SAMPLE
INDUSTRIAL ASSESSMENT SURVEY REPORT

Report Number: OK XXXX
Plant Location: Anytown, OK 74000
Principal Products: Industrial components
SIC code: 3900
NAICS code: 390000
Site Visit: November 30, 2019
Report Due: January 31, 2020

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The State University of New Jersey
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The primary objective of the IAC (beyond its educational mission of training students to become energy engineers) is to visit manufacturing facilities to identify the most significant opportunities to conserve energy, mitigate pollution, and reduce costs. IAC staff evaluate each opportunity, and if it appears reasonable, they express it as a recommendation in an assessment report like this one. These recommendations are based upon observations and measurements the IAC team has made in your plant, but because time was limited, the IAC staff do not claim to have complete knowledge of every aspect of the plant's operations. This report provides specific and quantitative suggestions of cost savings, energy conservation, and pollution prevention at your facility. However, the IAC team has not attempted to prepare engineering designs or otherwise perform services that you would expect from an engineering firm, a vendor, or a manufacturer's representative. When the need for that level of assistance arises, you should consult them directly.

This industrial assessment is one of a host of initiatives of the Office of Energy Efficiency and Renewable Energy (EERE) of the U.S. Department of Energy (http://www.eere.energy.gov/). IAC assessments are geared toward near-term solutions to improve the energy efficiency of American industry. The goal is to help American manufacturers save energy, improve productivity, reduce pollution, and continue to thrive during this time of volatile and generally rising energy costs. Operating within the EERE, the Advanced Manufacturing Office (AMO) offers a variety of services to assist American industry, and it provides the oversight and management of the IAC program. For more information about AMO programs, see this website: http://www1.eere.energy.gov/manufacturing/

Please note: Any pollution mitigation suggestions provided in this report may not address all of the environmental compliance needs that might exist at this industrial site. Conversely, the provision of a recommendation to reduce output of a specific pollutant does not constitute official notice that any lack of environmental compliance exists. Questions regarding compliance should be addressed to either a reputable environmental consulting firm or to the appropriate regulatory agency. Clients are encouraged to develop positive working relationships with regulators that will enable compliance problems to be addressed and resolved.

Please contact the IAC if you would like to discuss the content of this report or if you have other questions about energy use or pollution prevention. The IAC staff can be contacted as follows:

Industrial Assessment Center
Oklahoma State University
559 Engineering North
Stillwater, OK 74078
405-744-9578
EXECUTIVE SUMMARY

The energy consumption details for your facility are summarized as follows:

**ENERGY**

Electricity consumption at your facility for the twelve-month period from March 2018 to February 2019 consisted of 15,849,600 kWh of electricity.

Natural gas consumption for the twelve-month period from March 2018 to February 2019 consisted of 144,500 MMBtu of natural gas.

Propane consumption for the twelve-month period from February 2018 to January 2019 was 322 MMBtu of bulk delivered propane.

This is equivalent to 198,861 million British Thermal Units of energy. Total energy costs for the corresponding periods was $1,805,692.

**SAVINGS**

The assessment recommendation opportunities (ARs) contained in this report can save an estimated $123,822 each year. This includes savings on electricity and natural gas. In this report, the recommendations are organized by the systems they address and are denoted by the prefixes as follows:

- AR #1.X: Compressed Air
- AR #2.X: Lighting
- AR #3.X: Power factor improvement
- AR #4.X: Equipment insulation
- AR #5.X: HVAC
- AR #6.X: Boilers
- AR #7.X: Fork-trucks

The annual energy savings would amount to 943,397 kWh, 1,224 kW, and 8,412 MMBtus of natural gas. This translates to a savings of approximately 12% of your annual energy consumption and 5.6% of your annual energy consumption costs. The total energy saved is equivalent to 13,282 MMBtus, including kWh savings expressed as MMBtus at 3,412 Btu/kWh. This estimate is based on energy costs for the twelve-month period for electricity and natural gas mentioned above.

In the light of potentially increasing energy costs your actual savings may be greater. You should compare your current energy costs to the average costs used in this report and adjust the cost savings upward as necessary.

Finally, please note that US DOE program standards do not allow us to include lifecycle maintenance cost savings in our calculations. In some cases, these additional savings could be significant, such as in the case of conversions from traditional light sources to LED systems.
SUMMARY OF INDUSTRIAL ASSESSMENT
SURVEY DATA

Report No. OKXXXX     Site visit date: 30 Nov. 2019

Plant Details
SIC No.: 3900
NAICS No.: 390000
Employees: 200
Location: Anytown, OK
Zip Code: 74000
Products: Industrial components
Plant Area (built): 500,000 square feet

Annual Figures
Production: 40,000 tons
Sales: $75,000,000
Operating Hours: 4,160 hrs (production, not including maintenance & custodial hours)
2,600 hrs (office)

<table>
<thead>
<tr>
<th>Table 1. Energy Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Electricity</strong></td>
</tr>
<tr>
<td><strong>Electricity (demand)</strong></td>
</tr>
<tr>
<td><strong>Electricity fixed charges</strong></td>
</tr>
<tr>
<td><strong>Natural gas commodity &amp; delivery</strong></td>
</tr>
<tr>
<td><strong>Natural gas fixed charges</strong></td>
</tr>
<tr>
<td><strong>Propane</strong></td>
</tr>
</tbody>
</table>

$1,805,692
## Table 2: SUMMARY OF ASSESSMENT RECOMMENDATIONS

<table>
<thead>
<tr>
<th>AR No.</th>
<th>DESCRIPTION</th>
<th>TYPE</th>
<th>ARC*</th>
<th>ANNUAL SAVINGS</th>
<th>EMISSION REDUCTIONS</th>
<th>IMPLEMENTATION COST ($)</th>
<th>PAYBACK PERIOD (YR)**</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Electricity kWh/yr</td>
<td>Electricity kW/year</td>
<td>Fuel MMBtu/yr</td>
<td>Total MMBtu/yr</td>
<td>$/yr</td>
</tr>
<tr>
<td>1.1</td>
<td>Implement regular air leak maintenance program.</td>
<td>elec.</td>
<td>2.4236.2</td>
<td>147,040</td>
<td>-</td>
<td>-</td>
<td>502</td>
</tr>
<tr>
<td>1.2</td>
<td>Use blowers instead of compressed air for process cleaning on LVT Line.</td>
<td>elec.</td>
<td>2.4232.2</td>
<td>108,385</td>
<td>-</td>
<td>-</td>
<td>370</td>
</tr>
<tr>
<td>2.1</td>
<td>Replace exterior metal halide floods &amp; surface fixtures with LED fixtures.</td>
<td>elec.</td>
<td>2.7143.3</td>
<td>77,203</td>
<td>-</td>
<td>-</td>
<td>264</td>
</tr>
<tr>
<td>2.2</td>
<td>Retrofit F54T5HO fixtures in production area with LED tubes.</td>
<td>elec.</td>
<td>2.7143.3</td>
<td>590,436</td>
<td>1,134</td>
<td>-</td>
<td>2,016</td>
</tr>
<tr>
<td>3.1</td>
<td>Optimize facility power factor.</td>
<td>elec.</td>
<td>2.3212.2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4.1</td>
<td>Insulate oil pumping station (H.O.D.).</td>
<td>nat. gas</td>
<td>2.2511.1</td>
<td>-</td>
<td>-</td>
<td>1,799</td>
<td>1,799</td>
</tr>
<tr>
<td>5.1</td>
<td>Implement night and weekend setback in office area.</td>
<td>combined</td>
<td>2.6232.3</td>
<td>8,687</td>
<td>-</td>
<td>13</td>
<td>43</td>
</tr>
<tr>
<td>6.1</td>
<td>Replace over-sized boiler with smaller boiler.</td>
<td>Nat. gas</td>
<td>2.1223.1</td>
<td>-</td>
<td>-</td>
<td>6,600</td>
<td>6,600</td>
</tr>
<tr>
<td>7.1</td>
<td>Optimize number of fork-trucks in operation.</td>
<td>elec.</td>
<td>2.8227.4</td>
<td>11,646</td>
<td>90.00</td>
<td>-</td>
<td>40</td>
</tr>
</tbody>
</table>

Total of fork-trucks in operation: 943,397 $/yr, 1,224 MMBtu/yr, 8,412 MMBtu/yr, 11,633 lb/yr, 99,182 lb/yr, 1,659,855 lb/yr, 5,054 lb/yr, 2,132 lb/yr

** Summary **

- Total energy cost savings in this report ($/yr): 99,182
- Total CO2 reductions in this report (lb/yr): 1,659,855
- Total SO2 reductions in this report (lb/yr): 5,054
- Total NOX reduction in this report (lb/yr): 2,132


OKXXXX
SUMMARY OF ASSESSMENT RECOMMENDATIONS

Compressed air
AR #1.1: Implement air leak maintenance program.
The facility currently has three air compressors: one 200 hp Quincy 1000, one 350 hp Quincy 1500, and one 125 hp Gardner-Denver air compressor which provide a constant supply of air for plant operations. Facility staff reported 400 cfm of compressed air leaks. The air leaks cause 21% of air compressor output to be wasted in this compressed air system. So, implementing a compressed air leak management program would yield annual energy savings of 147,040 kWh and an annual dollar savings of $7,499.

AR #1.2: Use blowers instead of compressed air for process cleaning on LVT line.
The facility uses compressed air for cleaning off shavings in three locations in the LVT line. Replacing compressed air with one 12 hp, 500+ CFM and one 7.5 hp, 300 CFM blower would yield an annual energy savings of 108,385 kWh of electricity and an annual dollar savings of $5,528.

Lighting
AR #2.1: Replace the exterior 400-watt and 250-watt metal halide floods and surface-mount fixtures with LED fixtures.
The exterior of the plant is illuminated by metal halide 400-watt pole-mounted floods and 250-watt surface-mount fixtures. By replacing these fixtures with UL-"Wet" or IP65-rated LED fixtures, the plant could save 77,203 kWh and $3,937 per year.

AR #2.2: Retrofit F54T5HO fluorescent fixtures in the production area with LED tubes.
The production area is illuminated by four-lamp F54T5HO fluorescent open fixtures. By retrofitting these fixtures with 25-watt T5 line-voltage LED tubes, one-for-one, the plant could save 590,436 kWh and $43,176 per year.

Power factor correction
AR #3.1: Optimize facility power factor.
Electricity for the facility is provided by the City of Anytown Electric Utility. The facility is charged a fee for power factor below 0.80. Several solutions have been recommended for optimizing power factor. Purchasing and installing a 1500 kVAR capacitor on the consumer side of the utility meter will save the facility the cost of fees associated with low power factor and the cost of leasing an insufficient capacitor bank from the utility company, which in the 12 months preceding February 2019 cost the facility $13,080.

Equipment insulation
AR #4.1: Insulate oil pumping station (H.O.D.)
Insulation for the H.O.D. pumping station was not present at the time of the initial audit inspection or at 45 days post-inspection. Re-installing the insulation would save the facility $5,110 and 1,799 MMBtu of natural gas annually.
HVAC
AR #5.1: Implement night and weekend setback in office area.
The facility has 10,000 square feet of office area that is conditioned by multiple rooftop HVAC package units. The thermostats serving the area are non-programmable. We recommend replacing the non-programmable thermostats with programmable thermostats and implementing setbacks during hours when the office areas are not occupied. This program would save the facility $480 annually. Energy savings would be 13 MMBtu of natural gas and 8,687 kWh annually.

Boilers
AR #6.1: Install smaller boiler.
Currently the facility’s boilers are oversized for their application, with firing rates between 30% and 50%. We recommend installing a 60 hp boiler to replace the 350 hp boiler and keep the 200 hp boiler as backup. This would increase boiler efficiency to 86% from 80%, saving the facility $18,744 annually.

Fork-trucks
AR #7.1: Optimize the number of fork-trucks in operation.
The facility currently uses 24 fork trucks, 5 of which are propane powered. The remainder are electric. We recommend removing 4 electric fork trucks from service for optimum efficiency. This would save the facility a total of $1,628 in electric charges and demand reduction.
PLANT DESCRIPTION

This facility, located in Anytown, Oklahoma, makes resilient industrial components. The facility is in production for 24 hours a day, Monday through Thursday, with two 12 hour shifts per day. The office hours are Monday through Friday, 7AM to 5PM. The facility employs 200 people and produces 40,000 tons annually. Electric and water utilities are provided by the City of Anytown, and natural gas is supplied by American Energy and delivered by Heartland Natural Gas.

The facility’s production and warehouse areas are indoors and cover 490,000 square feet. Office area is 10,000 square feet. The following areas comprise the plant area:

- Office area
- Warehouse area
- Office/storage building
- Maintenance area
- Raw materials storage area
- Production line area
  - HMC
  - Gel line
  - Stamp presses
  - Press
  - Curing line
  - CNC line
The main energy consuming equipment is described as follows:

**Lighting system**
The production area is illuminated by four-lamp fluorescent F54T5HO open industrial fixtures, equipped with plastic-coated lamps. The CNC area is served by four-lamp fluorescent F32T8 enclosed hazardous-location (Class I Div. 2) fixtures. The offices are served by four-lamp fluorescent F32T8 lay-in grid troffers. The exterior of the facility is illuminated by 400-watt metal halide floods on 30’ poles and 250-watt metal halide surface-mount fixtures. EXIT lighting is provided by LED fixtures.
### Table 3: Existing lighting end use

<table>
<thead>
<tr>
<th>Fixt. Qty.</th>
<th>Description</th>
<th>kW/fixture</th>
<th>Hours/year</th>
<th>kWh/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>250</td>
<td>Misc. production areas: four-lamp F54T5HO fluorescent open fixtures</td>
<td>0.226</td>
<td>8,760</td>
<td>494,940</td>
</tr>
<tr>
<td>500</td>
<td>Misc. production areas: four-lamp F54T5HO fluorescent open fixtures</td>
<td>0.226</td>
<td>4,992</td>
<td>564,096</td>
</tr>
<tr>
<td>50</td>
<td>CNC area: four-lamp F32T8 fluorescent enclosed hazardous location</td>
<td>0.112</td>
<td>8,760</td>
<td>49,056</td>
</tr>
<tr>
<td>108</td>
<td>Offices: four-lamp F32T8 fluorescent lay-in grid troffers, with IS ballasts</td>
<td>0.112</td>
<td>2,600</td>
<td>31,450</td>
</tr>
<tr>
<td>55</td>
<td>EXTERIOR: 400-watt* metal halide floods, on 30' poles</td>
<td>0.458</td>
<td>4,100</td>
<td>103,279</td>
</tr>
<tr>
<td>9</td>
<td>EXTERIOR: 250-watt* metal halide surface-mount fixtures under awnings</td>
<td>0.290</td>
<td>4,100</td>
<td>10,701</td>
</tr>
<tr>
<td>10</td>
<td>LED EXIT signs</td>
<td>0.001</td>
<td>8,760</td>
<td>88</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>1,253,610</strong></td>
</tr>
</tbody>
</table>

* nominal watts, not including ballast watts

**Notes:**
1. All fluorescent wattages assume existing instant-start electronic ballasts.
2. Production area hours/year include shift work, custodial, & maintenance activities.
3. Office hours include normal business hours and custodial hours.

**HVAC**

The production area is heated during colder months by rooftop HVAC package units using natural gas and is not conditioned during the summer months. Offices are also heated and cooled by rooftop package units. Average age of HVAC units is around 30 years. On inspection, filters were fresh, and units appeared to be well-maintained by the in-house maintenance staff. Some areas in the warehouse are heated by radiant tube heaters.

**Compressed air**

Three air compressors supply compressed air at 110 psi for the entire plant. These compressors include one 350 hp Quincy 1500, one 200 hp Quincy 1000, and one 125 hp Gardner-Denver compressor. Required plant pressure is 85 psig.

**Boilers**

This facility is serviced by two steam boilers and two hot oil boilers. The steam boilers include one 200 hp, 60 psi Holman boiler, and one 350 hp, 110 psi Cyclotherm boiler. The two hot oil...
boilers are Gel oil boilers which is rated for 3,318 cfh at 394°F. Two boilers were in operation at the time of inspection: the Holman steam boiler and one Gel oil boiler.

**Electric motors**
The webbing process is powered by electric motors. The largest motor in the facility is the mixer motor, which is a 600 hp DC for the limestone mixing motor. This facility has a lower power factor, which can be indicative of high inductive loads.

**Process heating**
The process has heat added at several stages by several different methods. During forming, the material is heated by one 4,500 cfh C&F oven. In the webbing, heat is added by radiant electric infrared heaters. Heat is also regulated by hot oil and chilled water running through rollers in the webbing process.

**Cooling towers**
The facility is serviced by three cooling towers: a 450 ton Trane, a 250 ton Trane, and a 400 ton York cooling tower. The outlet temperature was reported by staff as 45°F.

**VOC incinerators**
Three VOC incinerators burn the volatile organic compounds produced by the facility in accordance with EPA regulations. These VOCs are driven by AC motors: one 600 hp, one 350 hp, and one 300 hp motor. These run 24/7 and are operated by older Variable Frequency Drives. These operate between 45 to 58 Hz during full operation and idle at 20 Hz.

**Forklifts and tow trucks**
The facility is serviced by 24 forklifts, 1 scissor lift, 1 scrubber, 4 seated tug trucks, and 8 standup tug trucks. The tug trucks and 5 of the forklifts run on propane, which is delivered in bulk by AmeriGas.

**Principal products**
This facility produces industrial components.

**Raw materials**
- Copper tubing
- Steel sheet and tubes
- Titanium rods
- Proprietary polymers, oils, and reagents.

**Waste**
- Metal shavings
• Cardboard
• Oils and solvents

**Best practices**
During our assessment, we observed several positive practices and energy conservation measures underway.

• Clean facility with good safety practices.
• Excellent in-house maintenance
• Thorough documentation
• Radiant tube heaters in the warehouse area
• Smart-chargers for electric forklift batteries.

**Primary Energy Consuming Equipment**

**Table 4: Electricity Consuming Equipment**

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Air compressors: 1 @ 350hp, 1 @ 200 hp, and 1 @ 125 hp.</td>
</tr>
<tr>
<td>8</td>
<td>8 HVAC units @ 4 tons each</td>
</tr>
<tr>
<td>3</td>
<td>1 @ 450 ton, 1 @ 400 ton, and 1 @ 250 ton cooling tower</td>
</tr>
<tr>
<td>1</td>
<td>600 hp DC motor</td>
</tr>
<tr>
<td>Multiple</td>
<td>Electric motors</td>
</tr>
<tr>
<td>3</td>
<td>1 @ 600 hp, 1 @ 350 hp, and 1 @ 300 hp VOC Incinerators</td>
</tr>
<tr>
<td>21</td>
<td>19 electric Forklifts, 1 scissor lift, and 1 scrubber</td>
</tr>
</tbody>
</table>

**Table 5: Natural gas consuming equipment**

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>8 natural gas rooftop heating units @ 4,950 MMBtu/h</td>
</tr>
<tr>
<td>4</td>
<td>Two 3,318 cfm Gel hot oil boilers, one 200 hp Holman steam boiler, one 350 hp Cyclotherm boiler.</td>
</tr>
</tbody>
</table>

**Table 6: Propane consuming equipment**

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>17</td>
<td>4 seated tug trucks, 8 standup tug trucks, and 5 forklifts</td>
</tr>
</tbody>
</table>
Table 7: Estimated energy balance by system

<table>
<thead>
<tr>
<th>System</th>
<th>Estimated electricity consumption (kWh)</th>
<th>% Annual bill</th>
<th>Estimated natural gas consumption (MMBtu)</th>
<th>% Annual bill</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air compressors</td>
<td>3,074,000</td>
<td>19.4%</td>
<td>0</td>
<td>0.0%</td>
</tr>
<tr>
<td>Lighting</td>
<td>1,253,610</td>
<td>7.9%</td>
<td>0</td>
<td>0.0%</td>
</tr>
<tr>
<td>Boilers - steam and oil</td>
<td>0</td>
<td>0.0%</td>
<td>122,000</td>
<td>84.4%</td>
</tr>
<tr>
<td>HVAC</td>
<td>47,000</td>
<td>0.3%</td>
<td>7,500</td>
<td>5.2%</td>
</tr>
<tr>
<td>Electric motors</td>
<td>3,324,990</td>
<td>21.0%</td>
<td>0</td>
<td>0.0%</td>
</tr>
<tr>
<td>Process curing</td>
<td>0</td>
<td>0.0%</td>
<td>5</td>
<td>0.0%</td>
</tr>
<tr>
<td>VOC incinerators</td>
<td>4,650,000</td>
<td>29.3%</td>
<td>14,995</td>
<td>10.4%</td>
</tr>
<tr>
<td>Forklift charging</td>
<td>3,500,000</td>
<td>22.1%</td>
<td>0</td>
<td>0.0%</td>
</tr>
<tr>
<td>Total</td>
<td>15,849,600</td>
<td>100%</td>
<td>144,500</td>
<td>100%</td>
</tr>
</tbody>
</table>

Lighting system

The major categories of the existing lighting system are described in the table below.

Table 8: Components of existing lighting system

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>750</td>
<td>Misc. production areas: four-lamp F54T5HO fluorescent open fixtures</td>
</tr>
<tr>
<td>50</td>
<td>Press ink room: four-lamp F32T8 fluorescent enclosed hazardous location</td>
</tr>
<tr>
<td>108</td>
<td>Offices: four-lamp F32T8 fluorescent lay-in grid troffers, with IS ballasts</td>
</tr>
<tr>
<td>55</td>
<td>EXTERIOR: 400-watt* metal halide floods, on 30' poles</td>
</tr>
<tr>
<td>9</td>
<td>EXTERIOR: 250-watt* metal halide surface-mount fixtures under awnings</td>
</tr>
<tr>
<td>10</td>
<td>LED EXIT signs</td>
</tr>
</tbody>
</table>

* nominal watts, not including ballast watts
PROCESS DESCRIPTION

This facility produces industrial components for other industries such as engine, turbine, and compressor manufacturers. One process line facilitates all the designs that originate from the Anytown facility. The facility machines metals like steel, aluminum and titanium, which are used as a feedstock. According to the nature of jobs, the feedstock is supplied to its specific machines. For example, if the machining requires facing, turning, milling, drilling and tapping of coupling, shafts, bushings and spacers, the feedstock is feed into the CNC machines. Likewise, if the machining requires creating tools and dies for drawn caps, brackets, gears, gaskets and splines, the feedstock is sent for stamping, progressive blanking and forming. Similarly, for handling bulk, complex, micro, thin gage and high strength stampings, the feedstock is fed into a variety of metal stamping methods including progressive, compound blanking, drawing, bending, coining and forming. All the parts so produced are thoroughly inspected to guarantee the demanding standards. The parts are then packaged and are made ready for shipping.
PROCESS FLOW DIAGRAM

Figure 2. Process Flow Diagram
UTILITY RATES

Electricity
Electricity is supplied to the facility by the City of Anytown. The average energy cost that will be used in the savings calculations is:

\[
\text{Energy Charge} = 0.051 \text{ / kWh} \\
\text{Demand Charge} = 11.52 \text{ / kW}
\]

Natural gas
Natural gas is supplied by American Energy and delivered by Heartland Natural Gas. The natural gas cost that we will use for our calculations to determine the savings is:

\[\text{Natural gas cost} = 2.84/\text{MMBtu}\]

Propane
AmeriGas delivers bulk propane to the facility. The cost of propane to be used in the savings calculations is:

\[\text{Propane cost} = 17.19/\text{MMBtu}\]

Water
Water is supplied and waste water services are provided by the City of Anytown. The cost of water and waste water to be used in the calculations are:

\[
\text{Water} = 7.09/\text{Tgal} \\
\text{Waste Water} = 3.34/\text{Tgal}
\]

Waste removal
Waste Removal Services are provided by Republic Services. Waste is removed by volume. Due to the correlation of volume to weight in the bill analysis, the cost of waste removal will be calculated by type and weight as follows:

\[
\text{Recyclable/Compostable Waste} = 53.93/\text{ton} \\
\text{Chip Waste} = 49.42/\text{ton} \\
\text{Manufacturing Bulk Waste} = 59.00/\text{ton}
\]

Labor cost
The burdened labor rate that will be used in the savings calculations is \(\$26/\text{hour}\).
HISTORICAL ENERGY CONSUMPTION TABLES
(March 2018 to February 2019)
# Table 9: Total Electricity Consumption

<table>
<thead>
<tr>
<th>Month</th>
<th>Electricity Consumption (kWh)</th>
<th>Electricity Consumption Charge ($)</th>
<th>Electricity Demand (kW)</th>
<th>Demand Charge* ($)</th>
<th>Capacitor Rental ($)</th>
<th>Power Factor Adjustment** ($)</th>
<th>Customer Charge ($)</th>
<th>Total ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mar-18</td>
<td>1,329,600</td>
<td>66,241</td>
<td>3,878</td>
<td>25,481</td>
<td>156</td>
<td>255</td>
<td>415</td>
<td>92,548</td>
</tr>
<tr>
<td>Apr-18</td>
<td>1,252,800</td>
<td>61,130</td>
<td>3,864</td>
<td>25,386</td>
<td>156</td>
<td>0</td>
<td>415</td>
<td>87,088</td>
</tr>
<tr>
<td>May-18</td>
<td>1,320,000</td>
<td>62,865</td>
<td>3,816</td>
<td>25,071</td>
<td>156</td>
<td>752</td>
<td>415</td>
<td>89,260</td>
</tr>
<tr>
<td>Jun-18</td>
<td>1,588,800</td>
<td>80,603</td>
<td>3,912</td>
<td>71,863</td>
<td>156</td>
<td>2,875</td>
<td>415</td>
<td>155,912</td>
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<tr>
<td>Jul-18</td>
<td>1,430,400</td>
<td>76,295</td>
<td>4,075</td>
<td>74,861</td>
<td>156</td>
<td>2,246</td>
<td>415</td>
<td>153,973</td>
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<tr>
<td>Aug-18</td>
<td>1,521,600</td>
<td>77,404</td>
<td>4,032</td>
<td>74,067</td>
<td>156</td>
<td>2,222</td>
<td>415</td>
<td>154,264</td>
</tr>
<tr>
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<td>1,464,000</td>
<td>74,219</td>
<td>3,869</td>
<td>71,070</td>
<td>156</td>
<td>2,132</td>
<td>415</td>
<td>147,992</td>
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<tr>
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<td>1,195,200</td>
<td>59,777</td>
<td>3,749</td>
<td>68,865</td>
<td>156</td>
<td>2,066</td>
<td>415</td>
<td>131,279</td>
</tr>
<tr>
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<td>1,377,600</td>
<td>72,335</td>
<td>3,850</td>
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<td>156</td>
<td>253</td>
<td>415</td>
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</tr>
<tr>
<td>Dec-18</td>
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<td>64,508</td>
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<td>27,436</td>
<td>156</td>
<td>0</td>
<td>415</td>
<td>92,516</td>
</tr>
<tr>
<td>Jan-19</td>
<td>1,046,400</td>
<td>54,377</td>
<td>4,094</td>
<td>26,900</td>
<td>156</td>
<td>269</td>
<td>415</td>
<td>82,118</td>
</tr>
<tr>
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<td>1,161,600</td>
<td>54,614</td>
<td>4,018</td>
<td>26,396</td>
<td>156</td>
<td>0</td>
<td>415</td>
<td>81,581</td>
</tr>
<tr>
<td>Totals</td>
<td>15,849,600</td>
<td>804,368</td>
<td>47,333</td>
<td>545,443</td>
<td>1,870</td>
<td>4,986</td>
<td>4,986</td>
<td>1,369,736</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Average Cost of Electricity ($/kWh)</th>
<th>0.051</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Demand Charge ($/kW)</td>
<td>11.52</td>
<td></td>
</tr>
</tbody>
</table>

* Summer Demand Charge: $18.37/kW, Winter Demand Charge: $6.57/kW
** No data given to calculate actual power factor
### Table 10: Total Natural Gas Consumption

**Natural Gas Consumption from March 2018 to February 2019**

<table>
<thead>
<tr>
<th>Month</th>
<th>Natural Gas (MMBtu)</th>
<th>Natural Gas Cost* ($/MMBtu)</th>
<th>Natural Gas Delivery Charge ($)</th>
<th>Fixed Demand Charge ($)</th>
<th>Demand (MMBtu)</th>
<th>Delivery Charges ($)</th>
<th>Taxes ($)</th>
<th>Total ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mar-18</td>
<td>15,967</td>
<td>43,568</td>
<td>315</td>
<td>1,671</td>
<td>903</td>
<td>676</td>
<td>889</td>
<td>47,119</td>
</tr>
<tr>
<td>Apr-18</td>
<td>12,267</td>
<td>30,406</td>
<td>242</td>
<td>1,671</td>
<td>903</td>
<td>646</td>
<td>621</td>
<td>33,585</td>
</tr>
<tr>
<td>May-18</td>
<td>12,951</td>
<td>32,438</td>
<td>255</td>
<td>1,671</td>
<td>903</td>
<td>646</td>
<td>662</td>
<td>35,672</td>
</tr>
<tr>
<td>Jun-18</td>
<td>12,395</td>
<td>31,852</td>
<td>244</td>
<td>1,671</td>
<td>903</td>
<td>645</td>
<td>650</td>
<td>35,062</td>
</tr>
<tr>
<td>Jul-18</td>
<td>9,979</td>
<td>25,912</td>
<td>197</td>
<td>1,671</td>
<td>903</td>
<td>643</td>
<td>529</td>
<td>28,952</td>
</tr>
<tr>
<td>Aug-18</td>
<td>10,928</td>
<td>28,148</td>
<td>215</td>
<td>1,671</td>
<td>903</td>
<td>644</td>
<td>574</td>
<td>31,252</td>
</tr>
<tr>
<td>Sep-18</td>
<td>9,691</td>
<td>24,962</td>
<td>191</td>
<td>1,671</td>
<td>903</td>
<td>642</td>
<td>509</td>
<td>27,975</td>
</tr>
<tr>
<td>Oct-18</td>
<td>9,613</td>
<td>24,761</td>
<td>189</td>
<td>1,671</td>
<td>903</td>
<td>643</td>
<td>505</td>
<td>27,770</td>
</tr>
<tr>
<td>Nov-18</td>
<td>14,026</td>
<td>36,128</td>
<td>276</td>
<td>1,671</td>
<td>903</td>
<td>656</td>
<td>737</td>
<td>39,468</td>
</tr>
<tr>
<td>Dec-18</td>
<td>11,358</td>
<td>29,256</td>
<td>224</td>
<td>1,671</td>
<td>903</td>
<td>654</td>
<td>597</td>
<td>32,401</td>
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<td>Jan-19</td>
<td>10,504</td>
<td>27,056</td>
<td>207</td>
<td>1,671</td>
<td>903</td>
<td>653</td>
<td>552</td>
<td>30,139</td>
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<tr>
<td>Feb-19</td>
<td>14,821</td>
<td>38,176</td>
<td>296</td>
<td>1,671</td>
<td>903</td>
<td>657</td>
<td>779</td>
<td>41,579</td>
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<tr>
<td><strong>Totals</strong></td>
<td><strong>144,500</strong></td>
<td><strong>372,663</strong></td>
<td><strong>2,852</strong></td>
<td><strong>20,047</strong></td>
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<td><strong>7,805</strong></td>
<td><strong>7,605</strong></td>
<td><strong>430,427</strong></td>
</tr>
</tbody>
</table>

**Natural Gas Cost ($/MMBtu)**: 2.84


### Table 11: Total Propane Consumption

**Propane Consumption from Feb. 2018 to Jan. 2019**

<table>
<thead>
<tr>
<th>Month</th>
<th>Total Bulk (Gallons)</th>
<th>Total Bulk (MMBtu)</th>
<th>Charge ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feb-18</td>
<td>287</td>
<td>27</td>
<td>590</td>
</tr>
<tr>
<td>Mar-18</td>
<td>283</td>
<td>26</td>
<td>462</td>
</tr>
<tr>
<td>Apr-18</td>
<td>259</td>
<td>24</td>
<td>395</td>
</tr>
<tr>
<td>May-18</td>
<td>415</td>
<td>38</td>
<td>659</td>
</tr>
<tr>
<td>Jun-18</td>
<td>339</td>
<td>31</td>
<td>526</td>
</tr>
<tr>
<td>Jul-18</td>
<td>389</td>
<td>35</td>
<td>557</td>
</tr>
<tr>
<td>Aug-18</td>
<td>281</td>
<td>26</td>
<td>425</td>
</tr>
<tr>
<td>Sep-18</td>
<td>220</td>
<td>20</td>
<td>344</td>
</tr>
<tr>
<td>Oct-18</td>
<td>349</td>
<td>32</td>
<td>573</td>
</tr>
<tr>
<td>Nov-18</td>
<td>210</td>
<td>19</td>
<td>306</td>
</tr>
<tr>
<td>Dec-18</td>
<td>235</td>
<td>21</td>
<td>331</td>
</tr>
<tr>
<td>Jan-19</td>
<td>261</td>
<td>21</td>
<td>359</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>3,535</strong></td>
<td><strong>322</strong></td>
<td><strong>5,529</strong></td>
</tr>
</tbody>
</table>

**Cost ($/MMBtu)**: $17.19
### Table 12: Total Water and Wastewater Consumption

<table>
<thead>
<tr>
<th>Month</th>
<th>Water Usage (Tgal)</th>
<th>Water Charge ($)</th>
<th>Waste Water Usage (gal)</th>
<th>Waste Water Cost ($)</th>
<th>Drainage Fee ($)</th>
<th>Customer Charge ($)</th>
<th>Total ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mar-18</td>
<td>319</td>
<td>2,241</td>
<td>80,000</td>
<td>253</td>
<td>55</td>
<td>628</td>
<td>3,188</td>
</tr>
<tr>
<td>Apr-18</td>
<td>345</td>
<td>2,420</td>
<td>96,000</td>
<td>294</td>
<td>55</td>
<td>628</td>
<td>3,387</td>
</tr>
<tr>
<td>May-18</td>
<td>392</td>
<td>2,750</td>
<td>98,000</td>
<td>323</td>
<td>55</td>
<td>628</td>
<td>3,756</td>
</tr>
<tr>
<td>Jun-18</td>
<td>611</td>
<td>4,292</td>
<td>153,000</td>
<td>504</td>
<td>55</td>
<td>628</td>
<td>5,480</td>
</tr>
<tr>
<td>Jul-18</td>
<td>758</td>
<td>5,179</td>
<td>184,000</td>
<td>609</td>
<td>55</td>
<td>628</td>
<td>6,470</td>
</tr>
<tr>
<td>Aug-18</td>
<td>716</td>
<td>5,122</td>
<td>179,000</td>
<td>603</td>
<td>55</td>
<td>640</td>
<td>6,420</td>
</tr>
<tr>
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<td>583</td>
<td>4,175</td>
<td>146,000</td>
<td>491</td>
<td>55</td>
<td>641</td>
<td>5,364</td>
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<tr>
<td>Oct-18</td>
<td>416</td>
<td>2,975</td>
<td>104,000</td>
<td>350</td>
<td>55</td>
<td>641</td>
<td>4,022</td>
</tr>
<tr>
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<td>459</td>
<td>3,289</td>
<td>115,000</td>
<td>387</td>
<td>55</td>
<td>641</td>
<td>4,371</td>
</tr>
<tr>
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<td>73,000</td>
<td>245</td>
<td>55</td>
<td>641</td>
<td>3,025</td>
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<tr>
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<td>61,000</td>
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<td>55</td>
<td>641</td>
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<td>63,000</td>
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<td>55</td>
<td>641</td>
<td>2,712</td>
</tr>
<tr>
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<td>38,091</td>
<td>1,342,000</td>
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<td>660</td>
<td>7,625</td>
<td>50,856</td>
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</table>

**Water Cost ($/Tgal)** 7.10  
**Waste Water Cost ($/gal)** 0.00333

### Table 13: Total Energy Consumption

<table>
<thead>
<tr>
<th>Month</th>
<th>Electricity (MMBtu)</th>
<th>Natural Gas (MMBtu)</th>
<th>Propane (MMBtu)</th>
<th>Total MMBtu</th>
<th>Electricity (MMBtu)</th>
<th>Natural Gas (MMBtu)</th>
<th>Propane (MMBtu)</th>
<th>Total ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mar-18</td>
<td>4,533</td>
<td>15,967</td>
<td>27</td>
<td>20,527</td>
<td>66,241</td>
<td>43,568</td>
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<td>12,267</td>
<td>26</td>
<td>16,564</td>
<td>61,130</td>
<td>30,406</td>
<td>462</td>
<td>91,958</td>
</tr>
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<td>24</td>
<td>17,475</td>
<td>62,865</td>
<td>32,438</td>
<td>395</td>
<td>95,688</td>
</tr>
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<td>5,417</td>
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<td>38</td>
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<td>31,852</td>
<td>659</td>
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<td>9,979</td>
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<td>14,887</td>
<td>76,295</td>
<td>25,912</td>
<td>526</td>
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</tr>
<tr>
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<td>5,188</td>
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<td>35</td>
<td>16,151</td>
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<td>557</td>
<td>106,109</td>
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<td>9,691</td>
<td>26</td>
<td>14,708</td>
<td>74,219</td>
<td>24,962</td>
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<td>99,606</td>
</tr>
<tr>
<td>Oct-18</td>
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<td>9,613</td>
<td>20</td>
<td>13,708</td>
<td>59,777</td>
<td>24,761</td>
<td>344</td>
<td>84,882</td>
</tr>
<tr>
<td>Nov-18</td>
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<td>32</td>
<td>18,755</td>
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<td>36,128</td>
<td>573</td>
<td>109,036</td>
</tr>
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<td>Dec-18</td>
<td>3,960</td>
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<td>19</td>
<td>15,338</td>
<td>64,508</td>
<td>29,256</td>
<td>306</td>
<td>94,071</td>
</tr>
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<td>10,504</td>
<td>21</td>
<td>14,093</td>
<td>54,377</td>
<td>27,056</td>
<td>331</td>
<td>81,765</td>
</tr>
<tr>
<td>Feb-19</td>
<td>3,960</td>
<td>14,821</td>
<td>24</td>
<td>18,805</td>
<td>54,614</td>
<td>38,176</td>
<td>359</td>
<td>93,149</td>
</tr>
<tr>
<td>Totals</td>
<td>54,039</td>
<td>144,500</td>
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<td>198,861</td>
<td>804,368</td>
<td>372,663</td>
<td>5,529</td>
<td>1,182,560</td>
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</tbody>
</table>

**Energy Cost ($/MMBtu)** $5.45
HISTORICAL ENERGY CONSUMPTION CHARTS
Figure 3: Total Electricity Consumption

Figure 4: Total Electricity Cost
Figure 5: Total Natural Gas Consumption

Figure 6: Total Natural Gas Consumption Cost
Figure 7: Total Bulk Propane Delivered

Figure 8: Total Bulk Propane Cost
Figure 9: Total Water Consumption

Figure 10: Total Water Consumption Cost
**Figure 11: Total Waste Water Usage**

**Figure 12: Total Waste Removal Cost**
Figure 13: Total Energy Consumption

Figure 14: Total Energy Cost
ASSESSMENT RECOMMENDATIONS (ARS)
AR #1.1: IMPLEMENT AIR LEAK MAINTENANCE PROGRAM  
(ARC 2.4236.2)

BACKGROUND
The plant has one 200 hp Quincy 1000, one 350 hp Quincy 1500, and one 125 hp Gardner-Denver air compressor which provide a constant supply of air for plant operations. These compressors operate 4,160 hours per year.

During the plant audit, the team observed audible leaks at several different locations around the plant. Air leaks increase the compressor’s “online” hours of operation by creating exaggerated air requirements and also cause a pressure drop in the air lines. Facility staff reported 400 cfm of compressed air leaks, which is equivalent to 20.5% of compressed air produced. Fixing air leaks on a regular basis will help the facility save energy and money.

RECOMMENDATION
We recommend that the facility incorporates a more aggressive air leak maintenance program. In addition to being a source of wasted energy, leaks can also contribute to other operating losses. Leaks cause drops in system pressure which can make air tools function less efficiently, adversely affecting production. By forcing the equipment to cycle more frequently, leaks shorten the life of almost all system equipment (including the compressor package itself). Increased running time can also lead to additional maintenance requirements and increased unscheduled downtime. Finally, leaks can lead to adding unnecessary compressor capacity. Eliminating the leaks can reduce the demand on the system and as it has a variable frequency drive inbuilt, will help to optimize the energy consumption.

Another way to detect leaks is to use an ultrasonic acoustic detector, which can recognize the high-frequency hissing sounds associated with air leaks. These portable units (Figure 1.1.1) consist of directional microphones, amplifiers, and audio filters, and usually have either visual indicators or earphones to detect leaks. Ultrasonic detectors are generally unaffected by background noises in the audible range because these signals are filtered out. By generally scanning around a test area, it is possible to very quickly hone it on a leak site and pinpoint its location. However, the air leak survey can be performed without an air leak detector since the air leaks are clearly audible in the absence of heavy equipment operation. In addition to ultrasonic air leak detection survey, using soapy water to detect air leaks may prove useful.

The values in the Table 1.1.1 represent tested CFM air flow through a round, sharp-edged orifice. These test results are particular to the pressure indicated. In a plant, you will probably never come across a perfect, round, sharp-edged orifice leak anywhere in your plant facility. Leaks occur in joints, couplings, slits or gashes in pipes and lines, and other types of fittings. Thus, the tables presented here can only be used as a guideline, and actual leak values may be more or less than what is listed here.

We provide a conservative estimate of the savings that can be incurred based on certain assumptions. The amount saved could easily be higher.

Table 1.1.1. Loss of energy due to air leaks²

| Leakage rates (cfm) for different supply pressures and approximately equivalent orifice sizes² |
|---------------------------------|-----|-----|-----|-----|-----|-----|
| Pressure (psig) | 1/64 | 1/32 | 1/16 | 1/8 | 1/4 | 3/8 |
| 70               | 0.3  | 1.2  | 4.8  | 19.2 | 76.7 | 173 |
| 80               | 0.33 | 1.3  | 5.4  | 21.4 | 85.7 | 193 |
| 90               | 0.37 | 1.5  | 5.9  | 23.8 | 94.8 | 213 |
| 100              | 0.41 | 1.6  | 6.5  | 26.0 | 104  | 234 |
| 125              | 0.49 | 2.0  | 7.9  | 31.6 | 126  | 284 |

**SUMMARY**

- Annual dollar savings ............................................................ $7,499/year
- Annual energy savings ........................................................... 147,040 kWh
- Implementation cost ............................................................... $1,898
- Payback period ....................................................................... 0.3 years

DATA

- Electricity consumption charge\(^3\) ........................................... $0.051/\text{kWh}
- Hours of operation\(^4\) ......................................................... 4,160 hrs/yr
- Compressor load factor\(^5\) .................................................... 63% 
- CFM produced by air compressors\(^6\) ................................. 1950 CFM
- CFM lost to leaks\(^7\) ............................................................ 400 CFM
- Estimated leak percentage repaired per year ........................... 70%
- kW required per cfm\(^8\) ...................................................... 0.1604 kW/ cfm
- Compressor Efficiency\(^9\) .................................................... 80%
- Time spent on air leak maintenance per month\(^10\) ............... 4 hours

CALCULATIONS

Percentage lost in leaks
= (Reported CFM lost) / (Total CFM produced)
= (400 CFM) / (1950 CFM)
= 20.5%

Potential kWh savings from CFM identified
= (Total CFM) (Percentage lost in leaks) (Estimated repairable leak percentage) (kW required/ cfm) (Operating hours) / (Compressor efficiency)
= (1950 cfm) (0.63) (0.205) (0.7) (0.1604 kW/ cfm) (4,160 hr/yr) / (0.80)
= 147,040 kWh

Annual dollar savings from energy conserved
= (Total Annual kWh savings) (Electric consumption rate)
= (147,040 kWh) ($ 0.051/kWh)
= $7,499/yr

Implementation cost\(^11\)
Distribution line connections in a compressed air system account for several varieties of leaks. Each leak repair requires its own methodology, and so repair costs and repair times vary. As an estimate, we assume about 145 air leaks will happen each year. We estimate that it would take one maintenance employee 20 minutes to repair a leak. We also assume that once a leak is fixed, maintenance work will be avoided for only a year.

= (Purchase cost of ultrasonic leak detector\(^12\)) + (Time spend on air leak maintenance monthly) (Labor cost) (12 months)

---

\(^3\) Data obtained from utility bill analysis
\(^4\) Data provided by facility staff
\(^5\) Average of respective compressor datasheet specifications weighted by CFM produced.
\(^6\) Data provided by facility staff
\(^7\) Ibid.
\(^8\) Average of respective compressor datasheet specifications weighted by CFM produced.
\(^9\) Estimate by audit team
\(^10\) Described under implementation cost in calculations.
\(^11\)
= ($650) + (4hrs/month) ($26/hrs) (12month)
= $1,898

Payback Period
= (Total Implementation cost) / (Total Annual dollar savings)
= ($1,898) / ($7,499)
= 0.3 years

12 Average cost of ultrasonic leak detector from Amprobe, Spectronics, and AccuTrak.
AR #1.2: USE BLOWERS INSTEAD OF COMPRESSED AIR FOR PROCESS CLEANING ON LVT LINE

(ENERGY ARC 2.4232.2)

BACKGROUND
The facility uses compressed air for cleaning off shavings in three locations in the LVT line: the end saw location, the rip saw location, and at the inspection conveyors. IAC staff timed the air usage at each location. At the end saw location, compressed air is used via handheld air blow gun for approximately 12 seconds every five minutes. At the rip saw location, compressed air is used via handheld air blow gun after every 10 seconds for 3 seconds. The air blow guns appear to be of ultimate flow tip design, which deliver higher air flow per CFM put in. Comparable air blow gun designs deliver 92 SCFM at 88% above standard designs. At the inspection conveyor, there are three compressed air knives which assure no shavings or other contaminates are packaged with the final product. These air knives operate full time during production at 100 cfm each. Compressed air is generated by three screw-type air compressors in this facility: one 200 hp Quincy 1000, one 350 hp Quincy 1500, and one 125 hp Gardner-Denver air compressor.

RECOMMENDED ACTION
Replace compressed air usage with electric blowers for process cleaning on the LVT line. Due to lower pressures in blowers, we are proposing a 12 hp, 500 CFM blower/air knife system as opposed to the 300 CFM compressed air/air knife system, and a 7.5 hp, 300 cfm blower that runs constantly with a nozzle on a flexible duct for directed air flow.
SUMMARY

- Total annual dollar savings .................................................... $5,528
- Annual Energy Savings .......................................................... 108,385 kWh/year
- Implementation cost ............................................................... $8,106
- Payback period ................................................................. 1.5 years

DATA

- Compressed air blow gun operating time $^{13}$ ......................... 13.85 seconds per minute
- Air blow gun operating capacity $^{14}$ ........................................... 80 cfm
- Air bar operating time $^{15}$ ...................................................... 4,160 hours/year
- Air bar operating capacity $^{16}$ ................................................. 100 cfm each
- Compressor load factor $^{17}$ ................................................... 63%
- CFM produced by air compressors $^{18}$ ....................................... 1,950 CFM
- Compressor Efficiency $^{19}$ .................................................. 80%
- kW required per cfm $^{20}$ ........................................................ 0.1604 kW / cfm
- Cost of electricity $^{21}$ ............................................................ $0.051/kWh
- Cost per proposed air knife $^{22}$ ................................................ $650
- Cost for 7.5 hp blower $^{23}$ .................................................... $2,500
- Cost for 12 hp blower $^{24}$ .................................................... $3,500
- Labor Cost .............................................................................. $26/hour

ASSUMPTIONS AND TECHNICAL CONSIDERATIONS

- Losses due to air leaks are not considered in the cost per CFM
- Compressed air systems are simple, and parts are easily replaced. Replacing the compressed air system with electric blowers may require more maintenance in the form of belts and air filters needing replacement regularly. This will also introduce another layer of complexity to the system, which could potentially cause interruptions in production.
- The pressures and volumes produced by the recommended pumps match the performance requirements.

CALCULATIONS

13 Observed by audit team
14 Comparable air blow guns with ultimate flow tip design.
15 Annual facility production hours multiplied by 60 minutes per hour
16 Data provided by facility staff
17 1,950 cfm observed by audit team / 3,116 cfm total capacity from manufacturer data sheets = 0.63
18 Data provided by facility staff
19 Estimate by audit team
20 Average of respective compressor datasheet specifications weighted by CFM produced.
21 Data obtained from utility bill analysis
22 Cost average for 12 inch air knife with ¼” NPT from Exair, Atlantic Blowers, and Air Control Industries.
23 Cost average for 7.5 hp blower from Chicago Blower, Atlantic Blowers, and Fuji Electric.
24 Cost Average for 10 hp to 15 hp blower from Chicago Blower, Atlantic Blowers, and Fuji Electric.
Current Energy Consumption per cubic foot
\[= \frac{(kW \text{ / CFM}) \times (1 \text{ hour} / 60 \text{ minutes})}{(compressor \text{ load factor}) / (compressor \text{ efficiency})}\]
\[= \frac{(0.1604 \text{ kW/CFM}) \times (1 \text{ hour} / 60 \text{ minutes})}{(0.63) / (0.80)}\]
\[= 0.002105 \text{ kWh / cubic foot}\]

Cubic feet of compressed air per year
\[= \frac{(\text{Compressed air blow gun operating time})}{(\text{seconds per minute})} \times \frac{(\text{minutes per hour})}{(\text{operating hours per year}) \times (\text{cfm capacity of air blow gun}) + (\text{Air knife operating time}) \times (\text{Air knife operating capacity}) \times (\# \text{ of air knives})}\]
\[= \frac{(13.85 \text{ seconds / minute})}{60 \text{ seconds / minute}} \times \frac{60 \text{ minutes / hour}}{(4,160 \text{ hours / year}) \times (80 \text{ cfm}) + (4,160 \text{ hours / year}) \times (100 \text{ cfm / air knife}) \times (3 \text{ air knives})}\]
\[= 79,489,280 \text{ cubic feet per year}\]

Current Annual Energy Consumption for Compressed Air on LVT Line
\[= (\text{Cubic Feet / year}) \times (\text{kWh per cubic foot})\]
\[= (79,489,280 \text{ cubic feet per year}) \times (0.002105 \text{ kWh / cubic foot})\]
\[= 167,325 \text{ kWh/year}\]

Current Annual Energy Cost for Compressed Air on LVT Line
\[= (\text{Current Annual Energy Consumption}) \times (\text{Cost per kWh})\]
\[= (167,325 \text{ kWh/year}) \times ($0.051 / \text{kWh})\]
\[= $8,534 / \text{year}\]

Proposed Annual Energy Consumption
\[= (\text{Total hp}) \times (\text{Conversion factor}) \times (\text{Operating hours})\]
\[= [(19 \text{ hp}) \times (0.7457 \text{ kW / hp}) \times (4,160 \text{ hours/year})]\]
\[= 58,940 \text{ kWh / year}\]

Proposed Annual Energy Cost
\[= (\text{Proposed Energy Consumption}) \times (\text{Cost of electricity})\]
\[= (58,940 \text{ kWh / year}) \times ($0.051/ \text{kWh})\]
\[= $3,006 / \text{year}\]

Annual Energy Savings
\[= (\text{Current Annual Energy Consumption}) – (\text{Proposed Annual Energy Consumption})\]
\[= (167,325 \text{ kWh / year}) – (58,940 \text{ kWh / year})\]
\[= 108,385 \text{ kWh / year}\]

Annual Dollar Savings
\[= (\text{Current Annual Energy Cost}) – (\text{Proposed Annual Energy Cost})\]
\[= ($8,534 / \text{year}) – ($3,006 / \text{year})\]
\[= $5,528 / \text{year}\]

Implementation Cost
\[= (\# \text{ of air knives}) \times (\text{cost per air knife}) + (\text{cost of 7.5 hp blower}) + (\text{cost of 12 hp blower}) + (\text{installation time}^{25}) \times (\text{Cost of labor})\]

\[^{25} \text{Estimate by audit team}\]
= (3) * ($650) + ($2,500) + ($3,500) + [(6 hours) * ($26/hour)]
= $8,106

**Payback Period**

= (Implementation Cost) / Annual Dollar Savings
= ($8,106) / ($5,528/year)
= 1.5 years
**AR # 2.1: REPLACE EXTERIOR METAL HALIDE FLOODS & SURFACE FIXTURES WITH LED FIXTURES**

(Energy ARC 2.7143.3)

**BACKGROUND**

The entire exterior of the plant is illuminated by 400-watt* metal halide pole-mounted floods (Figure 2.1.1) and 250-watt* metal halide surface-mount fixtures under awnings and over exterior doors (Figure 2.1.2). The floods are mounted approximately thirty feet above grade, while the surface-mount units are approximately twelve feet above loading docks and walkways. The fixture mounting locations are appropriate for the tasks of providing security and safety illumination. These fixtures currently operate dusk-to-dawn, 365 days per year, controlled by time switches. These existing non-cutoff fixtures produce wasted light due to their refractor and reflector designs, and this is particularly true for the surface-mount fixtures above the loading docks. Here is the existing system (Table 2.1.1):

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Description</th>
<th>Hours of operation/yr.</th>
</tr>
</thead>
<tbody>
<tr>
<td>55</td>
<td>400 watt* metal halide probe-start floods</td>
<td>4,100</td>
</tr>
<tr>
<td>9</td>
<td>250 watt* metal halide surface-mount units</td>
<td>4,100</td>
</tr>
</tbody>
</table>

* nominal watts, not including ballast watts

![Fig. 2.1.1. Existing 400-watt MH floods, on-site.](image1)

![Fig. 2.1.2. 250-watt metal halide unit, on-site.](image2)

**RECOMMENDED ACTION**

Replace each existing metal halide flood, one-for-one, with one LED flood rated at approximately thirty percent of the nominal wattage of the original fixture (Figure 2.1.3). Replace each existing metal halide surface-mount fixture, one-for-one, with one LED surface-mount unit rated at approximately thirty percent of the nominal wattage of the original fixture (Figure 2.1.4). Each new fixture should be rated UL "Wet" or IP65 for exterior locations.
Mount these at the existing fixture points. Control the new fixtures with photocells, for dusk-to-dawn operation. Confirm the existing service voltage to these mounting points before ordering the new fixtures to be sure that the voltage will be compatible with the LED drivers, and order accordingly. Repair or adjust all controls to prevent daytime operation, which wastes energy and increases on-peak demand. Table 2.1.2 shows the proposed system.

Fig. 2.1.3. LED 150-watt flood.26

Fig. 2.1.4. LED 80-watt canopy fixture.27

Photometric notes: The latest LED sources are significantly more efficient (in raw lumens per watt) than metal halide and HPS lamps, and they can provide a much higher coefficient of utilization than traditional light sources. Consider glare-control "cutoff" LED fixtures that control light spill, though these will be more expensive than standard "non-cutoff" units. Specify 5,000-degree-Kelvin LEDs for all of your exterior fixtures because LEDs operate most efficiently and reliably at this color temperature.

Table 2.1.2 - Proposed system

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Description</th>
<th>Hours of operation/yr.</th>
</tr>
</thead>
<tbody>
<tr>
<td>55</td>
<td>150 watt LED UL &quot;Wet&quot; or IP65 flood</td>
<td>4,100</td>
</tr>
<tr>
<td>9</td>
<td>80 watt LED UL &quot;Wet&quot; or IP65 canopy</td>
<td>4,100</td>
</tr>
</tbody>
</table>

COMBINED SUMMARY

- Annual energy savings..........................77,203 kWh/yr
- Peak demand reduction..........................Not applicable
- Total cost savings...............................$3,937/yr
- Implementation cost.............................$15,573
- Simple payback period...........................4.0 yrs


27 https://relightdepot.com/t-series-led-canopy-lighting-80w.html
DATA

- Energy cost.....................................................$0.051/kWh (not including demand)
- Demand cost...................................................$11.52/kW
- Labor cost.......................................................$26/hr

Present system -- 400-watt metal halide

- Number of fixtures........................................55
- Input wattage (lamp and ballast)...............0.458 kW* (magnetic ballast)
- Lamps per fixture........................................1
- Operating hours/yr..................................4,100 (dusk to dawn)
- Type of lamp........................................Philips MH400/U/ED28
- Rated Lamp life.................................20,000 hours
- Lamp cost (each)......................................$30.
- Total system mean lumens....................1,320,000 [(55 lamps) (24,000 mean lumens/lamp)]

*This is the total kW demand of one fixture (lamp and ballast). Source: Universal Ballast Navigator: http://unvlt.com/literature/ballast-navigator/

Proposed system -- 150-watt LED

- Number of LED fixtures................................55
- Input wattage (lamp and driver).............0.150 kW**
- Lamps per fixture..............................1
- Operating hours/yr..............................4,100 (dusk to dawn)
- Lamp type......................................LED, 5,000 Kelvin temperature, 70+ CRI
- Rated Lamp life...........................60,000 hours L70 rating (per IES LM-80)
- Lamp cost (each)..................................Not applicable--Not user serviceable.
- Total system initial lumens**...............1,137,400 [(55 fixtures) (20,680 lumens/fixture, per IESNA-79-08 standards)]

**This is the total kW demand of one fixture (LED module and driver). Reference fixture: https://www.shineretrofits.com/howard-lighting-xfl-5150-led-mv-tr-dlc-qualified-150-watt-led-flood-light-fixture-with-trunnion-mount-dimmable-5000k.html

Present system -- 250-watt metal halide

- Number of existing fixtures..............9
- Input wattage (lamp & ballast)............0.29 kW*
- Lamps per fixture.............................1
- Operating hours/yr..........................4,100 (dusk to dawn)
- Type of lamp................................Philips MH250/U
- Rated Lamp life..........................10,000 hours
- Lamp cost (each).............................$25.
- Total system mean lumens..................121,500 [(9 lamps) (13,500 mean lumens/lamp)]

*This is the total kW demand of one fixture (lamp and ballast). Source: Universal Ballast Navigator: http://www.unvlt.com/literature/navigator/bnav.html
Proposed system -- 80-watt LED

- Number of LED fixtures .....................9
- Input wattage (lamp and driver)...........0.080 kW**
- Lamps per fixture............................1
- Operating hours/yr. .........................4,100 (dusk to dawn)
- Lamp type .....................................LED, 5,000 Kelvin temperature, 70+ CRI
- Rated Lamp life ................................60,000 hours L70 rating (per IES LM-80)
- Lamp cost(each)...............................Not applicable--Not user serviceable.
- Total system initial lumens*** ..........85,932 [(9 fixtures) (9,548 lumens/fixture, per IESNA-79-08 standards, cool white type)]

** This is the total kW demand of one fixture (LED module and driver). Reference fixture: https://relightdepot.com/t-series-led-canopy-lighting-80w.html

***Mean lumens are not available, so initial lumens per fixture are shown here.

Similar fixtures are available from Cree, Rab Lighting, Maxlite, Topaz, Cooper, e-conolight, & Lithonia. Vendors of LED flood & wallpack fixtures include Graybar, Grainger, 1000bulbs.com, Goodmart.com, and AtlantaLightBulbs.com. Before purchase, contact your local utility to check on rebate programs, if available.

LED Illumination Notice: Properly designed LED fixtures and retrofit products can provide equivalent illumination on task with significantly lower lumen outputs than traditional light sources, such as metal halide and fluorescent. This phenomenon is recognized by every major light fixture and lamp manufacturer in this country, including Holophane, Cooper, General Electric, Lithonia, Hubbell, Philips, Osram-Sylvania, etc.

SAMPLE CALCULATIONS - 400 W. MH TO 150 W. LED

Existing system with 400-watt metal halide probe-start lamps and magnetic ballasts
= (Number of existing fixtures) (Existing fixture demand) (Operating hours/yr.)
= (55 fixtures) (0.458 kW/fixture) (4,100 hrs/yr via timer control)
= 103,279 kWh/yr

Proposed system with 150-watt LED flood fixtures
= (Number of proposed fixtures) (Proposed fixture demand) (Operating hours/yr.)
= (55 fixtures) (0.150 kW/fixture) (4,100 hrs/yr via timer control)
= 33,825 kWh/yr

Energy savings
= Existing kWh - Proposed kWh
= 103,279 kWh/yr – 33,825 kWh/yr
= 69,454 kWh /yr

Avoided energy cost (sample calc. only)
= (Energy savings/yr.) (Cost per kWh)
= (69,454 kWh/yr) ($0.051/kWh)
= $3,542/yr.

Demand savings
Not applicable because the kW reduction will occur during off-peak hours.
Avoided demand cost
Not applicable.

Total annual energy savings (entire system) from Table 2.1.3 below
(113,980 existing kWh/yr) - (36,777 proposed kWh/yr) = 77,203 kWh/yr

Total annual energy cost savings (entire system) from Table 2.1.3 below
(77,203 kWh/yr.) ($0.051/kWh) = $3,937/yr.

Table 2.1.3 - Savings calculation summary of entire system

<table>
<thead>
<tr>
<th>Existing system</th>
<th>Quantity</th>
<th>Description</th>
<th>Hours of op./yr.</th>
<th>kW/fixt.*</th>
<th>kWh/yr.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>55</td>
<td>400 w. MH flood</td>
<td>4,100</td>
<td>0.458</td>
<td>103,279</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>250 w. MH canopy</td>
<td>4,100</td>
<td>0.290</td>
<td>10,701</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Subtotal:</strong></td>
<td></td>
<td></td>
<td>113,980</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Proposed system</th>
<th>Quantity</th>
<th>Description</th>
<th>Hours of op./yr.</th>
<th>kW/fixt.**</th>
<th>kWh/yr.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>55</td>
<td>150 w. LED flood</td>
<td>4,100</td>
<td>0.150</td>
<td>33,825</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>80 w. LED canopy</td>
<td>4,100</td>
<td>0.080</td>
<td>2,952</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Subtotal:</strong></td>
<td></td>
<td></td>
<td>36,777</td>
</tr>
</tbody>
</table>

* This is the total kW demand of one fixture (lamp and ballast).
** This is the total kW demand of one fixture (LED module and driver).

Implementation cost - entire system
= [(Number of fixtures) (Cost per fixt.)] + [(Number of fixts.) (Estimated labor hrs/fixt.)
  (Labor cost/hr.)]
= [(55 fixtures) ($203 per fixture)28] + [(9 fixtures) ($146 per fixture)29] + [(55 fixtures at 30'
  mtng. height) (2.0 hrs/fixt.) ($26/hr*)] + [(9 fixtures at 12' mtng. height) (1.0 hr/fixt.) ($26/hr*)]
= $15,573. Implementation cost (There is no utility incentive available.)

28 Here is a reference flood fixture for the cost estimate in the calculation:

Here are two more sample 150-watt LED flood fixtures:


29 Here is a reference canopy fixture for the cost estimate in the calculation:
https://relightdepot.com/t-series-led-canopy-lighting-80w.html

Here are two more sample 80-watt LED canopy fixtures:


NOTE: All links above accessed on 29 May 2019.
*This assumes in-house labor, per feedback from the client.

**Simple payback period - entire system**

\[
\text{Simple payback period} = \frac{\text{Implementation cost}}{\text{Total combined annual savings/yr}}
\]

\[
= \frac{15,573}{3,937/\text{yr}}
\]

\[
= 4.0 \text{ years}
\]

**Disclaimer:** All product pricing and sourcing information is provided as a courtesy only and is not a quotation or endorsement of any specific brand or supplier. Oklahoma State University encourages you to compare several brands and suppliers before making a purchase decision. Project cost estimates above do not include taxes, shipping, & engineering fees, where applicable.
AR # 2.2: RETROFIT F54T5HO FIXTURES IN PRODUCTION AREA WITH LED TUBES
(Energy ARC 2.7143.3)

BACKGROUND
The production area is illuminated by four-lamp F54T5HO fluorescent open fixtures, suspended by chains approximately 23’ above the floor (Figure 2.2.1). These fixtures were installed six years ago and are in excellent condition. The client would like to re-use these fixture housings and the T5 miniature bipin lampholders (also known as non-shunted G5 miniature bi-pin tombstones). One-third of these fixtures operate 8,760 hours per year, and two-thirds operate 4,992 hours per year, including production, maintenance, and custodial hours. The illumination levels are appropriate for the various tasks. Visual comfort is generally acceptable, due to the relatively high mounting height and the use of moderate luminosity lamps.

Fig. 2.2.1. Four-lamp F54T5HO fixtures on-site.       Fig. 2.2.2. LED T5 direct-wire retrofit tube.

RECOMMENDED ACTION
Retrofit these fixtures with 25-watt (or similar wattage up to 27-watt) line-voltage LED T5 retrofit tubes (Figure 2.2.2). These tubes require removal of the existing fluorescent ballast and operate directly on the lighting circuit voltage from the circuit breaker panel. The latest generation of LED retrofit tubes provides significantly higher lumens per watt, higher lumen maintenance, and longer rated life than any fluorescent F54T5HO lamp. If properly installed, they should provide reliable service, no flicker, no hum, and overall lower life-cycle costs than fluorescent sources.

Replace the existing F54T5HO lamps with LED T5 retrofit tubes on a one-for-one basis. Here are some recommended specifications for these tubes. Each tube will feature:

- Internal driver, with a power factor of 98% or higher, if available.
- Operation at 120 or 277 volts, applied at the mini-bi-pin lampholders.
- Frosted (white opal) outer finish to reduce the intense glare (high luminosity) of LED's.
- DLC certified. See this site: https://www.designlights.org/
• Warranted against defects for five years. (Five-year written warranty)
• 5000 Kelvin color temperature, which is the most efficient type of LED tube. This is a blue-white color. Warmer-color LED tubes produce lower light output per watt.
• The outer tube should be UV-resistant acrylic, not glass. (The existing fluorescent F54T5HO lamps are equipped with plastic shatter-proof sleeves.)

Procedure for each retrofitted fixture:
1. Follow all safety rules for electrical work. Lock out/tag out the breaker for this circuit.
2. Schedule this work so that it will not disrupt or distract employees.
3. Remove the existing F54T5HO fluorescent lamps, and properly dispose of them.
4. Remove the ballast compartment cover and replace any worn wiring.
5. Inspect the existing lampholders. If these are unshunted mini-bi-pin units, you may re-use them. The line voltage LED tubes are designed to fit into these lampholders, which were originally designed for T5/T5HO rapid start lamps. The circuit will be completed at only one end of each LED tube. The lampholder at the other end will not be energized.
6. Remove the existing fluorescent ballast.
7. Follow the wiring instructions that accompany the LED tube to connect line voltage to the lampholder at one end of each LED tube. Use the same end for all four energized connections. Confirm that wiring and lampholders are rated for the line voltage that you will connect to them.
8. Re-install the ballast cover, but there will be no separate driver and no ballast.
9. Carefully install the line-voltage LED retrofit tubes into the pairs of unshunted mini-bi-pin lampholders. **NOTE:** Never install or remove LED retrofit tubes from an energized fixture.
10. Energize the fixture and check it for proper operation.

**Note:** You may re-use the existing unshunted mini-bi-pin lampholders (Figure 2.2.3) in each fixture if they are not cracked, charred, or otherwise degraded. During this retrofit, carefully examine the existing lampholders (where the lamp pins are inserted), and replace any that have weak springs, cracks, or other damage. Check all wiring and replace any that is worn, and be sure that all wire nuts are tight. If your fixtures are equipped with shunted mini-bi-pin lampholders (Figure 2.2.4), then remove them, and replace them with unshunted units.
SAFETY & CODE COMPLIANCE ADVISORY:
In performing this fluorescent-to-LED retrofit in your production fixtures, please conform to all relevant sections of the National Electrical Code. Further, you should perform the following steps:

- Label each LED-retrofitted fixture with a tag that indicates: "**Warning**: Do not install fluorescent lamps into this fixture. It has been modified to accept only line-voltage LED tubes. Line voltage (120 or 277 v.) has been wired to the lampholders in this fixture."

- Attach safety notification tags to fixtures in such manner that they will not degrade and fall off after months or years. Scotch tape and paper notices are not acceptable. Use cardboard safety tags that are wired to the fixture, away from any electrical connection.

- Train all maintenance staff to carefully determine the status of any fixture when replacing lamps or LED tubes, if you are not going to retrofit all fixtures at once. Maintenance personnel must check to determine if the fixture-in-question has been modified to accept LED tubes. Advise staff that many LED retrofit tubes look very similar to traditional fluorescent T5HO lamps--from the outside.

- Advise all maintenance staff: "Do not accidentally install LED retrofit tubes into fluorescent fixtures that have not yet been modified to accept LED tubes."

- If you will retrofit all of your fixtures at one time, then remove all of the fluorescent lamps (4' and/or 8') from your facility, including the units that you remove from the fixtures and any spare lamps in your maintenance-storage area.

Another important specification consideration is total harmonic distortion (THD). We recommend that any LED tubes or fixtures that you install should not exceed 20% THD. Please review this article on the impact of diode-based loads on power quality in your facility: *Understanding Harmonic Voltage and Current Distortion Levels At Your Facility* [http://ecmweb.com/power-quality/understanding-harmonic-voltage-and-current-distortion-levels-your-facility](http://ecmweb.com/power-quality/understanding-harmonic-voltage-and-current-distortion-levels-your-facility)

Finally, consider installing transient voltage suppressors and other protective components for all of the circuits that serve these fixtures. Please see this information about products that protect LED drivers from some adverse power conditions: [http://www.shineretrofits.com/shop-lighting/components-and-accessories/light-fixture-surge-protection.html](http://www.shineretrofits.com/shop-lighting/components-and-accessories/light-fixture-surge-protection.html)

**SUMMARY**
- Annual energy savings………………………………..590,436 kWh/yr
- Peak demand reduction………………………………94.5 kW (1,134 kW mo-yr)
- Total cost savings…………………………………….$43,176/yr
- Implementation cost………………………………….$71,250
- Simple payback period……………………………1.7 years

**DATA**
- Energy cost………………………………………….$0.051/kWh (without demand)
- Demand cost………………………………………….$11.52/kW
• Labor cost.................................................................$26/hr

Present system
• Number of fluorescent fixtures .......................750 @4-lamps each
• Input wattage (lamp & ballast)* .................0.226 kW/fixt.
• Operating hours.............................................250 fixts. @ 8,760 & 500 @ 4,992 hrs/yr
• Lamps per fixture .......................................4
• Lamp type ..................................................Philips F54T5/841/HO ALTO
• Rated lamp life ...........................................36,000 hrs
• Lamp cost ...............................................$7.50 (each)
• Total system mean lumens .......................14,250,000 [(3,000 lamps) (4,750 mean lumens/lamp)]

*This is the total kW demand of one fixture (lamps and ballasts). Source: Universal Ballast Navigator: http://unvlt.com/literature/ballast-navigator/

Proposed system
• Number of LED fixtures .........................750 @ 4 tubes each
• Input wattage (modules & driver)...............0.100 kW/fixture (electronic)*
• Operating hours.......................................250 fixts. @ 8,760 & 500 @ 4,992 hrs/yr**
• Lamps per fixture .....................................4
• Lamp type ..................................................LED, 5,000 Kelvin, ballast bypass
• Rated lamp life ...........................................50,000 hours (L70 method)
• Lamp cost ..................................................$14.00 (each)
• Total system mean lumens .......................9,600,000 [(3,000 tubes) (3,200 initial lumens/tube)] (Mean lumens are not available.)

*This is the total kW demand of one fixture (4 LED retrofit tubes with integral drivers @ 25 watts/tube).
**Occupancy sensors are not feasible for this application.

Reference LED tube for energy-saving calculations:

LED Illumination Notice: Properly designed LED fixtures and retrofit products can provide equivalent illumination on task with significantly lower lumen outputs than traditional light sources. This phenomenon is recognized by every major light fixture and lamp manufacturer in this country, including Holophane, Cooper, General Electric, Lithonia, Hubbell, Philips, Osram-Sylvania, etc. This recommendation is consistent with the guidelines of these manufacturers.

CALCULATIONS
Existing system with T5HO fluorescent fixtures
= (Number of existing fixtures) (Existing fixture demand) (Operating hours)
= [(250 fixtures) (0.226 kW/fixture) (8,760 hrs/yr)] + [(500 fixtures) (0.226 kW/fixture) (4,992 hrs/yr)]
= 1,059,036 kWh/yr

Proposed system with LED direct-wire retrofit tubes installed in existing fixtures
= (Number of proposed fixtures) (Proposed fixture demand) (Operating hours)
= [(250 fixtures) (0.100 kW/fixture) (8,760 hrs/yr)] + [(500 fixtures) (0.100 kW/fixture) (4,992 hrs/yr)]
= 468,600 kWh/yr

**Energy savings**
= Existing kWh - Proposed kWh
= 1,059,036 kWh/yr – 468,600 kWh/yr
= 590,436 kWh/yr

**Avoided energy cost**
= (Energy savings/yr.) (cost per kWh w/o demand)
= (590,436 kWh/yr) ($0.051/kWh)
= $30,112/yr.

**Demand savings**
= [(Existing fixture demand) (# of fixts.)] - [(Proposed fixture demand) (# of fixts.)]
= [(0.226 kW/fixture) (750 fixtures)] - [(0.100 kW/fixture) (750 fixtures)]
= 94.5 kW

**Avoided demand cost**
= (Demand saved/month) (Months/yr.) (Cost per kW)
= (94.5 kW) (12 months/yr.) ($11.52/kW)
= $13,064/yr.

**Total annual savings**
= (Energy cost savings) + (Demand cost savings)
= ($30,112/yr) + ($13,064/yr.)
= $43,176/yr.

**Implementation cost**
= [(Number of LED tubes) (Material cost per tube)] + [(Number of fixtures) (Estimated labor hrs/fixt.) (Labor cost/hr.)]
= [(3,000 tubes) ($14 per tube)] + [(750 fixtures) (1.5 hrs/fixt.) ($26/hr)]*
= $71,250. Estimated implementation cost *(Assuming in-house labor, per client feedback.)*

30 **Note:** Here are some sample products that will meet the specification noted in the recommendation above:

GreenCreative 98305

KT-LED25T5HO-48GC-850-D KEYSTONE

T5 LED 25W SE ByPass UNV 5000K

T5 LED Tube - 4 ft. T5 Replacement - 5000 Kelvin
https://www.1000bulbs.com/product/201555/LEDT-10058.html

NOTE: All links above accessed on 30 May 2019.
Simple payback period
= (Implementation cost)/(Total annual savings/yr)
= ($71,250)/($43,176/yr)
= 1.7 years

Utility rebate note
To the best of our knowledge, your distribution utility does not provide financial incentives for energy-efficient lighting improvements.

Disclaimer: All product pricing and sourcing information is provided as a courtesy only and is not a quotation or endorsement of any specific brand or supplier. The Web links provided in this report are not recommendations by Oklahoma State University of any brand, manufacturer, or distributor. Oklahoma State University encourages you to compare several brands and suppliers before making a purchase decision. Project cost estimates above do not include taxes, shipping, & engineering fees, where applicable.
AR #3.1: OPTIMIZE FACILITY POWER FACTOR

(ARC 2.3212.2)

BACKGROUND
The facility is serviced by the City of Anytown Electric Utility and has a primary metered connection. The City of Anytown charges a fee for power factors below 0.80, which appears in the utility bill as a “Power Factor Adjustment” charge in the “Current Charges – Other” section. The facility currently leases a capacitor bank from the City of Anytown at $155.83 per month. According to an employee of the City of Anytown, all leased capacitor banks in the industrial area of Anytown are 30+ years old. For the 12 months between March 2018 and February 2019, capacitor rental cost $1,870 and low power factor cost $11,210, totaling to a cost of $13,080.

Power factor (PF) is the relationship between working (active) power and total power consumed (apparent power). Active power is the power (kW) that is supplied by the power system to actually operate the inductive magnetic devices. On the other hand, reactive power (kVAR) is used solely to develop a magnetic field within the motor. The higher the power factor, the more effectively electrical power is being used.31

Essentially, PF is a measurement of how effectively electrical power is being used. Mathematically, PF is defined as the ratio of Active Power (kW) to Apparent Power (kVA):

\[
PF = \frac{\text{Active Power (kW)}}{\text{Apparent Power (kVA)}} = \cos \theta
\]

PF can vary from zero to one. A power factor of 1.00 indicates that 100% of the electrical current is contributing to the power in the load, while a power factor of 0.00 indicates that none of the current contributes to the power in the load.32

PF may be leading or lagging depending on the direction of VAR flow. When the load is inductive, the current lags the applied voltage, and the power factor is known as lagging power.

factor. Induction motors are generally the principal cause of low PF because there are so many in use and they are usually not fully loaded.

The correction of the condition of low PF is a problem of economic importance in the generation, distribution, and utilization of AC power. Facilities operating with large inductive loads should maintain the PF within the specified limits given by the power company to avoid being subjected to additional charges. However, in addition to avoiding penalties, an increased PF can have a significant impact on cost savings for the plant, such as increased plant capacity, improvement of voltage supply (if capacitors are inside the plant) and less power losses in feeders, transformers, and distribution equipment.

PF can be corrected by installing capacitor banks. These capacitors work as reactive current generators providing needed reactive power (kVAR). Properly sized capacitors will offset most of the lagging current of motors and other inductive loads and raise the power factor. These capacitors reduce the total current drawn from the distribution system and subsequently increase system capacity by raising the power factor level. Figure 3.1.2 shows the power factor correction that is proposed by using the power correction capacitors.

![Figure 3.1.2: Power Factor Correction](image)

### 3.1.2: Power Factor Correction

**RECOMMENDED ACTION**

During the twelve-month period from March 2018 to February 2019, the average power factor in the plant is 78.8% while the required power factor is 80%. The current power factor indicates significant reactive power generation inside the plant. Increase in the PF would increase the effectiveness of the electric power being used.

We recommend purchasing and installing a facility-owned capacitor bank to properly correct the PF in order to eliminate the power factor penalty that the facility is incurring as well as eliminate the monthly capacitor bank rental fee. We also recommend correcting to a minimum power factor of 0.90 in order to stay ahead of the trend of electric utility providers charging fees for PF below 0.90.
Technical considerations (TC)

TC 1: Alternative to purchasing your own capacitor bank.
The Anytown Electric Utility offers a 1200 kVAR Capacitor bank at $212.48 per month\(^\text{34}\), not including installation costs. This is double the size of the current capacitor bank and would improve PF above the minimum required by the City of Anytown. The facility would have to provide the pole and pay for installation, but the increased capacity would prevent the facility from being charged for poor power factor. Annual cost of a 1200 kVAR capacitor bank is $2,549. The facility’s power factor adjustment charges from April 2018 to March 2019 were $11,210. Cost of removal of the old capacitor bank and installation of a new capacitor bank would be determined by actual installation time and include the cost for crew and vehicle time, plus the cost of a new pole\(^\text{35}\), which is appraised at $610. Estimating the complete initial installation cost to be $3,000, the rental of the larger capacitor will pay back in 0.4 years.

TC 2: Check for proper function of existing PF Correction equipment.
It may be appropriate to contact the City of Anytown to ensure that the capacitor bank in use is currently operational.

TC 3: Use smaller capacitors at substations within the plant.
Facility staff provided data that indicated that PF is lower when the plant is not in production mode. The facility receives primary power from the utility, which is stepped down to 480 volts at 8 substations inside the facility. According to data provided by staff, the three VOC incinerators are driven by VFD controlled AC motors and supplied by substation #5. Substation #5’s PF is 50% when not in production and 70% when in production. The facility can identify substations with low PF such as #5, or even individual motors and systems with low PF, and install smaller, less expensive capacitor banks closer to the source of low PF. The low PF on these motors may indicate other issues as well, such as oversized motors for the application. The source referenced in Figure 3.1.3 can offer more detailed information on PF correction via VFD.

TC 4: PF of 600 hp DC Calendar mixing motor.
DC motors inherently do not have a power factor. At its core concept, PF is a relationship between voltage sine waves and current sine waves (as shown in Figure 3.1.3). There are no sine waves in direct current. However, the rectifiers and the transformer (assuming a transformer is necessary in this particular application) in the AC to DC conversion process can introduce harmonic distortions and affect the PF. Older and simpler systems are notorious for poor PF. The facility can install a PF correcting DC power source or possibly a harmonic filter to mitigate the AC to DC conversion impact on PF.

TC 5: Due diligence.
Please consult a licensed Professional Engineer (PE) regarding capacitor and harmonic filter installations. In some cases, a capacitor bank can cause additional issues such as generating damaging harmonic distortion. A more complex solution may be required, and a PE should be consulted before altering major electrical components such as the recommended capacitor bank.

SUMMARY
- Total Annual Dollar Savings .............................................................$13,080
- Energy Savings ..................................................................................0 kWh
- Implementation Cost .................................................................$57,161
- Payback Period...................................................................................4.37 years

DATA
- Average existing power factor37 ......................................................0.788
- Improved power factor .....................................................................0.90
- Highest kVAR correction factor required38 .................................1481
- Recommended capacitor bank rating39 .........................................1500 kVAR

---

37 Data obtained from records provided by facility staff.
38 Highest kVAR correction factor occurs in July 2018
• Cost of capacitor banks\textsuperscript{40} ................................................................. $55,911
• Installation cost\textsuperscript{41} ............................................................................. $1,250

Calculations for facility-owned capacitor bank
The complete calculations for power factor correction are shown in Table 3.1.1. A sample calculation for January 2019 is shown below. The calculation is based on eliminating the power factor penalty on this account by correcting the power factor to 90%. The savings from the decreased demand cost with increased power factor will justify the investment on correcting the power factor.

For existing power factor
kVAR data provided by staff
= 3159 kVAR

For corrected power factor
kVA requirement for January 2019
= (Actual kW) / (Corrected PF)
= (4,094) / (0.90)
= 4,549 kVA

θ calculation for January 2019
= \cos^{-1}(\text{Corrected PF})
= \cos^{-1}(0.9)
= 0.451

kVAR requirement for January 2019
= (kVA) (\sin \theta)
= (4,549) (\sin 0.451)
= 1,983 kVAR

kVAR correction required for January 2019
= (kVAR for existing PF) – (kVAR for corrected PF)
= (3,159 kVAR) – (1,983 kVAR)
= (1,176 kVAR)

Capacitor size requirement
The required kVAR of the recommended capacitor bank is the highest kVAR correction for the 12-month period.
= (1,481 kVAR)
The detailed breakdown of the calculated values for each month is provided in Table 3.1.1.

\textsuperscript{39}Max kVAR plus 2.5% margin
\textsuperscript{40}Lowest price for 1500 kVAR capacitor banks from Eaton, Galco, and ShiZuki.
\textsuperscript{41}RSMeans Mechanical Cost Data. 2009.
SAVINGS CALCULATION

Annual power factor adjustment fees\(^{42}\)
= $11,210

Capacitor bank annual lease cost\(^{43}\)
= $1,870

Total annual dollar savings
= (Power factor Adjustment Fee) + (Capacitor Bank Annual Lease Cost)
= ($11,210) + ($1,870)
= $13,080

Total implementation cost
= (Capacitor material cost) + (Installation cost)
= ($55,911) + ($1,250)
= $57,161

Payback period
= (Total Implementation cost) / (Total Annual dollar savings)
= ($57,161) / ($13,080)
= 4.37 years

<table>
<thead>
<tr>
<th>Month</th>
<th>Actual kW Demand</th>
<th>Existing Power Factor</th>
<th>Recommended Power Factor</th>
<th>Current kVAR</th>
<th>Required kVAR Correction</th>
<th>Required kVAR</th>
<th>PF Adjustment Fee</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mar-18</td>
<td>3878</td>
<td>0.80</td>
<td>0.90</td>
<td>3079</td>
<td>1878</td>
<td>1201</td>
<td>255</td>
</tr>
<tr>
<td>Apr-18</td>
<td>3864</td>
<td>0.78</td>
<td>0.90</td>
<td>3205</td>
<td>1871</td>
<td>1334</td>
<td>0</td>
</tr>
<tr>
<td>May-18</td>
<td>3816</td>
<td>0.77</td>
<td>0.90</td>
<td>3312</td>
<td>1848</td>
<td>1464</td>
<td>752</td>
</tr>
<tr>
<td>Jun-18</td>
<td>3912</td>
<td>0.77</td>
<td>0.90</td>
<td>3375</td>
<td>1895</td>
<td>1481</td>
<td>2875</td>
</tr>
<tr>
<td>Jul-18</td>
<td>4075</td>
<td>0.77</td>
<td>0.90</td>
<td>3306</td>
<td>1974</td>
<td>1333</td>
<td>2246</td>
</tr>
<tr>
<td>Aug-18</td>
<td>4032</td>
<td>0.78</td>
<td>0.90</td>
<td>3228</td>
<td>1953</td>
<td>1276</td>
<td>2222</td>
</tr>
<tr>
<td>Sep-18</td>
<td>3869</td>
<td>0.78</td>
<td>0.90</td>
<td>3185</td>
<td>1874</td>
<td>1311</td>
<td>2132</td>
</tr>
<tr>
<td>Oct-18</td>
<td>3749</td>
<td>0.79</td>
<td>0.90</td>
<td>3263</td>
<td>1816</td>
<td>1447</td>
<td>206</td>
</tr>
<tr>
<td>Nov-18</td>
<td>3850</td>
<td>0.79</td>
<td>0.90</td>
<td>3113</td>
<td>1865</td>
<td>1249</td>
<td>253</td>
</tr>
<tr>
<td>Dec-18</td>
<td>4176</td>
<td>0.79</td>
<td>0.90</td>
<td>3197</td>
<td>2023</td>
<td>1174</td>
<td>0</td>
</tr>
<tr>
<td>Jan-19</td>
<td>4094</td>
<td>0.82</td>
<td>0.90</td>
<td>3159</td>
<td>1983</td>
<td>1176</td>
<td>269</td>
</tr>
<tr>
<td>Feb-19</td>
<td>4018</td>
<td>0.81</td>
<td>0.90</td>
<td>3064</td>
<td>1946</td>
<td>1118</td>
<td>0</td>
</tr>
</tbody>
</table>

\(\text{Total} = $11,210\)

\(^{42}\text{Data obtained from utility bills.}\)
\(^{43}\text{Ibid.}\)
Please review the informative articles below that provide relevant guidance.

A Primer on Power Factor Correction
https://www.ecmweb.com/content/primer-power-factor-correction

The Economics of Improving Power Factor
https://www.csemag.com/articles/the-economics-of-improving-power-factor/
AR #4.1: INSULATE OIL PUMPING STATION
(H.O.D.)
(ARC 2.2511.1)

BACKGROUND
This facility uses hot oil to regulate temperatures in the webbing process and for other hot oil applications. The hot oil is produced by two 100 cfm natural gas boilers at around 400°F. At the pumping station, the team noted the average temperature of the exterior was 320°F via infrared camera. During plant inspection, the hot oil pumping station was completely uninsulated. Discussions with facility staff indicated that the area was recently repaired, and the insulation had not been replaced.

RECOMMENDED ACTION
Re-install HOD insulation.

SUMMARY
- Total Annual Dollars Saved...................................................$5,110
- Annual Energy Savings..........................................................1,799 MMBtu
- Implementation Cost..............................................................$63
- Payback Period.................................................................0.01 years

DATA
- Exterior Pipe Temperature44 ..............................................320°F
- Surrounding Temperature45 ..............................................82°F
- Labor hours46 .................................................................2.5 hours
- Cost of Insulation47 ..........................................................$0
- Insulation R-Value48 .........................................................4.3
- Surface Area49 .................................................................60 sq. ft./unit

ASSUMPTIONS
- Heat transfer is exclusively by radiation and natural convection.
- Surrounding air and surface temperatures are the average 82°F.
- The steel tubing acts as a blackbody, i.e. a perfect emitter of radiation.

44 Observed during audit team’s inspection via infrared camera.
45 Average between winter set temperature and summer interior unconditioned temperatures.
46 Estimate
47 Insulation already owned by facility.
48 R value of 1 inch thick fiberglass hot pipe insulation.
49 Data measured by audit team.
CALCULATIONS

Energy lost before insulation installation via heat radiation.
= (emissivity) (Stefan-Boltzmann constant) (Surface Area per unit) (# of units) [(Surface Temp\(^4\) – Surrounding Temp\(^4\))]
= (1.0) * (0.174 E-8 Btu/h.ft\(^2\).R\(^4\)) (60 sq. ft/unit) (6 units) [(780°R\(^4\) - 542°R\(^4\)]
= 177,806 Btu/hour

Energy lost before insulation via natural convection
= (heat transfer coefficient\(^{50}\)) (Surface Area per unit) (# of units) (Surface Temp – Surrounding Temp)
= (3.2 Btu/h.ft\(^2\).R.) (60 sq. ft / unit) (6 units) (320°F - 82°F)
= 274,176 Btu/hour

Total Energy lost before insulation
= (Energy lost via Radiation) + (Energy lost via natural convection)
= (177,806 Btu/hour) + (274,176 Btu/hour)
= 451,982 Btu/hour

Total Energy lost after insulation
= [(Surface Temp – Surrounding Temp) / [(Insulation R-Value) + (1 / (natural convection heat transfer coefficient) (thickness of insulation) (insulation area))] * (area)]
= [(320°F - 82°F) / [(4.3) + (1 / (3.2 Btu/h.ft\(^2\).R) (1/12 ft. thickness) * (60 sq. ft.))] * (60 square feet / unit) (6 units)]
= 19,640 Btu/hour

Total Annual Energy Saved
= [(Total Energy lost before insulation) – (Total Energy lost after insulation)] * (Production hours) (Conversion factor)
= [(451,982 Btu/hour) – (19,460 Btu/hour)] * (4,160 hours/year) (1 MMBtu / 1,000,000 Btu)
= 1,799 MMBtu / year

Total Annual Dollars Saved
= (Total Annual Energy Saved) (Cost of Natural Gas)
= (1,799 MMBtu/year) ($2.84/MBtu)
= $5,110 / year

Cost of Implementation
= (hourly cost of labor) (2.5 hours)
= ($26/hour) (2.5 hours)
= $63

Payback Period
= (Cost of implementation) / (Total Annual Dollars Saved)
= ($63) / ($5,110)
= 0.01 years

\(^{50}\) Solved using 180°F film temperature, Rayleigh number, Grashof number, and Nusselt number.
AR #5.1 IMPLEMENT NIGHT AND WEEKEND SETBACK IN OFFICE AREA
(ENERGY ARC 2.6232.3)

BACKGROUND
The facility’s office area has multiple package units of 4-ton capacity, used for heating and cooling purpose in the office area. The HVAC units are centrally controlled via non-programmable thermostats with no night setback ability (Fig. 5.1.1). The building is set at 71°F throughout the entire year, including weekends.

![Current thermostat installed](image)

Fig. 5.1.1. Current thermostat installed

The office area has non-programmable thermostats causing the space to be conditioned to the same set points during unoccupied office hours as during occupied hours. The disadvantage of using manually controlled thermostats that have no locking covers is that the temperature settings can be easily and frequently changed, which would affect the heating and cooling of office area and probably waste energy. Table 5.1.1 presents the HVAC list for the office area with the cooling and heating capacities of these units.

RECOMMENDED ACTION
We recommend you replace the non-programmable manual thermostats with programmable thermostats in the office areas to implement night and weekend setback. The basic principle of night and weekend setback operation is to reduce the energy requirement needed to heat or cool the space, during unoccupied time, by reducing the temperature set point. During a night setback
operation for example in winter months, after normal working hours, the system operates in an “Unoccupied Mode” and maintains a range of temperature, which is much below comfort zone, but saves a significant amount of energy. Such a program would reduce the thermostat set point by 5°F during the heating season and increases the set point by 5°F during the cooling season during unoccupied hours. ENERGYSTAR® industry data estimates that around 3% of energy is saved per degree Fahrenheit of setback.

Thus, the electric cooling and heating load is reduced by lowering the requirements at night when there is no occupancy in the office area. The setback has to be revoked prior to the office starting time, so that the temperature is raised to the desired level by the time of occupancy. This can be done by using programmable thermostats. This results in considerable energy and cost savings without affecting human comfort. Also, by installing programmable thermostats with locking covers, unauthorized changing of temperature settings is averted, thereby reducing waste and stabilizing energy usage. Fig. 6.1.2. is an example of a 7-day programmable thermostat.

![Image of a 7-day programmable thermostat](image)

**Fig. 5.1.2. Example of a 7-day programmable thermostat**

**ASSUMPTIONS**

- The HVAC load is zero when the temperature is equal to the set point.
- The overall heating efficiency of all HVAC units is estimated as 80%. The efficiencies of each unit can be seen on Table 6.1.1, these efficiency values are obtained from the specifications of the units.
- The cooling efficiencies of the units are obtained from the manufacturer’s website for each model and overall average is calculated as 0.98 kW/ton.
- The HVAC unit’s cooling is designed for a range of temperature up to 95°F. The full load of the HVAC unit is required when cooling at 95°F or more and the load decreases linearly for lower temperatures.
SUMMARY

- Annual dollar savings ........................................................... $480/year
- Natural gas savings .............................................................. 13 MMBtu/year
- Electricity savings ............................................................... 8,687 kWh/year
- Implementation cost ........................................................... $240
- Payback period .................................................................. 0.50 years

DATA

- Natural gas consumption cost ................................................ $2.84/MMBtu
- Electricity consumption cost .................................................. $0.051/kWh
- Cooling efficiency of units ...................................................... 1.26 kW/ton
- Number of Office units .......................................................... 5 units
- Cooling capacity of HVAC units 51 ........................................ 4 tons
- Heating capacity of HVAC units 52 ....................................... 0.54 MMBtu
- Heating efficiency 53 ............................................................. 80%
- Recommended setback for programmable thermostat .......... 5°F
- # of programmable thermostat required 54 ........................... 3
- Number of labor hours required 55 ......................................... 3 hours
- Cost of programmable thermostat 56 ..................................... $54

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51 The data obtained from the specifications of the model through the manufacturer’s website.
52 Ibid
53 Estimated by the audit team
54 Observed by the audit team
55 Estimated by the audit team
56 https://www.supplyhouse.com/Braeburn-5020-7-Day-Programmable-Thermostat-1-Heat-1-Cool-Premier-Series?gclid=Cj0KCQiAr93gBRDSARIsADvHiOra6t5aVf7BgaVzwFafHw9emtV10dJtFpZVYpvy197eVHzkdPd7fwaAl9XEALw_wcB
Table 5.1.1: HVAC list with cooling and heating capacities

<table>
<thead>
<tr>
<th>No.</th>
<th># of units</th>
<th>Model Number</th>
<th>Brand</th>
<th>Area</th>
<th>Type</th>
<th>Cooling Capacity (tons)</th>
<th>Cooling Efficiency (EER)</th>
<th>Efficiency (kW/ton=12/EER)</th>
<th>Total Cooling Capacity (ton)</th>
<th>Heating Capacity (Btuh)</th>
<th>Heating Efficiency (%)</th>
<th>Total Heating Capacity (Btuh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>1</td>
<td>BMA - 125 HBR</td>
<td>ICE</td>
<td>Office Area</td>
<td>Packaged Unit</td>
<td>4</td>
<td>9.5</td>
<td>1.26</td>
<td>20</td>
<td>54,000</td>
<td>80%</td>
<td>54,000</td>
</tr>
</tbody>
</table>

Average: 1.26 20.00 54,000
CALCULATIONS
Sample Calculations from Table 5.1.3
Cooling Energy Savings for Office Area

For 87.5°F ambient temperature and 71°F set point,

**Electricity load**
\[
= \frac{(\text{Ambient Temperature}) - (\text{Temperature set point})}{(\text{Design Temperature}) - (\text{Temperature set point})}
\]
\[
= \frac{(87.5 \text{ F}) - (71 \text{ F})}{(95 \text{ F}) - (71 \text{ F})}
\]
\[
= 0.69
\]

**Amount of electricity consumed**
\[
= (\text{Load factor}) (\text{Total tonnage}) (\text{Cooling efficiency}) (\text{Unoccupied hours})
\]
\[
= (0.69) (4 \text{ tons}) (1.26 \text{ kW/Ton}) (205 \text{ hours/year})
\]
\[
= 713 \text{ kWh/year}
\]

For 87.5°F ambient temperature and 76°F set point,

**Electricity load**
\[
= \frac{(\text{Ambient Temperature}) - (\text{Temperature set point})}{(\text{Design Temperature}) - (\text{Temperature set point})}
\]
\[
= \frac{(87.5 \text{ F}) - (76 \text{ F})}{(95 \text{ F}) - (76 \text{ F})}
\]
\[
= 0.61
\]

**Amount of electricity consumed**
\[
= (\text{Load factor}) (\text{Total Tonnage}) (\text{Cooling Efficiency}) (\text{Unoccupied hours})
\]
\[
= (0.61) (20 \text{ tons}) (1.26 \text{ kW/Ton}) (205 \text{ hours/year})
\]
\[
= 3,151 \text{ kWh/year}
\]

Total electricity consumption for cooling without setback in office (from Table 5.1.3)
\[
= 18,594 \text{ kWh/year}
\]

Total electricity consumption for cooling with setback in office (from Table 5.1.3)
\[
= 9,907 \text{ kWh/year}
\]
Energy savings for cooling - Office
= (Total electricity consumption for cooling without set back in office) – (Total electricity consumption for cooling with setback in office)
= (18,594 kWh/year) – (9,907 kWh/year)
= 8,687 kWh/year

Heating Energy Savings for Office Area

For 57.5°F ambient temperature and 71°F set point,

Heating load
\[
= \frac{(\text{Ambient Temperature}) - (\text{Temperature set point})}{(\text{Design Temperature}) - (\text{Temperature set point})}
\]
\[
= \frac{(57.5 \, \text{F}) - (71 \, \text{F})}{(10 \, \text{F}) - (71 \, \text{F})}
\]
= 0.22

Amount of natural gas consumed for heating
= (Load factor) (Total Heating Capacity/Efficiency) (Unoccupied hours)
= (0.15) (0.054 MMBtu/0.8) (491 hours/year)
= 5 MMBtu/year

For 57.5°F ambient temperature and 66°F set point,

Heating load
\[
= \frac{(\text{Ambient Temperature}) - (\text{Temperature set point})}{(\text{Design Temperature}) - (\text{Temperature set point})}
\]
\[
= \frac{(57.5 \, \text{F}) - (66 \, \text{F})}{(10 \, \text{F}) - (66 \, \text{F})}
\]
= 0.15

Amount of natural gas consumed for heating
= (Load factor) (Total Heating Capacity/Efficiency) (Unoccupied hours)
= (0.15) (0.054 MMBtu/0.8) (491 hours/year)
= 5 MMBtu/year

Total natural gas consumption for heating without setback in office (from table 5.1.1)
= 107 MMBtu/yr
Total natural gas consumption for heating with setback in office (from table 5.1.1)
= 94 MMBtu/yr

Natural gas savings for heating - Office
= (Total natural gas consumption without setback in office) - (Total natural gas consumption with setback in office)
= (107 MMBtu/yr) – (94 MMBtu/year)
= 13 MMBtu/year

Annual dollar savings by implementing night and weekend setback in office area
= (Total electricity savings) (Electricity cost) + (Total natural gas savings) (Natural gas cost)
= (8,687 kWh/year) ($0.051/kWh) + (13 MMBtu/year) ($2.84 /MMBtu)
= $480/year

Implementation cost
= (Number of thermostats) (Cost of programmable thermostat) + [(Labor cost) × (Number of labor hours)]
= (3 units) ($54) + [($26/hour) × (3 hours)]
= $240

Simple Payback
= (Implementation Cost) / (Annual Dollar Savings)
= ($240) / ($480/year)
= 0.50 years

Disclaimer: All product pricing and sourcing information is provided as a courtesy only and is not a quotation or endorsement of any specific brand or supplier. Oklahoma State University encourages you to compare several brands and suppliers before making a purchase decision. Project cost estimates above do not include taxes, shipping, and engineering fees, where applicable.

METHODOLOGY FOR TABLE 5.1.2
Table 5.1.2 uses bin hours for calculating potential energy use and savings for HVAC setback. To calculate unoccupied bin hours, the occupation schedule for office hours of 8 am to 5 pm were considered. This schedule was split between three “bins” that relate annual temperature data per time of day. The three bins are as follows: midnight to 8 am, 8 am to 4 pm, and 4 pm to midnight. Taking the bin hours at different times of day, we get an approximation of the total hours of unoccupied office hours at each range of temperature.
### Table 5.1.2: Weighted annual bin hours

#### Annual Bin Data

<table>
<thead>
<tr>
<th>TDB Bins (F)</th>
<th>Mid Point</th>
<th>24 to 08</th>
<th>08 to 16</th>
<th>16 to 24</th>
<th>Total</th>
<th>Total Occupied Hours</th>
<th>Total Unoccupied Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>8.93%</td>
<td>71.43%</td>
<td>4.46%</td>
<td>9.54%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>105 to 110</td>
<td>107.5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>100 to 105</td>
<td>102.5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>95 to 100</td>
<td>97.5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>90 to 95</td>
<td>92.5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>85 to 90</td>
<td>87.5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>80 to 85</td>
<td>82.5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>75 to 80</td>
<td>77.5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>70 to 75</td>
<td>72.5</td>
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<td>0</td>
<td>0</td>
<td>0</td>
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<td>65 to 70</td>
<td>67.5</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>60 to 65</td>
<td>62.5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>55 to 60</td>
<td>57.5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>50 to 55</td>
<td>52.5</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>45 to 50</td>
<td>47.5</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>40 to 45</td>
<td>42.5</td>
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<td>35 to 40</td>
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<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>30 to 35</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>25 to 30</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>20 to 25</td>
<td>22.5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>15 to 20</td>
<td>17.5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>10 to 15</td>
<td>12.5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5 to 10</td>
<td>7.5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0 to 5</td>
<td>2.5</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>-5 to 0</td>
<td>-2.5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>-10 to -5</td>
<td>-7.5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**Total (Hours):**
- 2,920 hours

---

57 Bin hours for Fort Smith, AR were utilized in this recommendation, the bin hours obtained from Kjelgaard, Michael J., Engineering Weather Data. New York: McGraw-Hill, 2001. Pg. 394.
Table 5.1.3 Annual energy savings from implementing night and weekend setback

<table>
<thead>
<tr>
<th>Assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The office area is occupied for 50 hours per week year round.</td>
</tr>
<tr>
<td>2. On weekends, the office area is unoccupied.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total Cooling Capacity</th>
<th>55 Tons</th>
<th>Total Heating Capacity</th>
<th>32 kW</th>
<th>Conditioned Area (Sq.Ft)</th>
<th>16,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling Efficiency</td>
<td>1.11 kW/ton</td>
<td>Heating Efficiency</td>
<td>0.80 kW/ton</td>
<td>Sq.Ft. per Ton Cooling</td>
<td>291</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>BIN HOUR TABULATION:</th>
<th>Unoccupied Cooling Energy Usage</th>
<th>5 F Higher setpoint during Unoccupied hours</th>
<th>Unoccupied Heating Energy Usage</th>
<th>5 F Lower setpoint during Unoccupied hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bin</td>
<td>Bin Hours*</td>
<td>Load kWh</td>
<td>kWh</td>
<td>Load kWh</td>
</tr>
<tr>
<td>105 to 110</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>100 to 105</td>
<td>0.04</td>
<td>2.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>95 to 100</td>
<td>0.13</td>
<td>5.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>90 to 95</td>
<td>0.21</td>
<td>8.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>85 to 90</td>
<td>0.29</td>
<td>11.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>80 to 85</td>
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<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>75 to 80</td>
<td>0.54</td>
<td>21.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>70 to 75</td>
<td>0.63</td>
<td>25.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>65 to 70</td>
<td>0.71</td>
<td>28.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>60 to 65</td>
<td>0.79</td>
<td>31.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>55 to 60</td>
<td>0.88</td>
<td>34.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>50 to 55</td>
<td>0.96</td>
<td>38.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>45 to 50</td>
<td>1.00</td>
<td>41.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>40 to 45</td>
<td>1.06</td>
<td>44.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>35 to 40</td>
<td>1.12</td>
<td>47.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>30 to 35</td>
<td>1.19</td>
<td>50.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>25 to 30</td>
<td>1.26</td>
<td>53.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>20 to 25</td>
<td>1.33</td>
<td>56.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>15 to 20</td>
<td>1.40</td>
<td>59.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>10 to 15</td>
<td>1.47</td>
<td>62.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>5 to 10</td>
<td>1.54</td>
<td>65.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>0 to 5</td>
<td>1.61</td>
<td>68.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>-5 to 0</td>
<td>1.68</td>
<td>71.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>-10 to -5</td>
<td>1.75</td>
<td>74.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>TOTAL</td>
<td>2,477</td>
<td>6,283</td>
<td>8,760</td>
<td>47,846</td>
</tr>
</tbody>
</table>

Cooling Savings 14,455 kwh
Heating Savings 8,707 kwh

58 Bin hours for Ft Smith, AR were utilized here; the bin hours obtained from Kjelgaard, M., *Engineering Weather Data*. NY: McGraw-Hill, 2001. Pg. 394.
AR #6.1 INSTALL SMALLER BOILER
(ENERGY ARC 2.1223.1)

BACKGROUND
The facility has two steam boilers namely Holman boiler of size 200 HP Holman boiler and 350 HP Cyclotherm boiler. From the plant visit, we found out that only the Holman boiler of size 200 HP was being operated and 350 HP boiler was as a backup. The firing rate of the boiler was very low at 30%-50%. The boiler was mainly used for space and process heating. After our meeting with plant management team, we found out that the steam boiler used is larger in size than what is currently needed. The bigger boiler was still there as a backup. The audit team conducted a combustion analysis on the stack of the steam boiler which was in operation and found that the efficiency of the boiler was 80.4%. The steam pressure requirement is 60-100 psi.

RECOMMENDED ACTION
For operating the boiler at high firing rate, we recommend the facility to install a brand-new small boiler of 60 HP. By installing the new boiler, the facility would achieve two types of savings. The first one is the efficiency of the boiler would increase up to 86%. Another saving would be savings based on decreasing the size of the boiler. We recommend the facility, to use the current in use boiler (Holman 200 HP) as a backup source which will be used during winter where the demand would be high. Furthermore, we recommend the client to sell the 350 HP boiler and acquire some salvage value.59

![Combustion Analysis result for the 200 HP Holman boiler](image)

Fig 6.1.1: Combustion Analysis result for the 200 HP Holman boiler

59 For the calculation, we will be considering the salvage of this current boiler and this will be additional benefit for the facility. This is because it comes under the same boiler family.
The new small boiler would be operated at high firing rate of 90%. By applying this, the overall maintenance cost will also be saved. This boiler will provide steam pressure of 100 psi. Some of the boilers recommended to look into are:

- Cleaver-Brooks CB-700-60\(^60\) and
- York Shipley YS5-60-150ST\(^61\)
- Clear fire H series\(^62\)

The above boilers are 60 HP size with high efficiency and high firing rate required for the facility.

**SUMMARY**

- Total dollar savings: ................................................................. $18,744
- Energy savings: ................................................................. 6,600 MMBtu
- Implementation cost: ................................................................. $ 35,736
- Payback period: ................................................................. 1.9 years

**DATA**

- Annual operating hours\(^63\) .................................................................4,160 hrs/yr
- Boiler rating for current steam boiler\(^64\) ...........................................200 HP (6.69 MMBtu)
- Boiler rating for proposed steam boiler\(^65\) ...........................................60 HP (2.09 MMBtu)
- Estimated current boiler load factor\(^66\) ...........................................50 %
- Estimated proposed boiler load factor\(^67\) ...........................................90 %
- Natural gas cost: ................................................................. $2.84/MMBtu
- Cost of new boiler\(^68\) .................................................................$44,000
- Installation cost for the new boiler\(^69\) ...........................................$8,800
- Efficiency of the current boiler\(^70\) ...........................................80.4%
- Efficiency of the proposed boiler\(^71\) ...........................................86%
- Salvage Value of the current 350 HP Cyclotherm boiler\(^72\) ............$1.5/lb of boiler
- Weight of the 350 HP Cyclotherm boiler\(^73\) .....................................12,000 lb
- Hourly cost of the labor\(^74\) ..........................................................$26/hr
- Hours required to remove the 350 HP boiler\(^75\) ................................12 hrs

---

\(^60\) [https://www.powermechanical.com/60-hp-new-used-boilers-for-sale.html](https://www.powermechanical.com/60-hp-new-used-boilers-for-sale.html)

\(^61\) Ibid


\(^63\) Data collected from site visit

\(^64\) Data collected during site visit

\(^65\) Data collected during site visit

\(^66\) Asked Boiler Operator in the site


\(^68\) [https://www.powermechanical.com/60-hp-new-used-boilers-for-sale.html](https://www.powermechanical.com/60-hp-new-used-boilers-for-sale.html)

\(^69\) Assumed 20% of the equipment cost

\(^70\) Data estimated from figure 6.6.1


\(^72\) Estimate provided by Mr. Stafford of Cyclotherm. Contact: cstafford@cyclotherm.com

\(^73\) Ibid

\(^74\) Data provided by the client
• Number of workers required to remove the boiler\(^{76}\) ....................3

**CALCULATIONS**

**Energy consumption of the current boiler**
\[
= (\text{Size of the boiler}) \times (\text{Loading factor}) \times (\text{Annual operating hours})
\]
\[
= (6.69 \text{ MMBtu}) \times (0.5) \times (4160 \text{ hours})
\]
\[
= 13,915 \text{ MMBtu}
\]

**Energy consumption of the proposed boiler**
\[
= (\text{Size of the boiler}) \times (\text{Loading factor}) \times (\text{Annual operating hours})
\]
\[
= (2.09 \text{ MMBtu}) \times (0.9) \times (4160 \text{ hours})
\]
\[
= 7,825 \text{ MMBtu/yr}
\]

**Energy savings related to decreasing size of the boiler**
\[
= \text{Energy consumption of the current boiler} - \text{Energy consumption of the proposed boiler}
\]
\[
= 13,915 \text{ MMBtu} - 7,825 \text{ MMBtu}
\]
\[
= 6,090 \text{ MMBtu/yr}
\]

**Energy savings by increased efficiency of the boiler**
\[
= \left[ \frac{(\text{Boiler capacity for new boiler}) \times (\text{load factor}) \times ((\text{new efficiency-old efficiency})/\text{new efficiency})}{\text{(operating hours)}} \right]
\]
\[
= \left[ \frac{(2.09 \text{ MMBtu}) \times (0.9) \times (0.86-0.804)/0.86)}{4,160 \text{ hrs/yr}} \right]
\]
\[
= 510 \text{ MMBtu/yr}
\]

**Total Annual Energy Savings**
\[
= \text{Energy Savings related to decreasing size of boiler} + \text{Energy savings by increased efficiency}
\]
\[
= 6,090 \text{ MMBtu/yr} + 510 \text{ MMBtu/yr}
\]
\[
= 6,600 \text{ MMBtu/yr}
\]

**Annual Cost Savings**
\[
= (\text{Annual Natural gas savings}) \times (\text{Gas cost})
\]
\[
= (6,600 \text{ MMBtu/yr}) \times ($2.84/\text{MMBtu})
\]
\[
= $18,744/\text{yr}
\]

**Salvage Value of the 350 HP Cyclotherm boiler**
\[
= (\text{Selling price of the boiler}) - (\text{Cost of removing the boiler})
\]
\[
= [(\text{Cost per lb of boiler}) \times (\text{Weight of boiler})] - [(\text{Number of employee required}) \times (\text{Number of working hours to remove boiler}) \times (\text{Hourly charge to remove boiler})]
\]
\[
= [(1.5$/\text{lb}) \times (12,000 \text{ lb})] - [(3) \times (12 \text{ hr}) \times ($26/hr)]
\]
\[
= $17,064
\]

\(^{75}\) Data estimated by Audit team
\(^{76}\) Data estimated by audit team
**Implementation Cost**\(^{77}\)  
= (Cost of new boiler) (Number of boiler) + (Installation cost of new boiler) – (Salvage Value of 350 HP Cyclotherm boiler)  
= ($44,000)\((1) + $8,800 - $17,064  
= $35,736

**Payback Period**  
= (Implementation cost)/ (Dollar savings)  
= ($35,736) / ($18,744/yr)  
= 1.9 years

---

\(^{77}\) Disclaimer: We have just used one of the cost among the above listed cost for the calculations. We do not promote any type company. Installation cost is an estimation which would include transportation as well as installing cost which is assumed 20% of the price of the equipment. Furthermore this AR is just a basic concept of how much the plant is going to save. We would recommend the facility to research more on this topic and choose the company of their liking.
AR #7.1 OPTIMIZE THE NUMBER OF FORKLIFT TRUCKS IN OPERATION
(ENERGY ARC 2.8227.4)

BACKGROUND
The facility currently has 24 fork-trucks for their storage and retrieval operations throughout the plant. Out of 24 fork-truck, 5 are powered by propane gas and the remaining 19 fork-trucks are powered by electric battery. The average charging time for each battery is 9 hours.

Fig.7.1.1 Forklift truck and charging port display.

RECOMMENDED ACTION
In the present scenario where the facility has 24 fork-trucks for their storage and retrieval requirements of material handling, the utilization rate of each for-truck is 53.3%. The fork-trucks of class I can be used optimally in the range of 60% - 70% utilization rate. For the recommendation, we suggest using 20 fork-trucks by removing 4 of the electric fork-truck from the operation to optimize the utilization of fork-trucks. For 20 fork-truck in operation, the utilization rate of each fork-truck is 64% which is in the optimal range of use.

SUMMARY
- Annual dollar savings ..........................................................$1,628/year
- Annual electricity savings......................................................11,646 kWh/year
- Annual peak demand savings...............................................89.76 kW
- Implementation cost...........................................................None

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OKXXXX
• Payback period.........................................................Immediate

DATA
• Electricity consumption cost\textsuperscript{78} ............................................$0.051/kWh
• Electricity demand charge\textsuperscript{79} .............................................$11.52/kW
• Number of fork-trucks currently in operation\textsuperscript{80} ............24
• Charging time of battery\textsuperscript{81} ................................................9 hours
• Finish Rate of Battery\textsuperscript{82} ..................................................39 Amps
• Nominal Battery Voltage\textsuperscript{83} ...........................................48 Volts
• Average Storage or Retrieval request for each forklift\textsuperscript{84} .8 / hour
• Total Storage or Retrieval request ..............................................24 forklift*8
  = 192 hours
• Average Service time\textsuperscript{85} .................................................4 min
• Average Service rate ...........................................................1 / 4 min

CALCULATIONS

Utilization rate of forklift at present
= (Storage or Retrieval request) / (# of forklifts) * (service rate)
= (3.2) / (24) *(0.25)
= 0.53
= 53%

Optimal Number of forklifts
= (Storage or Retrieval request) / (Optimal Utilization rate) (service rate)
= 3.2 / (0.65) (0.25)
= 20

Utilization rate of forklift for 20 forklift in service
= (Storage or Retrieval request) / (# of forklifts) * (service rate)
= (3.32) / (20) *(0.25)
= 0.64

kW Demand required per battery charge

\textsuperscript{78} Obtained from utility bill analysis
\textsuperscript{79} Ibid.
\textsuperscript{80} Reported by facility staff
\textsuperscript{81} Ibid.
\textsuperscript{82} Observed by audit team.
\textsuperscript{83} Ibid.
\textsuperscript{84} Reported by facility staff.
\textsuperscript{85} Ibid.
\[
\text{Annual Electricity kWh savings for 20 fork-trucks in service} = \left(\text{kW of one time charging of battery}\right) \times \left(\text{# hours required to charge battery}\right) \times \left(\text{Reduced number of frequencies of charging in a day}\right) \times \left(\text{# of operating days in a year}\right)
\]
\[
= (1.87) \times (9) \times (4) \times (173)
\]
\[
= 11,646 \text{ kWh}
\]

**Annual kWh Dollar savings**

\[
= (\text{Total Annual Electricity Savings}) \times (\text{Electricity cost})
\]
\[
= (47,532.096 \text{ kWh}) \times ($0.051 / \text{kWh})
\]
\[
= $594
\]

**Peak Demand Reduction for 20 fork-trucks in service per year**

\[
= (\text{kW Demand per Battery}) \times (\text{number of fork-trucks removed from service}) \times (\text{number of months per year})
\]
\[
= (1.87 \text{ kW/ fork-truck}) \times (4 \text{ fork-trucks}) \times (12 \text{ months})
\]
\[
= 89.76 \text{ kW}
\]

**Annual Demand Savings**

\[
= (\text{Peak Demand Reduction per month}) \times (\text{12 months/year}) \times (\text{Demand charge})
\]
\[
= (7.48 \text{ kW}) \times (12 \text{ months/year}) \times ($11.52/\text{kW})
\]
\[
= $1,034
\]

**Annual Dollar savings**

\[
= (\text{Annual kWh Dollar savings}) + (\text{Annual Demand Savings})
\]
\[
= ($594) + ($1,034)
\]
\[
= $1,628 / \text{year}
\]

**Implementation Cost**

\[
= \text{None}
\]

**Simple Payback**

\[
= \text{Immediate}
\]