Gas	1,000 BTU
1 gallon #2 Oil	140,000 BTU*
1 gallon #4 Oil	144,000 BTU*
1 gallon #6 Oil	152,000 BTU*
1 gallon propane	91,600 BTU*
1 ton coal	28,000,000 BTU*
1 boiler horsepower	9.81 KW
1 horsepower .	746 KW
1 ton refrigeration	12,000 BTU/hr

**Varies slightly with supplier*

1.2 Types of Energy Consumption

Below is a partial list of the ten most frequently used types of energy consumption in the industrial sector. First, identify the utilities your plant consumes, and then study your utility bills and rate structure. The informed consumer is best prepared to take actions which can decrease costs.

- ☐ Electrical Consumption and Demand
- ☐ Natural Gas
- ☐ L.P.G
- ☐ #1 Fuel Oil
- ☐ #2 Fuel Oil
- ☐ #4 Fuel Oil
- ☐ #5 Fuel Oil
- ☐ Coal
- ☐ Wood
- ☐ Paper

1.3 Terms and Analysis

In analyzing your bills, the following need to be considered:

Avoided Costs: The avoided cost is the cost per energy source that can be saved from implementing an energy efficient practice. The sample bills in section 1.4 show examples of how to calculate the avoided cost for electricity, natural gas and #2 Fuel Oil. Basically, the avoided cost is based on charges due to consumption. In many utilities, there are a set of charges in each billing cycle independent of your consumption. These set of charges should not be included in your avoided cost calculations. Therefore, the total costs you can avoid over the total consumption are your unit cost of energy that can be saved.

Seasonal Averages: In Figure 3, notice how the natural gas bill does a dip during the summer months. This is most likely due to heating the plant during the winter months. Similarly, some plants have summer seasonal increases due to air conditioning. Therefore, a seasonal average is the average of energy consumption and costs for the summer months and the winter months.

TIP **Understanding seasonal charges in your utility bill will aid you in making energy saving actions due to heating and cooling.**

Demand: (*Specific to Electricity ONLY*) Monthly spikes in demand can heavily increase your cost of electricity. If your demand costs and usage (Figure 1 & Figure 3) is inconsistent annually, please use the suggestions in Recommendation #2. 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.

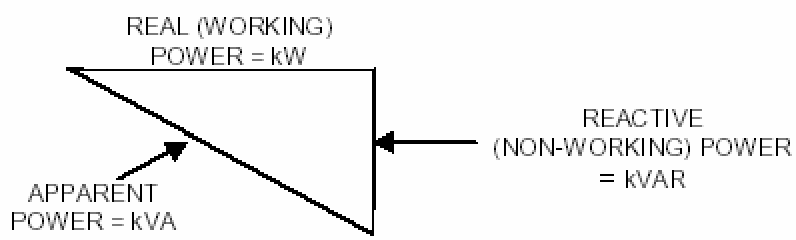
Power Factor[1]**:** *(Specific to Electricity ONLY)* The third component of the bill, power factor (reactive charge), is significant only if five percent or more of the bill is a penalty charge for having a low power factor. It most often is significant when the great majority of the electric consumption is taking place in electric motors.

TIP

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 diagram below helps to explain what power factor is and why an electric utility is concerned with your facility's power factor. Power Factor is the ratio of **Real Power**, measured in kilowatts (kW) to **Apparent Power**, measured in kilovolt-amps (kVA).

$$PF = \frac{kW}{kVA}$$



- **Apparent Power** is the amount of power provided to your facility by the electric utility.

- **Reactive Power** is non-working power, and is measured in kVARs. Inductive loads (e.g. transformers, electric motors, and high intensity discharge lighting) are a major portion of the power consumed in industrial facilities, and they require current to create a magnetic field. The current used to create the magnetic field is required to operate the device, but does not produce work.

- **Real Power** is the work done by the device, and is measured in kW. If your facility draws **100** kW Real Power and **100** kVAR Reactive (magnetizing) Power, then your utility must provide your facility with Apparent Power of **142** kVA. The power factor is 70%, which means that only 70% of the current provided by the electrical utility is being used to produce useful work.[2]

Late Charges: Notice if the utility bills contain late charges. **Paying bills on time will reduce excess fees from late charges and reduce the cost of energy to your facility from a few hundred dollars a year to a few thousand. This is one of the easiest manners to reduce your energy bills.**

TIP

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[1] Trabachino, Carole, "Energy Guidebook (Establishing an Energy Management Program and Identifying Energy Savings Opportunities)."
[2] Reducing Power Factor Cost, US Department of Energy Fact Sheet #

Utility Balance: Use the conversions from section 1.1 so that all the units of your energy bills are the same. Doing so will allow for a quantifiable comparison among the utility bills. Use this information to create a pie chart of the total consumption for each utility and the total costs for each utility. The pie charts will show which utilities your facility consumes the most and has the largest cost.

1.4 Sample Utility Analysis

In this section, a sample analysis of a manufacturer's utility bills is analyzed. The data collected is for a twelve month time period. The data was compiled using Microsoft Excel although similar programs are also available. Graphs were generated to notice if any trends in utilities exist.

To avoid complicating this example, fees and other costs were intentionally not included in this analysis.

Electricity

From the electrical summary in Table 1, the avoided cost of consumption and the avoided cost of demand can be calculated as follows:

$$\text{Avoided Cost (kWh)} = \frac{\$245{,}355}{3{,}871{,}000kWh} = \$0.0633828 / kWh$$

$$\text{Avoided Cost (kW)} = \frac{\$106{,}319}{11{,}507kW} = \$9.2395063 / kW$$

Table 1: Electrical Billing Summary

Date (months)	Consumption kWh	Consumption Cost ($)	Peak Demand kW	Demand Cost ($)
Jan	198,800	$12,975	948	$8,759
Feb	331,200	$20,374	912	$8,427
Mar	245,000	$13,951	710	$6,560
Apr	305,600	$18,902	948	$8,759
May	368,000	$22,621	1,222	$11,290
Jun	318,400	$19,651	888	$8,205
Jul	289,200	$18,855	890	$8,223
Aug	335,600	$21,720	964	$8,907
Sep	367,600	$23,638	952	$8,796
Oct	387,200	$25,384	1,144	$10,570
Nov	350,000	$22,583	824	$7,613
Dec	374,400	$24,701	1,105	$10,210
Totals	**3,871,000**	**$245,355**	**11,507**	**$106,319**

The avoided costs will be used later in calculations for possible electrical and cost saving opportunities in section 4. Now, examine the graphs generated from Table 1. In Figure 1, the consumption is represented by the bars while demand is represented by points on the graph connected by a line. From this graph, it becomes apparent that the process schedule is probably not constant since there are dips and spikes through out the year. Also, there are no noticeable seasonal trends. However, since the dips and spikes in demand are not consistent a possible energy savings opportunity could be to decrease the demand (refer to Recommendation #3). In addition, from Figure 3, notice how demand and electrical consumption are independent from each other. The largest demand spike (May) does not simultaneously occur with the largest monthly consumption (October).

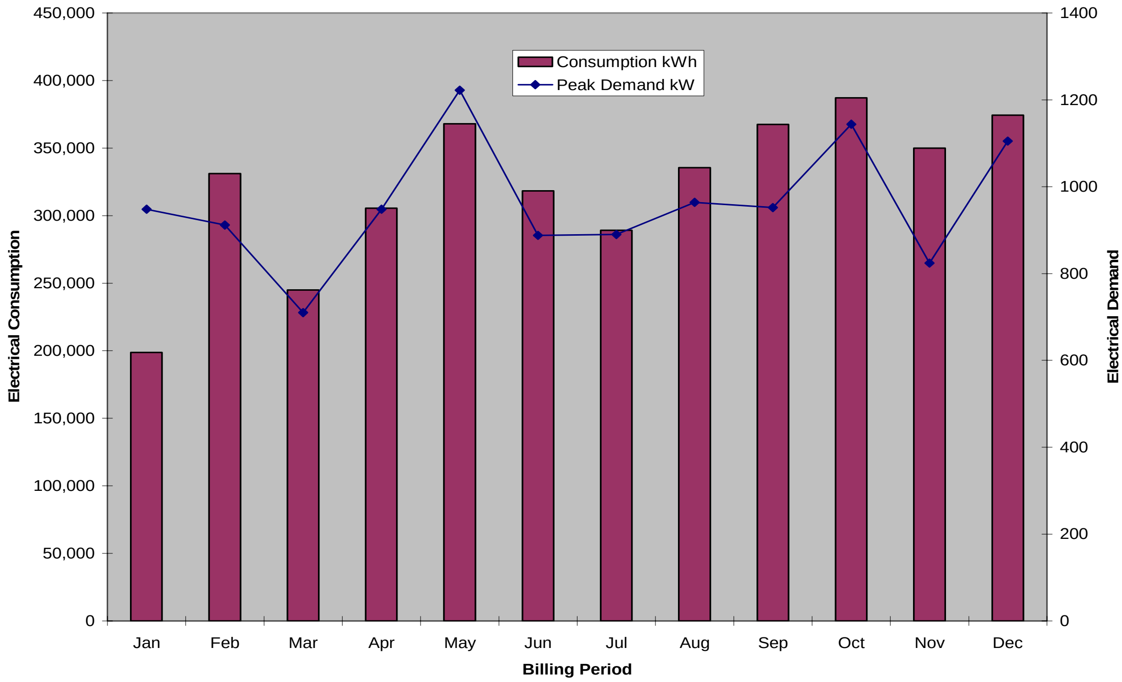


Figure 1: Annual Electrical Consumption

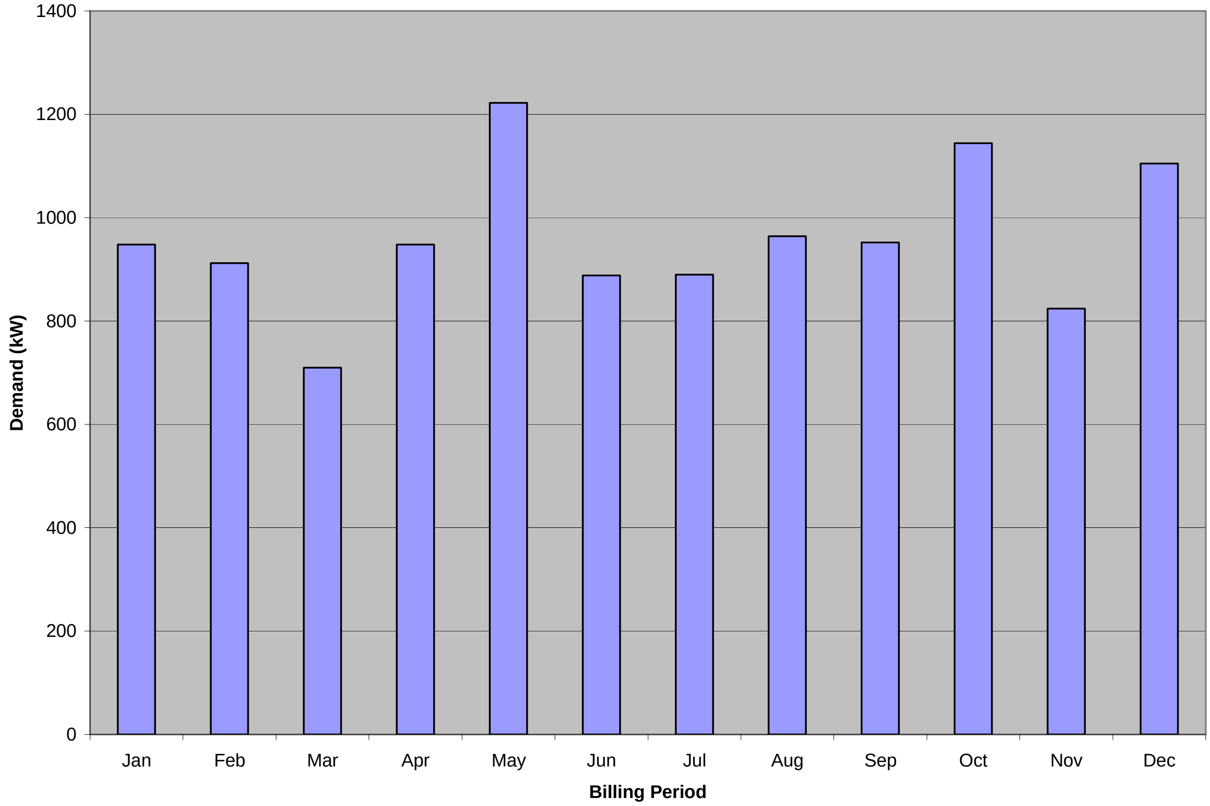


Figure 2: Annual Electrical Demand

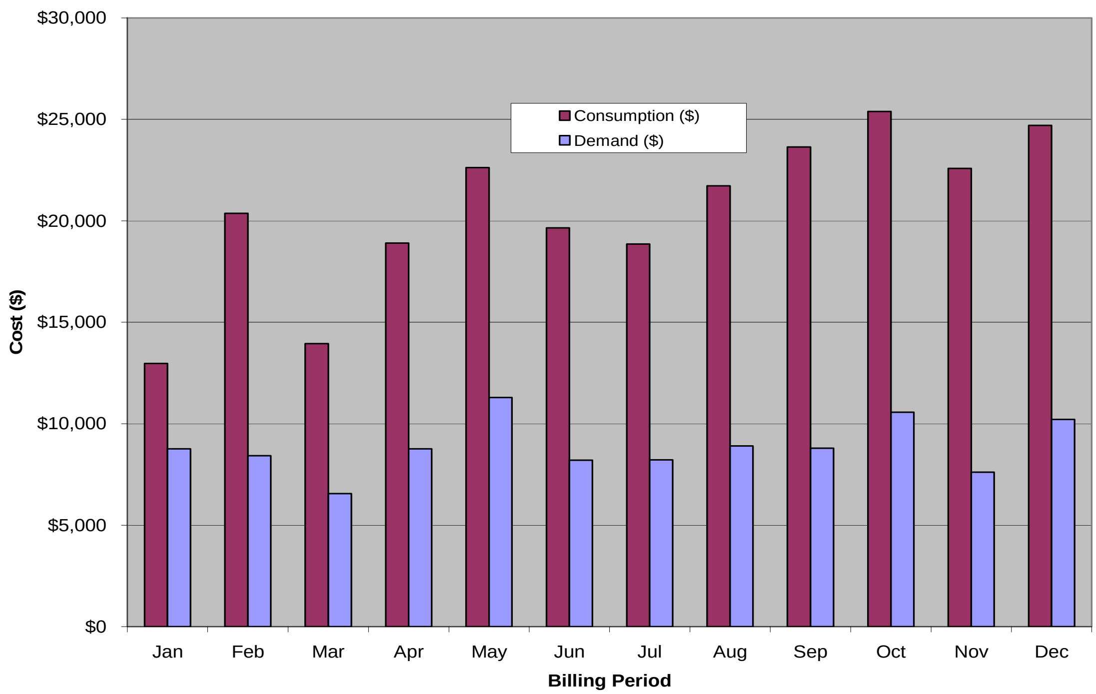


Figure 3: Annual Electrical Costs

Natural Gas

Gas consumption is measured in therms. The avoided cost of gas is calculated as the total annual cost divided by the amount of gas consumed.

$$\text{Avoided Cost (therms)} = \frac{\$36{,}593}{56{,}787\,therms} = \$0.6443904 / therms$$

In Figure 4 and Figure 5, notice the lower gas usage in the summer months than the winter months. This is due to a seasonal trend. In this case the baseline use is $2093 from May to October. Therefore the seasonal charges are $. In this manner, an energy conservation practice may be used to decrease the cost of natural gas (i.e., heat recovery). The same can be done with electricity for cooling in the summer months. The dashed line represents process gas use. Gas use in excess of this line is for space heating. We estimate that about 1/3 of gas use is for process heating and 2/3 is for space heating.

Table 2: Natural Gas Summary

DATE	Therms	Cost ($)
Jan	8,877	5,722
Feb	7,618	4,852
Mar	4,232	2,689
Apr	3,761	2,457
May	3,410	2,220
Jun	3,212	2,088
Jul	3,050	1,983
Aug	3,123	2,036
Sep	3,157	2,055
Oct	3,348	2,177
Nov	4,722	3,069
Dec	8,277	5,245
Totals	**56,787**	**36,593**

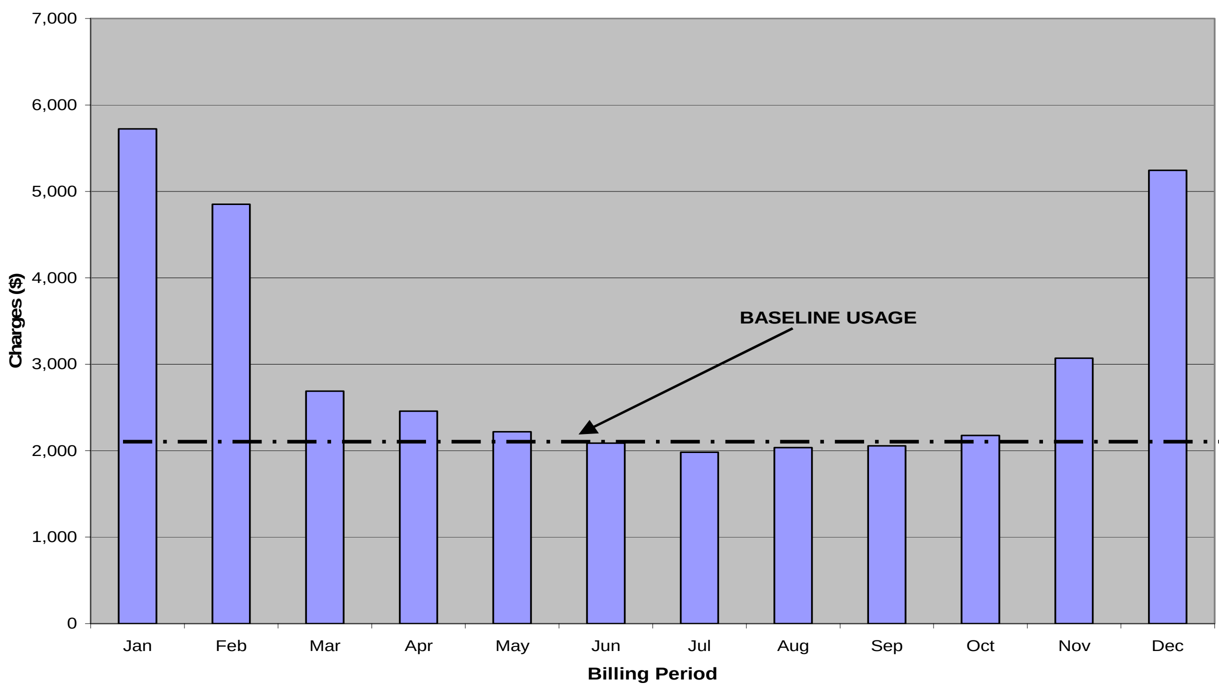


Figure 4: Natural Gas Costs

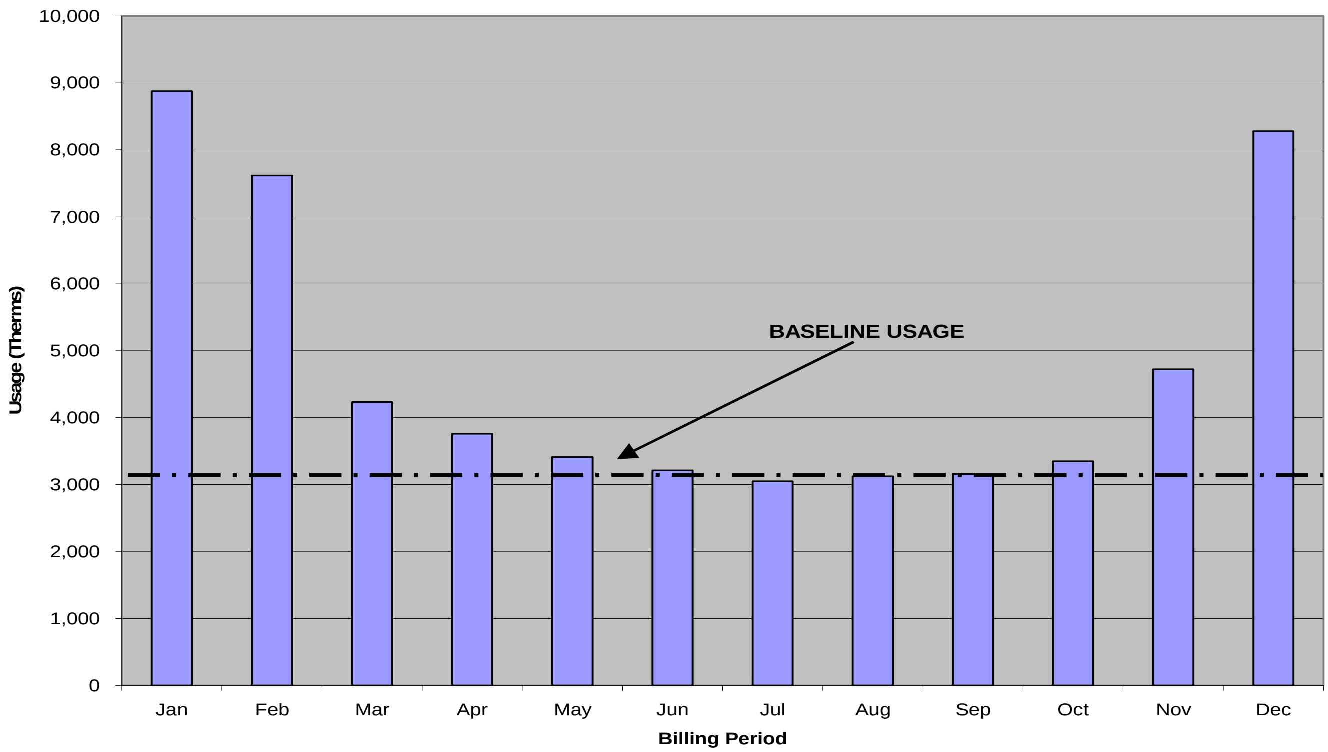


Figure 5: Annual Natural Gas Usage

#2 Fuel Oil

From the consumption summary in Table 3, the avoided cost of consumption and the avoided cost of demand can be calculated as follows:

Avoided Cost (gallon) =

$$\frac{\$10{,}600}{10{,}339\,gallons} = \$1.0252442\,/\,gallon$$

From Figure 7, #2 fuel oil seems to also have a seasonal trend due to space heating. Follow example from natural gas for seasonal trends in energy consumption.

Table 3: #2 Fuel Oil Consumption History

DATE	CONSUMPTION	Cost
Dec	499	$450
Jan	3,014	$3,536
Feb	1,120	$1,264
Mar	2,683	$2,512
Apr	1,070	$1,116
May	469	$418
Jun	0	$0
Jul	0	$0
Aug	141	$118
Sep	0	$0
Oct	522	$444
Nov	821	$742
TOTALS	**10,339**	**$10,600**

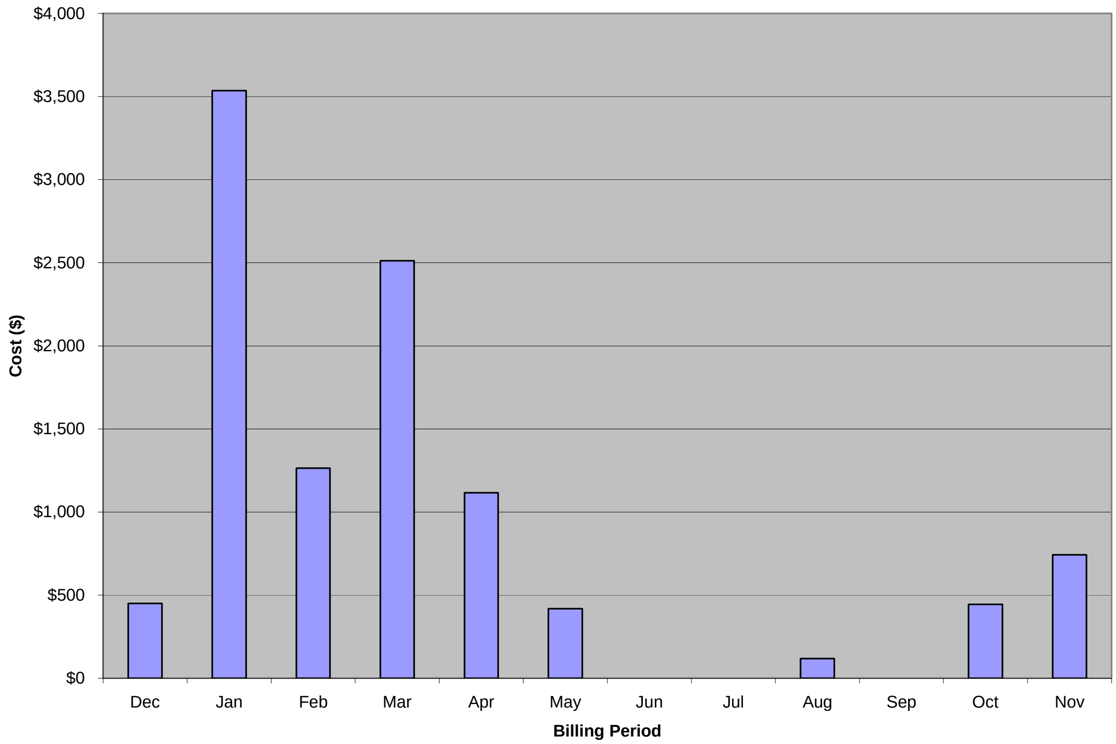


Figure 6: #2 Fuel Oil Annual Cost

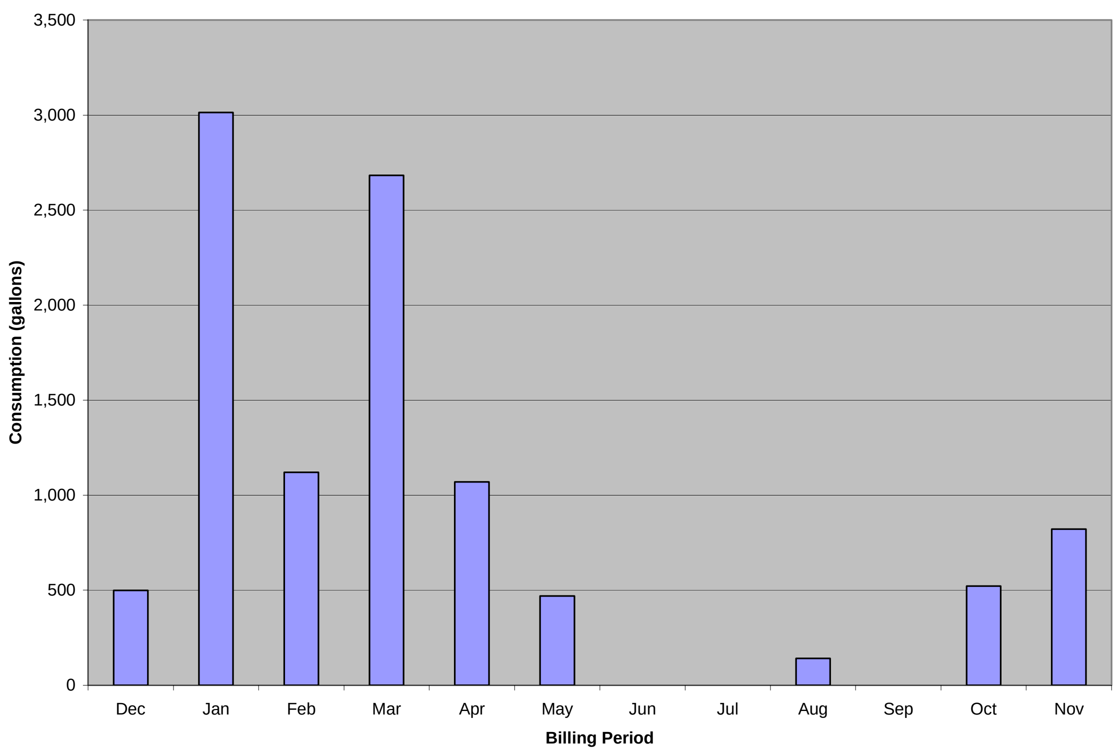


Figure 7: #2 Fuel Oil Annual Consumption

Utility Balance

From generating Figure 8 and Figure 9, it becomes apparent in this example that electricity is the most consumed energy source and the costliest to the example facility. In this manner, reducing electrical consumption should be examined.

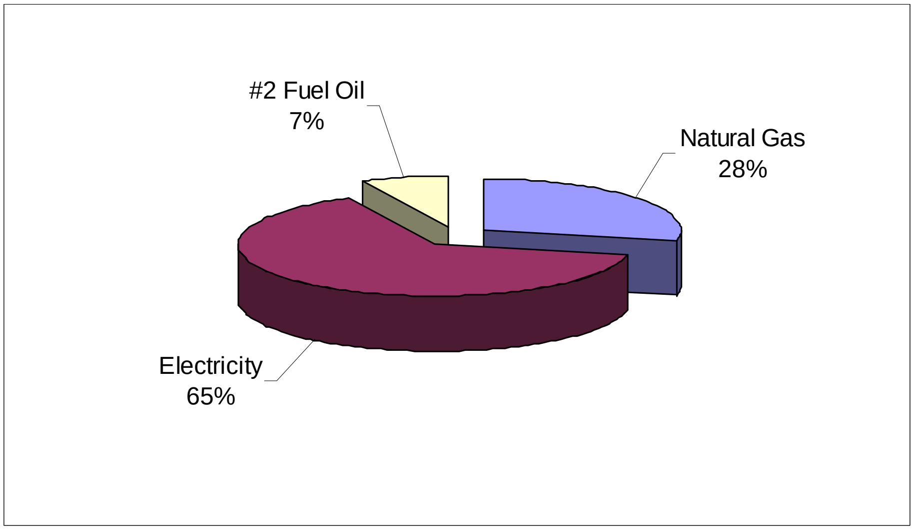


Figure 8: Utility Usage Comparison

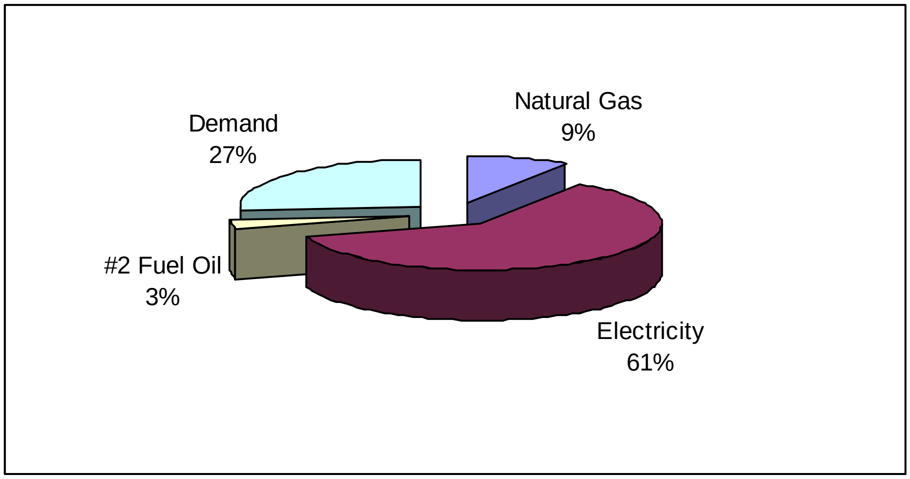


Figure 9: Utility Cost Comparison

1.5 Electric Power and Billing Review

Meters

Yes **No**

❑ ❑ Are there different kinds of meters?

What kinds of meters, i.e. what do they record?

____

____

❑ ❑ Is more than one meter employed in the plant (see electric bills)?

❑ ❑ Have you had discussions with electric utility billing agents taken place in last two years to determine appropriateness of rate scale used?

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?

Power Factor

❑ ❑ Does the bill show a power factor penalty?

❑ ❑ Does the bill have a consistent power factor value?

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.)

Step 2 - Major Energy Consuming Equipment

The next step is to identify energy consuming equipment in your facility. Follow the guide below to first identify your production equipment and then generate a list with the information necessary in calculations for potential energy savings opportunities. The following section will also provide you with information on determining where the majority of your energy is exhausted in your facility.

2.1 Lighting

For each location in your facility, follow these steps in order to analyze if your facility maybe be a candidate for energy saving opportunities in lighting.

- Using a light meter, measure the light levels at the working height level for each area. Suggested light levels are published by the Illuminating Engineering Society of North America.
- Count each lamp by type and location. Record the type, watts and hours of operation for each lamp. If the lamp has a ballast, record its ballast type.

Types of Electric Lighting

1. **Incandescent Lights**
    a. Work by heating a tungsten filament
    b. Low lighting and energy efficiency
    c. Start quickly, light does not fade with time
2. **Fluorescent Lights**
    a. Work by energizing Ar, Ar-Ne or Kr noble gases inside a tube
    b. Higher efficiency then incandescent lights, start quickly, light fades only slightly with time
    c. All fluorescent lights require ballasts, the ballast regulates voltage but uses some energy itself
3. **High Intensity Discharge Lights**
    a. Used for applications with higher ceilings, most common form of industrial lighting
    b. All HID lamps require a ballast and take a few minutes to start up.
    c. Types of common types of HID are
        i. **Mercury Vapor (MV)**
            1. Light output degrades continuously and significantly over lifetime
        ii. **Metal Halide**
            1. Produce white light with CRI of about 65
            2. Lighting efficiency of about 70
        iii. **High Pressure Sodium**
            1. Produce yellow light
            2. Light efficiency of about 95 Lumen/Watt

2.2 Air Compressors

For each air compressor, find:

- Type of air compressor
  - *Rotary Screw Compressors*: These compressors operate quietly and are reliable for 100% continuous duty. Rotaries are efficient fully loaded.
  - *Reciprocating*: Capable of providing high pressure along with variable loading. These are usually fount in many gas process applications. They are Noisy.
  - *Centrifugal*: Centrifugals are large multi-stage compressors that use a combination of rotational speed and tip speed to produce pressure differences.
- Operating air pressure
- Horsepower rating: The horsepower rating is usually found on the compressor's motor or is specified at the time of purchase.
- Operating hours: The hours per year the compressor is turned on.
- Load factor: The percent of work the compressor does.
- Efficiency: Specified at time of purchase.
- SCFM or CFM for each compressor.

The following list contains definitions of efficiencies you should be familiar with when analyzing their compressed air system.

> *Compression Efficiency: Ratio of theoretical power to power actually imparted to the air or gas delivered by the compressor.*
>
> *Isothermal efficiency: Ratio of the theoretical work (as calculated on a isothermal basis) to the actual work transferred to a gas during compression.*
>
> *Mechanical Efficiency: Ratio of power imparted to the air or gas to brake horsepower (bhp)*
>
> *Volumetric Efficiency: Ratio of actual capacity to piston displacement.*

2.3 Boilers

Boiler Considerations:

- Boiler Horsepower
- Boiler Efficiency
- Air/Fuel Ratio
- Fuel Source
- Operating Hours
- Length and Size of Steam Lines

Because not all plants nor there processes are identical, there are numerous types of boilers varying in shapes, sizes, and forms available. The most efficient type of boiler depends on the process and the environment of the facility. Boilers that use steam-water circulation include natural draft and forced draft. In natural draft there is no control of the air/fuel ratio, whereas in the forced draft, the air/fuel ratio is controlled by the blower. Yet both of these can only operate at sub critical pressure working with the circulation of fluid in evaporating tubes. Depending on the amount of pressure, the boiler will operate under natural circulation or forced circulation. For these types of boilers, one should be aware of high-temperature corrosion that may exist. Next, we have fuel or heat source boilers. The fuel can be natural gas, liquid petroleum fuel, coal, and wood. When choosing this type of boiler, one should consider the composition of the flue gas. In order for the boiler to work efficiently, the percentages of the oxygen, carbon dioxide and excess air must meet the optimum requirements. Also included in this category are waste-heat boilers which utilize the waste heat from any other industrial process as the heating source. Lastly there are boilers which function using the firing method. Similarly to the previous type, these boilers use fuel such as coal but with a lower slag viscosity and low iron content.

In order to determine the most efficient boiler for a particular industry, a few points must be taken into consideration. The ideal boiler should operate based on the Carnot cycle. This cycle includes two reversible isothermal and reversible adiabatic processes. The Carnot cycle is the most efficient cycle for all temperatures. The second thing that should be considered as previously mentioned is the flue gas composition and the stack temperature if the boiler is fuel heated. These values should be adjusted accordingly. The intake of air or the amount of fuel (air/fuel ratio) is significant in the efficiency of a boiler as well. The minimum air intake openings for a given input should be measured along with amount of fuel that is burned. Finally the sufficiency and/or the consistency of heat can also determine the effectiveness of the boiler.

2.4 Motors

Motors consume about 75% of all the electricity used by industry. Therefore, careful maintenance and attention must be paid to these.

Motor Considerations:

- Motor Horsepower
- Load Factor
    - *The load factor is the percentage use of equipment over a period of time.*
- Efficiency
    - *When solving for energy efficiency in electric motors, the motors efficiency needs to be considered. When one discusses efficiency in motors, they are stating what percentage of the electrical energy supplied to the motor is used. Some of the electrical energy is not utilized. It is transformed to heat energy which is why motors get hot. As motors age, the efficiency of the motor decreases. Motor efficiencies are available through the manufacturer in addition to motor performance curves. If the equipment is available, you can also measure the efficiency of the motor from IEEE Standard 112, Methods E/F.*

- Drive System (i.e. belt, VSD, etc.)
- Policy on Rewinding

Energy Policy ACT (EPACT):

EPACT became effective in October 1997 which requires general-purpose, T-frame, foot-mounted, continuous-rated, polyphase, squirrel-cage, induction motors of National Electrical Manufacturers Association (NEMA) designs A and B that are manufactured for sale in the United States rated 1 through 200 horsepower to meet minimum efficiency standards. EPACT also applies to 6 pole (1200 rpm), 4 pole (1800 rpm), and 2 pole (3600 rpm) open and enclosed motors.

EPACT does not apply to definite-purpose motors or special purpose motors. EPACT makes provision for the Secretary of Energy to expand the scope of motors covered to include motors less than 1 hp or greater than 200 hp. Although many manufacturers now sell premium motors that meet these efficiency standards, most currently available motors do not. EPACT should increase the availability of energy-efficient motors for many end-use applications. In addition to motor efficiency standards, EPACT requires testing procedures and labeling.

2.5 Furnaces

The various types of furnaces depend upon the type of fuel used. A typical furnace consists of a casing, heat exchangers, a combustion system, a forced draft blower, induced-draft blower, a circulating air blower, motor, air filter, and other small elements.

The most common type of furnace is one which uses natural gas as the fuel source. The difference between a natural gas furnace and a propane furnace is the pressure at which the gas is injected from the manifold to the burners. The pressure of the propane furnace is noticeably higher than that of the natural gas. Yet, it is possible to convert one furnace to the other given the required parts. Oil furnaces are the least common. What makes this type of furnace different from the others is that it is equipped with pressure atomizing burners and electric ignition lights the burner. The last type of furnaces is the electric powered. Unlike the other furnaces in which natural gas, oil, or propane fuels go through a combustion process to develop heat used in furnaces or burners, this burner requires a more complex means of producing heat.

When considering a natural gas furnace, one must look at the steady-state efficiency. This requires the one to measure the fuel input, flue loss, and the condensate loss. Utilization efficiency determines the exhausted latent and sensible heat, cyclic effects, infiltration, and pilot burner effect which must also be taken into account. Lastly, the annual fuel utilization must meet the standard values. For the propane furnaces, one of the most important details which must be addressed is the pressure and whether there is any leakage. The oil furnaces require more of an analysis of the oil flow rate to determine its efficiency. As for the electric furnaces, one should look at the amount of energy used with respect to how much heat was produced. It is also necessary to focus on the type of burner system the furnace utilizes. There are two basic types of burner systems. One involves the use of a proportional mixer. The amount of gas drawn is proportional to the air flow. Then there are nozzle mix burners. These burners use orifices to measure the pressure and adjust the proportions of the air and gas. When considering energy efficiency of the burner, one must look at the seals, the insulation, and the thermostats and other controls.

2.6 Chillers

Chiller Considerations:

- Load Factor
- Operating Hours
- Compressor Type
- Chiller Capacity
- Full-load Efficiency
- Temperature Readings
    - Water Supply
    - Ambient Air
    - Cooling Air Temperature

One option to consider with a chiller is the fuel source. Typically, chillers are electric but natural gas chillers are gaining in popularity due to the significant energy cost savings from the cheaper fuel. Therefore, consider the payback of a new gas chiller.

Another point to examine in your chiller system is the chillers load. If the chiller is operating below full load throughout the day, a variable speed drive may provide savings.

2.7 Cooling Towers

Cooling Tower Considerations:

- Type
- Number of Towers
- Number of cells in each tower
- Cooling Tower Motors
    - Horsepower
    - Speeds

There are two main types of cooling towers:

1. Direct contact (or, open cooling tower) - Uses spray filled towers.
2. Closed-circuit cooling tower.

A cooling tower system usually contains pumps fans and motors. When analyzing the cooling tower system, the system energy costs, demand charges and maintenance costs are usually the main considerations.

When considering the cooling tower system, the most important optimization of the system can be realized with the utilization of better controls that will decrease the fans operating time. For example variable frequency drives will decrease the speed of the motor and fan system depending on the system load and can lead to significant energy savings.

One simple way to keep the cooling tower operating at peak efficiency is proper maintenance since the efficiency can decrease sufficiently. In one case, the buildup in cooling water will decrease the heat transfer rate driving up the energy consumption and costs. Significant buildup will lead to additional increased maintenance costs and losses due to downtime.

Combined with chillers, cooling towers can improve the chiller efficiency leading to energy and monetary savings.

2.8 Creating a List

Now that the facilities major energy consuming equipment has been identified, organize your plants equipment in a list. Refer to Figure 10: Major Energy Consuming Equipment on the next page. The figure represents a list of equipment from a sample plant that will be used throughout this workbook.

Major Plant Energy Consuming Equipment

Major Plant Energy Consuming Equipment

ELECTRICITY

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)

NATURAL GAS

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

#2 FUEL OIL

Heating/Cooling/Ventilating Equipment

1-250 Boiler HP Fuel Oil fired boiler

Figure 10: Major Energy Consuming Equipment

Step 3 - Manufacturing Process

Opportunities for energy, waste minimization and productivity enhancements are recognized by following the manufacturing process from the point where the raw material enters the plant to the point of departure of the finished product; simultaneously allowing time for analysis of the physical condition of the facility as well as additional internal subsystems which supply energy to the process. Needless to say, not every manufacturing process has the same steps in production. Therefore, the process needs to be examined anew by every assessor. There are, however, general guidelines which when followed will yield a significant return. Below are conventional issues, important for self analysis, which are usually addressed by assessors.

3.1 The Manufacturing Process

3.11 Raw Material

How do raw materials enter the plant?

____

____

____

Yes **No**

❑ ❑ Are air seals used around truck loading doors?

❑ ❑ Are loading doors closed when not in use?

❑ ❑ Are radiant heaters installed in dock area?

Yes **No**

❑ ❑ If **Yes**, are the radiant heaters exposed to wind/convection currents which will significantly reduce their effectiveness?

❑ ❑ Are people being used efficiently at the dock area?

How are the materials distributed to the manufacturing operation?

____

____

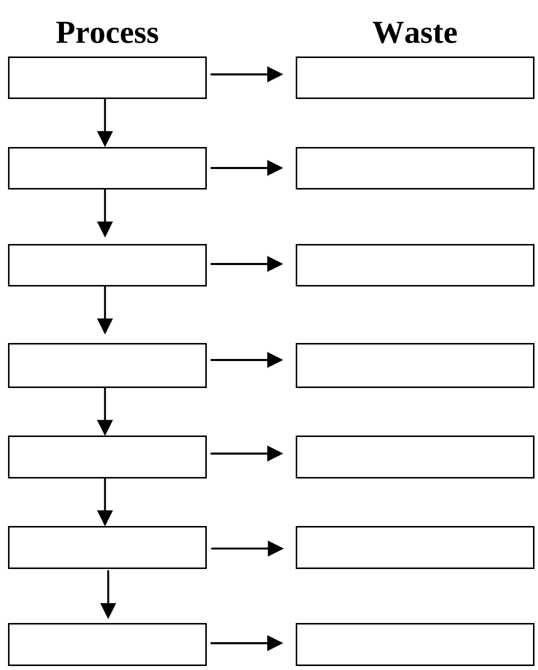
____

Are forklift trucks batteries operated or propane driven? ❑ Operated ❑ Propane

Yes	**No**	
❑	❑	If **battery** operated, are they being recharged during off peak hours (at night)?

Yes	**No**	
❑	❑	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?

3.12 The Manufacturing Process



What preprocessing is done to the raw material?

____

____

____

Yes	**No**	
❑	❑	Is there a mixer?
❑	❑	Is there a cutting operation?
❑	❑	Does the raw material flow through this process without problems?

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

____

____

____

Yes	**No**	
❑	❑	Is there a heating operation?
❑	❑	Is an oven/furnace involved?
❑	❑	Does it have a stack damper?

What is the fuel source? ___________

Yes	**No**	
❑	❑	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)?

❑Inside ❑ Outside

What is the surface temperature and surface area of the apparatus? ___________

Is the oven furnace flue gas used or just exhausted? ❑Flue ❑Exhausted

Are heated process fluids (or steam) used? ❑Process Fluids❑Steam

Yes	**No**	
❑	❑	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? ________________

Yes	**No**	
❑	❑	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, and/ or agitating liquids?

❑Cooling product ❑ Cooling Equipment ❑Agitating Liquid

Yes	**No**	
❑	❑	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?

Type of Motor	Quantity	HP	Operating Hours

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?

Yes **No**

❑ ❑ Are exhaust/supply fans shut down during non-working hours?

What is the temperature of the work space?

Yes **No**

❑ ❑ Is it air-conditioned?

What are the ceiling heights in the work area?

Yes **No**

❑ ❑ Are de-stratification fans used?

❑ ❑ Are set back timers used to control space temperature during non-working hours?

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? ____________________

Yes **No**

❑ ❑ Is rinse water reused?

What is the source of water (well, city water, recycled via cooling tower)?

____

Yes **No**

❑ ❑ Is counter current rinsing used to reduce waste water?

❑ ❑ Are there leaks present?

❑ ❑ 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?

Waste Produced	Process Origin	Quantity	Disposal	Disposal Cost	Associated Raw Material	Amount of Raw Material Purchased

3.13 Finished Product

What energy interactions are involved with packaging, warehousing, shipping, of the final product?

____

____

____

Yes **No**

❑ ❑ Are motion sensors or timers used to turn off lights when no one is present?

❑ ❑ Are motion sensors present on the walls of the warehouse?

If **Yes**, what kind?

____

What is the temperature at which the warehouse must be maintained? ________________

At what temperature **is** the warehouse maintained? ______________________________

Yes **No**

❑ ❑ Can a dry sprinkler system be employed to eliminate need of warehouse heating?

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

____

____

____

Yes	**No**	
❑	❑	Is there a lot of waste to the packaging process?

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

____

____

____

Yes	**No**	
❑	❑	Same questions about loading docks, radiant heaters, and efficient use of people which applied to raw materials entering the plant.

3.2 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.

3.21 Manufacturing Subsystems

Subsystem	Purpose	Quantity	Power (Btu/hr, kW, ton, or hp)	Operating Hours
Ovens				
Boilers				
Chillers				
Cooling Towers				
Air Compressors				
HVAC				

3.22 Boilers

Operation

Yes **No**

❑ ❑ 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 O_2 content and temperature of the flue gas of the boiler?

____

Yes **No**

❑ ❑ Is a feed-water 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?

3.23 Chillers

Operation

Yes **No**

❑ ❑ 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 instead of conditioned air?

3.24 Air Compressors

Operation

Yes **No**

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

❑ ❑ Are compressed air leaks present?

❑ ❑ Is there a maintenance program in place to eliminate compressed air leaks?

❑ ❑ 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?

<u>Yes</u> **<u>No</u>**

❑ ❑ 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.)?

Maintenance

<u>Yes</u> **<u>No</u>**

❑ ❑ 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?

3.25 Building and Grounds

Lighting

Location	Type of Lighting	Watts	Quantity	Operating Hours
Dock Area				
Warehouse				
Production Area				
Offices				

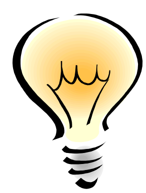
Yes **No**

❑ ❑ 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.

❑ ❑ Can you reduce exterior lighting to minimum safe level or use timers or photocells to turn off exterior lights when daylight permits?

Ventilation

Yes **No**

❑ ❑ Can you use minimum acceptable ventilation and minimize building exhausts.

3.26 Building Envelope

Yes **No**

❑ ❑ 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 - 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 of major plant energy consuming equipment. This list of recommendations was generated from the Industrial Assessment Center database as some of the most frequently recommended. Although each plant has a unique process, the IAC has found that most plants have similar process equipment (i.e., motors, air compressors, boilers, etc.). Through these similarities, generalizations on recommendations can be made.

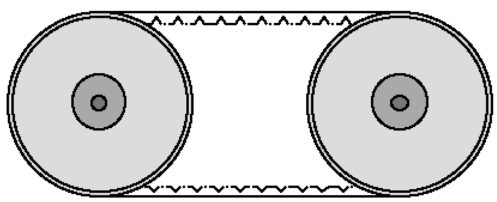
4.1 Replace Drive Belts on Large Motors with Energy Efficient Cog Belts

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 HP. The slitter and its take-up motors are driven through V-belts for an additional 60 HP, for a total of 212.5 HP.

Recommended Action

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 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.[3] To reduce the losses, we recommend replacing the V-belts with energy efficient cog belts. These belts slip less and can bend more easily than standard V-belts.



Anticipated Savings

Studies have shown that typical well-maintained industrial V-belts are about 92% efficient. Field tests of cog belts for both large and small drives show gains in efficiency from 2.0% to 5%. Conservative values for gains in efficiency range from 1% - 3%[4]. For our calculations, we will use (and recommend) a conservative value of 2.0%. We can calculate the yearly electric consumption savings using the following formulae:

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

$$\boxed{ES = PS \times H}$$

Where:

PS = the anticipated reduction in electric power in kW.

---

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

[4] "Building Energy Efficiency Into Fan Systems," Plant Engineering, October 2000.

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 212.5 HP based on the equipment list contained in the plant background section.
η	=	average efficiencies of the motors (0.85)
LF	=	average load factor (80%).
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)

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

$$PS = (212.5\ \text{HP}/0.85) \times (0.7459\ \text{kW/HP}) \times 0.80 \times 0.02 = 2.98\ \text{kW}$$
$$ES = 2.98\text{kW} \times 2{,}080\ \text{hrs/yr} = 6{,}206\ \text{kWh/yr}$$

And the annual cost savings would be the sum of the electric and demand cost savings(see Electricity Consumption Table, page 8):

$$\text{Consumption Savings} = (\$0.0634/\text{kWh}) \times (6{,}206\ \text{kWh/yr}) = \$393/\text{yr}$$
$$\text{Demand Savings} = \frac{\$9.24}{\text{kW-month}} \times 2.98\ \text{kW} \times 12\ \text{months/yr} = \$331/\text{yr}$$

Annual Cost Savings = $724

Implementation

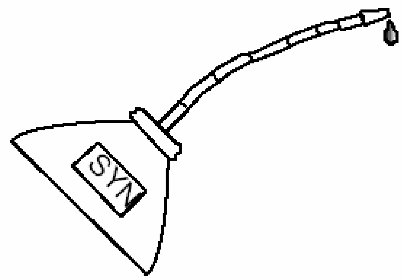
There is a premium cost associated with cog belts. However, this premium has been shown by many vendors to be offset by a longer lifetime of the belt. Since the premium is on the order of 20%-30%[3] there should be an equivalent increase in belt cost, but replacing belts more infrequently will not increase the overall expenditures. Therefore, the payback period is immediate if the belts are replaced with cog belts as needed.

ADDITIONAL CONSIDERATIONS

The amount of energy savings realized by replacing standard v-belts with cog belts has been argued to exist under certain conditions. Since cog belts reduce slippage, a gain in speed may occur. For many applications, such as when the system should be loaded between 80% and 110%, this is a benefit. But for the cases where there are no benefits for higher speeds, the pulley ratios must be readjusted[4]. Also a sheave at least one size smaller is recommended by many vendors.

[3] "Building Energy Efficiency Into Fan Systems," Plant Engineering, October 2000.
[4] "Case Study – Cog Belts," Michigan Manufacturer Technology Center, 1999. http://meds.mmtc.org/frame.asp?X=Cog%20Belts&Y=background.

4.2 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. Tests and experience have proven that synthetics can greatly extend drain intervals, provide better fuel economy, reduce engine wear and enable vehicles to operate with greater reliability. These benefits more than offset initial price differences. [5] [6]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. However, due to the lack of sufficient independent case studies, conservative savings of 3-7% are recommended.[7]

Anticipated Savings

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.

[5] "8myths about synthetic lubricants; even mechanic have been misled by these persistent myths." February, 2002. Ed Newman.
[6] Pirro, D.M., Wessol, A.A. "Lubrication Fundamentals" Second Edition, Revised and Expanded. New York, 2001.
[7] Nadel, Shepard, Greenberg, Katz, and Almeida. "Energy-Efficient Motor Systems: A Handbook on Technology, and Policy Opportunities." ACEEE. Washington, DC, 1992. pp.179.

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 7%)

Therefore:

PS = (347.5 HP) x (1-0.85) x (0.7459kW/HP) x 0.75 x 0.07 = 2.04 kW
ES = (2.92 kW) x (2,080 hrs/yr) = 4243 kWh/yr

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

Consumption Savings = ($0.0634/kWh) x (6,074 kWh/yr) = $269/yr

Demand Savings =$9.24kW-month x 2.04 kW x 12 months/yr = $226/yr

Total Annual Savings = $495

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.

Please note: **There are several classes of synthetic lubricants that 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[5] are available which can also provide information on acceptable lubricants.**

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

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

this recommendation is:

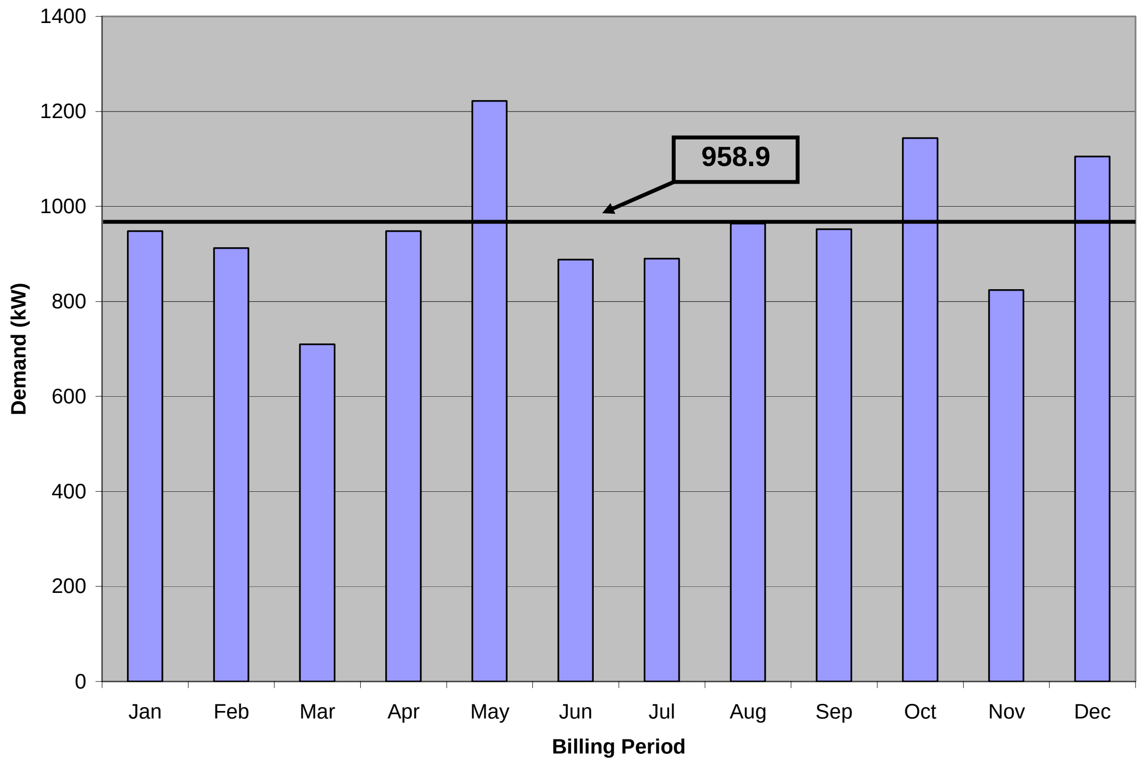
($800 implementation cost) / ($495/yr) = 1.6 year payback

Simple Payback = 1.6 years

4.3 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. Bylaw, 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 consecutive15 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).*

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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:

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

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 ways. 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:

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

Then the yearly total is,

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

Total Annual Savings = $15,948

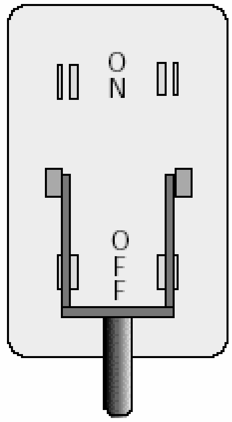
Implementation

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

4.4 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:

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

Where:

ES = the realized energy savings (kWh/yr)
HP = Total horsepower of idling motors
(0.7 x 207.5 HP = 145 HP)
CV = Conversion factor (0.7459 kW/HP)
HR = Annual hours of unnecessary idling

(2 hrs/day x 7 days/week x 52 weeks/yr = 728 hours/yr)

IL = Idle load horsepower consumption of motor (10%)[9]

η = the average efficiency of the motors (85%)

Therefore,

$$ES = \frac{145 \times 0.7459 \times 728 \times 0.10}{.85} = 9{,}263\ kWh/yr$$

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:

$$\boxed{\mathbf{CS = ES \times EC}}$$

Where:

EC = the electricity cost per kilowatt-hour ($/kWh)

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

[9] This is a conservatively low estimate that varies among motors due to the motors individual characteristics.

4.5 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 or on nights and weekends. This unnecessary heating represents lost energy and capital.

Recommended Action

Purchase and install 7-day set back timers in order to lower the plants thermostat settings 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 non-operational is represented by P_O:

$$Po = \left(\frac{Hours / weerk(non - operational)}{Total\_hours / week} \right) x100$$

$$Po = \left(\frac{24x7 - 8x5}{168} \right) x100$$

Po = 76%

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

$$\boxed{\Delta T = T_p - \{65 - (DDY/HD)\}}$$

Where:

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

Therefore the average temperature difference during the winter months is:

$$\Delta T = 70^oF - \{65\ ^oF - (5674\ ^oDays / 190\ Days\} = 35\ ^oF$$

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 °F during non-working hours, the energy savings which will result can be calculated with the following formula:

$$\boxed{ES = (RT/\Delta T) \times P_o \times AH}$$

Where,

- ES = Energy savings (kWh/yr)
- RT = Reduction in temperature during off hours (15 ^oF)
- ΔT = Average difference between inside and outside winter temperature.
- P_o = Percent of week plant is not operating (76%)
- AH = Annual consumption due to heating

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

Further, 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.

$$AH_{F.Oil} = 10{,}339 \text{ gallons/yr}$$

And

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

The annual cost savings would be,

$$CS = (\$0.644/\text{therm}) \times (6{,}028 \text{ therms/yr}) + (\$1.03/\text{gal}) \times (3{,}368 \text{ gal/yr})$$

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

The annual natural gas consumption due to 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 natural gas use associated with production is:

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

The amount of natural gas for heating ($AH_{N.G.}$) is then the difference between total usage and the production usage.

$$AH_{N.G.} = 56{,}787 \text{ therms/yr} - 38{,}280 \text{ therms/yr} = 18{,}507 \text{ therms/yr}$$

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 $50. We suggest the purchase of digital seven day set back timers which in many cases can be programmed from a PC and accessed via modem. The price for a single, multi-channel programmable timer will be approximately $100.

Installation of the units should be done by professional electricians and the time required for installation and programming is estimated to be 4 hours at $25/hr. Therefore a typical price for one unit including installation is about $200.

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

($200 implementation cost) / ($7,351/yr) = ~ 1 week (.25 months)

Simple Payback = .25 months

A Note About Weather Data

The weather data from this recommendation is available from various sources. TMY (Typical Meteorological Data) is available online at:

- *http://caes.rutgers.edu*
- *http://rredc.nrel.gov/solar/pubs/tmy2/*

You can also get data from your local airport and local chamber of commerce as well as the following weather sites on the world-wide web.

- *http://www.nws.noaa.gov/*
- *http://worldclimate.com*

4.6 Implement Periodic Inspection and Adjustment of Combustion in A Natural Gas Fired Boiler

Current Practice and Observations

During the audit, analysis on the exhaust from the boilers revealed excess oxygen levels which result in unnecessary energy consumption. This excess air was defining a low efficiency on the combustion process.

Recommended Action

Significant factors such as environmental considerations, cleanliness, quality of fuel, stack temperature, excess air in flue gas etc. contribute to the efficient combustion of fuels in boilers. It, therefore, becomes necessary to carefully monitor the performance of boilers and tune the air/fuel ratio quite often. We recommend 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.[10] Using a stack thermometer, personnel were able to determine that the 300 HP boiler gave a temperature of 400 ºF 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%; resulting in a possible fuel savings of 3%.[11]

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:

$$ES = EC \times EU \times FS$$

Where,

EC = % of Energy Consumed
EU = Energy Usage per year
FS = Percent possible Fuel Savings
ES = (1.0) x (56,787 therms) x (0.02) = 1,136 therms/yr

Cost Savings ($/yr) then result in:

CS = (ES) x (cost/therm) = 1,136 therms/yr x $0.644/therm = $732/yr

[10] Energy Management Handbook, Turner, Wayne, p. 111.
[11] http://www.oit.doe.gov/bestpractices/steam/pdfs/boiler.pdf.

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

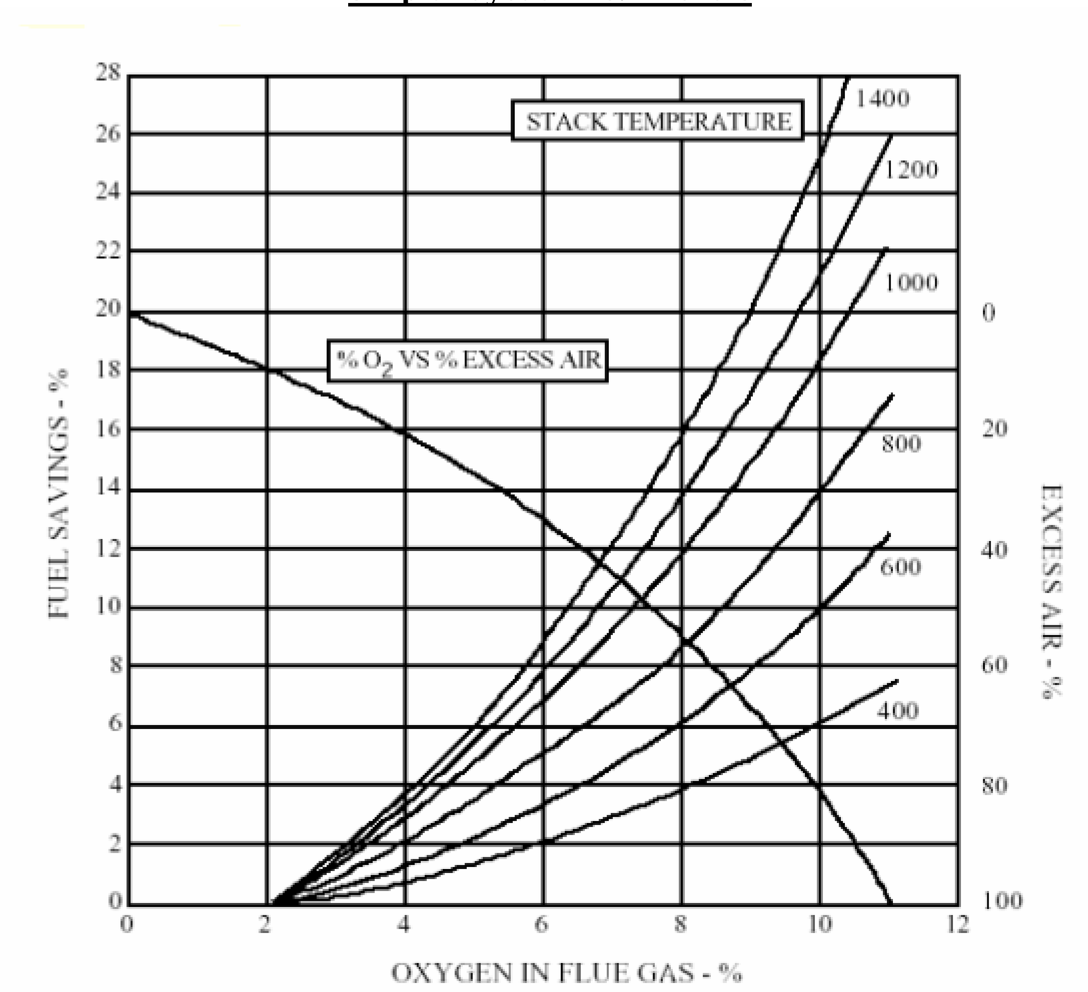


Figure 11: Natural Gas Fuel Savings Available by Reducing Excess Air to 10%[12]

Note: Fuel savings determined by these curves reflect the following approximation: The improvement in efficiency that can be realized by reducing excess air in radiant heaters, combination radiant heaters, convective heaters or boilers without air pre-heaters is 1.5

[12] *Energy Conservation Program Guide for Industry and Commerce,* Natural Bureau of Standards Handbook 114, September 1974, p.3-48.

times the apparent efficiency improvement from air reduction and decrease in flue gas.

4.7 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

Please refer to Recommendation 6.
Note: The use of oil in a boiler, rather than natural gas, proves to be more efficient in the combustion process. Government mandated efficiency of boilers range from 78% to 90%.[13] This should be taken into consideration when inspecting boilers.

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.[14] The boiler we measured had an O_2 level of 8.5 % and a stack temperature of 400 ºF. From 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.[15]

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

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[13] http://www.residential.carrier.com/faq/boilers.htm.
[14] Energy Management Handbook, Turner, Wayne, p. 111.
[15] http://www.oit.doe.gov/bestpractices/steam/pdfs/boiler.pdf.

<u>Simple Payback = 1.2 years</u>

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

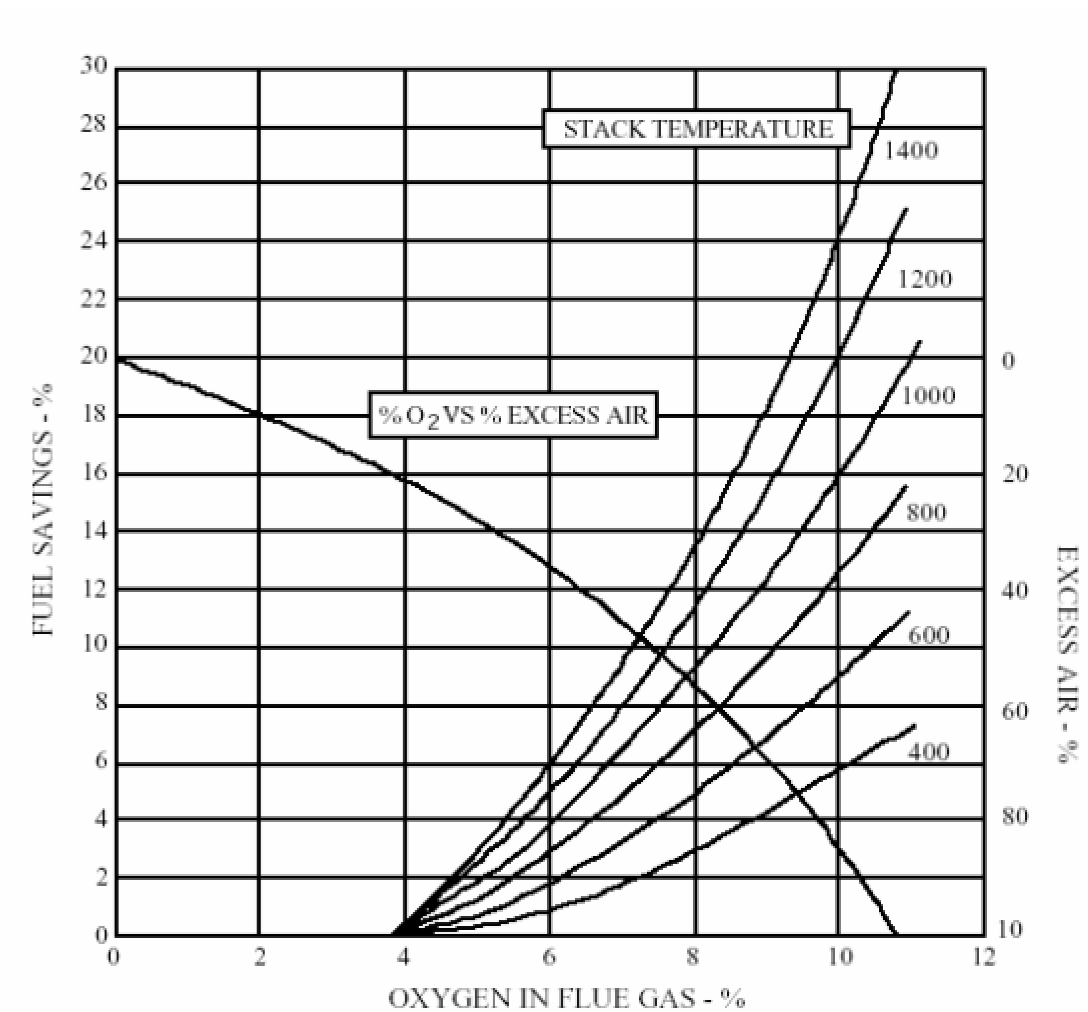

Figure 12: Liquid Petroleum Fuel Savings Available by Reducing Excess Air to 20%[16]

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

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

4.8 Preheat Boiler Combustion Air with Stack Waste Heat

Current Practice and Observations

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

Recommended Action

Stack exhaust losses are part of all fuel-fired processes. They increase with the exhaust temperature and the amount of excess air the exhaust contains. In order to reduce fuel consumption, we recommend installing 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. Recuperation has the advantage that it maximizes heat utilization inside the furnace, improves the furnace operations and reduces pollution caused by un-burnt fuel and high temperature gases. It is very economical, simple to install & operate, and is virtually maintenance free.[17]

Anticipated Savings

The energy bills over the year show an annual natural gas consumption of 56,787 therms. The boiler combustion efficiency was measured at 82%.[18]

A high quality recuperator could recover up to 60% of this waste heat.[19]

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, ratio of the quantity of heat absorbed by the working fluid to the available heat of fuel[20]
RC = Percent of energy recoverable by recuperator
ES = (56,787 therms) x (1 - 0.82) x (0.6) = 6,133 therms/yr

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[17] http://www.easternequip.com/info.htm.
[18] http://oee.nrcan.gc.ca/publications/infosource/pub/cipec/BoilersHeaters.cfm?PrintView=N&Text=N#2.
[19] http://www.seav.vic.gov.au/ftp/advice/business/info_sheets/HeatRecoveryInfo_0_a.pdf.
[20] Boilers, Evaporators, and Condensers, Kakac, Sadik, p. 398.

With a cost saving of,

Cost Saving = (6,133 therms/yr) x ($0.644/therm) = $3,950/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 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.

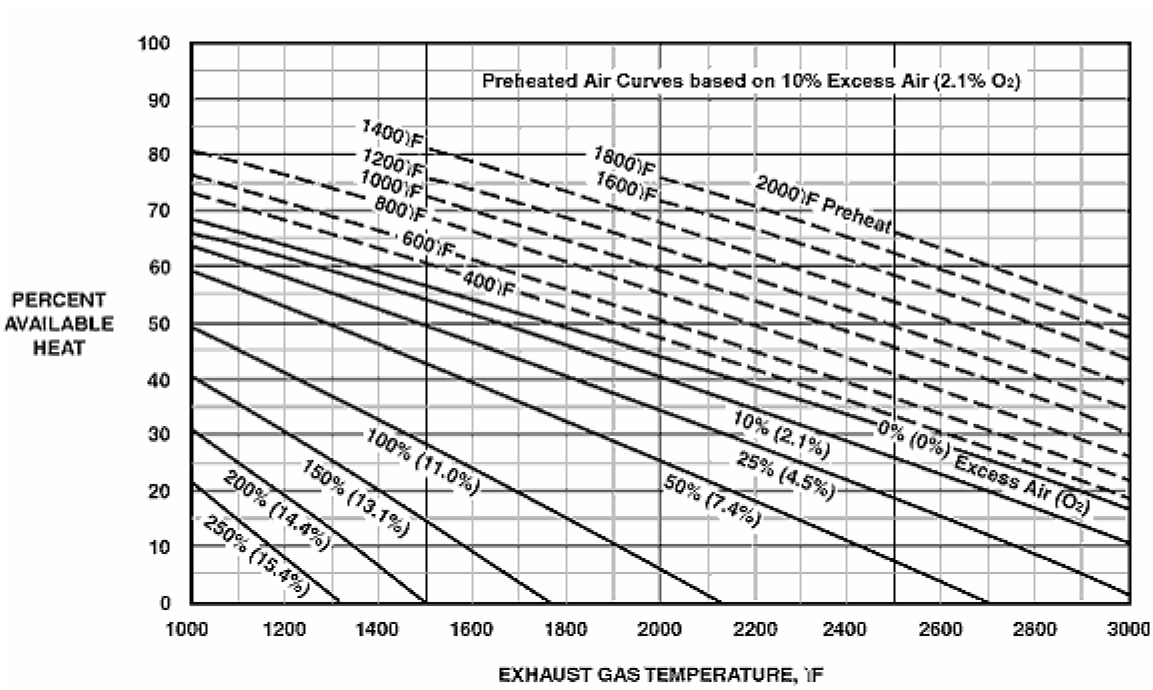


Figure 13: Effects of preheating combustion air on available heat.[21]

[21] http://www.oit.doe.gov/bestpractices/energymatters/fall2001_waste_heat.shtml.

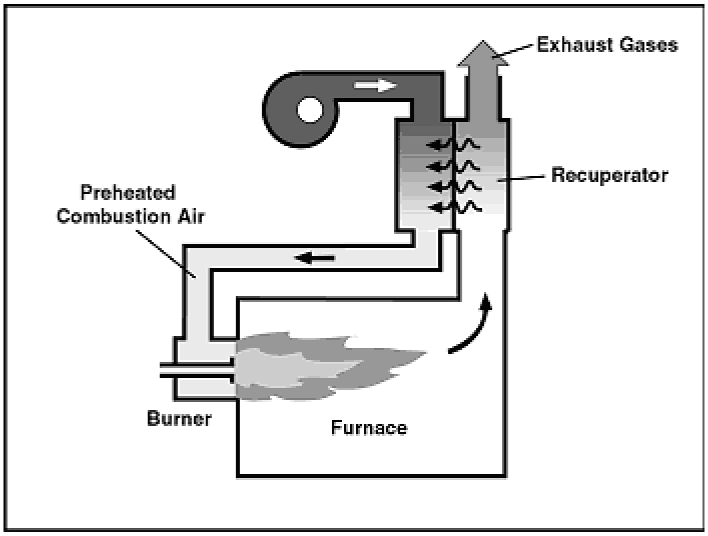


Figure 14: Recuperators transfer heat from outgoing gas to incoming combustion air without allowing streams to mix.[22]

Percent Fuel Savings Gained from Using Preheated Combustion Air

Furnace Exhaust Temperature, °F	Preheated Air Temperature, °F					
	600	800	1,000	1,200	1,400	1,600
1,000	13	18	–	–	–	–
1,200	14	19	23	–	–	–
1,400	15	20	24	28	–	–
1,600	17	22	26	30	34	–
1,800	18	24	28	33	37	40
2,000	20	26	31	35	39	43
2,200	23	29	34	39	43	47
2,400	26	32	38	43	47	51

Fuel: Natural gas at 10 percent excess air
Source: IHEA Combustion Technology Manual (see references)

Figure 15: Fuel Savings from Preheated Combustion Air[23]

[22] Ibid.
[23] http://www.oit.doe.gov/bestpractices/process_heat/pdfs/et_preheated.pdf.

4.9 Insulate Condensate Return Tank

Current Practice and Observations

It was observed that the condensate return tank for the 300 HP boilers 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.

While at the plant, the dimensions of the condensate return tank were measured and the surface area was found to be approximately 57 ft^2. The cost of Natural Gas for this facility, taken from the past years utility bills, is $9.54/ MMBtu.

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:

$$Q = h \times A \times (DT) \times H$$

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-ºF)[24]
A	=	the estimated surface area (57 sq.ft.)
DT	=	average temperature difference between the tank surface and ambient air (estimated to be 152 ºF- 77 ºF = 75 ºF)
H	=	Hours per year operation (8 hrs/day x 5 dys/wk x 51 wks/yr = 2,080 hrs/yr)

The temperature of the tank was measured at 152ºF and the temperature of the ambient air around the tank was measured at 77 ºF. Therefore,

$$DT = 152\ ºF - 77\ ºF = 75\ ºF$$

Thus,

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

[24] from National Bureau of Standards Handbook #121, Table 7.1

What is Combustion Efficiency?

The input minus stack (flue gas outlet) loss, divided by input, and generally ranges from 88 to 95% combustion efficiency. [25]

One can assume that sufficient insulation will achieve an efficiency of 98%[26] and accounting for the efficiency of the boiler (approximately 82%), the energy loss reduction will be:

$$0.98 \times 21.3 \times 10^6 \text{ BTU/yr} \times 0.82 = 17.1 \text{ MMBtu /yr}$$

Therefore, the total cost savings would be:

$$\text{Savings} = (\$9.54/\text{MMBtu}) \times (18.7 \text{ MMBtu/yr}) = \$163/\text{yr}$$

Total Annual Savings: $163

Implementation

To obtain permanent insulation, 2” Fiberglass insulation should be used. As specified for a boiler, the estimated cost of 2” Fiberglass insulation is $10.20[27] per square foot, parts and labor included.

The total cost of installing the insulation will be:

$$(\$10.20/\ ft^2) \times (57\ ft^2) = \$581.40$$

The payback period for this recommendation is:

$$(\$581) / (\$163/\ \text{year}) = 3.56 \text{ years}$$

Simple Payback = 3.56 years

[25] HVAC Systems and Equipment, ASHRAE HANDBOOK, I-P Edition, 2000. p. 27.5
[26] Efficiency value taken from North American Insulation Manufacturers Alliance, calculated using NAIMA 3E Plus Program www.naima.org/releases/burnsharbor.html
[27] Roth, Donald; Architects Contractors Engineers Guide to Construction Costs; BNI Building News, 2003.

4.10 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 wintertime.

Anticipated Savings

For this roof (built up roof, no suspended ceiling and no insulation) the average overall thermal conductance is approximately 0.25 BTU/hr-ft^2-°F[28]. The installation of R-11 fiberglass insulation to the underside will decrease the coefficient by 97% to 0.075 BTU/hr-ft^2-°F. The heating degree days were found to be 5,542 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):

$$ES = (A \times (R_{old} - R_{new}) \times HDD \times (H/\eta))/ C_1$$

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 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 (90%)
C_1	=	Conversion Constant, (1 x 10^6 Btu/ MMBtu)

ES = ((5,600 ft^2) x (0..25 – 0.075 Btu/hr-ft^2-°F) x (5,542 F-day/yr) x ((24 hrs/day) / 0.9))/ 10^6

= 174 MMBtu/yr

[28] 1989 ASHRAE Handbook Fundamental I-P Edition, American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc., 1989, pp. 22.2-22.3.

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 (0.14 MMBtu/gal)
CF	=	Cost of #2 fuel oil ($1.50/ gallon)

CS = ((174 MMBtu/yr) / (0.14 MMBtu/gal)) x ($1.60/ gallon)
= $1,280/ year

Total Annual Savings = $1,280

Implementation

The estimated cost of flexible 3 $^{5}/_{8}$" R 13 fiberglass insulation is:

Labor	$0.25/ sf
Material	$0.33/ sf
Total	$0.58/ sf

The total implementation cost is:

IC = (5,600 sf) x ($0.58/ sf) = $3,248.00

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

($3,248) / ($1,280/ year) = 0.117 years

Simple Payback = 2.5 yrs

Recommendation No. 11

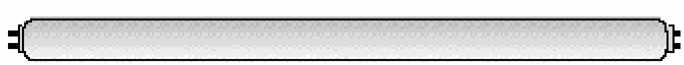
4.11 Replace Standard Fluorescent Lighting With Energy Efficient Tubes

Lighting Survey

Survey all areas of the plant and determine the existing lighting. Make sure to record the lamp and ballast wattages, the bulb diameters (in 1/8's of an inch) and lengths, and the number of lamps installed per fixture. If there are lamp-less ballasts, make note of whether the ballasts have been disconnected from the power source, as they will continue to draw power even without a lamp attached. You should also record the existing lighting levels in various areas of the plant using a light-meter, and determine the proper number of lamps required to achieve the desired lighting levels.

Lighting recommendations will fall into a number of easily recognizable categories

- *Replace current lights (whether incandescent or T-12 fluorescent) with high efficiency T-8 fluorescent.*
- *Disconnect superfluous lighting in order to reduce levels (measured in foot-candles) to at or above minimum recommended values.*
- *Disconnect or cap unutilized ballasts so as not to waste energy.*
- *Install occupancy sensors or 24-hr-7-day timers.*



Current Practice and Observations

The plant operates for one 8-hour shift per day, 5 days per week, and 51 weeks per year for a total operating time of 2,040 hours per year.

The plant is lit with approximately fifty 8 ft, 2x75W T-12 fluorescent fixtures. The illuminance level in the plant was measured as 50 footcandles at the time of the assessment. It was also noticed that the lights were left on even when the facility was not in use, and after speaking with plant personnel, we discovered that the lights are typically left on continuously between Monday and Friday, even though they are only needed during a single 8 shift per operating day.

Recommended Action

Energy-efficient lamps and electronic ballasts are recommended for all of the plant's lighting fixtures. Fluorescent lamps in 2-lamp and 4-lamp, 4-foot fixtures should be replaced with energy efficient T8 lamps that are rated at 32 watts each. Fluorescent lamps in 2-lamp, 8-foot fixtures should be replaced with energy-efficient lamps that are rated at 60 watts each.

	Lamp Type	Number of Fixtures	Lamps per fixture	Lamp Wattage	Ballast Type (Factor)	Connected Load (W)	Total Power (W)	Operating Hours	Annual Deman d
Existing	Standard, 75 Watt	50	2	75	Standard (1.15)	173	8,650	5,304	1,496.45
Proposed	Energy Efficient, 59 Watt	50	2	59	Standard (.9)	106	3,750	5,304	

Background

Higher efficiency lighting has been a focus for many lighting manufacturers in recent years. New technology has led to innovative lamps that have a longer rated life and require less wattage with a minimal reduction in overall lumen output. Essentially, the new lamps provide more efficient lighting by placing 3 phosphors within the tubes. They give more light per surface area, which has allowed the lamps to be reduced in diameter from 1.5 inches (T-12 size) to 1 inch (T-8 size).

Most of these lamps were designed as direct replacements for the old inefficient lamps, so the existing fixtures can be used in most cases. However, due to the lower power requirements of the new lamps, existing fixtures will have to be retrofitted with low-power ballasts.

The improved ballasts use integrated circuit technology to do the job formerly done by copper wire wound around an iron core. This reduces the energy lost as heat generation and has allowed the lamps to be driven at a high frequency (they operate at 20,000 Hz and above) which increases the time-averaged value of the light output and greatly reduces the chance of flicker or the strobe effect of the 60 Hz ballasts they replace. Electronic ballasts are available from a number of manufacturers with various models that apply to most fluorescent fixtures and applications.

It is, however, important to purchase ballasts that are ideally suited for their intended use and environment. For example, Rapid Start electronic ballasts start quickly (< 1 sec) and operate for approximately 15,000 switch cycles before failure. They are ideal for applications requiring several lamp starts per day. Programmed Start (Pre-heat) ballasts more accurately control the start temperature of the electrodes and thus take longer to ignite, but they typically operate for up to 50,000 switch cycles prior to failure. Programmed Start ballasts are ideal for applications where frequent starts are expected, i.e. areas with occupancy sensors. The final method of fluorescent lamp "ignition" is Instant Start, which eliminates electrode heating to maximize energy savings. Instant

Start ballasts and lamps are ideal in situations where very long "burn" periods are expected, as their typical life is around 10,000 switch cycles.[29]

A note about ballast factors

The term "ballast factor" is one that is oft misrepresented by industrial energy auditors. The ballast factor of a specific Ballast-Lamp system is defined as a factor of its light lumen output comparable to the light output of an ideal, laboratory reference ballast. In other words, if a ballast-lamp system is expected to emit 95% of the luminance emitted from the laboratory reference system, than its ballast factor is .95.

Because energy consumption is closely correlated to light output in fluorescent lamps, auditors often times use the ballast factor as an indicator of the actual power consumption.

As noted in by Durmus Kaya in Energy Engineering1, "depending on the type of ballast used, the total fixture wattage can actually be less than the sum of its parts." This is not to imply that energy efficient ballast violates Conservation of Energy, but rather that it can reduce a lamps power draw to below the rated power.

Anticipated Savings

If all fluorescent lamps at the facility were replaced with high efficiency lamps and ballasts, the anticipated savings would be calculated as follows.

$$CEU = \frac{Hc \times NFc \times (LPF \times (LP \times BFc))}{C}$$

$$CD = \frac{NFc \times (LPF \times (LP \times BFc))}{C}$$

Where,

CEU = Current Energy Usage (kWh/yr)
CD = Current Demand (kW)
Hc = Hours lights are currently in use. (Hrs/yr)
NFc = Number of Fixtures currently installed (Lamps)
LPF = Lamps per fixture (2 lamps)
LP = Power usage of Lamp. (Watts/Lamp)
BFc= Ballast Factor (1.15)
C = conversion factor. (1000 W/kW)

And,

$$H_C = [(51 \text{ weeks/year}) \text{ x } ((4\text{x}24) + 8) \text{ hrs/week}] = 5304 \text{ hrs/year}$$

[29] Advance Transformer Company: www.advancetransformer.com

Current electrical demand due to lighting is,

$$CD = \frac{50 \times (2 \times (75 \times 1.15))}{1000}$$
$$CD = 8.625 \text{ kW}$$

Corresponding to an annual energy usage of,

$$CEU = \frac{5{,}304 \times 50 \times (2 \times (75 \times 1.15))}{1000}$$

$$CEU = 53{,}820 \text{ kWh/yr}$$

The same equations can be utilized to determine the demand and consumption anticipated after implementation of the proposed lighting system.

Proposed electrical demand is,

$$PD = \frac{50 \times (2 \times (59 \times .9))}{1000}$$

$$PD = 5.31 \text{ kW}$$

Corresponding to an annual energy usage of,

$$PEU = \frac{5{,}304 \times 50 \times (2 \times (59 \times .9))}{1000}$$

$$PEU = 28{,}164.2 \text{ kWh/yr}$$

The total annual electrical savings are contributed by both reductions in demand and in consumption.

TES = [(CD – PD) x MC_D x 12] + (CEU – PEU) x MC_C

Where,

TES = Total Electrical Savings
MC_D = Marginal Cost of Demand ($/ kW)
MC_C = Marginal Cost of Consumption ($.0634 / kWh)

TES = (8.625 kW – 5.31 kW) x 12 x $9.24/kW + (53820 kWh – 28164.2 kWh) x $.0634/kWh

TES = $367.57 + $1626.59

TES = $1994.16

Implementation Cost

Implementation of this recommendation requires the purchase and installation of high-efficiency fluorescent lamps and ballasts. All prices are according to the McMaster-Carr supply catalog[30], and an assumed labor cost of $20.00 per hour.

Item	Cost	Quantity	Total
Instant Start, F96-T8 Bulb	$7.30 / bulb	50	$365.00
Instant Start, F96T8 ballast	$41.96 / unit	25	$1049.00
Labor for system installation.	$20 / hour	16 ⅔ hrs (20 min. to remove/install each fixture).	$333.33
			$1747.33

Simple Payback

Simple Payback = Implementation Cost / Annual Savings
= $1747.33 / $1994.16 = .876 years ≈ 10.5 months.

Useful Information

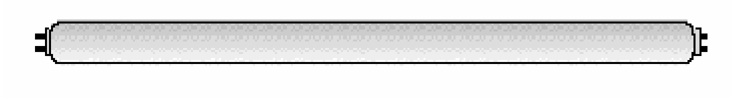
Average Maintained Illumination (Footcandles) = (Total Lamps x Lumens/Lamp x Coefficient of Utilization x Light Loss Factor) ÷ Area in Square Feet

Required Light Output/Fixture (Lumens) = (Maintained Illumination in Footcandles x Area in Square Feet) ÷ (Number of Fixtures x Coefficient of Utilization x Ballast Factor x Light Loss Factor)

Simple Payback on an Investment (Years) = Net Installation Cost ($) ÷ Annual Energy Savings ($)

[30] McMaster-Carr Supply Company. Catalog 108, pg 588 – 594.

4.12 Reduce Illuminance To Minimum Required Levels Via Delamping



Recommended Action

Reduce the lighting levels to the minimum suggested values. The recommended luminance for a warehouse of this type is 25, as suggested by the Illuminating Engineering Society. We recommend reducing the number of fixtures by 50%, or to a total of 25 fixtures. This will effectively reduce the light output to 60%-80% of the original levels (or to between 30 and 40 lumens considering the original measured value of 50 lumens).

Anticipated Savings

Refer to the calculations from Recommendation #11. The Current Energy Usage and Current Demand are the same.

Current electrical demand due to lighting is,

$$CD = \frac{50 \times (2 \times (75 \times 1.15))}{1000}$$

$$CD = 8.625 \text{ kW}$$

Corresponding to an annual energy usage of,

$$CEU = \frac{5{,}304 \times 50 \times (2 \times (75 \times 1.15))}{1000}$$

$$CEU = 53{,}820 \text{ kWh/yr}$$

These same equations can be utilized to determine the demand and consumption anticipated after de-lamping.

Proposed electrical demand is,

$$PD = \frac{25 \times (2 \times (75 \times 1.15))}{1000}$$

$$PD = 4.313 \text{ kW}$$

Corresponding to an annual energy usage of,

$$PEU = \frac{5{,}304 \times 25 \times (2 \times (75 \times 1.15))}{1000}$$

$$PEU = 22{,}874 \text{ kWh/yr}$$

The total annual electrical savings are contributed by both reductions in demand and in consumption.

$$\text{TES} = [(\text{CD} - \text{PD}) \text{ x } \text{MC}_\text{D} \text{ x } 12] + (\text{CEU} - \text{PEU}) \text{ x } \text{MC}_\text{C}$$

Where,

TES = Total Electrical Savings
MC_D = Marginal Cost of Demand ($/ kW)
MC_C = Marginal Cost of Consumption ($.0634 / kWh)

TES = (8.625 kW – 4.313 kW) x 12 x $9.24/kW + (53,820 kWh – 22,874 kWh) x $.0634/kWh

TES = $478+ $1961

TES = $2,439

The labor costs associated with de-lamping the 25 extraneous fixtures are due to labor costs. Assuming $20/hr for labor and ½ hour to delamp each fixture, total implementation cost will be about $250. Therefore,

Simple Payback = $250/$2,439 = 2 months

4.13 Install Timers On Lighting System

Recommended Action

Install timers or occupancy sensors in order to ensure that the warehouse lights only operate during periods of activity.

Anticipated Savings

The following calculations are meant to determine the savings seen by your facility in the event that you reduce the operating hours of your lighting system. By installing a timer, you will be able ton ensure that the lights only operate during the daily 8 hour production shift.

$$CEU = \frac{Hc \times NFc \times (LPF \times (LP \times BFc))}{C}$$

$$CD = \frac{NFc \times (LPF \times (LP \times BFc))}{C}$$

Where,

CEU = Current Energy Usage (kWh/yr)
CD = Current Demand (kW)
Hc = Hours lights are currently in use. (hrs/yr)
NFc = Number of Fixtures currently installed (Lamps)
LPF = Lamps per fixture (2 lamps)
LP = Power usage of Lamp. (Watts/Lamp)
BFc= Ballast Factor (1.15)
C = conversion factor. (1000 W/kW)

And,

H_C = [(51 weeks/year) x ((4x24) + 8) hrs/week] = 5304 hrs/year

Corresponding to an annual energy usage of,

$$CEU = \frac{5{,}304 \times 50 \times (2 \times (75 \times 1.15))}{1000}$$

$$CEU = 53{,}820 \text{ kWh/yr}$$

These same equations can be utilized to determine the demand and consumption anticipated after the installation of a timing system.

But annual energy usage will decrease in conjunction with the decreased operating hours,

$$PEU = \frac{2{,}040 \times 50 \times (2 \times (75 \times 1.15))}{1000}$$

$$PEU = 17{,}595 \text{ kWh/yr}$$

The total annual electrical savings are contributed by a reduction in the annual electrical consumption.

$$\text{TES} = (\text{CEU} - \text{PEU}) \text{ x } \text{MC}_\text{C}$$

Where,

TES = Total Electrical Savings
MC_D = Marginal Cost of Demand ($/ kW)
MC_C = Marginal Cost of Consumption ($.0634 / kWh)

TES = (53,820 kWh – 17,595 kWh) x $.0634/kWh

TES = $2,297

Implementation Cost

According to the manufacturers, lighting timers for industrial applications can cost between $15 and $45.00 per unit. Assuming that this facility will require a total of 5 timers, one for each lighting sector, and that the effective cost will be the average of the range, the cost of purchasing hardware will be $150.00. Additional cost will be attributed to labor, which at $20.00/hour and 30 minutes to install each unit, will total $50.00.

Simple Payback = Implementation Cost / Annual Savings

= $200.00 / $2,297 ≈ 1 month

4.14 Redirect Air Compressor Intake to Use Outside Air

Current Practice and Observation:

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 °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.

> **Important Note**
>
> For a screw type compressor, it has been recommended not to use outside air. However, similar savings can be seen if the air intakes are redirected to a cooler location inside the plant.

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:

Where,

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

Assuming an average indoor intake temperature of 90°F and determining that the average outdoor temperature was 51°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:

$$CS = HP \times (1 / \eta) \times LF \times H \times WHP \times CF \times WR$$

Where,

CS	=	the anticipated cost savings ($/yr)
HP	=	the horsepower for the operating compressor (60 HP)
η	=	the efficiency of the compressor motor (85%)[31]
LF	=	average partial load factor (estimated here to be 0.6)
H	=	annual operating time (8 hrs/day) x (5 days/wk) x (52 wks/yr) =2,080 hrs/yr
WHP	=	Conversion factor (.7459 kW/HP)
CF	=	Consumption cost Factor ($.0634/kWH)

Therefore,

CS = 60 HP0.85 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**

[31] Based on manufactures supplied data, corrected to site conditions.

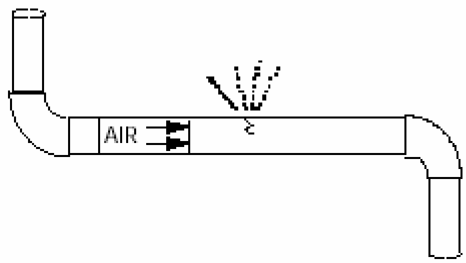
Payback Period:

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

4.15 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)[32]
A	=	area of the hole [in2]
P	=	pressure in the line at the hole [psia]
T	=	temperature of the air in the line [°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 x 0.65 x (0.04909 in^2) x (114.7 psia) x $(75 + 460)^{-0.5}$ = 303 lbm/hr
$m_{1/32}$ = 1915.2 x 0.65 x (0.00077 in^2) x (114.7 psia) x $(75 + 460)^{-0.5}$ = 4.75 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°F.

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

$$PR = 0.0687 \times (1/\eta) \times (T1+460) \times \ln (p2p1)$$

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

$$PR = 0.0687 \times (10.65) \times (550) \times \ln (124.714.7) = 124.3 \text{ BTU/lbm}$$

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

[32] Usually between 0.6 and 0.7.

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 kWhlbm) x (317.25 lbm/hr) x (2,080 hrs/yr) x .6 x ($0.0634/kWh
= $914/yr

<u>Total Annual Cost = $914</u>

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, and 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

<u>Simple Payback = 0.4 months</u>

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.

4.16 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:

$$CS = HP / \eta \times LF \times H \times S \times WHP \times CF$$

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)

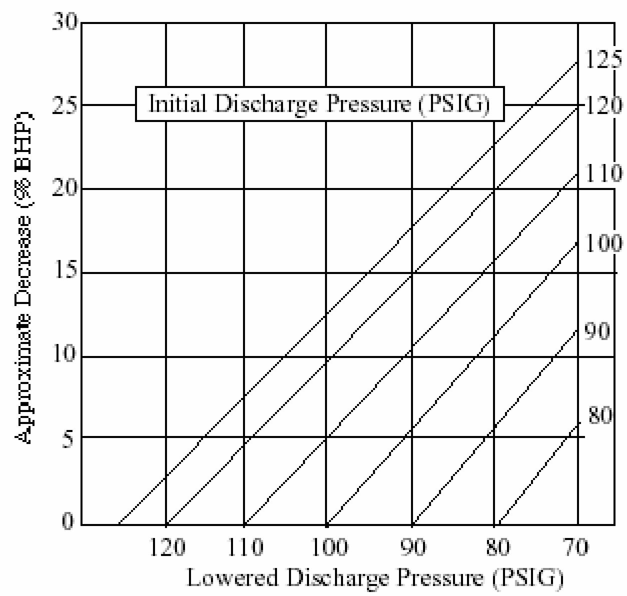
Therefore,

CS = 60 HP0.85 x (0.6) x (2,080 hr/yr) x (.075) x (0.7459 kW/HP) x $.0634/kWH)
= $316/yr

Total Annual Savings = $316

Implementation

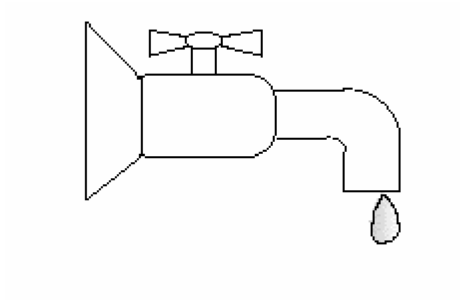
In order to lower the discharge pressure on the compressor, a simple adjustment of the pressure control may be all that is necessary. However, the manufacturer should be consulted in case any additional modifications need to be made or to inform you of any particular limitations inherent in your model.



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

<u>Simple Payback = immediate</u>

4.17 Minimize Waste of Tap Water



Current Practices and Observation

It was noted that tap water is used to cool the 60 horsepower air compressor by letting it flow freely through the compressor coils. The temperature of the cooling water at the inlet was 65°F and the exit water was 85°F. The compressor oil temperature was found to be 90°F. The unrestricted flow results in a significant amount of wastewater.

Recommended Action

Reduce flow of tap water used for cooling by installing a gate valve and/ or recirculating water through a cooling tower.

The air compressor specifications indicate that the operating temperature of the oil should be maintained at approximately 150 °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 (n gallons per hour) for a 20°F temperature rise is given by the equation below.

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

Where,

GPH	=	gallons per hour
f	=	the fraction of compressor power lost to water cooling (0.2)
HP	=	horsepower, 60
CF	=	conversion factor (2,545 BTU/HP-hr)
GPP	=	gallons of water per pound mass (0.12 gallons/lbm)
CP	=	specific heat of water (1BTU/lbm-°F)
Δ	=	temperature rise of water through the compressor (20°F)

It is assumed that letting the water temperature to rise to 145°F, the compressor oil temperature will be maintained at 150°F. The flow rate can be reduced by yielding the flow rate as and the cost savings as:

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

Where,

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 hrs/day) x (5 days/week) x (52 weeks/yr) = 2,080 hrs/yr
CF	=	Cost of tap water consumption ($18/ 1000 gallons)

Thus, the cost with the gate valve flow restrictor:

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

Cooling tower makeup water is estimated to be no more then 10 gallons per hour for this size unit, thus 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

According to several manufacturers, the average cost of a gate valve is $20.00. Also, it can be installed by maintenance personnel. Based on the implementation cost and the reduction in tap water use, the simple payback period is:

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

The implementation cost with a cooling tower is considerably greater. It is estimated to be $7,500.00 for a 5 ton unit, which would be adequate for this sized application. Based on this implementation cost and reduction in cost of wasted tap water, the simple payback period for this recommendation is:

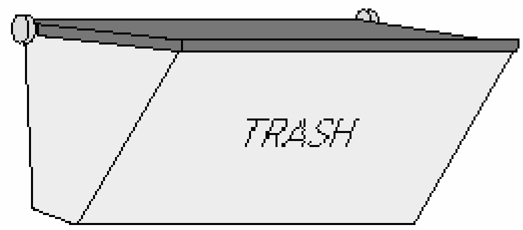
($7,500.00 implementation cost)/ ($6,477.00/ yr) = 1.2 years

Simple Payback = 1.2 years

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

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.

4.18 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:

$$\boxed{\begin{array}{c} \mathbf{SWRV = PC \times CTV} \\ \\ \mathbf{SWS = SWRV \times UCD} \end{array}}$$

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

Therefore,

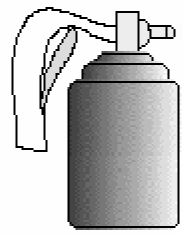
$$SWRV = 0.15 \times 4{,}000\ yd^3/yr = 600\ yd^3/yr$$
$$SWS = 600\ yd^3/yr \times 2\ \$/yd^3 = \$1{,}200/yr$$

<u>Implementation</u>

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.

<u>Simple Payback = immediate</u>

4.19 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 land 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 (over sprayed 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
T_{ec}	=	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
SWDc = Solid waste disposal cost with conventional spray gun, \$/yr
SWDp = Solid waste disposal cost with HVLP spray gun, \$/yr

Therefore,

OSSc = 340 gal/yr - 136 gal/yr = 204 gal/yr
OSSp = 247 gal/yr - 136 gal/yr = 111 gal/yr
SWGc = 5 x 204 gal/yr = 1,020 gal/yr
SWGp = 5 x 111 gal/yr = 555 gal/yr
SWDc = 1,020 gal/yr x \$140/55 gal = \$2,596/yr
SWDp = 555 gal/yr x\$140/55 gal = \$1,413/yr
SWR = 1,020 gal/yr - 555 gal/yr = 465 gal/yr
WCS = \$2,596/yr - \$1,413/yr = \$1,183/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 Mssion Reduction (SAER) is thus:

SAER = PS x 2.83 lbm/gal = 93 gal/yr x 2.83 lbm/gal = 263 lbm/yr

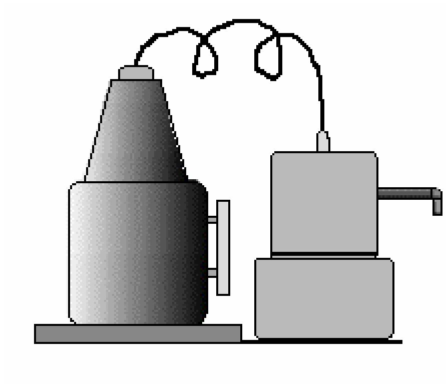
Implementation

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

Payback =IC/CS =\$1000/\$3043/yr = 0.33 years = 4 months

Simple Payback = 4 months

4.20 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 (= 6.715 lbm/ gal) is approximately \$3.20 per gallon (\$0.46/ pound, \$3.09/ 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:

$$NB = VOL / GB$$

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

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

Using the manufacturer's 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:

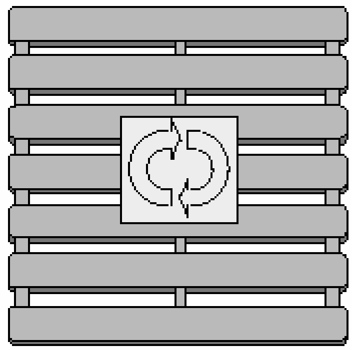
$$IC = \$6{,}700 + \$200 + \$300 = \$7{,}200$$

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

($7200 implementation cost) / $1958/yr savings = 3.7 years.

<u>Simple Payback = 3.7 years</u>

4.21 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.

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

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

$$\text{Annual Savings} = \$2{,}100/\text{yr} + \$1{,}875/\text{yr} = \$3{,}975/\text{yr}$$

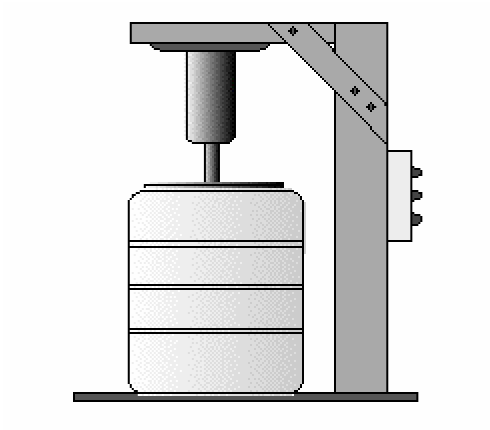
Total Annual Savings = $3,975/year

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

4.22 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:

$$\frac{\$385 \text{ implementation cost}}{\$10350/\text{yr cost savings}} = 2 \text{ weeks}$$

Simple Payback (Paper Cleaning Towels) = 2 weeks

Additional Resources

The 22 recommendations presented in this text are only a sample many other possible energy saving measures available to manufacturers willing to dedicate themselves to the pursuit of energy efficient practices. In order to assist ambitious industrial, the DOE and its partner organizations have made available a vast library of online tools, including tip-sheets, case studies, training manuals, and software packages. As follows is a list of some of these valuable resources.

Best Practices – The Department of Energy www.oit.doe.gov/bestpractices/
An excellent launch pad for research on energy-saving initiatives, this sight includes efficiency guidelines for every segment of a production process, including sections on compressed air systems, motors, process heating, and steam. Many of the following resources have been developed or compiled by the Best Practices program.

Compressed Air
A number of tools have been created by the DOE's Office of Industrial Technology to aid companies in optimizing their compressed air systems. These include tips on how to:

- Determine the cost of compressed air at your plant,
- Eliminate inappropriate uses of compressed air, and
- Minimize compressed air leaks.

The Compressed Air Challenge (www.CompressedAirChallenge.org), a national collaboration created to help compressed users optimize their systems, also offers some helpful information. Especially beneficial is the AirMaster+ software, a free program that will analyze data specific to your compressed air system.

KNOW PRESSURE COMPRESSED AIR CHALLENGE®

Steam
The OIT's Best Practices program has made available information on the optimization of all four stages of steam systems, including generation, distribution, use and recovery. Their extensive collection of resources includes information on:
Calculating the true cost of steam,
Selecting low-emission boilers and combustion equipment,
Numerous industry-specific case studies,
Financing options (and financial justification) for steam system improvements,

Software: Two free programs are currently available from the O.I.T. The Steam System Assessment Tool, and The Steam System Scoping Tool. Both allow the user to assess the cost of their steam-use, determine system efficiency, and browse energy saving measures.

3E Plus (available at pipeinsulation.org), offers the primary service of calculating ideal insulation thicknesses for piping and other thermal equipment. This information allows the user to translate energy losses into actual dollars, and select the insulation that will be cost effective for their system.

Motors
MotorMaster 3.0 is a valuable software package developed by the D.O.E. It assists facility managers who must determine how to plan around expected motor burn-out by comparing the options of motor rewinding and motor replacement. The program contains an extensive database of info pertaining to motor efficiency, power, and cost.

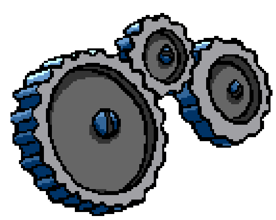
The Pump System Assessment Tool, allows industrial users to measure flow rate, head, speed, power, and duration in order to quantify savings opportunities. The program uses achievable pump performance data from Hydraulic Institute standards and motor performance data from the MotorMaster+ database to calculate potential energy and associated cost savings[33].

Process Heating
A significant number of tip-sheets and technical publications on the topic of efficient process heating have been organized by the Best Practices program. Especially useful is the

Lighting
Before attempting any significant lighting installations you need to ensure that the proposed system meets illumination requirements for the tasks/areas that will be affected. Information regarding task specific lighting requirements can be obtained from the Illuminating Engineering Society of North America (IESNA)[34]. Additionally, comprehensive charts listing ballast and lamp characteristics have been compiled by NEMA[35].

Productivity
The *Industrial Productivity Training Manual* was written for the Industrial Assesment Center (IAC) program with the goal of familiarizing industrial auditors with common methods of increasing process productivity. Among the topics addressed are:

- Bottlenect mitigation
- Defect reduction
- Preventive/predictive maintenance
- Labor optimization
- Scheduling
- Floor layout



This manual is available from the Center for Advanced Energy Systems at Rutgers University.[36]

[33] http://www.oit.doe.gov/bestpractices/energymatters/may2000_bp_tools.shtml
[34] IESNA, Lighting Power Density Models. http://12.109.133.232/cgi-bin/lpd/lpdhome.pl
[35] National Electrical Manufacturers Association, http://nema.org/lampballastmatrix/
[36] http://iac.rutgers.edu/programs/prodabstr.html