SAMPLE REPORT

Iowa State University
Industrial Assessment Center
(A U.S. Department of Energy Sponsored Program)

INDUSTRIAL ASSESSMENT REPORT
No. 666

AUDIT DATE: March 1, 2005
LOCATION: Ames, IA – Story county
PRINCIPAL PRODUCTS: Industrial Equipment
S.I.C. CODE: 3266
N.A.I.C.S. CODE: 335894
REPORT DATE: April 1, 2005

Team Leader: Dr. Greg Maxwell
Pablo Rivera, Graduate Engineer
Alex Rodrigues, Graduate Engineer
Eric Kamm, Student Engineer
Trevor Gilbertson, Student Engineer

1 Lead Student
2 Safety Coordinator

Iowa State University
Industrial Assessment Center
2043 Black Engr. Bldg.
Ames, Iowa 50011
(515) 294-3080
PREFACE

The work described in this report is a service of the Iowa State University Industrial Assessment Center (IAC). The project is funded by the Industrial Technologies Program under the U.S. Department of Energy office of Energy Efficiency and Renewable Energy, with supervision of CAES, the Center for Advanced Energy Systems, at Rutgers, The State University of New Jersey.

The primary objective of the IAC is to identify, evaluate, and recommend opportunities to conserve energy, minimize waste, and improve productivity by conducting assessments at industrial sites. Data are gathered through measurements and observations during a one-day site visit. Because the site visits by IAC personnel are brief, there are no claims made in regards to a comprehensive knowledge of all plant operations. Specific and quantitative recommendations of cost savings, energy conservation, waste minimization, and productivity improvements for the plants served are attempted at all times. However, we do not attempt to prepare detailed engineering designs or otherwise perform services expected from an engineering firm, vendor, or manufacturer's representative. When an assessment recommendation (AR) involving engineering design and capital investment is attractive to the company and engineering services are not available in-house, it is recommended that a consulting engineering firm be engaged to do the detailed engineering design and cost estimations for implementing the AR.

Energy conservation, waste minimization, and productivity improvement recommendations are not intended to deal with the issues of compliance with applicable environmental regulations. Questions regarding compliance should be addressed to either a reputable engineering firm experienced with environmental regulations or to the appropriate regulatory agency. Clients are encouraged to develop positive working relationships with regulators so matters pertaining to compliance can be addressed and resolved.

The assumptions and equations used for the recommended ARs are given in the report. The values used in evaluating the equations are intended to be conservative. If the client does not agree with the assumed values, the client may adjust the assumptions and, using the same equations, calculate new values for the energy savings, waste reduction, and cost savings for each AR.
The contents of this report are offered only as guidance. Iowa State University Industrial Assessment Center, and all technical sources referenced in this report (a) make no warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, nor that the use of any information, apparatus, method, or process disclosed in this report may infringe on privately owned rights; (b) assume no liabilities with respect to the use of, or for damages resulting from the use of, any information, apparatus, method or process disclosed in this report. This report does not reflect official views or policies of the previously mentioned institutions.

As discussed during our visit to the plant, we will contact key facility personnel within six to twelve months to collect information on which, if any, of our recommendations have been or will be implemented. This involves only a short telephone conversation.

Please feel free to contact the Iowa State IAC if there are any questions or comments related to this report. The IAC staff can be contacted as follows:

ISU IAC Director: Gregory M. Maxwell, Ph.D.
Associate Professor
Mechanical Engineering
(515) 294-8645

Assistant Director: Ron M. Nelson, Ph.D., P.E.
Professor
Mechanical Engineering
(515) 294-6886

Assistant Director: Frank E. Peters, Ph.D.
Associate Professor
Industrial and Manufacturing Systems Engineering
(515) 294-3855
TABLE OF CONTENTS

1. EXECUTIVE SUMMARY .................................................................5

2. GENERAL BACKGROUND ..............................................................8
   2.1 Facility Description .................................................................8
   2.2 Process Description ...............................................................10
   2.3 Major Energy Consuming Equipment .......................................12
   2.4 Energy Forms and Use in the Plant ..........................................12
   2.5 Other Assessment Services Offered and Performed .................13
   2.6 Other Measures Recently Implemented (Prior to Assessment Visit) ....13

3. ENERGY AND WASTE ACCOUNTING ............................................14
   3.1 Energy Accounting ...............................................................14
   3.2 Waste Accounting ...............................................................19
   3.3 Water Accounting ...............................................................19

4. ASSESSMENT RECOMMENDATIONS ............................................27
   AR No. 1 Improve Power Factor ...................................................28
   AR No. 2 Reduce Compressed Air Leaks .......................................34
   AR No. 3 Install an Air Receiver and a Pressure Control Valve ..........42
   AR No. 4 Recover Waste Heat From Air Compressors ....................45
   AR No. 5 Reduce Plant Air Exhaust by Improving Ventilation Design ...48
   AR No. 6 Replace Standard V-Belts With Notched V-Belts ...............53
   AR No. 7 Install High Efficiency Lighting ......................................57
   AR No. 8 Install Pre-filters on Main Paint Booth .............................64
   AR No. 9 Install Laser Cutting System .........................................68
5. ADDITIONAL ASSESSMENT ITEMS CONSIDERED ........................................... 73

5.1 Install Electronic Ballasts and T8 Lamps ............................................................. 73
5.2 Install Occupancy sensors ..................................................................................... 73
5.3 Install High Efficiency Motors ............................................................................. 74

6. RESOURCE DIRECTORY ......................................................................................... 75

6.1 State Programs ...................................................................................................... 75
6.2 National Resources ............................................................................................... 75
1. EXECUTIVE SUMMARY

Report No.: 666
S.I.C. No.: 3266 Location: Ames, IA Assessment Date: 04/01/05

Principal Products: Industrial Equipment

Annual production: 2,000 Annual Sales: $50 million
No. of Employees: 100 No. of ARs: 9

Estimated Cost of the Audit to the Client: 8 hours, $400

The cost saving opportunities that were evaluated for your facility are referred to as Assessment Recommendations (ARs). This report describes nine assessment recommendations which the audit team feels should be considered. The nine recommendations along with potential cost saving, implementation cost, and simple payback are shown in Table 1.1.

Table 1.1 Summary of Assessment Recommendations Cost Savings

<table>
<thead>
<tr>
<th>AR Description</th>
<th>Total Potential Cost Savings ($/year)</th>
<th>Implementation Costs ($)</th>
<th>Simple Payback</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Improve Power Factor</td>
<td>3,669</td>
<td>3,750</td>
<td>1.0 yr</td>
</tr>
<tr>
<td>2. Reduce Compressed Air Leaks</td>
<td>1,216</td>
<td>416</td>
<td>4 mo</td>
</tr>
<tr>
<td>3. Install an Air Receiver and a Pressure Control Valve</td>
<td>5,245</td>
<td>7,072</td>
<td>1.4 yr</td>
</tr>
<tr>
<td>4. Recover Waste Heat From Air Compressors</td>
<td>3,182</td>
<td>1,044</td>
<td>4 mo</td>
</tr>
<tr>
<td>5. Reduce Plant Air Exhaust by Improving Ventilation Design</td>
<td>12,016</td>
<td>2,495</td>
<td>3 mo</td>
</tr>
<tr>
<td>6. Replace Standard V-Belts With Notched V-Belts</td>
<td>528</td>
<td>136</td>
<td>4 mo</td>
</tr>
<tr>
<td>7. Install High Efficiency Lighting</td>
<td>1,628</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>8. Install Pre-filters on Main Paint Booth</td>
<td>4,044</td>
<td>440</td>
<td>2 mo</td>
</tr>
<tr>
<td>9. Install Laser Cutting System</td>
<td>852,215</td>
<td>1,270,000</td>
<td>1.5 yr</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td>883,743</td>
<td>1,285,353</td>
<td></td>
</tr>
</tbody>
</table>

The cost savings are based on reductions in energy usage, productivity improvement, and waste minimization. Table 1.2 summarizes these values for each AR.
Table 1.2 Summary of Assessment Recommendations Resource Savings

<table>
<thead>
<tr>
<th>AR Description</th>
<th>Potential Electricity Usage Savings (kWh/yr)</th>
<th>Potential Demand Savings (kW-mo/yr)</th>
<th>Potential Natural Gas Usage Savings (MMBtu/yr)</th>
<th>Potential Labor Reduct (hr/yr)</th>
<th>Primary Area* Affected</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Improve Power Factor</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>P</td>
</tr>
<tr>
<td>2. Reduce Compressed Air Leaks</td>
<td>33,016</td>
<td>64.6</td>
<td>-</td>
<td>-12</td>
<td>E</td>
</tr>
<tr>
<td>3. Install an Air Receiver and a Pressure Control Valve</td>
<td>63,700</td>
<td>420.0</td>
<td>-</td>
<td>-</td>
<td>E</td>
</tr>
<tr>
<td>4. Recover Waste Heat From Air Compressors</td>
<td>-</td>
<td>-</td>
<td>480</td>
<td>-</td>
<td>E</td>
</tr>
<tr>
<td>5. Reduce Plant Air Exhaust by Improving Ventilation Design</td>
<td>11,658</td>
<td>22.8</td>
<td>1,725</td>
<td>-</td>
<td>E</td>
</tr>
<tr>
<td>6. Replace Standard V-Belts With Notched V-Belts</td>
<td>7,890</td>
<td>34.8</td>
<td>-</td>
<td>-</td>
<td>E</td>
</tr>
<tr>
<td>7. Install High Efficiency Lighting</td>
<td>99,405</td>
<td>194.4</td>
<td>-</td>
<td>-</td>
<td>E</td>
</tr>
<tr>
<td>8. Install Pre-filters on Main Paint Booth</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>80</td>
<td>P</td>
</tr>
<tr>
<td>9. Install Laser Cutting System</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2,080</td>
<td>P</td>
</tr>
<tr>
<td>Totals</td>
<td>215,669</td>
<td>736.6</td>
<td>2,314</td>
<td>2,148</td>
<td></td>
</tr>
</tbody>
</table>

* E = energy, W = waste, P = productivity

The energy consumption and corresponding costs at this facility from December 2002 through November 2003 are summarized in Table 1.3.

Table 1.3 Annual Energy Consumption and Corresponding Costs

<table>
<thead>
<tr>
<th>Energy Source</th>
<th>Billing Units</th>
<th>MMBtu</th>
<th>$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity</td>
<td>1,982,400 kWh</td>
<td>6,765</td>
<td>130,953</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>86,497 therms</td>
<td>8,651</td>
<td>61,881</td>
</tr>
<tr>
<td>Totals</td>
<td></td>
<td>15,416</td>
<td>192,834</td>
</tr>
</tbody>
</table>

The energy conservation ARs could save an estimated 2,941 MMBtu each year or 19.1% of this plant’s total energy usage. The ARs could also save an estimated 736.6 kW-months of demand each year, or 11% of the average monthly demand. The recommended productivity AR could save 2,160 labor hours.

Comments

It should be noted that a "law of diminishing returns" applies to the total cost savings. That is, the figures in Table 1.1 are based on the sum of the cost savings for each AR as if they were independent. They are not; for example, if AR No. 3, Install an Air receiver and a Pressure Control Valve, were implemented, the compressed air line pressure would be lower than at
present and therefore, the magnitude of the air leaks and the cost savings to be realized by implementing AR No. 2, Reduce Compressed Air Leaks, would be less than indicated above. When deciding which recommended ARs to implement, AR interaction should be taken into consideration.
2. GENERAL BACKGROUND

2.1 Facility Description

The company considered in this report produces telescopic high-reach forklifts, which are distributed internationally and nationally. Typically, 150 employees are involved in the manufacturing of 1,650 units for an annual sales figure of approximately $120,000,000. Approximate operating schedules of the various areas considered in this report are given in Table 2.1.

<table>
<thead>
<tr>
<th>Area</th>
<th>Operating Schedule</th>
<th>Days/wk</th>
<th>Wk/yr</th>
<th>Total hr/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offices</td>
<td>7 a.m. to 5 p.m.</td>
<td>Mon - Fri</td>
<td>52</td>
<td>2,600</td>
</tr>
<tr>
<td>Production</td>
<td>24 hr/day</td>
<td>Mon - Thu</td>
<td>52</td>
<td>4,992</td>
</tr>
<tr>
<td>Production</td>
<td>7 a.m. to 11 p.m.</td>
<td>Fri</td>
<td>52</td>
<td>832</td>
</tr>
<tr>
<td>Production</td>
<td>7 a.m. to 1 p.m.</td>
<td>Sat</td>
<td>52</td>
<td>312</td>
</tr>
</tbody>
</table>

The facility is comprised of one building, with a total area of approximately 200,000 sq ft. Most of the manufacturing processes are performed in the Production area. It is estimated that 4% of the building area is dedicated to office space. A simple layout of the facility is given in Figure 2.1.

The building walls are constructed with a metal structure and 6” fiberglass insulated panels; metal beams support the 6” fiberglass insulated roof. Only Offices are air-conditioned. Space heating in the plant is done by natural gas burners at the makeup air units.
Figure 2.1 Simple Facility Layout
2.2 Process Description

A simplified description of the manufacturing processes performed at this facility is given in this section. It is not intended to be a complete detailed description, but rather to provide general information on the processes, with a focus on energy requirements and significant waste streams.

This plant manufactures industrial equipment. Production begins with the arrival of pre-cut steel, other raw materials, and assembly parts. Materials are delivered to the corresponding storage area while assembly parts can go directly to the corresponding assembly area. Some materials are placed on a short-term storage location. The main raw material is pre-cut steel which is used to produce the telescopic boom and the chassis. The pre-cut steel is first finished by machining processes, which include boring, chamfering, and forming. Then parts are pre-assembled in jigs for welding. Manual welding or robotic welding completes the main parts. Next, parts go for finishing, trimming and inspection. The final operation for making the parts is painting, which is performed with an electrostatic liquid painting system, for which parts are prepared either by blasting or by a phosphate wash. After inspection, parts go to the corresponding assembly area. All parts are finally assembled together in a separate area. All equipments are tested for correct functioning before they are sent to the shipping area.

A process flowsheet, which shows the incoming and outgoing material streams of the facility, is presented in Figure 2.2.
Figure 2.2 Process Flowsheet
2.3 Major Energy Consuming Equipment

The following list is an approximate summary of the major energy-consuming equipment at this facility.

1. Electrical
   
   A. Air Compressors
      (2) 100 hp Screw type unit, operating pressure at 110 psig
      (1) 25 hp Reciprocating unit, used as a Back-up
   
   B. Major Process Related Equipment
      (32) welders, 15 kW each
      Several punch presses
      Several lathes, mills, drills, and folding presses
   
   C. HVAC (Heating, Ventilation and Air Conditioning)
      Fans
      Several extraction fans
      Cooling
      (4) packaged air conditioning units, 62,000 Btu/hr each
   
   D. Lighting
      180 kW total estimated installed capacity

2. Natural Gas
   
   A. Major Process Related Equipment
      (1) paint drying booth, 2.0 MMBtu/hr
   
   B. Space Heating
      (3) make up air units, 5.9 MMBtu/hr each

2.4 Energy Forms and Use in the Plant

   Electrical energy is used for operating process-related equipment, lighting, compressing air, and space cooling. Natural gas is used for paint drying and heating of the plant. No other energy sources or fuels are consumed at this facility.
2.5 Other Assessment Services Offered and Performed

According to facility personnel, no offers for assessments were made by other groups within the last five years.

2.6 Other Measures Recently Implemented (Prior to Assessment Visit)

Some other significant energy conservation and waste minimization measures had been implemented prior to the visit by the ISU assessment team, based on investigation and action by facility personnel. These actions are summarized below.

2.6.1 Previous Waste Minimization Efforts

- Steel recycling
- Solvent recycling or disposal through licensed third party
3. ENERGY AND WASTE ACCOUNTING

3.1 Energy Accounting

An essential component of any energy management program is a continuing account of energy use and its corresponding cost. For energy, this can be developed by keeping up-to-date records of energy consumption and associated costs on a monthly basis. When utility bills are received, it is recommended that energy use and costs be recorded as soon as possible. A separate record will be required for each type of energy used, i.e., gas, electric, oil, etc. A combination will be necessary, for example, when both gas and oil are used interchangeably in a boiler. A single energy unit should be used to express the heating values of the various fuel sources so that a meaningful comparison of fuel types and fuel combinations can be made. The energy unit used in this report for comparison is the Btu, British thermal unit, or million Btu’s (MMBtu). The conversion factors are:

<table>
<thead>
<tr>
<th>ENERGY CONVERSION FACTORS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Unit</strong></td>
</tr>
<tr>
<td>1 MBtu</td>
</tr>
<tr>
<td>1 MMBtu</td>
</tr>
<tr>
<td>1 kWh</td>
</tr>
<tr>
<td>1 therm</td>
</tr>
<tr>
<td>1 hp-h (motor horsepower)</td>
</tr>
<tr>
<td>1 hp-h (boiler horsepower)</td>
</tr>
<tr>
<td>1 ton-h (refrigeration)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ENERGY CONTENT OF FUELS*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fuel Unit</strong></td>
</tr>
<tr>
<td>1 cu ft natural gas</td>
</tr>
<tr>
<td>1 gallon No. 2 oil (diesel)</td>
</tr>
<tr>
<td>1 gallon No. 4 oil</td>
</tr>
<tr>
<td>1 gallon No. 5 oil</td>
</tr>
<tr>
<td>1 gallon No. 6 oil</td>
</tr>
<tr>
<td>1 gallon gasoline</td>
</tr>
<tr>
<td>1 gallon propane</td>
</tr>
<tr>
<td>1 ton coal</td>
</tr>
</tbody>
</table>

*varies with supplier
The value of energy and cost records can be understood by examining those represented for your facility on the following pages. The electrical energy usage and monthly demand are tabulated by months in Table 3.1.1, and the natural gas energy usage in Table 3.1.2. Table 3.1.3 summarizes this information. Total annual energy usage and energy costs are shown in Figures 3.1.1 and 3.1.2. Figure 3.1.3 shows the annual electrical cost broken down as the total cost, usage cost, demand cost, and other cost. A pie chart illustrating the percentage of energy use for various functions is shown in Figure 3.1.4, and another pie chart illustrating the percentage of energy costs for various functions is shown in Figure 3.1.5. From these figures, trends and irregularities in energy usage and costs can be detected and the relative merits of energy conservation and load management can be assessed.

In addition to plotting monthly energy consumption and cost, it may also be desirable to plot the ratio of monthly energy consumption to monthly production. An appropriate measure of production should be used consistent with the company's production record-keeping procedures. The measure of production can be gross sales, number of units produced or processed, pounds of raw material used, etc. It is important that the same time period be used for energy consumption and production.

**Marginal Costs**

Economists define the marginal cost of a good as the price paid for one additional unit. This concept is useful in energy calculation since the value of energy saved or the cost of additional energy purchased will be at the marginal rate.

Marginal rates are almost always lower than average rates. There are two common reasons for the difference. One is that fixed costs such as meter charges are usually constant each month no matter how much energy is purchased. The other reason is that many utility companies charge less per unit as the quantity purchased increases.
Electricity Billing

The electrical usage and demand are tabulated in Table 3.1.1. The total electrical usage and demand for each month is the sum of the usage and demand readings of the only electrical meters at this facility. The usage cost is the sum of energy charges and the demand cost is the sum of the billed demand charges. There is a flat rate throughout the day for either energy and demand usage, i.e., there are not Peak hours defined. Other costs consist of all other charges that do not depend on usage or demand. For this facility, other costs consist of the Sales Tax. The total cost is simply the sum of all electrical costs.

The electric demand charges come from applying a fixed tiered billing structure, the first 100 kW are billed at one rate, the second 400 kW at a different rate, and the remainder kW at a third rate. Every three months the utility company adjusts these rates.

The facility is billed extra charges if the average power factor (PF) is below 95%, which is seen on the bills. If the power factor is above 95%, there are not extra charges. The low power factor charge, LPF, can be calculated as:

\[
LPF = \left( \frac{\text{demand} \times (95\%)}{(PF)} - \text{demand} \right) \times \text{(cost of first tier of demand)}
\]

For example, for the month of January, the plant’s demand was 529.2 kW with a power factor of 89.4%, therefore the correction can be calculated as:

\[
LPF = \left( \frac{529.2 \times (95\%)}{(89.4)} - 529.2 \right) \times (\$8.07/kW)
\]

\[
LPF = \$267.50
\]

The marginal rate for electric energy, MRE, is the rate of the last kWh added to the bill in the billing period. There are no different rates for different consumption levels. However, there is a monthly Power Cost Adjustment that the utility company charges to recover the costs of the fuel used to produce the electricity. The marginal rate for electricity is simply the quotient of the summation of the energy costs by the number of kWh spent for each month. For the month of December 2002, the marginal rate was calculated as:

\[
MRE = \left( \frac{\text{(Energy Cost)} + \text{(Power Cost Adjustment)}}{\text{(Energy Consumed)}} \right)
\]

Substituting values

\[
MRE = \left( \frac{(3,073.04) + (1,877.67)}{(139,500)} \right)
\]
MRE = $0.0355/kWh

Electricity used in the plant is almost 68% of the cost but only 44% of the total energy usage.

**Electric Bill Sample Calculation**

The following is an example of the electric charges for this facility for the month of December 2002:

- Billing Demand = 529.2 kW
- Energy Consumed = 135,900 kWh

**Demand Charges:**
- 100 kW @ $8.07/kW = $807.00
- 400 kW @ $7.37/kW = $2,948.00
- 29.2 kW @ $6.67/kW = $194.76

**Low Power Factor charges:**
- LPF = $267.50

**Energy Charges:**
- 139,500 kWh @ $0.02203/kWh = $3,073.19
- 139,500 kWh @ $0.01346/kWh = $1,877.67

**Other Costs:**
- State Sales Tax = $550.08

**Total Electric Charges:**

Demand Charges + Energy Charges + LPF + Other Costs = $9,718.20

In order to calculate the marginal cost for demand usage, MCD, it is necessary to account for the effect of the low power factor in the final bill as well as looking at the cost of the last kW added to the billing demand. Following with the example, for the month of December 2002, the marginal cost for demand can be estimated as:

\[ MCD = (\text{cost of last kW added}) + \left[ \frac{(95\%)/(PF) - 1}{PF} \right] \times \text{(First Tier Cost)} \]

Substituting values,

\[ MCD = ($6.67/kW) + \left[ \frac{(95\%)/(0.894) - 1}{0.894} \right] \times ($8.07/kW) \]

\[ MCD = $7.18/kW \]
Natural Gas Billing

The natural gas usage is tabulated in Table 3.1.2. The total natural gas usage is tabulated for the only meter for each month. The usage cost is the gas cost and the delivery charges. Other costs consist of all other charges that do not depend on usage. For this facility, other costs consist of basic service charge and sales tax. The total cost is simply the sum of all costs associated with natural gas. There are no discounts for large quantity purchases. For the determination of the yearly average marginal cost, a weighted average is calculated. Each month’s marginal rate is weighted by the monthly gas therms consumed. Natural gas use for heating the plant is 48% of the total energy usage but only 28% of the cost. Natural gas used for the process is 8% of the total energy usage but only 4% of the cost.

Natural Gas Bill Sample Calculation

The following is an example of the natural gas charges for this facility for the month of December 2002

Total Billed Usage = 1,368.7 MMBtu

Energy Charges:

1,368.7 MMBtu @ $4.7111/MMBtu = $6,448.08

Delivery Charges:

1,368.7 MMBtu @ $0.7201/MMBtu = $985.60

Other Costs:

Service Charges + State and Local Taxes = ($60.00) + (449.42) = $509.42

Total Natural Gas Charges:

Energy Charges + Other Costs = $7,943.10

The marginal rate for natural gas, MGC, for this month is simply the gas unitary cost plus the unitary delivery charge:

\[ \text{MGC} = (3.031) + (0.821) = $3.85/MMBtu \]
3.2 Waste Accounting

The manufacturing operations in this plant utilize various raw materials and produce several waste streams. The values shown for the annual waste generation were found through examination of monthly invoices for various waste streams and through discussions with plant personnel on the day of the assessment.

Table 3.2.1 summarizes the waste streams at this facility and the costs associated with each waste stream.

3.3 Water Accounting

The water consumption, sewer disposal and corresponding costs at this facility from January 2003 through December 2003 are summarized in Table 3.3.1. The water usage cost and sewer costs are calculated with different rates with their corresponding usage in cubic feet and summed in the total cost column. Figure 3.3.1 shows the total annual water and sewer usage in cubic feet. All water usage pays sewer charges.

The costs for water and sewer are shown graphically in Figure 3.3.2. There are no other costs other than direct costs for water and sewer usage. The sewer usage costs are higher than the water usage costs. This fact is also evident in the pie chart, which graphically outlines the percentages of costs.
Table 3.1.1 Electric Energy Use by Month

<table>
<thead>
<tr>
<th>Date</th>
<th>Usage (kWh)</th>
<th>Usage Cost ($)</th>
<th>Demand (kW)</th>
<th>Demand Cost ($)</th>
<th>Other Cost ($)</th>
<th>Total Cost ($)</th>
<th>Marginal Cost ($/kWh)</th>
<th>Marginal Cost ($/kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dec-02</td>
<td>139,500</td>
<td>4,951</td>
<td>529</td>
<td>4,217</td>
<td>550</td>
<td>9,718</td>
<td>0.0355</td>
<td>7.18</td>
</tr>
<tr>
<td>Jan-03</td>
<td>177,300</td>
<td>6,164</td>
<td>597</td>
<td>4,738</td>
<td>654</td>
<td>11,556</td>
<td>0.0348</td>
<td>7.23</td>
</tr>
<tr>
<td>Feb-03</td>
<td>164,100</td>
<td>5,896</td>
<td>580</td>
<td>4,573</td>
<td>627</td>
<td>11,096</td>
<td>0.0359</td>
<td>7.15</td>
</tr>
<tr>
<td>Mar-03</td>
<td>155,700</td>
<td>5,618</td>
<td>541</td>
<td>4,275</td>
<td>593</td>
<td>10,486</td>
<td>0.0361</td>
<td>7.12</td>
</tr>
<tr>
<td>Apr-03</td>
<td>172,200</td>
<td>6,115</td>
<td>541</td>
<td>4,256</td>
<td>622</td>
<td>10,993</td>
<td>0.0355</td>
<td>7.09</td>
</tr>
<tr>
<td>May-03</td>
<td>171,900</td>
<td>6,111</td>
<td>533</td>
<td>4,109</td>
<td>614</td>
<td>10,834</td>
<td>0.0356</td>
<td>6.88</td>
</tr>
<tr>
<td>Jun-03</td>
<td>163,200</td>
<td>5,854</td>
<td>535</td>
<td>4,120</td>
<td>598</td>
<td>10,572</td>
<td>0.0359</td>
<td>6.92</td>
</tr>
<tr>
<td>Jul-03</td>
<td>168,300</td>
<td>6,130</td>
<td>606</td>
<td>4,615</td>
<td>644</td>
<td>11,389</td>
<td>0.0364</td>
<td>6.92</td>
</tr>
<tr>
<td>Aug-03</td>
<td>180,600</td>
<td>6,495</td>
<td>582</td>
<td>4,491</td>
<td>659</td>
<td>11,645</td>
<td>0.0360</td>
<td>6.96</td>
</tr>
<tr>
<td>Sep-03</td>
<td>159,300</td>
<td>5,852</td>
<td>584</td>
<td>4,486</td>
<td>621</td>
<td>10,959</td>
<td>0.0367</td>
<td>7.00</td>
</tr>
<tr>
<td>Oct-03</td>
<td>160,800</td>
<td>5,840</td>
<td>550</td>
<td>4,262</td>
<td>606</td>
<td>10,708</td>
<td>0.0363</td>
<td>6.99</td>
</tr>
<tr>
<td>Nov-03</td>
<td>169,500</td>
<td>6,129</td>
<td>542</td>
<td>4,245</td>
<td>623</td>
<td>10,997</td>
<td>0.0362</td>
<td>7.07</td>
</tr>
<tr>
<td>Total</td>
<td>1,982,400</td>
<td>6,765</td>
<td>71,155</td>
<td>N/A</td>
<td>52,387</td>
<td>130,953</td>
<td>N/A</td>
<td>84.52</td>
</tr>
<tr>
<td>Avg</td>
<td>165,200</td>
<td>5,930</td>
<td>560</td>
<td>4,366</td>
<td>618</td>
<td>10,913</td>
<td>0.0359</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Note: Marginal cost for Natural Gas Usage is based on a weighted average

Table 3.1.2 Natural Gas Energy Use by Month

<table>
<thead>
<tr>
<th>Date</th>
<th>Usage (Therms)</th>
<th>Usage (MMBtu)</th>
<th>Usage Cost ($)</th>
<th>Other Cost ($)</th>
<th>Total Cost ($)</th>
<th>Marginal Cost ($/MMBtu)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dec-02</td>
<td>13,687</td>
<td>1,369</td>
<td>7,434</td>
<td>509</td>
<td>7,943</td>
<td>5.43</td>
</tr>
<tr>
<td>Jan-03</td>
<td>23,813</td>
<td>2,381</td>
<td>14,975</td>
<td>1,280</td>
<td>16,255</td>
<td>6.29</td>
</tr>
<tr>
<td>Feb-03</td>
<td>16,924</td>
<td>1,692</td>
<td>12,678</td>
<td>824</td>
<td>13,502</td>
<td>7.49</td>
</tr>
<tr>
<td>Mar-03</td>
<td>7,001</td>
<td>700</td>
<td>6,328</td>
<td>447</td>
<td>6,775</td>
<td>9.04</td>
</tr>
<tr>
<td>Apr-03</td>
<td>2,496</td>
<td>250</td>
<td>1,525</td>
<td>155</td>
<td>1,680</td>
<td>6.11</td>
</tr>
<tr>
<td>May-03</td>
<td>1,390</td>
<td>139</td>
<td>948</td>
<td>120</td>
<td>1,068</td>
<td>6.82</td>
</tr>
<tr>
<td>Jun-03</td>
<td>735</td>
<td>74</td>
<td>552</td>
<td>97</td>
<td>649</td>
<td>7.51</td>
</tr>
<tr>
<td>Jul-03</td>
<td>728</td>
<td>73</td>
<td>524</td>
<td>95</td>
<td>619</td>
<td>7.20</td>
</tr>
<tr>
<td>Aug-03</td>
<td>710</td>
<td>71</td>
<td>453</td>
<td>91</td>
<td>544</td>
<td>6.38</td>
</tr>
<tr>
<td>Sep-03</td>
<td>1,380</td>
<td>138</td>
<td>899</td>
<td>118</td>
<td>1,017</td>
<td>6.52</td>
</tr>
<tr>
<td>Oct-03</td>
<td>5,776</td>
<td>578</td>
<td>3,503</td>
<td>273</td>
<td>3,776</td>
<td>6.06</td>
</tr>
<tr>
<td>Nov-03</td>
<td>11,857</td>
<td>1,186</td>
<td>7,537</td>
<td>516</td>
<td>8,053</td>
<td>6.36</td>
</tr>
<tr>
<td>Total</td>
<td>86,497</td>
<td>8,651</td>
<td>57,356</td>
<td>4,525</td>
<td>61,881</td>
<td>N/A</td>
</tr>
<tr>
<td>Avg</td>
<td>7,208</td>
<td>721</td>
<td>4,780</td>
<td>377</td>
<td>5,157</td>
<td>6.63</td>
</tr>
</tbody>
</table>

Note: Marginal cost for Natural Gas Usage is based on a weighted average.
Table 3.1.3 Summary of Total Energy Usage

OVERALL ANNUAL
ENERGY & COST SUMMARY:

Total Energy = 15,416 MMBtu/yr
Total Cost = 192,834 $/yr

ENERGY END USES

<table>
<thead>
<tr>
<th>Usage Type</th>
<th>MMBtu</th>
<th>% MMBtu</th>
<th>Cost ($)</th>
<th>% Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling</td>
<td>203</td>
<td>1%</td>
<td>3,929</td>
<td>2%</td>
</tr>
<tr>
<td>Process Electric</td>
<td>6,562</td>
<td>43%</td>
<td>127,024</td>
<td>66%</td>
</tr>
<tr>
<td>Process Gas</td>
<td>1,211</td>
<td>8%</td>
<td>8,663</td>
<td>4%</td>
</tr>
<tr>
<td>Heating</td>
<td>7,440</td>
<td>48%</td>
<td>53,218</td>
<td>28%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>15,416</strong></td>
<td><strong>100%</strong></td>
<td><strong>192,834</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

AVERAGE MARGINAL RATES

- Electrical Usage = 0.0359 ($/kWh)
- Electrical Usage = 10.52 ($/MMBtu)
- Electrical Demand = 84.52 ($/kW-yr)
- Natural Gas = 6.63 ($/MMBtu)
Figure 3.1.1 Annual Energy Usage

Figure 3.1.2 Annual Energy Costs
Figure 3.1.3 Annual Electrical Costs
Figure 3.1.4 Percentage of Energy Usage

Figure 3.1.5 Percentage of Energy Costs
### Table 3.2.1 Annual Waste Generation and Corresponding Costs

<table>
<thead>
<tr>
<th>Plant Source</th>
<th>Waste Stream Components</th>
<th>Approximate Annual Generation (Billing Units)</th>
<th>Approximate Annual Generation (lb)</th>
<th>Disposal Method</th>
<th>Off-site Removal Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production</td>
<td>Steel trimmings and scrap</td>
<td>**</td>
<td>**</td>
<td>Recycled</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Waste paper, pallets, and</td>
<td>40 pulls</td>
<td>110,000</td>
<td>Landfill</td>
<td>6,000</td>
</tr>
<tr>
<td></td>
<td>filters</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solvents</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>Third Party Disposal</td>
<td>0</td>
</tr>
<tr>
<td>Totals</td>
<td>-</td>
<td>-</td>
<td>110,000</td>
<td>-</td>
<td>6,000</td>
</tr>
</tbody>
</table>

**Data not available**

### Table 3.3.1 Annual Water and Sewer Use by Month

<table>
<thead>
<tr>
<th>Date</th>
<th>Water Usage (cu ft)</th>
<th>Water Usage Cost ($)</th>
<th>Water Cost ($/cu ft)</th>
<th>Sewer Usage (cu ft)</th>
<th>Sewer Usage Cost ($)</th>
<th>Sewer Cost ($/cu ft)</th>
<th>Other Costs ($)</th>
<th>Total Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan-01</td>
<td>2,674</td>
<td>79.18</td>
<td>0.0296</td>
<td>2,674</td>
<td>78.2</td>
<td>0.0292</td>
<td>0</td>
<td>157</td>
</tr>
<tr>
<td>Feb-01</td>
<td>4,011</td>
<td>96.48</td>
<td>0.0241</td>
<td>4,011</td>
<td>114.3</td>
<td>0.0285</td>
<td>0</td>
<td>211</td>
</tr>
<tr>
<td>Mar-01</td>
<td>2,674</td>
<td>79.18</td>
<td>0.0296</td>
<td>2,674</td>
<td>78.2</td>
<td>0.0292</td>
<td>0</td>
<td>157</td>
</tr>
<tr>
<td>Apr-01</td>
<td>4,011</td>
<td>96.48</td>
<td>0.0241</td>
<td>4,011</td>
<td>114.3</td>
<td>0.0285</td>
<td>0</td>
<td>211</td>
</tr>
<tr>
<td>May-01</td>
<td>4,011</td>
<td>96.48</td>
<td>0.0241</td>
<td>4,011</td>
<td>114.3</td>
<td>0.0285</td>
<td>0</td>
<td>211</td>
</tr>
<tr>
<td>Jun-01</td>
<td>4,011</td>
<td>96.48</td>
<td>0.0241</td>
<td>4,011</td>
<td>114.3</td>
<td>0.0285</td>
<td>0</td>
<td>211</td>
</tr>
<tr>
<td>Jul-01</td>
<td>4,011</td>
<td>96.48</td>
<td>0.0241</td>
<td>4,011</td>
<td>114.3</td>
<td>0.0285</td>
<td>0</td>
<td>211</td>
</tr>
<tr>
<td>Aug-01</td>
<td>4,011</td>
<td>96.48</td>
<td>0.0241</td>
<td>4,011</td>
<td>114.3</td>
<td>0.0285</td>
<td>0</td>
<td>211</td>
</tr>
<tr>
<td>Sep-01</td>
<td>4,011</td>
<td>96.48</td>
<td>0.0241</td>
<td>4,011</td>
<td>114.3</td>
<td>0.0285</td>
<td>0</td>
<td>211</td>
</tr>
<tr>
<td>Oct-01</td>
<td>4,011</td>
<td>96.48</td>
<td>0.0241</td>
<td>4,011</td>
<td>114.3</td>
<td>0.0285</td>
<td>0</td>
<td>211</td>
</tr>
<tr>
<td>Nov-01</td>
<td>5,348</td>
<td>113.78</td>
<td>0.0213</td>
<td>5,348</td>
<td>150.4</td>
<td>0.0281</td>
<td>0</td>
<td>264</td>
</tr>
<tr>
<td>Dec-01</td>
<td>4,011</td>
<td>96.48</td>
<td>0.0241</td>
<td>4,011</td>
<td>114.3</td>
<td>0.0285</td>
<td>0</td>
<td>211</td>
</tr>
<tr>
<td>Totals</td>
<td>46,795</td>
<td>1,140.46</td>
<td>46,795</td>
<td>1,335.5</td>
<td>0</td>
<td>2,477</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Avg</td>
<td>3,900</td>
<td>95.04</td>
<td>0.0244</td>
<td>3,900</td>
<td>111.3</td>
<td>0.0285</td>
<td>0</td>
<td>206</td>
</tr>
</tbody>
</table>

1 ft³ = 7.48 Gallons
Figure 3.3.1 Annual Water and Sewer Usage

Figure 3.3.2 Annual Water and Sewer Costs
4. ASSESSMENT RECOMMENDATIONS

The following sections describe each of the assessment recommendations for this facility. Included in each discussion is a summary of the recommended action, a background description, the calculation of anticipated savings, and an estimate of the implementation cost. Finally, it should be noted that, in general, these recommendations do not take into account any possible future savings attributed to such things as changing rates and/or regulations.
AR No. 1 - Improve Power Factor

Recommended Action

Install capacitors to correct for low power factor.

Estimated Cost Savings = $3,699/yr

Estimated Implementation Cost = $3,750

Simple Payback = 1 year

Background

Power factor is a way of quantifying the reaction of alternating current (AC) electricity to various types of electrical loads. Inductive loads, such as motors and fluorescent lamp ballasts, cause the voltage and current to shift out of phase. The utility company must supply additional power, measured in kilovolt-amps (kVA), to make up for the phase shift. The total power requirement of the load is made up of two components, the resistive, or real, component and the reactive component. The resistive component, measured in kilowatts (kW) by a watt meter, does the useful work. The reactive component, measured in reactive kilovolt-amps (kVAR), represents the current needed to produce the magnetic field for the operation of a motor or other inductive device. This component does no useful work, is not registered on a power meter, but contributes to the heating of generators, transformers and transmission lines, constituting a loss for the utility company.

The ratio of real, usable power (kW) to apparent power (kVA) is known as the power factor. To reduce reactive losses, the user should increase the power factor to a value as close to unity (1.0) as is practical for the entire manufacturing plant. The utility supplying electricity to this facility assesses a power factor charge when the power factor falls below a specified level because more apparent power must be supplied as the user's power factor decreases.
For example, it is assumed that a manufacturing plant has an average annual power factor of 0.78. A power factor of 0.78 means that for every 78 kW of usable power that the plant requires, the utility must supply 78 kW/(PF) or 100 kVA. If the plant's power factor is changed from 0.78 to 0.95, then for every 78 kW required by the plant, the utility needs only to supply 78 kW/0.95 or 82 kVA.

The utility supplying electricity to this facility assesses a power factor charge when the power factor is below 95%. This charge is often accomplished by increasing the billing demand (kW) by 1% for each 1% by which the power factor is less than 95%.

Capacitor banks can be installed to decrease the reactive power (kVAR) and thus the apparent power. Capacitors draw current that leads the voltage, while inductive loads draw current that lags the voltage. The net result is that the current in the supply line is brought more closely in phase with the supply voltage. A power factor of 1.0 indicates that the current and the voltage are exactly in phase.
Capacitors can be installed at any point in the electrical system and will improve the power factor between the point of application and the power source. Capacitors can be added at each piece of equipment, ahead of groups of small motors, or at main services. The advantages and disadvantages of each type of installation are highlighted in Table 4.1.2.

**Table 4.1.1** Types of Capacitor Installation

<table>
<thead>
<tr>
<th>Type of Capacitor Installation</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>individual equipment</td>
<td>increased load capabilities of distribution system and better voltage regulation</td>
<td>smaller capacitors cost more per kVAR than larger units</td>
</tr>
<tr>
<td>grouped equipment</td>
<td>increased load capabilities of the service</td>
<td>switching means may be required to control the amount of capacitance used</td>
</tr>
<tr>
<td>Main service</td>
<td>low installation costs</td>
<td>Switching means will usually be required to control the amount of capacitance used. Does not improve load capabilities of distribution system.</td>
</tr>
</tbody>
</table>

Using the geometric relationships between kW, kVA, and kVAR as shown in the Figure 4.1.1, it is possible to calculate the capacitance factor, CF, which is the reactance of the capacitors needed to adjust the power factor per kW of electrical power. The capacitance factor, CF, is given in units of kVAR/kW in the relationship given below.

\[
CF = \tan \left[ \arccos(PF_c) \right] - \tan \left[ \arccos(PF_p) \right]
\]

where

- \( \tan \) = tangent function
- \( \arccos \) = inverse cosine function (\( \cos^{-1} \))
- \( PF_c \) = current power factor, no units
- \( PF_p \) = proposed power factor, no units

From power factor measurements that are posted on the utility bills the current minimum power factor is 0.883. The power factor below which the utility penalizes customers is 0.95.

---

1. Energy Management, Ottaviano, pg. 2.2-8.
Thus, the kVAR/kW of capacitors needed to avoid power factor charges can be computed as follows:

\[ CF = \tan [\arccos (0.883)] - \tan [\arccos (0.95)] \]

\[ CF = 0.203 \text{ kVAR/kW} \]

Table 4.1.2, generated from the above equation, provides the capacitance factor that can be used to determine the amount of capacitance required to correct from an existing to a desired power factor. The number in the table is multiplied by the current demand (kW) to get the amount of capacitors (kVAR) needed to correct from the existing to the desired power factor.

Table 4.1.2 Power Factor Correction

<table>
<thead>
<tr>
<th>Existing Power Factor</th>
<th>Corrected Power Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.00</td>
</tr>
<tr>
<td>0.66</td>
<td>1.138</td>
</tr>
<tr>
<td>0.68</td>
<td>1.078</td>
</tr>
<tr>
<td>0.70</td>
<td>1.020</td>
</tr>
<tr>
<td>0.72</td>
<td>0.964</td>
</tr>
<tr>
<td>0.74</td>
<td>0.909</td>
</tr>
<tr>
<td>0.76</td>
<td>0.855</td>
</tr>
<tr>
<td>0.78</td>
<td>0.802</td>
</tr>
<tr>
<td>0.80</td>
<td>0.750</td>
</tr>
<tr>
<td>0.82</td>
<td>0.698</td>
</tr>
<tr>
<td>0.84</td>
<td>0.646</td>
</tr>
<tr>
<td>0.86</td>
<td>0.593</td>
</tr>
<tr>
<td>0.88</td>
<td>0.540</td>
</tr>
<tr>
<td>0.90</td>
<td>0.484</td>
</tr>
<tr>
<td>0.92</td>
<td>0.426</td>
</tr>
<tr>
<td>0.94</td>
<td>0.363</td>
</tr>
<tr>
<td>0.96</td>
<td>0.292</td>
</tr>
<tr>
<td>0.98</td>
<td>0.203</td>
</tr>
<tr>
<td>0.99</td>
<td>0.142</td>
</tr>
</tbody>
</table>

For this facility, the maximum monthly demand load during the previous year is approximately 606 kW. The power factor correction as calculated above is 0.203. Table 4.1.2 can also be used to determine the amount of capacitors needed to correct this power factor to 95% where there would be no power factor charge. The amount of capacitors needed, kVAR, can now be determined:

\[ \text{kVAR} = (D) \times (CF) \]
where
\[ D = \text{maximum annual demand, kW} \]
\[ CF = \text{correction factor, as calculated above or read from table, kVAR/kW} \]

Therefore,
\[ \text{kVAR} = (606) \times (0.203) = 123 \text{ kVAR} \approx 125 \text{ kVAR} \]

The cost savings can be calculated by multiplying the demand cost by the increased demand due to low power factor for each month, as follows:
\[ \text{CS} = (\text{Dpf}) \times (\text{demand cost}) \]

The increased billing demand due to low power factor, Dpf, is estimated as:
\[ \text{Dpf} = \{ (D) \times \left[ (\text{PFp}) / (\text{PFc}) \right] \} - (D) \]

where
\[ D = \text{measured peak demand for the month, kW} \]
\[ \text{PFp} = \text{minimum power factor necessary to avoid power factor charges, no units} \]
\[ \text{PFc} = \text{current power factor, no units} \]

As an example for your facility, the cost due to low power factor in December 2002 is found as:
\[ \text{Dpf} = \{ (529.2) \times \left[ (0.95) / (0.894) \right] \} - (529.2) \]
\[ \text{Dpf} = 33.14 \text{ kW} \]

Following with the substitutions,
\[ \text{CS}_{\text{Dec}} = (33.14) \times (8.07) = $268 \]

Table 4.1.3 details the potential cost savings. The total cost savings for the year analyzed would be:
\[ \text{CS} = $3,699/yr \]
Table 4.1.3 Summary of Cost Savings

<table>
<thead>
<tr>
<th>Month</th>
<th>Power Factor</th>
<th>Demand (kW)</th>
<th>Cost ($/kW)</th>
<th>CS ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dec-02</td>
<td>0.8940</td>
<td>529.2</td>
<td>8.07</td>
<td>268</td>
</tr>
<tr>
<td>Jan-03</td>
<td>0.8880</td>
<td>597.0</td>
<td>8.07</td>
<td>336</td>
</tr>
<tr>
<td>Feb-03</td>
<td>0.8882</td>
<td>579.6</td>
<td>7.99</td>
<td>322</td>
</tr>
<tr>
<td>Mar-03</td>
<td>0.8906</td>
<td>541.2</td>
<td>7.99</td>
<td>288</td>
</tr>
<tr>
<td>Apr-03</td>
<td>0.8938</td>
<td>540.9</td>
<td>7.99</td>
<td>272</td>
</tr>
<tr>
<td>May-03</td>
<td>0.8910</td>
<td>533.1</td>
<td>7.77</td>
<td>274</td>
</tr>
<tr>
<td>Jun-03</td>
<td>0.8871</td>
<td>534.6</td>
<td>7.77</td>
<td>295</td>
</tr>
<tr>
<td>Jul-03</td>
<td>0.8870</td>
<td>606.0</td>
<td>7.77</td>
<td>334</td>
</tr>
<tr>
<td>Aug-03</td>
<td>0.8830</td>
<td>581.7</td>
<td>7.81</td>
<td>345</td>
</tr>
<tr>
<td>Sep-03</td>
<td>0.8866</td>
<td>583.5</td>
<td>7.81</td>
<td>326</td>
</tr>
<tr>
<td>Oct-03</td>
<td>0.8843</td>
<td>549.6</td>
<td>7.81</td>
<td>319</td>
</tr>
<tr>
<td>Nov-03</td>
<td>0.8839</td>
<td>542.4</td>
<td>7.88</td>
<td>320</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td>3,699</td>
</tr>
</tbody>
</table>

Implementation Cost

As calculated on the previous page, the installation of capacitors rated at 125 kVAR would be required to correct for low power factor. The installation of these capacitors should increase the power factor to the desired level of 95%. With this improved power factor there would be no power factor charge. The installed cost for capacitors is estimated as $30/kVAR, and therefore the implementation cost, IC, is estimated as:

\[
IC = (125 \text{ kVAR})(30/\text{kVAR}) = 3,750
\]

Therefore, the annual cost savings of $3,699/yr would pay for the implementation cost of $3,750 within 1 year. To determine the exact optimum power correction factor and the specification of the capacitors requires engineering work beyond the scope of this report. It is recommended that additional professional advice be obtained from a capacitor supplier or an engineering firm. Finally, note that no energy savings can be attributed to this action; the savings are strictly monetary.
AR No. 2 - Reduce Compressed Air Leaks

**Recommended Action**

Repair leaks in compressed air lines on a regular basis.

- Estimated Electrical Demand Savings = 5.38 kW-mo/yr or 64.6 kW-mo/yr
- Estimated Electrical Energy Savings = 33,016 kWh/yr
- Estimated Electrical Demand Cost Savings = $455/yr
- Estimated Electrical Energy Cost Savings = $1,181/yr
- Estimated Net Cost Savings = $1,216/yr
- Estimated Implementation Cost = $416
- Simple Payback = 4 months

**Background**

Compressed air is sometimes referred to as the most expensive "utility" in a plant. Air compressors can consume a great deal of electrical energy and contribute significantly to electric demand. Blow-offs using compressed air and avoidable air leaks are therefore quite costly. Repairing even small leaks can lead to significant savings. The following table lists the various air compressors at this facility and the operating conditions.

**Table 4.2.1 Compressor Operating Conditions**

<table>
<thead>
<tr>
<th>Compressor #</th>
<th>Compressor Type</th>
<th>Motor Size</th>
<th>Operating Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Screw</td>
<td>100 hp</td>
<td>110</td>
</tr>
<tr>
<td>2</td>
<td>Screw</td>
<td>100 hp</td>
<td>110</td>
</tr>
<tr>
<td>3</td>
<td>Reciprocating</td>
<td>25 hp</td>
<td>Back-up</td>
</tr>
</tbody>
</table>

On the day of the audit, specific leaks were located and tagged in the facility. These locations are summarized in Table 4.2.2.
### Table 4.2.2 Location of Air Leaks

<table>
<thead>
<tr>
<th>No.</th>
<th>Location</th>
<th>Hole Diameter (in)</th>
<th>Leak Time (hr/yr)</th>
<th>Line Pressure (psig)</th>
<th>Line Pressure (psia)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Small Paint Booth</td>
<td>1/16</td>
<td>6,136</td>
<td>80</td>
<td>94.2</td>
</tr>
<tr>
<td>2</td>
<td>Small Paint Booth</td>
<td>1/16</td>
<td>6,136</td>
<td>80</td>
<td>94.2</td>
</tr>
<tr>
<td>3</td>
<td>Loading Dock Post</td>
<td>1/64</td>
<td>6,136</td>
<td>110</td>
<td>134.2</td>
</tr>
<tr>
<td>4</td>
<td>Behind 25 hp Compressor</td>
<td>1/32</td>
<td>6,136</td>
<td>100</td>
<td>114.2</td>
</tr>
<tr>
<td>5</td>
<td>East Fabrication</td>
<td>1/64</td>
<td>6,136</td>
<td>110</td>
<td>134.2</td>
</tr>
<tr>
<td>6</td>
<td>Blasting Machine</td>
<td>1/64</td>
<td>6,136</td>
<td>60</td>
<td>74.2</td>
</tr>
<tr>
<td>7</td>
<td>I-13 Machine Air Tool</td>
<td>1/32</td>
<td>6,136</td>
<td>110</td>
<td>134.2</td>
</tr>
<tr>
<td>8</td>
<td>Welding East Wall</td>
<td>1/32</td>
<td>6,136</td>
<td>110</td>
<td>134.2</td>
</tr>
<tr>
<td>9</td>
<td>Etching Wash</td>
<td>1/32</td>
<td>6,136</td>
<td>110</td>
<td>134.2</td>
</tr>
<tr>
<td>10</td>
<td>Blasting Machine</td>
<td>1/16</td>
<td>6,136</td>
<td>110</td>
<td>134.2</td>
</tr>
<tr>
<td>11</td>
<td>Conveyor North Wall</td>
<td>1/32</td>
<td>6,136</td>
<td>110</td>
<td>134.2</td>
</tr>
<tr>
<td>12</td>
<td>Main Paint Booth</td>
<td>1/32</td>
<td>6,136</td>
<td>110</td>
<td>134.2</td>
</tr>
<tr>
<td>13</td>
<td>Main Paint Booth</td>
<td>1/32</td>
<td>6,136</td>
<td>110</td>
<td>134.2</td>
</tr>
<tr>
<td>14</td>
<td>Main Paint Booth</td>
<td>1/32</td>
<td>6,136</td>
<td>110</td>
<td>134.2</td>
</tr>
<tr>
<td>15</td>
<td>Bucket Welding</td>
<td>1/32</td>
<td>6,136</td>
<td>110</td>
<td>134.2</td>
</tr>
<tr>
<td>16</td>
<td>Bucket Welding</td>
<td>1/64</td>
<td>6,136</td>
<td>110</td>
<td>134.2</td>
</tr>
</tbody>
</table>

### Anticipated Savings

Since the air compressors will typically be operating when the monthly demand peak is set, savings will be accrued in two forms. These are demand savings and energy savings. Cost savings will result from reduced electrical demand and reduced electrical usage costs. The demand savings is calculated in kW and then multiplied by the number of operating hours to estimate energy savings in kWh. The demand savings, energy savings, and cost savings are calculated below.

#### Demand Savings

The estimated demand savings, DS, can be realized by fixing all the air leaks in a particular area. The demand savings will be seen by the following relationship.

\[
DS = (TL) \times (C_1)
\]

where

- \(TL\) = the estimated amount of power lost due to all leaks, hp
- \(C_1\) = conversion constant, 0.746 kW/hp

This facility has more than one air compressor supplying compressed air to the line. However, it was observed through the use of power-loggers, that one of the 100 hp screw air...
compressor was responsible for almost 100% of the compressed air production. As a result, only one compressor was considered in the analysis. As both 100 hp screw air compressors are identical, it does not affects the results whichever is in use.

The volumetric flow rate of free air, $V$, exiting the hole is dependent upon whether the flow is choked. When the ratio of atmospheric pressure to line pressure, $P_{\text{atm}}/P_{\text{line}}$, is less than 0.5283, the flow is said to be choked (i.e. it is traveling at the speed of sound). The volumetric flow rate of free air, $V$, exiting the leak under choked flow conditions is calculated as follows:

\[
V_j = \frac{(T_{\text{in}} + 460) \times \left( \frac{P_{\text{line}}}{P_{\text{atm}}} \right) \times (C_4) \times (C_5) \times (C_6) \times (C_d) \times \left( \frac{D_j^2}{4} \right) \times (P_1)}{(T_{\text{line}} + 460)^{0.5}}
\]

where
- $T_{\text{in}} =$ temperature of the air at the inlet of compressor “$i$”, °F
- $P_{\text{line}} =$ line pressure at leak “$j$”, psia
- $P_{\text{atm}} =$ atmospheric pressure, 14.2 psia (based on 1,000 ft above sea level)
- $C_4 =$ isentropic sonic volumetric flow constant, 28.37 ft/sec-°R^{0.5}
- $C_5 =$ conversion constant, 60 sec/min
- $C_6 =$ conversion constant, 1/144 ft^2/in^2
- $C_d =$ coefficient of discharge for square edged orifice, 0.8 no units^2
- $D_j =$ leak diameter, in
- $P_1 =$ $\pi$, 3.1416
- $T_{\text{line}} =$ average line temperature, °F

Thus, the volumetric flow rate of air exiting the leak at the Small Paint Booth area that can be contributed to the 100 hp screw air compressor is:

\[
V_1 = \frac{(85 + 460) \times \left( \frac{94.2}{14.2} \right) \times (28.37) \times (60) \times \left( \frac{1}{144} \right) \times (0.8) \times \left( \frac{0.0625^2}{4} \right) \times (3.1416)}{(75 + 460)^{0.5}}
\]

\[
V_1 = 4.53 \text{ cfm}
\]

In order to calculate the power loss from each leak, each volume component must be evaluated separately, and then summed together. The power loss from each component, $L_j$, is

estimated as the power required to compress the volume of air lost, VL, from atmospheric pressure, \( \text{Patm} \), to the compressor discharge pressure, \( \text{Po} \), as follows\(^3,4\):

\[
L_j = \frac{(\text{Patm}) \times (C_2) \times (V_i) \times \left[ \frac{(k)}{(k - 1)} \right] \times (N) \times (C_3) \times \left\{ \left[ \frac{(\text{Po})}{(\text{Patm})} \right] \frac{(k - 1)}{(k \times N)} - 1 \right\}}{(\text{Ea}_i) \times (\text{Em}_i)}
\]

where

- \( C_2 \) = conversion constant, 144 in\(^2\)/ft\(^2\)
- \( k \) = specific heat ratio of air, 1.4, no units
- \( N \) = number of stages of compressor “i”, no units
- \( C_3 \) = conversion constant, 3.03 \times 10\(^{-5}\) hp-min/ft-lb
- \( \text{Po} \) = compressor operating pressure, psia
- \( \text{Ea} \) = air compressor isentropic (adiabatic) efficiency\(^5\), no units
  (0.82 for rotary screw compressors)
- \( \text{Em} \) = compressor motor efficiency, no units

The power loss component for the leak found at the Small Paint Booth area can now be calculated as:

\[
L_1 = \frac{(14.2) \times (144) \times (4.53) \left[ \frac{(1.4)}{(1.4 - 1)} \right] \times (1) \times (3.03 \times 10^{-5}) \left\{ \left[ \frac{(124.2)}{(14.2)} \right] \frac{(1.4 - 1)}{(1.4 \times 1)} - 1 \right\}}{(0.82) \times (0.936)}
\]

\[
L_1 = 1.10 \text{ hp}
\]

The demand savings, \( \text{DS}_1 \), from the air leak found in the Paint Booth (shipping) area will be:

\[
\text{DS}_1 = (\text{TL}_1) \times (0.746 \text{ kW}/\text{hp})
\]

\[
\text{DS}_1 = (1.10) \times (0.746)
\]

\[
\text{DS}_1 = 0.82 \text{ kW}
\]

From Table 4.2.3, it is seen that the total estimated monthly demand savings, found from summing the demand savings for each leak, is:

---


\[ DS = 5.38 \text{ kW} \]

**Energy Savings**

The energy savings realized by repairing air leaks, \( ES \), can be calculated as follows:

\[ ES = (DS) \times (H) \]

where

\[ H = \text{operating hours of the compressor in each area, hr/yr} \]

Therefore, the savings associated with the Small Paint Booth will be:

\[ ES_1 = (0.82) \times (6,136) \]
\[ ES_1 = 5,032 \text{ kWh/yr} \]

Table 4.2.3 describes the savings associated with fixing the air leaks. The total estimated energy savings, \( ES \), can be found in Table 4.2.3 as:

\[ ES = 33,016 \text{ kWh/yr} \]

**Cost Savings**

The annual cost savings, \( CS_i \), associated with each leak can be estimated as follows:

\[ CS_i = (ECS_i) + (DCS_i) \]

where

\[ ECS_i = \text{energy cost savings, $/yr} \]
\[ DCS_i = \text{demand cost savings, $/yr} \]

The energy cost savings can be calculated as follows:

\[ ECS_i = (E_i) \times \text{(unit usage cost, $/kWh)} \]
\[ ECS_i = (5,032 \text{ kWh/yr}) \times ($0.0359/\text{kWh}) \]
\[ ECS_i = $181/\text{yr} \]

The total estimated annual energy cost savings, \( ECS \), can be found in Table 4.2.3 as:

\[ ECS = $1,181/\text{yr} \]

And the demand cost savings can be calculated as:

\[ DCS_i = (DS_i) \times \text{(unit demand cost, $/kW-yr)} \]
\[ DCS_i = (0.82 \text{ kW}) \times ($84.52/\text{kW-yr}) \]
\[ DCS_i = $69/\text{yr} \]
The total estimated annual demand cost savings, CS, can be found in Table 4.2.3 as:

\[ \text{DCS} = \$455/yr \]

Substituting values,

\[ CS_i = (181) + (69) \]
\[ CS_i = \$250/yr \]

The total estimated annual cost savings, CS, can be found in Table 4.2.3 as:

\[ CS = \$1,636/yr \]

**Increased Costs**

Inspecting the compressed air system and detecting leaks has a cost associated. It is recommended on a regular basis to conduct an air leak detection survey. The period between surveys cannot be determined due to the fact that it cannot be predicted how many air leaks will be found. It is recommended to continue with inspections once a year, during the yearly plant shut down, and adjust the period between surveys according to results. Also, plant personnel should be encouraged to report leaks if discovered, and corrective actions could be scheduled. It is assumed that for this facility, a crew of two people would be able to inspect the compressed air system in six ours.

So, the increased costs, IC, can be estimated as:

\[ IC = (N) \times (HS) \times (LC) \]

where

\[ N = \text{number of inspectors, person} \]
\[ HS = \text{hours to conduct the survey, hr/yr} \]
\[ LC = \text{labor cost, $/hr} \]

Substituting values:

\[ IC = (2) \times (6) \times (35) \]
\[ IC = \$420/yr \]

Finally, the net cost savings, NCS, for implementing this recommendation, are estimated by the following equation:
\[ \text{NCS} = (\text{ECS}) + (\text{DCS}) - (\text{IC}) \]

Substituting values,

\[ \text{NCS} = (1,181) + (455) - ($420/\text{yr}) \]
\[ \text{NCS} = $1,216/\text{yr} \]

Table 4.2.3 also gives the volumetric flow rate, power lost due to the leak, energy and demand savings and total cost savings for fixing the leaks.

<table>
<thead>
<tr>
<th>No.</th>
<th>Volumetric flow rate (cfm)</th>
<th>Power Loss (hp)</th>
<th>Demand Savings (kW)</th>
<th>Energy Savings (kWh/yr)</th>
<th>Demand Savings ($/yr)</th>
<th>Energy Savings ($/yr)</th>
<th>Total Savings ($/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.00</td>
<td>1.10</td>
<td>0.82</td>
<td>5,032</td>
<td>69</td>
<td>181</td>
<td>250</td>
</tr>
<tr>
<td>2</td>
<td>4.53</td>
<td>1.10</td>
<td>0.82</td>
<td>5,032</td>
<td>69</td>
<td>181</td>
<td>250</td>
</tr>
<tr>
<td>3</td>
<td>0.37</td>
<td>0.09</td>
<td>0.07</td>
<td>430</td>
<td>6</td>
<td>15</td>
<td>21</td>
</tr>
<tr>
<td>4</td>
<td>1.37</td>
<td>0.33</td>
<td>0.25</td>
<td>1,534</td>
<td>21</td>
<td>55</td>
<td>76</td>
</tr>
<tr>
<td>5</td>
<td>0.37</td>
<td>0.09</td>
<td>0.07</td>
<td>430</td>
<td>6</td>
<td>15</td>
<td>21</td>
</tr>
<tr>
<td>6</td>
<td>0.22</td>
<td>0.05</td>
<td>0.04</td>
<td>245</td>
<td>3</td>
<td>9</td>
<td>12</td>
</tr>
<tr>
<td>7</td>
<td>1.49</td>
<td>0.36</td>
<td>0.27</td>
<td>1,657</td>
<td>23</td>
<td>59</td>
<td>82</td>
</tr>
<tr>
<td>8</td>
<td>1.49</td>
<td>0.36</td>
<td>0.27</td>
<td>1,657</td>
<td>23</td>
<td>59</td>
<td>82</td>
</tr>
<tr>
<td>9</td>
<td>1.49</td>
<td>0.36</td>
<td>0.27</td>
<td>1,657</td>
<td>23</td>
<td>59</td>
<td>82</td>
</tr>
<tr>
<td>10</td>
<td>5.98</td>
<td>1.45</td>
<td>1.08</td>
<td>6,627</td>
<td>91</td>
<td>238</td>
<td>329</td>
</tr>
<tr>
<td>11</td>
<td>1.49</td>
<td>0.36</td>
<td>0.27</td>
<td>1,657</td>
<td>23</td>
<td>59</td>
<td>82</td>
</tr>
<tr>
<td>12</td>
<td>1.49</td>
<td>0.36</td>
<td>0.27</td>
<td>1,657</td>
<td>23</td>
<td>59</td>
<td>82</td>
</tr>
<tr>
<td>13</td>
<td>1.49</td>
<td>0.36</td>
<td>0.27</td>
<td>1,657</td>
<td>23</td>
<td>59</td>
<td>82</td>
</tr>
<tr>
<td>14</td>
<td>1.49</td>
<td>0.36</td>
<td>0.27</td>
<td>1,657</td>
<td>23</td>
<td>59</td>
<td>82</td>
</tr>
<tr>
<td>15</td>
<td>1.49</td>
<td>0.36</td>
<td>0.27</td>
<td>1,657</td>
<td>23</td>
<td>59</td>
<td>82</td>
</tr>
<tr>
<td>16</td>
<td>0.37</td>
<td>0.09</td>
<td>0.07</td>
<td>430</td>
<td>6</td>
<td>15</td>
<td>21</td>
</tr>
</tbody>
</table>

From Table 4.2.3, it can be seen that the cost of compressed air leaks increases as the size of the leak increases. This fact can be seen even more clearly in the following air leak graph, Figure 4.2.1. Figure 4.2.1 is based upon the operating conditions for this facility including the energy costs, line pressure, and operating hours. As part of a continuing program to find and repair compressed air leaks, this graph can be referenced to estimate the cost of any leaks that may be found.
Implementation Cost

Implementation of this AR will involve repairing the air leaks found in the facility. The cost estimate for materials needed in these repairs is found from the 2000-2001 Grainger General Catalog and are shown in Table 4.2.4.

Table 4.2.4 Materials Costs for Air Leak Repairs

<table>
<thead>
<tr>
<th>Description</th>
<th>Unit Price ($)</th>
<th>Number of Units</th>
<th>Total ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>200 psi General purpose hose</td>
<td>94.00/(100 ft length)</td>
<td>1</td>
<td>94</td>
</tr>
<tr>
<td>Coupling</td>
<td>6.00 ea</td>
<td>7</td>
<td>42</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>Total</strong></td>
</tr>
</tbody>
</table>

It is estimated that two air leaks could be repaired in one hour. Thus, the 16 leaks could be repaired in approximately 8 hours at a labor cost of $35/hr. The annual net cost savings of $1,216/yr will pay for the estimated implementation cost of $416 within 4 months.
AR No. 3 – Install an Air Receiver and a Pressure Control Valve

**Recommended Action**

Install an air receiver (surge tank) in the compressed air system and a pressure control valve. This can eliminate the use of the second compressor.

- Estimated Electrical Demand Savings = 35.0 kW each month, or 420.0 kW-mo/yr
- Estimated Electrical Energy Savings = 63,700 kWh/yr
- Estimated Cost Savings = $5,245/yr
- Estimated Implementation Cost = $7,072
- Simple Payback Period = 1.4 years

**Background**

 Receivers are usually a necessary part of a Compressed Air System. Adding more compressed air storage decreases the number of times a compressor must alternate between loaded and unloaded states. In addition, the receiver provides a buffer of air for the system. This buffer allows peaks in the load to be supplied by air from the receiver and hence avoiding an additional compressor to get into service, as well as assuring all equipments fed by the system always have acceptable pressure levels for operation.

 Normally at this facility, a lead 100 hp screw air compressor runs the entire shifts, while a secondary 100 hp screw air compressor runs during moments of peaks in consumption. The second compressor operates approximately for six hours unloaded every day, and about an hour supplying air to the line. The installation of the receiver tank could allow the lead compressor to successfully carry the entire load every day.

 In addition, it is recommended a constant pressure valve be installed after the receiver. As significant amount of compressed air is being used in air leaks and blow-offs, limiting the pressure of the system automatically limits the amount of air lost in leaks or other loads dependant on line pressure.
**Anticipated Savings**

The secondary 100 hp screw air compressor contributes to the demand reading, therefore savings will accrue from the decrease in monthly demand and the decrease in annual energy usage. The demand savings are calculated in kW and then multiplied by the number of operating hours to get energy savings in kWh. The demand savings, energy savings and cost savings are calculated below.

**Demand Savings**

The annual demand savings, DS, after the receiver has been installed can be estimated as follows:

\[
DS = (DU)
\]

where

\[
DU = \text{demand when compressor is unloaded, kW}
\]

The demand contribution when the compressor is unloaded was measured with power loggers on the day of the audit. As the secondary compressor runs unloaded for at least 15 minutes before being automatically shut off, the demand contribution is just the unloaded power.

\[
DS = 35\text{ kW}
\]

**Energy Savings**

The annual energy savings that could be realized by avoiding the use of the secondary compressor, ES, can be estimated by the following equation:

\[
ES = (DS) \times (H)
\]

Where

\[
H = \text{secondary compressor operational yearly hours, hr/yr}
\]

\[
H = (7\text{ hr/day}) \times (5\text{ day/week}) \times (52\text{ week/yr})
\]

\[
H = 1,820\text{ hr/yr}
\]

Following through with the previous calculation,

\[
ES = 35 \times 1,820
\]
ES  =  63,700 kWh/yr

**Electrical Cost Savings**

Annual electrical cost savings, ECS, for the 40 hp compressor is estimated as:

\[
ECS  =  [ (DS) \times \text{(unit cost of demand)} ] + [ (ES) \times \text{(unit cost of electricity)} ]
\]

\[
ECS  =  [ (35 \text{ kW}) \times ($84.52/\text{kW-yr}) ] + [ (63,700 \text{ kWh/yr}) \times ($0.0359/\text{kWh}) ]
\]

ECS  =  $5,245/yr

**Implementation Costs**

Implementing this measure will require purchasing and installing a receiver (surge tank). The receiver size that would be needed is estimated in 1,000 gallons. The costs associated with purchasing and installing this size receiver are broken down in Table 4.3.1.

<table>
<thead>
<tr>
<th>Description</th>
<th>Unit Price ($)</th>
<th>Number of Units</th>
<th>Total ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,000 gallons receiver</td>
<td>3,000</td>
<td>1</td>
<td>3,000</td>
</tr>
<tr>
<td>1&quot; relief valve</td>
<td>72</td>
<td>1</td>
<td>72</td>
</tr>
<tr>
<td>3&quot; flow pressure control valve</td>
<td>750</td>
<td>1</td>
<td>750</td>
</tr>
<tr>
<td>miscellaneous materials</td>
<td>800</td>
<td>1</td>
<td>800</td>
</tr>
<tr>
<td>Delivery of materials</td>
<td>350</td>
<td>1</td>
<td>350</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>4,972</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

It is estimated that 60 hours of labor would be necessary to install the receiver, at a labor cost of $35/hr result in a total labor cost of $2,100. The total implementation cost of the project is $7,072. The annual savings of $5,245 would pay for the implementation cost within 1.4 years.
Install ductwork to allow warm air from the air compressors outlet to be used to supplement the plant heating load for neighboring areas of the plant.

Estimated Energy Savings = 480 MMBtu/yr
Estimated Cost Savings = $3,182/yr
Estimated Implementation Cost = $1,044
Simple Payback Period = 4 months

Background

Presently, waste heat from the air compressor is discharged outside. By installing additional ductwork, the compressor waste heat would be available to heat the other areas in the plant. During the months when heating is not required, the heat from the compressor should still be ducted to the outside so no additional heating loads are added which will warm the plant. A simple damper in the ductwork can be used to switch from a cooling to heating season setting.

Anticipated Savings

By recovering the heat lost from the air compressor and using it to supplement the natural gas heaters in the plant, an energy savings, ES, will accrue due to the decrease in natural gas used in the existing heaters. By using less gas and therefore less energy, a cost savings, CS, will occur. The procedure used here calculates the rate of heat loss in MMBtu per hour and then multiplies by the seasonal operating hours to get the savings in MMBtu. The energy savings and cost savings are calculated below.

Energy Savings

It is estimated that typically screw compressors can have about 60% of their energy recovered in the form of heat. On the day of the audit, power measurements taken for the 100 hp
screw air compressor indicated an average power requirement of 75 kW. Thus, a simple calculation can estimate the amount of energy that can be recovered.

\[ Q = (D) \times (H) \times (FHR) \]

where,

- \( D \) = average demand of the compressor, 80 kW
- \( H \) = estimated hours when heat recovery is plausible, h/yr
- \( FHR \) = fraction of heat available for recovery, no units

Thus, the total amount of energy recovered is:

\[ Q = (75) \times (2,500) \times (0.60) \]
\[ Q = 112,500 \text{ kWh/yr} \]

The rate of heat loss from the compressor is the total heat added to the plant by the compressor. Given this information, the natural gas energy savings from the heat added to the plant each year can be estimated as:

\[ ES = \frac{(Q) \times (C_1) \times (C_2)}{(Eff)} \]

where,

- \( C_1 \) = conversion constant, 3,412 Btu/kWh
- \( C_2 \) = conversion constant, \( 10^{-6} \) MMBtu/Btu
- \( Eff \) = efficiency of the heating system, no units

Substituting values,

\[ ES = \frac{(112,500) \times (3,412) \times (10^{-6})}{(0.80)} \]
\[ ES = 480 \text{ MMBtu/yr} \]

**Costs Savings**

The annual energy cost savings for the decreased use of the natural gas heaters, ECS, is calculated as follows:

\[ ECS = (ES) \times \text{(marginal unit usage cost of gas $/MMBtu)} \]
\[ ECS = (480) \times (6.63) \]
\[ ECS = $3,182/\text{yr} \]
There will not be significant additional operation cost associated with the proposed installation. The existing compressor fan would be able to force the air into the plant.

**Implementation Cost**

Sheet metal ductwork would be easily used to move the waste heat from the compressor outlet to the rest of the plant. The total implementation cost for material and labor to make this modification to the compressor room is broken down in Table 4.4.1.

**Table 4.4.1 Costs for Implementing the Ductwork**

<table>
<thead>
<tr>
<th>Description</th>
<th>Unit Cost</th>
<th># of Units</th>
<th>Total ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Damper</td>
<td>$157 ea</td>
<td>2</td>
<td>314</td>
</tr>
<tr>
<td>Duct 3’x5’</td>
<td>$20/ft</td>
<td>5</td>
<td>100</td>
</tr>
<tr>
<td>Labor</td>
<td>$35/hr</td>
<td>18</td>
<td>630</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td></td>
<td></td>
<td><strong>1,044</strong></td>
</tr>
</tbody>
</table>

The annual cost savings of $3,182/yr will pay for the implementation cost of $1,044 within 4 months.
**AR No. 5 – Reduce Plant Air Exhaust by Improving Ventilation Design**

**Recommended Action**

Add a 16,000 cfm fan at a convenient location and avoid using one of the 32,600 cfm exhaust fan. This action would reduce the overall electrical energy and demand requirements, and reduce the gas usage for heating of the plant.

- Estimated Electrical Demand Savings = 1.9 kW each month, or 22.8 kW-month/yr
- Estimated Electrical Energy Savings = 11,658 kWh/yr
- Estimated Gas Usage Savings = 1,725 MMBtu/yr
- Estimated Cost Savings = $12,016/yr
- Estimated Implementation Cost = $2,495
- Simple Payback = 3 months

**Background**

The existing plant ventilation system has eleven 5 hp air exhaust fans (32,600 cfm), and two 1.5 hp air exhaust fans (10,600 cfm). The amount of air drawn from the plant is controlled manually by choosing which exhaust fans should be in operation. Normally, several of the 5 hp fans and the two 1.5 hp fans operate. According to the activity on the plant, and in order to evacuate fumes generated at the Welding area, additional fans are brought into service. On the day of the audit, it was observed that the locations of the fans do not favor the air circulation from the “clean” areas to the Welding area. Actually, it causes a path for fumes to move into the “clean” areas such as Fabrication, Boom Assembly, and Tractor Assembly. The problem is fixed by exhausting more air from these areas while creating even more conditions for the fumes to be driven into these areas.

It is recommended to perform a detailed ventilation study, which would probably result in the addition of new exhaust fans at more convenient locations. For estimating the savings from implementing this recommendation, it is assumed that by installing a 2 hp air exhaust fan (16,000 cfm) at a convenient location, one of the 5 hp air exhaust fans (32,600 cfm) would not be
used. This would reduce the demand and energy used by the ventilation system and also reduce the amount of plant air being exhausted. As a consequence, the heating energy that must be used to condition the outdoor air which makes up the exhaust would be reduced.

**Anticipated Savings**

The anticipated savings for the recommendation would be accrued in three forms: electric demand savings, electric energy savings, and gas usage savings with the associated cost savings.

**Demand Savings**

The calculations are based on the required power by the different motor sizes. The demand savings, DS, for the smaller fan motor can be estimated using the following relationship:

\[
DS = (CD) - (PD)
\]

where:

\[
CD = \text{the current demand of a 5 hp motor, kW}
\]
\[
PD = \text{the proposed demand of a 2 hp motor, kW}
\]

The current demand, CD, can be estimated as follows:

\[
CD = (\text{HP}) \times (C_1) \times (\text{LF}) \div (\text{EFF})
\]

where

\[
\text{HP} = \text{motor horsepower, hp}
\]
\[
C_1 = \text{conversion constant, 0.746 kW/hp}
\]
\[
\text{LF} = \text{load factor, no units}
\]
\[
\text{EFF} = \text{efficiency of fan motor, no units}
\]

Substituting values:

\[
CD = [(5) \times (0.746) \times (0.9) \div (0.885)]
\]
\[
CD = 3.8 \text{ kW}
\]

By performing the same calculations for the 2 hp motor. Substituting values.

\[
PD = [(2) \times (0.746) \times (0.9) \div (0.846)]
\]
\[
PD = 1.9 \text{ kW}
\]
Following with substitutions,

\[
DS = (3.8) - (1.9) \\
DS = 1.9 \text{ kW}
\]

**Electrical Energy Savings**

The electrical energy savings, \(ES\) can be calculated using the following relationship:

\[
ES = (DS) \times (H)
\]

where:

\[
H = \text{hours of operation of the system per year, hr/yr}
\]

Substituting values,

\[
ES = (1.9) \times (6,136) \\
ES = 11,658 \text{ kWh/yr}
\]

**Gas Usage Savings**

The energy savings from reducing the amount of exhaust air comes from a reduction in the natural gas consumption by the makeup air system.

To estimate the reduction in gas usage for heating for the exhaust systems after a 2 hp fan is used in substitution of a 5 hp fan, the following energy balance equation was used.

\[
Q_{ma} = (\text{CFM}) \times (\rho) \times (C_p) \times [(T_i) - (T_o)] \times (C_2) \times (C_3)
\]

where,

\[
Q_{ma} = \text{energy reduction in heating from the gas air heaters, MMBtu/hr} \\
\text{CFM} = \text{reduction in volumetric flow rate, ft}^3/\text{min} \\
C_p = \text{constant pressure specific heat of air, 0.24 Btu/(lb-°F)} \\
\rho = \text{air density at plant air temperature, lb/ft}^3 \\
T_i = \text{plant winter temperature, °F} \\
T_o = \text{average outside air temperature, °F} \\
C_2 = \text{conversion constant, 60 min/hr} \\
C_3 = \text{conversion constant, } 10^{-6} \text{ MMBtu/Btu}
\]

Substituting values,
\[ Q_{ma} = \left( \frac{32,600 - 16,000}{32 - 65} \right) \times 0.24 \times 60 \times 60 \times 10^{-6} \]

\[ Q_{ma} = 0.552 \text{ MMBtu/hr} \]

Now, it is possible to calculate the natural gas energy savings, \( GES \), as:

\[ GES = \left( Q_{ma} \right) \times (HH) / (EFF_{HS}) \]

where,

\[ HH = \text{hours of operation of the plant’s heating system} \]
\[ EFF_{HS} = \text{efficiency of the plant’s heating system, no units} \]

Substituting values,

\[ GES = (0.552) \times (2,500) / (0.80) \]
\[ GES = 1,725 \text{ MMBtu/hr} \]

\noindent \textit{Cost Savings}

The estimated annual cost savings, \( CS \), from implementing this recommendation are obtained by adding the costs savings from the natural gas energy reduction, \( GES \), to the electrical costs savings from using a smaller fan’s motor.

\[ CS = (GCS) + (ECS) + (DCS) \]

Applying the monthly marginal energy rates, the natural gas cost savings from reducing the amount of exhaust air were calculated.

The annual energy cost savings for the decreased use of the natural gas heaters, \( GCS \), is calculated as follows:

\[ GCS = (ES) \times \text{marginal unit usage cost of gas $/MMBtu} \]
\[ GCS = (1,725) \times (6.63) \]
\[ ECS = $11,436/yr \]

The demand cost savings, \( DCS \) can be calculated using the following relationship:

\[ DCS = (DS) \times \text{marginal demand cost, $/kW-yr} \]

Substituting values,

\[ DCS = (1.9 \text{ kW}) \times ($84.52/kWyr) \]
\[ DCS = $161/yr \]
The electrical energy cost savings are estimated by multiplying the total electrical energy reduction by the average marginal rate for electrical energy.

\[
ECS = (ES) \times (\text{marginal electrical energy cost, } \$/\text{kWh})
\]

\[
ECS = (11,658) \times (0.0359)
\]

\[
ECS = $419/\text{yr}
\]

Substituting values,

\[
CS = (11,436) + (419) + (161)
\]

\[
CS = $12,016/\text{yr}
\]

Implementation Cost

The implementation cost for this recommendation is the cost of the new exhaust fan and the labor required to install this type of system. Table 4.5.2 shows the estimated cost of the components that are necessary to accomplish this recommendation.

<table>
<thead>
<tr>
<th>Table 4.5.1 Estimated Costs for Installing the New Air Exhaust Fan.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Component</strong></td>
</tr>
<tr>
<td>(1) Air Exhaust Fan, 2 hp</td>
</tr>
<tr>
<td>Installation materials: cables, terminals, boxes, etc</td>
</tr>
<tr>
<td>Labor (40 hr at $35/hr)</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
</tr>
</tbody>
</table>

Therefore, the total yearly cost savings of $12,016 would pay for the total implementation cost of $2,495 within 3 months.
Recommended Action

Replace the standard V-belts and sheaves on the production equipment listed below with notched V-belts on a replacement basis.

- Estimated Electrical Demand Savings = 2.9 kW each month, or 34.8 kW-mo/yr
- Estimated Electrical Energy Savings = 7,890 kWh/yr
- Estimated Energy Cost Savings = $283/yr
- Estimated Demand Cost Savings = $245/yr
- Estimated Implementation Cost = $136
- Simple Payback = 4 months

Background

The use of notched V-belts has been demonstrated to provide energy savings through reduction of belt slippage on drive sheaves. Notched V-belts bend easier than regular belts and therefore wrap around the sprockets more closely. This results in reduced slippage during regular operation with allowance for slippage during startup. Manufacturers claim energy savings of three to five percent when standard V-belts are replaced with notched V-belts, depending on the type of equipment driven, operation cycles and maintenance of existing V-belts. For this application, savings are estimated as approximately three percent based on manufacturer's literature.

Anticipated Savings

The motors in question typically run during the time when the monthly demand peak is set, and thus contribute to the peak. As a result, savings will be accrued in two forms: demand savings and energy savings. Cost savings will result from reduced electrical demand and reduced electrical energy usage costs. The demand savings is calculated in kW and then multiplied by the number of operating hours to get energy savings in kWh. The demand savings, energy savings, and cost savings are calculated below.
Demand Savings

The electrical demand savings, DS, due to replacement with notched V-belts can be estimated as follows:

\[ DS = \frac{(N) \times (HP) \times (LF) \times (CF) \times (FS) \times (C)}{(EFF)} \]

where

N = number of motors of given size, no units
HP = power rating of motors driving the equipment considered, hp
LF = fraction of rated power at which equipment operates, no units
CF = coincident factor
FS = fractional energy savings, no units
C = conversion constant, 0.746 kW/hp
EFF = efficiency of motor driving equipment considered, no units

For example, replacing the existing belt drive on the 40 hp motor of the MAU, results in the following demand savings, DS₁:

\[ DS₁ = \frac{(1) \times (40) \times (0.9) \times (0.03) \times (0.746)}{(0.935)} \]

\[ DS₁ = 0.86 \text{ kW} \]

A summary of demand savings is given in Table 4.6.1.

Energy Savings

The electrical energy savings, ES, due to replacement with notched V-belts can be estimated as follows:

\[ ES = (DS) \times (H) \times (UF) \]

where

H = annual operating hours of the equipment, hr/yr
UF = fraction of operating time that motor is in use, no units

For example, replacing the existing belt drive on the 40 hp motor of the MAU, results in the following energy savings, ES₁:

\[ ES₁ = (0.86) \times (2,500) \times (1) \]

\[ ES₁ = 2,150 \text{ kWh/yr} \]
A summary of energy savings is also given in Table 4.6.1.

**Cost Savings**

Annual cost savings for the 40 hp motor of the MAU, \(CS_1\), is estimated as:

\[ CS_1 = (ECS_1) + (DCS_1) \]

where

\[ ECS_1 = \text{energy cost savings, $/yr} \]
\[ DCS_1 = \text{demand cost savings, $/yr} \]

The energy cost savings for the same motor can be calculated as follows:

\[ ECS_1 = (ES_1) \times (\text{unit energy cost, $/kWh}) \]
\[ ECS_1 = (2,150) \times ($0.0359/kWh) \]
\[ ECS_1 = $77/yr \]

The total estimated annual energy cost savings, \(ECS\), can be found in Table 4.6.1.

\[ ECS = $283/yr \]

Similarly, the demand cost savings for the 40 hp motor of the MAU, \(DCS_1\), can be calculated as:

\[ DCS_1 = (DCS_1) \times (\text{unit demand cost, $/kWh}) \]
\[ DCS_1 = (0.86) \times ($84.52/kW) \]
\[ DCS_1 = $73/yr \]

The total estimated annual demand cost savings, \(DCS\), can be found in Table 4.6.1.

\[ DCS = $245/yr \]

Finally, the total estimated annual cost savings result from adding the total energy cost savings to the total demand cost savings:

\[ CS = (283) + (245) \]
\[ CS = $528/yr \]

Table 4.6.1 contains a summary of the savings calculations for all motors considered at this facility.

From Table 4.6.1, the total demand savings, \(DS\), is estimated as 2.9 kW, and the total energy savings, \(ES\), is estimated as 7,890 kW/yr, which corresponds to a cost savings of $528/yr.
Table 4.6.1 Summary of Savings Calculations

<table>
<thead>
<tr>
<th>Item name</th>
<th>N</th>
<th>HP</th>
<th>EFF</th>
<th>LF</th>
<th>UF</th>
<th>FS</th>
<th>H (hr/yr)</th>
<th>DS ($/yr)</th>
<th>DCS ($/kWh/yr)</th>
<th>ES ($/yr)</th>
<th>ECS ($/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AHU 1</td>
<td>1</td>
<td>40</td>
<td>0.935</td>
<td>0.9</td>
<td>1</td>
<td>0.03</td>
<td>2,500</td>
<td>0.86</td>
<td>72.69</td>
<td>2,150</td>
<td>77.19</td>
</tr>
<tr>
<td>AHU 2</td>
<td>1</td>
<td>40</td>
<td>0.935</td>
<td>0.9</td>
<td>1</td>
<td>0.03</td>
<td>2,500</td>
<td>0.86</td>
<td>72.69</td>
<td>2,150</td>
<td>77.19</td>
</tr>
<tr>
<td>AHU 3</td>
<td>1</td>
<td>40</td>
<td>0.935</td>
<td>0.9</td>
<td>1</td>
<td>0.03</td>
<td>2,500</td>
<td>0.86</td>
<td>72.69</td>
<td>2,150</td>
<td>77.19</td>
</tr>
<tr>
<td>Oven</td>
<td>1</td>
<td>15</td>
<td>0.950</td>
<td>0.9</td>
<td>1</td>
<td>0.03</td>
<td>4,500</td>
<td>0.32</td>
<td>27.05</td>
<td>1,440</td>
<td>51.70</td>
</tr>
<tr>
<td>Totals</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2,90</td>
<td>245.12</td>
<td>7,890</td>
<td>283.27</td>
<td></td>
</tr>
</tbody>
</table>

Implementation Cost

The total implementation cost, IC, to replace the standard belt drive systems with notched V-belts on a replacement basis can be estimated from the following equation:

\[
IC = [(NB) \times (PC)]
\]

where

\[
NB = \text{number of belts}
\]

\[
PC = \text{premium cost for the corresponding notched V-belt, $/belt}
\]

The price per notched V-belt is quoted from the 2005 Grainger Catalog. For example, the implementation cost, IC₁, for replacing the existing belt drive on 40 hp motor of the MAU is estimated as follows:

\[
IC₁ = [(4) \times (10.60)]
\]

\[
IC₁ = $42.40
\]

Table 4.6.2 summarizes the implementation cost for each machine drive system and the corresponding payback period.

Table 4.6.2 Summary of Costs and Payback

<table>
<thead>
<tr>
<th>Item name</th>
<th># of Belts</th>
<th>Premium Cost per Belt ($/belt)</th>
<th>Total Belt Cost ($/yr)</th>
<th>Simple Payback (yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AHU 1</td>
<td>4</td>
<td>10.60</td>
<td>42.40</td>
<td>0.3</td>
</tr>
<tr>
<td>AHU 2</td>
<td>4</td>
<td>10.60</td>
<td>42.40</td>
<td>0.3</td>
</tr>
<tr>
<td>AHU 3</td>
<td>4</td>
<td>10.60</td>
<td>42.40</td>
<td>0.3</td>
</tr>
<tr>
<td>Oven</td>
<td>2</td>
<td>4.26</td>
<td>8.52</td>
<td>0.1</td>
</tr>
<tr>
<td>Totals:</td>
<td></td>
<td></td>
<td>135.72</td>
<td></td>
</tr>
</tbody>
</table>
The estimated annual cost savings of $528/yr will pay for the estimated implementation cost of $136 within 4 months.
**AR No. 7 - Install High Efficiency Lighting**

**Recommended Action**

Replace existing lamps with high-efficiency (low wattage) lamps as the existing lamps burn out. The projected savings, listed below, will be achieved when all lamps have been replaced. Until then, savings will be less than the total amount.

- Estimated Electrical Demand Savings = 16.2 kW-mo/yr or 194.4 kW-mo/yr
- Estimated Electrical Energy Savings = 99,405 kWh/yr
- Estimated Electrical Energy Cost Savings = $3,568/yr
- Estimated Electrical Demand Cost Savings = $1,369/yr
- Estimated Annual Cost Savings = $4,937/yr
- Estimated Annual Cost Premium = $3,309/yr
- Estimated Annual Net Savings = $1,628/yr

**Background**

Improved lighting technology has led to lamps that have longer life and require less wattage at a minimal decrease in overall lumens. These improved lamps have been designed as a direct replacement for the standard lamps without the need for purchasing new fixtures.

**Anticipated Savings**

Detailed tables of the lighting calculations for the areas mentioned are shown in Tables 4.7.1 and 4.7.2. The values given in the Existing Lighting table are the result of a lighting survey conducted on the day of the audit. Values in the Proposed Lighting table are calculated based on replacing the existing lamps with high efficiency lamps. The demand savings is calculated in kW and then multiplied by the number of operating hours to get energy savings in kWh. The demand savings, energy savings, and cost savings are calculated below.
### Table 4.7.1 Existing Lighting

<table>
<thead>
<tr>
<th>Area No.</th>
<th>Area</th>
<th>Lamp Type</th>
<th>Ballast Usage (frac.)</th>
<th>Lamp Life (Hrs)</th>
<th>Lamp Wattage (W)</th>
<th>No. of Lamps</th>
<th>Total Demand (kW)</th>
<th>Usage Time (hr/yr)</th>
<th>Total Energy Usage (kWh/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Main Assembly</td>
<td>MH-400</td>
<td>0.2</td>
<td>20,000</td>
<td>400</td>
<td>92</td>
<td>44.2</td>
<td>6,136</td>
<td>271,211</td>
</tr>
<tr>
<td>2</td>
<td>Truck Assembly</td>
<td>MH-400</td>
<td>0.2</td>
<td>20,000</td>
<td>400</td>
<td>27</td>
<td>13.0</td>
<td>6,136</td>
<td>79,768</td>
</tr>
<tr>
<td>3</td>
<td>Welding</td>
<td>MH-400</td>
<td>0.2</td>
<td>20,000</td>
<td>400</td>
<td>71</td>
<td>34.1</td>
<td>6,136</td>
<td>209,238</td>
</tr>
<tr>
<td>4</td>
<td>Paint</td>
<td>MH-400</td>
<td>0.2</td>
<td>20,000</td>
<td>400</td>
<td>22</td>
<td>10.6</td>
<td>6,136</td>
<td>65,042</td>
</tr>
<tr>
<td>5</td>
<td>Axle Assembly</td>
<td>MH-400</td>
<td>0.2</td>
<td>20,000</td>
<td>400</td>
<td>12</td>
<td>5.8</td>
<td>6,136</td>
<td>35,589</td>
</tr>
<tr>
<td>6</td>
<td>Shipping / Storage</td>
<td>MH-400</td>
<td>0.2</td>
<td>20,000</td>
<td>400</td>
<td>110</td>
<td>52.8</td>
<td>6,136</td>
<td>323,981</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>160.5</strong></td>
<td></td>
<td><strong>984,829</strong></td>
</tr>
</tbody>
</table>

MH-400  400 Watt Metal Halide

### Table 4.7.2 Proposed Lighting

<table>
<thead>
<tr>
<th>Area No.</th>
<th>Lamp Type</th>
<th>Ballast Usage (frac.)</th>
<th>Lamp Wattage (W)</th>
<th>No. of Lamps</th>
<th>Total Demand (kW)</th>
<th>Total Energy Usage (kW)</th>
<th>Monthly Demand Savings (kW)</th>
<th>Energy Saved (kW/hr)</th>
<th>Energy Cost Savings ($/yr)</th>
<th>Demand Cost Savings ($/yr)</th>
<th>Total Cost Savings ($/yr)</th>
<th>Simple Payback (yrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>MH-360</td>
<td>0.2</td>
<td>360</td>
<td>92</td>
<td>39.7</td>
<td>243,599</td>
<td>4.5</td>
<td>27,612</td>
<td>991</td>
<td>380</td>
<td>1,371</td>
<td>2.1</td>
</tr>
<tr>
<td>2</td>
<td>MH-360</td>
<td>0.2</td>
<td>360</td>
<td>27</td>
<td>11.7</td>
<td>71,791</td>
<td>1.3</td>
<td>7,977</td>
<td>286</td>
<td>110</td>
<td>396</td>
<td>2.2</td>
</tr>
<tr>
<td>3</td>
<td>MH-360</td>
<td>0.2</td>
<td>360</td>
<td>71</td>
<td>30.7</td>
<td>188,375</td>
<td>3.4</td>
<td>20,863</td>
<td>749</td>
<td>287</td>
<td>1,036</td>
<td>2.2</td>
</tr>
<tr>
<td>4</td>
<td>MH-360</td>
<td>0.2</td>
<td>360</td>
<td>22</td>
<td>9.5</td>
<td>58,292</td>
<td>1.1</td>
<td>6,750</td>
<td>242</td>
<td>93</td>
<td>335</td>
<td>2.1</td>
</tr>
<tr>
<td>5</td>
<td>MH-360</td>
<td>0.2</td>
<td>360</td>
<td>12</td>
<td>5.2</td>
<td>31,907</td>
<td>0.6</td>
<td>3,682</td>
<td>132</td>
<td>51</td>
<td>183</td>
<td>2.1</td>
</tr>
<tr>
<td>6</td>
<td>MH-360</td>
<td>0.2</td>
<td>360</td>
<td>110</td>
<td>47.5</td>
<td>291,460</td>
<td>5.3</td>
<td>32,521</td>
<td>1,168</td>
<td>448</td>
<td>1,616</td>
<td>2.2</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>144.3</strong></td>
<td><strong>885,424</strong></td>
<td><strong>16.2</strong></td>
<td><strong>99,405</strong></td>
<td><strong>3,568</strong></td>
<td><strong>1,369</strong></td>
<td><strong>4,937</strong></td>
<td><strong>2.2</strong></td>
</tr>
</tbody>
</table>

MH-360  360 Watt Metal Halide

**Demand Savings**

The annual demand savings, DS, after all the lamps have been replaced in any area of the facility, can be estimated as follows:

$$DS = (CD) - (PD)$$

where

- **CD** = current demand, kW
- **PD** = proposed demand, kW

The current and proposed demand from the lighting system in any area of the facility can be estimated as follows:
CD or PD = (N) x (W) x [ 1 + (FB) ] x (C2)

where
N = number of lamps, no units
W = wattage of the individual lamps, W
FB = fractional increase in power draw due to ballast, no units
C2 = conversion constant, 0.001 kW/W

Lighting manufacturers' literature shows that high intensity discharge ballasts typically draw about 20% of the energy consumed by the lamp. Incandescent lamps have no ballast, so the value used for the fractional increase in power due to ballast draw is zero.

As an example, the current demand, CD1, by the lights in the Main Assembly area is:

\[ CD_1 = (92) \times (400) \times [1 + (0.2)] \times (0.001) \]
\[ CD_1 = 44.2 \text{ kW} \]

The proposed demand, PD1, for the lights in the same area is estimated as:

\[ PD_1 = (92) \times (360) \times [1 + (0.2)] \times (0.001) \]
\[ PD_1 = 39.7 \text{ kW} \]

Thus, the estimated demand savings, DS1, for retrofitting the 400 W lamps in the Main Assembly area with 360 W lamps are given by the following:

\[ DS_1 = (CD_1) - (PD_1) \]
\[ DS_1 = 4.50 \text{ kW} \]

Table 4.7.2 describes the monthly demand savings associated with the proposed high efficiency lamps. The total demand savings, DS, can be found in Table 4.7.2.

\[ DS = 16.2 \text{ kW} \]

Energy Savings

The energy savings, ES, can be calculated by multiplying the demand savings by the operating hours of the lighting. Therefore, the energy savings associated with this measure can be calculated as follows:

\[ ES = (DS) \times (H) \]

where
\[ H = \text{operating hours of the lighting system, hr/yr} \]

As an example, the energy savings for the Main Assembly area, \( ES_1 \), is

\[
ES_1 = (4.5) \times (6,136) \\
ES_1 = 27,612 \text{ kWh/yr}
\]

The total energy savings, \( ES \), can be found in Table 4.7.2.

\[ ES = 99,405 \text{ kWh/yr} \]

Cost Savings

The cost savings associated with the proposed electronic ballasts and high efficiency lamps is broken down by area in Table 4.7.2. The anticipated annual cost savings, \( CS_i \), associated with the replacement of all lamps in a particular area is estimated as:

\[
CS_i = (ECS_i) + (DCS_i)
\]

where

\[
\begin{align*}
ECS_i &= \text{energy cost savings, $/yr} \\
DCS_i &= \text{demand cost savings, $/yr}
\end{align*}
\]

The energy cost savings can be calculated as follows:

\[
ECS_i = (ES_i) \times (\text{unit usage cost, $/kWh})
\]

As an example, the energy cost savings for the Main Assembly area, \( ES_1 \), is

\[
ECS_1 = (ES_1) \times (\text{unit usage cost, $/kWh}) \\
ECS_1 = \$991/yr
\]

The total estimated annual energy cost savings, \( ECS \), can be found in Table 4.7.2

The demand cost savings can be calculated as follows:

\[
DCS_i = (DS_i) \times (\text{unit usage cost, $/kW-yr})
\]

As an example, the demand cost savings for the Main Assembly area, \( ES_1 \), is

\[
DCS_1 = (DS_1) \times (\text{unit usage cost, $/kW-yr}) \\
DCS_1 = \$380/yr
\]

The total estimated annual demand cost savings, \( DCS \), can be found in Table 4.7.2

Following with the example, the total estimated cost savings for the Main Assembly area, \( CS_1 \), is
The total cost savings, $CS_1$, associated with implementing this measure in all of the areas considered is summarized in Table 4.7.2.

$$CS_1 = (991) + (380)$$

$$CS_1 = $1,371/yr$$

**Incremental Savings**

The total annual energy and cost savings will be achieved once all of the lamps have been replaced. Until then, savings will be less than the total amount.

The incremental demand, energy, and cost savings can be estimated by multiplying the annual savings in any area by the fraction of lamps that will be replaced each year in the same area. The fraction of lamps that will be replaced per year, $f$, can be estimated as follows:

$$f = \frac{\text{annual operating hours}}{\text{hours of total lamp life}}$$

The hours of total lamp life can be obtained from the *Illuminating Engineering Society 1985 Ready Reference* book. As an example, the expected life of a metal halide lamp is 20,000 hours. Thus, the value of $f$ for the new 360 W metal halide lamps in the Main Assembly area is estimated as:

$$f = \frac{6,136}{20,000}$$

$$f = 0.31$$

Therefore, the demand, energy, and cost savings for the first year in this same area are estimated as:

$$\text{DS(1st)} = f \times \text{(DS)}$$

$$\text{DS(1st)} = (0.31) \times (4.5 \text{ kW})$$

$$\text{DS(1st)} = 1.4 \text{ kW}$$

$$\text{ES(1st)} = f \times \text{(ES)}$$

$$\text{ES(1st)} = (0.31) \times (27,612 \text{ kWh/yr})$$

$$\text{ES(1st)} = 8,560 \text{ kWh/yr}$$

$$\text{CS(1st)} = f \times \text{(CS)}$$

$$\text{CS(1st)} = (0.31) \times ($1,371/yr)$$

$$\text{CS(1st)} = $425/yr$$
Second year savings would be two times the above figures, and so forth, until the maximum annual savings of $4,937 is achieved. The incremental savings for the first two years of the replacement process are summarized in Table 4.7.3.

Table 4.7.3 Summary of Savings for First Two Years

<table>
<thead>
<tr>
<th>Area No.</th>
<th>Lamp Type</th>
<th>f Value</th>
<th>1st Year Cost Premium</th>
<th>Cumulative Cost Premium in 2nd Year</th>
<th>1st Year Demand Energy Savings (kW)</th>
<th>2nd Year Demand Energy Savings (kW)</th>
<th>1st Year Demand Energy Savings (kWh/yr)</th>
<th>2nd Year Demand Energy Savings (kWh/yr)</th>
<th>1st Year Cost Savings ($)</th>
<th>2nd Year Cost Savings ($)</th>
<th>1st Year Cost Savings ($)</th>
<th>2nd Year Cost Savings ($)</th>
<th>1st Year Cost Savings ($)</th>
<th>2nd Year Cost Savings ($)</th>
<th>1st Year Cost Savings ($)</th>
<th>2nd Year Cost Savings ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>MH-400</td>
<td>0.31</td>
<td>911</td>
<td>1,822</td>
<td>1.4</td>
<td>8,560</td>
<td>2.8</td>
<td>17,119</td>
<td>118</td>
<td>307</td>
<td>425</td>
<td>237</td>
<td>615</td>
<td>852</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>MH-400</td>
<td>0.31</td>
<td>268</td>
<td>536</td>
<td>0.4</td>
<td>2,473</td>
<td>0.8</td>
<td>4,946</td>
<td>34</td>
<td>89</td>
<td>123</td>
<td>68</td>
<td>178</td>
<td>246</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>MH-400</td>
<td>0.31</td>
<td>703</td>
<td>1,406</td>
<td>1.1</td>
<td>6,468</td>
<td>2.1</td>
<td>12,935</td>
<td>93</td>
<td>232</td>
<td>325</td>
<td>177</td>
<td>464</td>
<td>641</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>MH-400</td>
<td>0.31</td>
<td>218</td>
<td>436</td>
<td>0.3</td>
<td>2,093</td>
<td>0.7</td>
<td>4,185</td>
<td>25</td>
<td>75</td>
<td>100</td>
<td>59</td>
<td>150</td>
<td>209</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>MH-400</td>
<td>0.31</td>
<td>119</td>
<td>238</td>
<td>0.2</td>
<td>1,141</td>
<td>0.4</td>
<td>2,283</td>
<td>17</td>
<td>41</td>
<td>58</td>
<td>34</td>
<td>82</td>
<td>116</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>MH-400</td>
<td>0.31</td>
<td>1,090</td>
<td>2,180</td>
<td>1.6</td>
<td>10,882</td>
<td>3.3</td>
<td>20,163</td>
<td>135</td>
<td>362</td>
<td>497</td>
<td>279</td>
<td>724</td>
<td>1,003</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Totals</td>
<td></td>
<td></td>
<td>3,309</td>
<td>6,618</td>
<td>5.0</td>
<td>30,817</td>
<td>10.1</td>
<td>61,631</td>
<td>422</td>
<td>1,106</td>
<td>1,528</td>
<td>854</td>
<td>2,213</td>
<td>3,067</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Implementation Cost

The cost of implementing this energy conservation measure is based only on the cost premium for high efficiency lamps, since the cost of replacing burned-out lamps is assumed to be normal maintenance cost. Table 4.7.4 illustrates the cost premium associated with different types of lamps.

Table 4.7.4 Summary of Lamp Costs

<table>
<thead>
<tr>
<th>Existing Lamp</th>
<th>Proposed Lamp</th>
<th>Cost Difference ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metal Halide 400 W</td>
<td>Metal Halide 360 W</td>
<td>31.96</td>
</tr>
</tbody>
</table>

The annual lamp cost premium, LCP, for high efficiency lamps is calculated as follows:

\[
LCP = (f) \times (N) \times (CP)
\]

where

- \( N \) = number of lamps, no units
- \( CP \) = cost premium per lamp, $

As an example, the lamp cost premium for the lamps in the Main Assembly area is estimated as:

\[
LCP_1 = (0.31) \times (92) \times (31.96)
\]

\[
LCP_1 = $911
\]
Table 4.7.3 summarizes the annual lamp cost premium for each area considered at this facility. The total annual lamp cost premium is estimated as $3,309/yr.

When all changes are fully implemented there will be total cost savings of approximately $4,937/yr and an annual lamp cost premium of approximately $3,309/yr. These values result in net annual savings of $1,628/yr.

Another way to look at the savings is to consider the simple payback periods. The simple payback period, SP, is calculated as follows:

\[ SP = \frac{(N) x (CP)}{(CS)} \]

As an example, the simple payback period to replace all of the lamps in the Main Assembly on a replacement basis is estimated as:

\[ SP_1 = \frac{(92) x ($31.96)}{($1,371/yr)} \]
\[ SP_1 = 2.1 \text{ years} \]

Table 4.7.3 summarizes the simple payback period for each area considered at this facility.
AR No. 8 – Install Pre-filters on Main Paint Booth

Recommended Action:

Cover paint filters on the Main Paint Booth with pre-filters. This action would cut down on the number of filters the company replaces every year.

Estimated Filtering Material Cost Savings = $1,244/yr
Estimated Labor Cost Savings = $2,800/yr
Estimated Total Cost Savings = $4,044/yr
Estimated Implementation Cost = $440
Simple Payback = 2 months

Background:

Pre-filters can increase the life of the filters by collecting about 80% of the over spray. They are designed to catch all the large globules of paint and allowing only the smaller emissions to reach the filters. Because filters are intended to handle the smaller particles, not the larger ones, the pre-filter system can increase the life of the filters by a ratio of approximately 4:1. Thus, on the proposed operation filters will need to be changed only once a month instead of weekly. After pre-filters are installed, the number of filters used will be reduced. Therefore, there will be filter cost savings as well as labor savings.

Anticipated Savings:

Savings from this recommendation will accrue in two ways: filter cost savings and labor savings. Cost savings will accrue because fewer filters will be purchased due to pre-filter usage. Labor savings will accrue because less time will be spent changing filters due to the extension on
the life of the filters. Because the new pre-filter system is designed for quick replacement of the pre-filter material, the labor necessary to change the pre-filters can be neglected.

*Filter Cost Savings:*

According to information gathered on the day of the audit from plant personnel, the four filters on the Main Paint Booth are changed once a week. By installing paint pre-filters over the filters the same way they are presently done on the Small Paint Booth, it is estimated that filters will only be changed once every four weeks. The pre-filter material will be pulled over the filters from a roll mounted above the filters. The Main Paint Booth filters are ten feet long, and a roll of pre-filter material is 100 feet long and cost $38.25/roll. So the cost of each pre-filter can be estimated as $3.825. The estimated filter cost savings (FCS) can be calculated with the following equation:

\[
FCS = (CF) - (PF)
\]

Where,

- **CF** = current filter costs, $/yr
- **PF** = proposed filter costs, $/yr

The current filter cost is the cost to replace filters and can be calculated with the following equation:

\[
CF = (N) \times (FC) \times (NYC)
\]

Where,

- **N** = number of filters changed, filters/change
- **FC** = cost of each filter, $/filter
- **NYC** = current number of changes per year, changes/year

Following through with the equation:

\[
CF = (4) \times (12.75) \times (52)
\]
In order to find the proposed cost, several factors must be taken into account, as shown in the following equation:

\[
PC = (N) \times ((FC) \times (NYP) + (N) \times (BC) \times (NYC))
\]

Where,

- \( NYP \) = proposed number of changes per year, changes/yr
- \( BC \) = pre-filter material cost, $/pre-filter

Following through with the equation:

\[
PC = (4) \times ((12.75) \times (12) + (4) \times (3.825) \times (52))
\]

\[
PC = \$1,408/yr
\]

From these numbers, the cost savings results:

\[
FCS = (2,652) - (1,408)
\]

\[
FCS = \$1,244/yr
\]

**Labor savings**

Currently, two employees spend one hour every week replacing filters on the Main Paint Booth. If paint pre-filters are installed as suggested, the number of times filters are replaced will be reduced; therefore cutting the labor that is needed to replace filters. The labor hours would be reduced to 24 hr/yr from 104 hr/yr, which means a yearly labor savings, \( LS \), of 80 hr/yr. The paint pre-filters that are suggested have a very simple design, meaning that the time it takes to replace them will be negligible. The following equation can be used to calculate the labor savings by installing the paint baffles:

\[
LCS = (LS) \times (HW)
\]

Where,

- \( HW \) = hourly wage for labor, $/hr
Substituting values,

\[
\begin{align*}
\text{LCS} & = (80) \times (35) \\
\text{LCS} & = 2,800/yr
\end{align*}
\]

**Total Cost Savings**

Finally, the total cost savings, TCS, are simply the summation of the filter cost savings and the labor cost savings as:

\[
\begin{align*}
\text{TCS} & = (\text{LCS}) + (\text{FCS}) \\
\text{TCS} & = (2,800) + (1,244) \\
\text{TCS} & = 4,044/yr
\end{align*}
\]

**Implementation Cost**

The implementation cost is the cost associated with installing the paint pre-filter system. It is estimated that the installation of the paint pre-filter should cost approximately $300 in supplies and fixtures and will take two employees two hours to complete. The following equation will give the implementation cost (IC)

\[
\begin{align*}
\text{IC} & = [(\text{N}) \times (\text{HW}) \times (\text{H})] + (\text{SC})
\end{align*}
\]

Where,

\[
\begin{align*}
\text{N} & = \text{number of employees, no units} \\
\text{SC} & = \text{cost of supplies, fixtures, $}
\end{align*}
\]

Following through with the equation:

\[
\begin{align*}
\text{IC} & = [(2) \times (35) \times (2)] + (300) \\
\text{IC} & = 440
\end{align*}
\]

The annual net cost savings of $4,044 will pay for the implementation cost of $440 within two months.
Recommended Action

Install an industrial laser metal cutter to obtain cost savings from reducing manufacturing costs, improving plant layout and facility utilization, reducing inventory costs, and avoiding non-value added labor.

Estimated Manufacturing Costs Savings = $750,750
Estimated Inventory Costs Savings = $28,665/yr
Estimated Labor Savings = 2,080 hr/yr
Estimated Labor Savings = $72,800/yr
Estimated Total Costs Savings = $852,215/yr
Estimated Implementation Cost = $1,270,000
Simple Payback Period = 1.5 years

Background

Currently the facility receives prefabricated parts from an external manufacturer in order to supply these parts to Fabrication to make the final products. Because the process relies on external conditions, such as shipping, a 25-day inventory turnover is required to keep production running steady. Currently, prefabricated parts and parts in process are often stored outside where weather and other natural occurrences begin to oxidize them. In order to assure the product meet quality standards, the parts must be cleansed with a phosphate wash or sandblasted. After cleaning, parts are stored inside near the Fabrication area at which they are needed. Storage of these parts occupies valuable space within the facility and can sometimes hinder production. In addition to high maintenance and inventory costs, purchasing these prefabricated parts cost more than if they were produced in-house.

The long inventory turnover, additional cost of cleaning and welding preparation, and high cost of prefabricated parts are major expenses for the company that could be avoided by installing an industrial laser metal cutter. The cutter will reduce the inventory and turnover rate
by cutting parts on site without creating an additional stockpile and will still easily feed production. This lower inventory will also open up space in the existing facility, ease production flow, and increase productivity.

The implementation of a laser metal cutter would not be limited to simply installing a cutter in the current facility, but would be much better utilized if installed in an addition to the existing facility.

**Anticipated Savings**

It is estimated that there three main sources for savings by implementing an industrial laser cutter, which are: manufacturing costs savings, inventory reduction, and labor savings.

**Manufacturing Costs Savings**

The facility orders prefabricated parts from an external source as part of the production process. Implementation of a laser metal cutter will replace prefabricated parts with sheets of steel that the facility can cut as needed, which will reduce the overall manufacturing costs. The manufacturing costs savings, MCS, can be estimated as:

\[
MCS = (W) \times (U) \times [(CP) - (EP)]
\]

where

- \(W\) = the average weight of each unit made of prefabricated steel, lbs/unit
- \(U\) = number of units produced per year, unit/yr
- \(CP\) = current price for prefabricated steel, $/lb
- \(EP\) = estimated in-house cost for cut steel, $/lb

Substituting values,

\[
MCS = (6,500) \times (1,650) \times [(0.45) - (0.38)]
\]

\[
MCS = $750,750/yr
\]

**Inventory Cost Savings**
By installing a laser metal cutter the facility could decrease the inventory capital. It is estimated that the difference in the amount of money tied up in inventory before and after the laser cutter implementation could be invested into another project or location generating money instead of laying dormant in inventory. The inventory costs savings, IS, can be estimated as:

\[
IS = (U) \times (W) \times (MARR) \times \left[ (N_1) \times (CP) - (N_2) \times (EP) - (N_3) \times (RP) \right]
\]

where

- \( U \) = average number of units produced per day, units/day
- \( W \) = the weight of each unit that is composed of prefabricated steel, lb/unit
- \( N_1 \) = current inventory turnover, day
- \( N_2 \) = estimated inventory turnover, day
- \( N_3 \) = estimated stock steel turnover, day
- \( CP \) = current cost of steel per pound, $/lb
- \( EP \) = estimated cost of steel per pound, $/lb
- \( RP \) = market cost of steel per pound, $/lb
- \( MARR \) = company’s marginal rate of return, %

Note that the MARR is merely the interest rate that the company believes it could get if funds were invested elsewhere.

\[
IS = (6) \times (6,500) \times (0.10) \times \left[ (25) \times (0.45) - (5) \times (0.38) - (10) \times (0.20) \right]
\]

\[
IS = $28,665/yr
\]

**Labor Cost Savings**

The facility’s inventory currently has on average a 25-day turnover rate, where significant amounts of prefabricated material are stored outside. In order to meet company standards, these parts are sprayed with a phosphate wash or sandblasted. It is assumed that after the new system is in place, enough space will be freed to store parts inside the facility. This would eliminate the need for taking care of oxidized parts, hence eliminating the labor associated. It is estimated that the amount of non-value-added work is equivalent to one employee full time over the course of one year. The estimated labor savings, LS, can be estimated as:
LS = (H) x (employee wage, $/hr)

Where

H = hours each employee works per year, hr/yr

It was estimated that a full-time employee works 2,080 hours per year at the rate of $35/hr, resulting in labor costs savings of:

LS = (2,080) x (35)
LS = $72,800/yr

**Total Cost Savings**

The total costs savings from implementing this recommendation are summarized in Table 4.9.1.

<table>
<thead>
<tr>
<th>Type of Savings</th>
<th>($/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturing Costs</td>
<td>750,750</td>
</tr>
<tr>
<td>Inventory Costs</td>
<td>28,665</td>
</tr>
<tr>
<td>Labor Costs</td>
<td>72,800</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td><strong>852,215</strong></td>
</tr>
</tbody>
</table>

The total cost savings, CS, are shown in Table 4.9.1.

CS = $852,215/yr
Implementation Cost

For this project it is estimated that the company would invest $800,000 for the laser metal cutter machine. Along with the purchase of the machine there are costs for installation, training of employees, software, and the new facility that would house the laser metal cutter. Table 4.9.2 shows all the estimated costs for a conservative implementation of a laser metal cutter.

### Table 4.9.2 Implementation Costs

<table>
<thead>
<tr>
<th>Description</th>
<th>($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laser Metal Cutter</td>
<td>800,000</td>
</tr>
<tr>
<td>Installation</td>
<td>100,000</td>
</tr>
<tr>
<td>Training</td>
<td>50,000</td>
</tr>
<tr>
<td>Facility (5,000 ft²)</td>
<td>300,000</td>
</tr>
<tr>
<td>Software</td>
<td>20,000</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td><strong>1,270,000</strong></td>
</tr>
</tbody>
</table>

The annual cost savings of $852,215/yr will pay for the implementation cost of $1,270,000 within 1.5 years.
5. ADDITIONAL ITEMS CONSIDERED

Some items discussed during the audit at this facility have energy savings or waste minimization potential but would require relatively lengthy simple payback periods. Other items would save very little, and are presented here for general information only; the items do not require extensive discussion. Finally, investigation of some measures is beyond the scope of this report. Calculations of savings and costs for all of these items are not included in the main body of the report, but results are summarized here for general information.

5.1 Install Electronic Ballasts and T8 Lamps

It is suggested to retrofit the existing four-foot and eight-foot fluorescent light fixtures in the offices with electronic ballasts and T-8 lamps. Improved lighting technology has led to fluorescent lamps and ballasts that have both higher efficiency and also give better color rendering to objects viewed under their light. If this recommendation were implemented, it would save approximately 9 kW of demand each month, and 10,000 kWh/yr in energy per year. However, with an estimated implementation cost of $4,000, the simple payback period of 6 years seems too long and the recommendation cannot be justified at this time. However, it may happen in the future that the utility company offer a rebate that could help reduce the payback period.

5.2 Install Occupancy Sensors

Install occupancy sensors in the office areas at this facility to reduce electrical energy usage when rooms are unoccupied. For small rooms, occupancy sensors can be used in place of wall switches. An override switch allows the user to still maintain control manually. There are several types of occupancy sensors available. Infrared units turn the lights off and on by detecting differences in the heat given off by a human body and the surroundings. Infrared occupancy sensors work best in enclosed offices where the sensor has a clear view of the entire area. Infrared occupancy sensors should not be used in restrooms or areas where only very small motion is present. Ultrasonic sensors work by bouncing ultrasonic sound waves off objects in
the room. The lights are turned on when the sound waves return at a faster or slower rate indicating that someone has entered the room. Applications for these sensors include bathrooms and larger office spaces.

Because of the reduced number of hours of office space use, the cost savings from implementing this recommendation would pay for the implementation cost in about four years. Therefore, this recommendation cannot be justified at this time.

5.3 Install High Efficiency Motors

Depending on the horsepower rating of a given high efficiency motor, operating efficiencies of Premium Efficiency motors may be from 1% to 10% higher than the operating efficiencies of the existing motors. The electric motors in this facility typically contribute to the demand reading, therefore savings will accrue from the decrease in monthly demand and the decrease in annual energy usage. However, in absence of rebates from the utility company to help pay for the transition, the payback period for the motors considered is about nine years and the recommendation cannot be justified.
6. RESOURCE DIRECTORY

There are many other sources of implementation assistance and information available to manufacturers. In this section is a list of government-sponsored economic development offices and information sources known to the audit team. Other programs may also be available. Internet URLs have been added when applicable.

6.1 State Programs

Iowa Department of Natural Resources (DNR) Energy Bureau 515/281-5385
http://www.state.ia.us/dnr/organiza/egd/eb.htm

Iowa DNR Waste Reduction Assistance Program, 515/281-8927
http://www.recycleiowa.org/wrap/wrap.html

Iowa Manufacturing Technology Center, 515/965-7125
http://www.tecnet.org/iowamtc/

Iowa Waste Exchange, 319/273-2079
http://www.recycleiowa.org/tech/bawss.html

Iowa Waste Reduction Center, 319/273-8905
http://www.iwrc.org/

Minnesota Office of Environmental Assistance, 612/296-3417

Minnesota Technical Assistance Program, 612/627-4646
http://es.epa.gov/program/regional/state/minn/mntap/mntap.html

Keep Nebraska Beautiful Waste Exchange, 800/486-4562
http://www.knb.org/knb/exchange.html

Nebraska Industrial Competitiveness Service, 402/471-3755
http://nics.ded.state.ne.us/

6.2 National Resources

http://www.eren.doe.gov/

North American Insulation Manufacturers Association
http://www.pipeinsulation.org/ (information on pipe insulation)

Office of Industrial Technologies Program, US Department of Energy
http://www.eere.energy.gov/industry/