Chapter 12

Process Energy Management

12.0 INTRODUCTION

In many facilities, energy management is simply a matter of managing the energy required for lighting and space conditioning. In many others, however, energy management is much more complex and involves large motors and controls, industrial insulation, complex combustion monitoring, unique steam distribution problems, significant amounts of waste heat, etc. Typical facilities offering large energy management opportunities include industrial facilities, large office and commercial operations, and government institutions such as schools, hospitals and prisons. Such facilities generally have specialized industrial, commercial or institutional processes that incorporate many of the concepts covered in other chapters. These processes require thorough analytical evaluations to determine the appropriate energy-saving measures. This chapter provides some examples.

The energy manager must be careful in process energy management. Processes can be quite complex, so a full understanding of the entire process is necessary. Examining only one area of a process and making energy use changes to that part may have adverse effects in another area. For example, small changes in heat treatment temperatures or atmosphere can sometimes dramatically decrease the product quality or subsequent workability.

In this chapter we first present a suggested procedure for process energy improvement. Then, motors and controls are discussed since they form an integral part of most processes. Next, some sample case studies of process energy management opportunities are provided. Finally, we outline some common process activities where better energy management can be practiced. Air compressors are also discussed.
12.1 STEPS FOR PROCESS IMPROVEMENT

Readers who have studied work simplification and improvement may remember the suggested order of changes as (1) eliminate; (2) combine; (3) change equipment, person, place, or sequence; and (4) improve [1].

The same order of change is appropriate for process energy management, but as mentioned earlier, the analyst must understand the entire system and the cascading impacts that changes might effect. In terms of energy management, examples of the preceding changes include the following:

- **Eliminate.** Does that cooling water really need to be there? Sometimes process cooling water is not really necessary; eliminating it saves pumping and chilling costs. Is the paint oven really necessary? Some newer paints will air dry quite well, and paint oven costs can be substantial.

- **Combine.** Machining operations can often be combined with jig and fixture modifications or changes in equipment. This saves the energy used by the additional machines; it also reduces material handling and may save process storage energy. Sometimes combining processes also saves the energy necessary to bring the material back to a required workability.

- **Change equipment, person, place, or sequence.** Equipment changes can offer substantial energy savings as the newer equipment may be more energy efficient. For example, new electric welders are considerably more energy efficient than older ones. Changing persons, place, or sequences can offer energy savings as the person may be more skillful, the place more appropriate, and the sequence better in terms of energy consumption. For example, bringing rework back to the person with the skill and to the place with the correct equipment can save energy.

- **Improve.** Most energy management work today involves improvement in how energy is used in the process because the capital expenditure required is often minimized. Examples include reducing excess air for combustion to a minimum, reducing temperatures to the minimum required (don’t forget chilling—maybe the freezer temperature can be increased a few degrees), and removing excess lighting. Im-

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proving does sometimes require large amounts of capital. For example, insulation improvements can be expensive, but energy savings can be large, and there can be improved product quality.

12.2 MOTORS AND ADJUSTABLE SPEED DRIVES

Motor energy use represents well over half of all the electric energy consumed by industrial, commercial and institutional facilities. Motors are found on almost every piece of equipment used to perform a process in manufacturing, mining and agriculture. Even pieces of equipment that perform special functions often have motors as their principal part—for example, chillers and air compressors.

Because of the widespread application of electric motors in almost every facility, they are excellent candidates for improvements to their efficiencies and improvements in their utilization in machines and processes. Just a small improvement in electric motor efficiency can produce significant savings in the energy cost of operating a piece of equipment. The annual cost of operating a motor can often be five to ten times the original purchase price of the motor.

Many motor applications require variable speeds, or should use variable speeds to match the actual loads, and thus the area of motor controls is also very important. Adjustable speed drives—or variable speed drives—are motor control systems that reduce the energy input to a motor when it is not fully loaded. These ASDs or VSDs can produce substantial savings in the operational costs of motors, and can often improve the operation of the system that previously used a motor without a speed control.

12.2.1 High Efficiency Motors

Electric motors account for about three-quarters of all the electric energy used by industry (Figure 1.5, Chapter One), and almost half of all electric use by commercial facilities. Energy efficient motors are now readily available that are two to eight percent more efficient than the standard motors they would replace. Table 12-1 provides data on the efficiencies and cost premiums for motors in size ranges from 0.75 horsepower to 250 horsepower [2]. Since typical motors last over twenty years, using high efficiency motors offers business and industry substantial energy and dollar savings.
Table 12-1. Motor data.

<table>
<thead>
<tr>
<th>hp Rating</th>
<th>Standard Efficiency</th>
<th>High Efficiency</th>
<th>Premium ($)</th>
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<tbody>
<tr>
<td>.75</td>
<td>0.740</td>
<td>0.817</td>
<td>35</td>
</tr>
<tr>
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<tr>
<td>2</td>
<td>0.791</td>
<td>0.864</td>
<td>56</td>
</tr>
<tr>
<td>3</td>
<td>0.814</td>
<td>0.888</td>
<td>73</td>
</tr>
<tr>
<td>5</td>
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<td>0.890</td>
<td>69</td>
</tr>
<tr>
<td>7.5</td>
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<td>0.902</td>
<td>97</td>
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<td>10</td>
<td>0.864</td>
<td>0.910</td>
<td>111</td>
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<tr>
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<td>0.875</td>
<td>0.916</td>
<td>149</td>
</tr>
<tr>
<td>20</td>
<td>0.886</td>
<td>0.923</td>
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<td>0.897</td>
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<tr>
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<td>0.940</td>
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<tr>
<td>125</td>
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<td>0.952</td>
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<tr>
<td>250</td>
<td>0.943</td>
<td>0.956</td>
<td>2,159</td>
</tr>
</tbody>
</table>

Motor efficiency is a measure of the effectiveness with which electrical energy is converted to mechanical energy. Motor losses occur in five major areas: core losses, stator losses, rotor losses, stray load losses, and windage and friction losses. High efficiency motors are designed and manufactured to reduce these losses. In addition to having lower losses, high efficiency motors also have higher power factors during operation. Cost premiums for high efficiency motors range from 10% to 30%, but since a motor may use 75 times its initial cost in electric energy over its lifetime, the savings potential is great [3]. Many motors in commercial facilities, industries and institutions run 6000 to 8000 hours per year, so very cost-effective paybacks can be achieved.

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Example 12-1: Ace Industries has a 50-hp air compressor that operates at full-load, all day for 365 days per year. If the motor for the air compressor cost $1400, the motor efficiency is 90%, and electricity costs $7.00/kW/month and $0.05/kWh, how much does it cost to operate the air compressor for one year? How much money will be spent to operate the air compressor over a ten-year period?

Solution: If a motor were 100% efficient, there would be an electric load of 0.746 kW/hp, or 37.3 kW. Since the motor is only 90% efficient, its electric load is:

\[ \text{Electric load} = \frac{(50 \text{ hp}) \times (0.746 \text{ kW/hp})}{0.9} = 41.44 \text{ kW} \]

The annual demand charge is then:

\[ \text{Demand charge} = (41.44 \text{ kW}) \times \frac{($7.00/\text{kW/month}) \times (12 \text{ months/year})}{(0.9)} = $3481/\text{yr} \]

The annual energy charge is:

\[ \text{Energy charge} = (41.44 \text{ kW}) \times (8760 \text{ h/yr}) \times ($0.05/\text{kWh}) = $18,151/\text{yr} \]

The total electric cost of operating the motor is then:

\[ \text{Total cost} = $3841 + $18,151 = $21,992/\text{yr} \]

Since the purchase cost for the motor was $1400, the annual electric cost for operating the motor/air compressor is over fifteen times the initial purchase price.

If the air compressor operates for ten years, the total operating cost will be $21,992 \times 10 = $219,920. This is over 150 times the initial purchase price of the motor.

As this example shows, the original purchase cost of a motor can be a small part of the life-cycle cost. Thus, it is important to consider other factors besides the initial cost when buying a new motor for a piece of equipment.
Example 12-2: ACE Industries has been experiencing a period of rapid growth in the success of their products, and they plan to expand their production capacity by building a second plant nearby. They determine that they need another 50-hp air compressor which will also run continuously at full load. They can purchase either the Standard or the Deluxe Model air compressor with the difference being that the Deluxe Model has a high efficiency motor. The motor efficiency for the Standard Model is 91.5%, and for the Deluxe Model it is 93.8%. The additional cost for the Deluxe Model is $470. Is this a good investment for ACE Industries?

ACE Industries also wants to know what kind of “cushion” they have on this decision, since their forecast for new business could be too optimistic. If the new air compressor is only run for two shifts a day, for a total of 5000 hours per year, is the additional investment still worthwhile?

Solution: The electric load for each model of the motor is found, and the difference will be used to compute the savings. The reduction in electric demand is:

\[
\begin{align*}
\text{Standard Model demand} & = (50 \text{ hp}) \times (0.746 \text{ kW/hp}) / (0.915) \\
& = 40.77 \text{ kW} \\
\text{Deluxe Model demand} & = (50 \text{ hp}) \times (0.746 \text{ hp}) / (0.938) \\
& = 39.77 \text{ kW} \\
\text{Demand savings} & = 1 \text{ kW}
\end{align*}
\]

\[
\begin{align*}
\text{Annual demand cost savings} & = (1 \text{ kW}) \times (7.00 / \text{kW month}) \\
& \times (12 \text{ months/yr}) \\
& = 84 / \text{yr}
\end{align*}
\]

\[
\begin{align*}
\text{Annual energy cost savings} & = (1 \text{ kW}) \times (8760 \text{ h/yr}) \times (0.05 / \text{kWh}) \\
& = 438 / \text{yr}
\end{align*}
\]

Total electric cost savings = $522/yr

We can now compute several economic decision criteria to evaluate how good an investment the additional $470 would be. Using equation 4-1, and the method of section 4.8.3 from Chapter Four gives:
Simple Payback Period = $470 / $522/yr = 0.9 years

If the motor has a lifetime of ten years running full-time, we can find the ROR as the solution to:

$$522 \times (P/A, i, 10) = 470$$

ROR = 111%

If ACE Industries has an investment rate of 12%, we can find the Benefit-Cost Ratio as:

$$B/C = \frac{522 \times (P/A, 12\%, 10)}{470} = 1.11 \times 5.6502 = 6.27$$

By any one of these three economic evaluation measures, the decision to buy the Deluxe Model with the high efficiency motor is an excellent investment if the motor runs 8760 hours each year. To see how sensitive this result is to the use of the motor, we need to recompute the savings if the motor is only used 5000 hours each year.

The demand savings is the same. The new energy cost savings is:

Energy cost savings = (1 kW) \times (5000 \text{ hours/yr}) \times ($0.05/\text{kWh})

= $250/\text{year}

Total cost savings = $84 + $250 = $334

The new values of the economic measures are:

SPP = 1.41 years

ROR = 70.7%

B/C = 4.02

These are still excellent values for the three economic decision measures. Most companies would still find the investment in the more expensive motor highly attractive, even with the reduced hours of operation of the air compressor.
A number of computer programs have been written to help perform the economic analysis involved in motor selection. One of the best is the MotorMaster program written and made available by the Washington State Energy Office [4]. This program has an extensive data base on motor prices and efficiencies, and is updated twice a year.

12.2.2 Motor Load Factors

The full load horsepower output rating of a motor is stamped on the motor’s nameplate. However, just because we find a motor that is stamped 20-hp does not mean that the motor is running at full load - which is 20-hp. A motor is a load driven machine, and will supply only that amount of power needed by the load. For example, a 20-hp motor may be driving a fan that needs only 15-hp. The load on the motor can be expressed as a percent of full load, and this is called the load factor for the motor. In this case, the load factor would be 15/20 or 75%.

From the authors’ energy audit experience, few motors run at anywhere near full load. A common assumption made by many energy auditors and analysts is that motor load factors are around 80%. This value is rarely seen in motors other than those specifically sized for known loads in heating, ventilating and air conditioning systems for buildings. In most other applications, motors experience variable loads that average well below 80%. One energy analyst presented data to show that 75% of all motors in his experience have load factors less than 60% [9].

One of the authors of this book has performed over 100 audits of medium-sized manufacturing companies, and the average motor load factors have ranged from about 30-40%. Individual motors, such as found on a wall ventilating fan, may well have load factors of 80%. However, many other pieces of equipment such as some air compressors, conveyors, pumps, dust collector fans, saws, drills and punches have extremely variable load factors which are generally much less than 50%. Pumps and fans with variable loads are usually ideal candidates for use of adjustable speed drives to reduce the energy input when the motor load is low.

To account for the fact that motors typically operate with load factors less than one, the basic motor equation for computing the electrical load must be modified to include a load factor term.

\[
\text{kW} = \frac{\text{hp} \times (0.746 \text{ kW}) \times (\text{LF})}{\text{Efficiency \text{ hp}}}
\]

For example, if we have a 100-hp motor that is 95% efficient and is running at 60% load, its electrical power consumption is:
\[ kW = \frac{100 \text{ hp} \times 0.746 \text{ kW} \times 0.6}{0.95 \text{ hp}} \]
\[ = 47.1 \text{ kW} \]

If the motor had been operating at full load, its power consumption would have been 78.5 kW.

**12.2.3 Rewinding electric motors**

There is at least one other important factor in motor replacement selection, and that is the potential for rewinding a motor that has failed. There are three options available for a facility that has just experienced a motor failure. One, they can buy a standard efficiency motor to replace the failed one. Two, they can buy a high efficiency replacement. Three, they can send the failed motor out to be repaired, and potentially rewound. Example 12-2 illustrated how cost-effective it can be to buy a more expensive, high-efficiency motor for a piece of equipment that is used heavily.

The cost of rewinding a motor is often substantially less than the cost of purchasing a new motor—whether it is a standard-efficiency model or a high-efficiency model. However, it is fairly common for motors to be damaged during the rewinding process, and to suffer losses in efficiency of 1-2% [5]. Example 12-2 showed the economic impact of a 2.3 percentage point difference in motor efficiency. Often, a 1 percentage point loss in efficiency will result in the cost of the additional electricity being greater than the total cost of rewinding. Thus it is important to consider this factor when replacing a motor. Not all rewinding operations damage motors, but the loss of efficiency is quite common.

**12.2.4 Motor drives and controls**

In addition to improving the efficiency of the motor itself, there are many other opportunities for energy savings in the complete motor system. One opportunity is in the use of solid-state, electronic controls that can provide soft-starts, speed control and power factor correction.

For large motors that have variable loads, the addition of electronic speed controllers—or adjustable speed drives (ASDs)—can be very cost effective. ASDs are electronic devices that vary the speed of a motor to match that of the load being put on the motor. The size of a motor is usually based on maximum load, even though normal design conditions seldom require this full load size. An ASD will reduce the speed of the motor by adjusting the frequency, voltage, or current of the motor input so that the motor performance exactly matches the present load. ASDs are also called Variable Speed Drives (VSDs) or Variable Frequency Drives (VFDs).
Fans and pumps are typical applications where ASDs can improve motor performance. The cube law for fans discussed in Chapter Six (Equation 6-14) showed the potential for substantial energy savings when the speed of a fan is reduced. Since the energy used in many fan and pump applications is proportional to the cube of the flow rate, then small reductions in the required flow rates translate to large savings in energy needed. In addition, many motors are purposefully over-sized to have a safety factor in handling the required load. This over-sizing is not beneficial to energy efficiency, and results in many motors running at conditions that unnecessarily waste energy. Properly sizing motors is probably one of the most cost-effective EMOs that a facility could implement.

ASD costs vary with the size of the motor. Equipment costs range from $150 to $450 per horsepower for ASDs smaller than 50 horsepower, and $100 to $150 per horsepower for larger units [6]. General estimates are that ASDs can save an average of 20-30 percent of the energy used for a typical motor.

Example 12-3: In one industrial application, three cyclone fans used for ventilating stack gases were replaced with one larger fan motor having an ASD. The cost of the new fan, motor, and installation of new ductwork was $18,250. The cost of the ASD was $20,000. The electrical consumption from the new system dropped 500,000 kWh/yr from that of the old fan system. If the facility paid $0.061/kWh, determine the cost-effectiveness of this EMO.

Solution: The electrical cost savings from the new system is found as:

\[
\text{Annual savings} = (500,000 \text{ kWh/yr}) \times (0.061/\text{kWh}) \\
= 30,500
\]

The total cost of implementation is the sum of the costs for the new fan, motor, ductwork, installation and the ASD:

\[
\text{Total implementation cost} = 18,250 + 20,000 \\
= 38,250
\]

The SPP for this EMO is found using Equation 4-1 from Chapter Four:

\[
\text{SPP} = \frac{38,250}{30,500/\text{yr}} = 1.25 \text{ years}
\]
If the new system had an expected lifetime of 15 years, the ROR can be found as the solution to:

\[
30,500 \left( \frac{P}{A, i, 15} \right) = 38,250
\]

\[
\text{ROR} = 79.7\%
\]

These two measures demonstrate that this was an excellent EMO investment.

---

### 12.2.5 Other factors in motor system efficiency

In addition to the efficiency of the motor itself and the use of adjustable speed drives, there are still several other factors that affect the overall motor system efficiency. One of these factors is the mechanism for the transmission of power from the motor to the load. In particular, care should be taken to insure that efficient pulleys, drives, belts and gears are used to couple the motor to the load.

**Belts.** Many motors are coupled to their loads with belt drives. There are several types of belts, including V-belts, cogged V-belts, and synchronous belts. Standard V-belts are the most common type of drive belt, and have transmission losses that occur because of flexing and slippage of the belt. The cogged V-belts and the synchronous belts are more efficient because they do not allow the same amount of flexing and slippage as the standard V-belts. Motor system performance can be improved by 2-4% with the use of these more efficient belts.

**Lubrication.** Motor lubrication is also a factor in motor efficiency. There are synthetic lubricants available that reduce the friction losses in motor-driven equipment. Savings of 1-2% are common, and much larger savings are possible for some equipment. Often, however, manufacturers recommend that these synthetic lubricants be used only in new pieces of equipment, so that there is no contamination of the synthetic lubricant.

**Maintenance.** Motor maintenance is also a factor. This area was discussed in some detail in Chapter Ten on Maintenance. The operating temperature of a motor should be checked periodically, as well as its mechanical and electrical condition. Each motor in a facility should be inspected periodically to determine the condition of its bearings and its pulley and belt alignment if it uses a belt drive. The bearing condition of a motor can be checked with an industrial stethoscope. In this procedure, the stethoscope
is used to measure the noise at both ends of a motor that uses chains or belts to drive equipment. In a normal motor, the active end will read 2-3 db louder than the fixed end. If there is no difference or if the fixed end is louder than the active end, the bearings at the fixed end are worn; if the active end is 4-6 db louder than the fixed end, the bearings are badly worn; if the active end is 7-8 db louder, the bearing housing is turned inside the motor; and if the active end is 9 db or more louder than the fixed end, the motor should be replaced immediately. This procedure, developed at Safeway Stores by Mr. Harold Tornberg, has proved practical in industry.

12.2.6 Utility rebates for motors and drives

A general discussion of electrical utility company rebates and incentives was given in Chapter Three. However, since most utilities offer rebates and incentives for electric motor system improvements, it is worth mentioning again. There are generally two forms that the rebates and incentives take for motor systems: an incentive based on kW savings, or an incentive based on the horsepower of the motor involved. The level of the rebate or incentive for a peak load reduction due to a motor system improvement depends greatly on the individual utility. If the utility is working hard to limit its peak demand so that it will not have to add new power generation capability, the incentives may be quite large. Incentives of a few hundred dollars per kW of motor load reduced are quite common.

The incentive may also be related to the horsepower of the motor replaced or the horsepower of the motor that an adjustable speed drive was added onto. For a high efficiency motor replacement, the utility usually has a list of minimum efficiencies that qualify for rebates. If a customer replaces a motor with one that meets the minimum efficiency level, then the customer is automatically eligible for the rebate. This may be in the range of $6 – $15 per hp. Rebates for ASDs generally would qualify for levels of $100 to $300 per hp.

Example 12-4: In Example 12-2, ACE Industries would receive a $6/hp rebate from its electric utility if the company purchases the high efficiency 50-hp motor for the air compressor. How does this rebate influence the cost effectiveness of the purchase decision for ACE Industries?

Solution: The rebate of $6/hp reduces the cost of the motor by:

\[
\text{Cost reduction} = (6/\text{hp}) \times (50 \text{ hp}) = 300
\]
Thus, the cost to ACE Industries is now only:

\[
\text{Motor cost} = \text{price differential—utility rebate} \\
= $470 - $300 \\
= $170
\]

The new SPP for operating the motor 8760 hours is:

\[
\text{SPP} = \frac{$170}{\$522/\text{yr}} = 0.33 \text{ years}
\]

For 5000 hours of operation, the SPP is:

\[
\text{SPP} = \frac{$170}{\$334/\text{yr}} = 0.51 \text{ years}
\]

The utility rebate significantly improves the attractiveness of this EMO. A simple payback period of four to six months for this motor purchase would be considered a highly cost-effective investment by most companies.

12.3 AIR COMPRESSORS

Many facilities use substantial quantities of compressed air to power machinery, process operations and control systems. This becomes a large energy cost, and the compressed air system should be designed and operated so that it is as energy efficient as possible. Selecting the best types and sizes of air compressor units is important in achieving this goal. A high efficiency motor should be specified for any air compressor, unless it is one that will only be used for short periods of time.

12.3.1 Types of air compressors

There are two major classifications of air compressors: positive displacement compressors and dynamic compressors [7,8]. A reciprocating compressor is an example of a positive displacement compressor. In this type of compressor, successive volumes of air are trapped in a closed space, and the pressure is increased as the piston moves toward the top of the cylinder and reduces the size of the closed space. Reciprocating air compressors have good energy efficiency characteristics at both part-load and full-load. It is more difficult to capture the waste heat from a reciprocating compressor than from a rotary screw or centrifugal air compressor
since the pistons in the reciprocating unit are exposed to the open air around the machine.

The rotary screw compressor is another example of a positive displacement air compressor. In this unit, air enters the inlet and is trapped between mating male and female rotors and compressed to the required discharge pressure. Rotary screw compressors have excellent efficiencies at full-load conditions, and average efficiencies at part-load conditions. Heat recovery is easiest from the rotary screw compressors since the entire compressor section is enclosed.

The centrifugal air compressor is an example of a dynamic compressor, where air is compressed by the dynamic action of rotating impellers or vanes imparting velocity and pressure to the air. Almost all large air compressors (greater than 3000 CFM and 50-psig) are centrifugal compressors. The efficiency of these centrifugal air compressors is lower than either the reciprocating or rotary screw models, so smaller air compressors are almost never the centrifugal type. Heat recovery is also somewhat difficult from these compressors.

12.3.2 Designing the compressed air system

Most facilities have a number of air compressors that can be operated in combinations to satisfy the demand for compressed air at any time. Large units are needed for periods of high demand, and smaller units are needed to supply reduced amounts of compressed air during weekends or periods of slack production. A centralized air compressor facility together with a common-header and a computer control system for managing the load should provide efficient, cost-effective operation for most plants. In some cases there are large distances between parts of a facility that need compressed air. In those cases it might be more efficient to provide a small compressor at each location to minimize the energy lost in transmitting the compressed air through long pipelines.

Air compressors operate most efficiently when they use cool air for the intake. One of the factors that should be considered in designing the compressed air system is the access to cool intake air. Air compressors are often located in parts of a facility which are quite warm, and the air intakes use this warm air. In these cases, an outside air intake vent should be installed to allow the compressors to use cooler air.

12.3.3 Waste heat recovery from air compressors

Nearly 90% of the energy that goes into an air compressor becomes waste heat. Thus, it is important to recognize the value of air compressors as waste heat sources. Warm air can be recovered for space heat or process
drying, or water can be heated for washing parts, cleaning equipment or for bathroom use. Air compressors can often be located next to the place where their waste heat will be utilized. This can save on costs of ducting and piping that would have been needed to move the waste heat from a compressor located some distance away.

The use of waste heat from a compressor to heat a facility is illustrated in Section 12.4.2. In this example, it is very cost-effective to install the ducting to transfer the hot exhaust air from the compressor to the warehouse where it can reduce the need for using gas to provide space heat. Since the heat is only needed a few months of the year, it must be vented outside during the other months.

12.3.4 Improving the operation of the compressed air system

One way to determine how much energy is being used in the compressed air distribution system is to attach a recording ammeter to one leg of the motor driving the air compressor. This gives both the time and the amount of energy consumption and can point to excess usage or to leaks as possible problems. The assignment of dollar values to air leaks of various sizes is possible, and the amount of air lost to leakage can be a significant fraction of the total air used. In facilities where the air leaks are small, more attention should probably be paid to the ways in which the air is used. In any case, monitoring the electrical consumption of the compressor motor can determine whether this use of energy is worth the attention of the auditor. Replacing standard-efficiency motors with high-efficiency motors for air compressors is usually a very cost-effective EMO.

While considering the compressed air system, think of replacing air-powered equipment by equipment powered by electricity. An air-powered hoist, for example, uses 5-hp in the air compressor for every hp that would be used if the hoist were electrical. When the main function of the air compressor is to control HVAC equipment, water or oil in the control air can wreak the controls on the equipment. Most air compressors have water or oil traps at the bottom, and they can be inspected to see if they are acting as the manufacturer intended. Obtain the operating manual before attempting the inspection; otherwise you may manipulate the safety valve rather than the water trap, with hazardous results. If water or oil is not removed at the compressor, it may travel to the thermostats and impede their operation. Each thermostat operates differently, however, and inspecting a thermostat for oil or water is a task best left to a vendor or to a trained service person.

In addition, clean dry air is so important for the proper operation and longevity of air-powered controls and tools, that most facilities have
an air dryer that is placed in the air supply line after the compressor. This may be a mechanical vapor-compression cycle dryer (similar to an air conditioner), or it can be a desiccant-type dryer where the desiccant material is periodically reconditioned on an automatic basis.

Electric motors transmit power to compressors through belts, and a misalignment of the belt pulleys can cause severe damage and early failure of both bearings and belts. Other problems that can occur with compressors include inoperable switches, gauges that do not work, loose or frayed wiring, and leaks. Look for these problems, and listen for sounds of escaping air. If compressor problems persist, the cost savings of a working control system more than pays for the help of a trained technician.

12.4 EXAMPLES OF PROCESS ENERGY IMPROVEMENTS

In this section, some examples of abbreviated studies of process energy improvements are presented. They are intended as illustrative examples only and should not be used as general calculation guidelines. Individual circumstances will vary from these examples, and calculations should be tailored to fit the specific conditions of the facility being studied.

12.4.1 Recuperator for a Large Brick Kiln

Summary:
The two drying kilns at a large brick manufacturing company presently use ambient air for the combustion air. The air intake for the kiln burner could be modified to draw air from the cooling section of the kiln, thus serving as a recuperator. (A recuperator is a device that preheats the combustion air for a boiler, furnace or oven. Preheating the combustion air increases the system efficiency.) This air has the full oxygen content, yet has been heated as it has cooled the hot bricks.

A simple insulated duct could connect the cooling section to the combustion air intake duct. It is recommended that the air drawn from the cooling section be no more than 800°F and the duct be insulated. Usually the higher the temperature of the combustion air, the more efficient the combustion process. Unfortunately, when dealing with temperatures

*The airflow is calculated from the proposed burner consumption after excess air control is optimized.
above 800°F, there is a risk of the burners becoming too hot, resulting in a shorter burner life. By using air at 800°F and taking into account the heat loss in the duct, the risk of harming the burners is reduced. Additional controls may also be needed on the air intake motor due to higher air temperatures. Also, a filtering system may be needed if the new air source has unwanted dust particles.

The cost-effectiveness analysis of this EMO follows.

**Data:**

- Present air intake temperature: 90°F
- Proposed air intake temperature: 800°F
- Airflow*: 3548 cfm/kiln
- Specific heat of air (Cp) at 800°F: 0.259 Btu/lb °F
- Specific heat of air (Cp) at 90°F: 0.240 Btu/lb °F
- Density of air (p) at 800°F: 0.03 lb/ft³
- Density of air (p) at 90°F: 0.075 lb/ft³
- Heat loss through ductwork: 30% (using 3-inch hot pipe insulation)
- Operating hours: 8760 h/year
- Natural gas cost: $3.30/Mcf

**Calculations:**

In raising the combustion air temperature, the air mass flow rate must remain constant in order to maintain a correct air-fuel mix:

- **Energy Savings:**
  - Air mass flow rate = m
  - = (3548 ft³/min) × (.075 lb/ft³)
  - = 266.1 lb/min
  
  - Savings in Btus = (air mass flow) × (T₂ – T₁) × (average specific heat) × (1 – total heat loss)
  
  - = (266.1 lb/min) × (800°F – 90°F) × (.250 Btu/lb°F) × (60 min/h) × (8760 h/year) × (2 kilns) × (1 – .30)
  
  - = 34,756 × 10⁶ Btu/year

- Gas savings in Mcf = (34,756 × 10⁶ Btu/yr) × (1 Mcf/10⁶ Btu)
  
  - = 34,756 Mcf/year
(Note: This is a conservative estimate for the savings in gas because it does not include the efficiency of the gas heater.)

- **Cost Savings:**
  \[
  \text{savings in } \$ = (34,756 \ \text{Mcf/year}) \times (\$3.30/\text{Mcf}) \\
  = \$114,695/\text{year}
  \]

**Implementation Cost Data:**
- Length of duct: 75 ft/kiln
- Ductwork: 304 stainless steel at $5.45/lb
  - (24-in.-diameter duct of 14-gauge steel: 20 lb/ft)
- Insulation for ductwork: $10.00/ft
- Engineering design cost: $5000
- Labor and contingency: $5000

- **Implementation Cost:**
  \[
  \text{Implementation cost} = [(75 \ \text{ft}) \times ($5.45/lb) \times (20 \ \text{lb/ft}) + (75 \ \text{ft}) \times ($10.00/ft)] \times (2 \ \text{kilns}) + $5000 + $5000 \\
  = $27,850
  \]

- **Simple Payback Period:**
  \[
  SPP = \frac{\text{implementation cost}}{\text{annual savings}} \\
  = \frac{$27,850}{\$114,695/\text{year}} \\
  = 0.24 \text{ year}
  \]

Thus, this EMO is highly cost-effective.

**12.4.2 Heat Recovery from Compressors to Space Heat a Warehouse**

**Summary:**
An industrial warehouse is heated with natural gas. The shop next to the warehouse has one 75-hp and one 100-hp air compressor. By installing ductwork from the air compressors to the warehouse, the hot air from the compressors can be used to heat the warehouse. Two dampers are required so that air may be exhausted in the summertime. For this system, automatic dampers might be required so that the temperature of the air for space heating will not be too high. The system can then mix cool
outside air with the hot compressor exhaust air if needed.
The cost-effectiveness analysis of this EMO follows.

**Data:**
- Compressor size: 100 and 75-hp
- Average air temperature before compressor ($T_1$): 90°F
- Average air temperature after compressor ($T_2$): 110°F
- Hot air flow rate from 100-hp compressor: 10,000 cfm
- Operation hours: 992 h/year (24 h/day, 5 days/week; 4 h/day, 1 day/week; 8 weeks/year)
- Natural gas cost: $3.30/Mcf
- Efficiency of gas heater: 0.80
- Percent load on compressor: 75%
- Ductwork length: 35 ft each (70 ft for both)

**Calculations:**
The Btu savings as well as dollar savings from using the hot air from these compressors can be calculated.

- **Energy Savings:**
  \[
  \text{Btu savings} = (\text{air flow rate}) \times (\text{density of air}) \times (\text{specific heat of air}) \times (\text{temperature difference}) \times (\text{load factor})
  \]
  
  For the 100-hp compressor,
  \[
  \text{Btu savings} = (10,000 \text{ ft}^3/\text{min}) \times (.075 \text{ lb/ft}^3) \times (.24 \text{ Btu/lb}^\circ F) \\
  \times (110-90^\circ F) \times (60 \text{ min/h}) \times (992 \text{ h/year}) \times (.75 \text{ load})
  \]
  \[
  = 160.7 \times 10^6 \text{ Btu/year}
  \]

  For the 75-hp compressor, we'll assume that the savings will be about 75% of savings for the 100-hp compressor, so we have
  \[
  \text{Btu savings} = (160.7 \times 10^6 \text{ Btu/year})(.75)
  \]
  \[
  = 120.5 \times 10^6 \text{ Btu/year}
  \]

  Total Btus saved = (160.7 $\times 10^6 + 120.5 \times 10^6 \text{ Btu/year})
  \[
  = 281.2 \times 10^6 \text{ Btu/year}
  \]

  Total Mcf saved = (281.2 $\times 10^6 \text{ Btu/year})(1 \text{ Mcf/10}^6 \text{ Btu}) \times (1/.80)
  \[
  = 351.5 \text{ Mcf/year}
  \]
Total $ saved = (351.5 Mcf/year) \times ($3.30/Mcf) = $1,160/year

**Implementation Cost:**
- Material cost (for the air intake ductwork):
  - Insulated flexible duct with vinyl-coated spring steel (or aluminum): $2.90/linear foot
  - Two dampers: $30 each
- Labor cost (for installation of the duct):
  - Two persons: $20/h each
  - Time: 8 hours

\[
\text{Total cost} = \text{material cost} + \text{labor cost} \\
= (\text{duct cost/linear ft}) \times (\text{total linear ft}) \\
+ (2 \text{ dampers}) \times ($30/\text{damper}) + (\text{number of laborers}) \times (\text{number of h worked}) \times (\text{wage/h}) \\
= (\$2.90/\text{linear ft}) \times (70 \text{ ft}) + (\$30/\text{damper}) \times \\
(2 \text{ dampers}) + (2 \text{ laborers}) \times (8 \text{ h}) \times (\$20/\text{h}) \\
= $583
\]

**Simple Payback Period:**
\[
\text{SPP} = \frac{\text{implementation cost}}{\text{annual savings}} = \frac{$583}{\$1160/\text{year}} = 0.5 \text{ year}
\]

This EMO is also highly cost-effective.

**12.4.3 Installation of an Economizer for a Plastic Plant**

**Summary:**
This EMO considers the installation of an economizer and an associated control system in a plastics plant. To remove the heat being generated by a large injection molder, the plant currently air-conditions 9 months a year (March through November), three shifts a day. The economizer control will read the dry and wet bulb temperatures to determine if the outside air conditions (temperature and humidity) are more desirable than the present return air. When outside air is more desirable (less enthalpy), the economizer cycle will allow the use of cooler outside air to replace the need for additional conditioned air so that the least amount of
energy will be expended to get the air to the desired temperature and humidity.

It was assumed that the return air was at 78°F and 50% relative humidity (a conservative estimate), which corresponds to an enthalpy reading of 30 Btu/lb (air). Btu savings occur when the enthalpy of the outside air is less than the return air. The savings can be easily calculated in this manner by using bin data, which give the number of hours of weather experience in a month at a given temperature range for the geographic area where the facility is located. (See Table 12-2 at the end of this chapter for bin data.)

The cost-effectiveness analysis of this EMO follows.

**Data:**
- Electrical energy cost: $.034/kWh
- Return air: 78°F, 50% relative humidity
- Air flow rate of unit: 7120 ft³/min
- Operation time: 3 shifts (24 h/day Monday-Friday; 4 h/day Saturday) COP of air conditioner = 3.0

**Calculations:**

- **Energy Savings**

  \[
  \text{Savings in Btus} = \left( \frac{\text{total savings of Btu•h/lb air•year}}{\text{cfm of unit}} \times 60 \text{ min/h} \right) \times (0.075 \text{ lb/ft}^3 \text{ air}) \times \left( \frac{1}{\text{COP}} \right)
  \]

  (See Table 12-3 at the end of this chapter for the calculation of the total savings of Btu•h/lb air•year)

  \[
  = \left( 25,858.5 \frac{\text{Btu•h/lb air•year}}{\text{cfm of unit}} \times 60 \frac{\text{min}}{\text{h}} \times 0.075 \frac{\text{lb}}{\text{ft}^3 \text{ air}} \times \frac{1}{3} \right)
  \]

  \[
  = 276.2 \times 10^6 \text{ Btu/year}
  \]

- **Savings in dollars**

  \[
  = (\text{Btu/year}) \times \left( \frac{\text{kWh}}{3412 \text{ Btu}} \times \frac{\text{cost}}{\text{kWh}} \right)
  \]

  \[
  = (276.2 \times 10^6 \text{ Btu/year}) \times \left( \frac{1 \text{ kWh}}{3412 \text{ Btu}} \times \frac{0.034}{\text{kWh}} \right)
  \]

  \[
  = \$2752.29/\text{yr}
  \]
Implementation Cost Data:

Two 7.5-ton economizer units: $1216 each
Installation cost: $600

Implementation cost = 2($1216) + $600
= $3032

Simple Payback Period:

\[
SPP = \frac{\text{implementation cost}}{\text{annual savings}} = \frac{$3032}{$2752/\text{year}} = 1.1 \text{ years}
\]

This EMO is also quite cost-effective.

12.4.4 HPS Relamp of Refrigerated Storage

Summary:

This EMO recommends a major relamping of a refrigerated storage area at a meat packing company. The storage area presently uses 150-Watt incandescent lamps. Relamping would replace the existing lamps with 70-Watt high pressure sodium (HPS) lamps and maintain the same level of illumination.

High-pressure sodium lighting is one of the most efficient high-intensity discharge (HID) sources and has excellent lumen maintenance over the lifetime of the lamps. The yellow color of HPS lamps has been a limiting factor for many interior applications, but improvements in color rendition have made its application for interior lighting acceptable even for color-critical areas.

The cost-effectiveness analysis of this EMO follows.

Data:

Present lighting:

Type: incandescent
Size: 150 W
(150-W input to fixture)
Quantity: 68
Lamp cost: $1.10

Initial lumens: 2350
Life: 2500 h

Proposed lighting data:

Type: high-pressure sodium
Size: 70 W
(88-W input to fixture)
Spacing-to-mounting- Fixure cost: $91.55

Initial lumens: 5400
Life: 20,000 h

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height ratio: 2.0  
Lamp cost: $39.69
Electrical energy cost: $0.034/kWh
Demand cost:  
$4.97 (June-October)
$3.29 (November-May)
$3.99 (average year-round)

Total area: 9800 ft
t
Mounting height: 8.5 ft
Hours of operation:  
4576 h/year (16 h/day, 5.5 days/week, 52 weeks/year)
Cooling unit coefficient of performance (COP): 2.5

**Calculations:**

Present illumination = (68 lamps)(2350 lumens/lamp)
= 159,800 lumens

number of HPS lamps required = \[
\frac{159,800 \text{ lumens}}{5400 \text{ lumens/lamp}}
\]
= 30 lamps

area of lighting/HPS lamp = \[
\frac{9800 \text{ ft}^2}{30 \text{ lamps}}
\]
= 326.67 ft²/lamp

spacing requirements = \[
\left(326.67 \text{ ft}^2\right)^{1/2}
\]
= 18.07 ft/lamp

space±to±mounting±height ratio = \[
\frac{18.07 \text{ ft}}{8.5 \text{ ft}} = 2.1
\]

(This is extremely close to the recommended spacing-to-mounting-height ratio of 2.0 obtained from the manufacturer’s catalog.)

- **Energy savings:**

Present kWh = \[
(68 \text{ lamps}) \times (150 \text{ W/lamp}) \times (4576 \text{ h/year}) \times \frac{1 \text{ kW}}{1000 \text{ W}}
\]
= 46,675.20 kWh/year
Proposed kWh = (30 lamps) × (88 W/lamp) × (4576 h/year) 
               × (1 kW/1000 W) 
= 12,080.64 kWh/year

Savings in kWh = (46,675.20 kWh/year – 12,080.64 kWh/year) 
= 34,594.56 kWh/year
= (34,594.56 kWh/year) × (3412 Btu/kWh) 
= 118.04 × 10^6 Btu/year

• Demand savings:
  Present kW (demand) = (68 lamps) × (150 W/lamp-month) 
                        × (1 kW/1000 W) 
= 10.20 kW/month

  Proposed kW (demand) = (30 lamps) × (88 W/lamp-month) 
                         × (1 kW/1000 W) 
  Savings in kW (demand) = 10.20 kW/month – 2.64 kW/month 
= 7.56 kW/month

• Replacement cost savings:
  Present replacement cost = (68 lamps) × ($1.10/lamp) × 
                           (1/2500 h) × (94567 h/year) 
= $136.91/year

  Proposed replacement cost = (30 lamps) × ($39.69/lamp) 
                           × (1/20,000 h) × (4576 h/year) 
= $272.43/year

  Savings in replacement cost = $136.91/year – $272.43/year 
= – $135.52/year

• Savings in reduced refrigeration needs:
  (The reduction in wattage from HPS relamping will also reduce 
  the amount of heat generated by the lamps that must be removed by 
  the refrigeration system. This translates to a savings in energy (kWh) 
  but not a savings in demand (kW) since the air conditioner still 
  operates at its rated kW.)

  Present cost of heat removal = (46,675.20 kWh/year) × 
                               (1/2.5) × ($0.034/kWh) 
= $634.78/year

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Cost of heat removal with proposed lighting
\[
= (12,080.64 \text{ kWh/year}) \times (1/2.5) \times (.034/\text{kWh})
\]
\[
= \$164.30/\text{year}
\]

Total savings in refrigeration cost
\[
= \$634.78/\text{year} - \$164.30/\text{year}
\]
\[
= \$470.48/\text{year}
\]

Total savings in $ = savings in kWh cost + savings in kW cost + savings in replacement cost + savings in heat removal cost
\[
= (34,594.56 \text{ kWh/year}) \times (.034/\text{kWh}) + (7.56 \text{ kW/month}) \times (12 \text{ months/year}) \times ($3.99/\text{kW}) - $135.52/\text{year} + $470.48/\text{year}
\]
\[
= \$1873.15/\text{year}
\]

Implementation Cost:
- Fixtures: (30 fixt.) \times ($91.55/\text{fixt.}): \$2746.50
- Lamps: (30 lamps) \times ($39.69/\text{lamp}): \$1190.70
- Labor (for adding HPS lamps):
  \[
  (30 \text{ fixt.}) \times (1 \text{ h/fixt.}) \times ($15/\text{h}): \$450.00
  \]
- Labor (incandescent lamp removal):
  \[
  (68 \text{ fixt.}) \times (.5 \text{ h/fixt.}) \times ($15/\text{h}): \$510.00
  \]
- Total: \$4897.20

Simple Payback Period:
\[
\text{SPP} = \frac{\text{implementation cost}}{\text{annual savings}} = \frac{\$4897.20}{\$1873.15/\text{year}} = 2.61 \text{ years}
\]

This EMO has a SPP that is over two years, but many companies would still find it an attractive investment.

12.4.5 Sawdust Collection Control System

Summary:
A wood shop at a furniture factory has a sawdust collection system which collects sawdust from five machines. The system uses overhead
hoods with vacuum motors, and exhausts the dust and air to the outside through ductwork. The dust collection system operates at all times the plant is in operation. By installing a damper and a control system to shut off the air collection system from any one of the machines not in use, significant savings will be realized.

Each of the five vacuum ducts must have a damper, and a speed control is required for the vacuum motor. Used in conjunction with a programmable controller, the damper corresponding to a specific machine will open that duct when the machine is turned on while the speed of the vacuum motor is increased proportionately. When no machines are in use, the motor is completely shut off. This EMO provides savings both in electricity to run the vacuum motor and in the gas used to heat the air that is being evacuated from the plant.

The cost-effectiveness analysis of this EMO follows.

**Data:**
- Vacuum electric motor: 20-hp
  - Operating time of motor: 8.5 hours a day
  - Load on motor: 100%
  - Efficiency of motor: 88%
- Duct system: Exhausts 6500 ft³ of air per minute
- Efficiency of gas heating plant: 70%
- Each machine is used approximately 2 hours/day.

**Electric cost:**
- Demand charge: $4.50/kW/month
- Energy charge: $0.02915/kWh
- Natural gas cost: $3.50/10⁶ Btu

**Calculations:**

- **Energy Savings:**
  
  Electricity cost = demand charge + consumption charge
  
  = (20 hp) × (0.746 kW/hp) × (1/.88) × (12 months) × ($4.50/kW/month) +
  
  (20 hp) × (0.746 kW/hp) × (1/.88) × (8.5 h/day) × (250 days/year)
  
  × ($0.02915/kWh)
  
  = $915.55 + $1050.23
  
  = $1965.78

  Electricity savings = demand savings + energy savings
demand savings = \[(\text{motor capacity}) \times (0.746 \text{ kW/hp}) \times (1/\text{efficiency}) \times (12 \text{ months/year}) \times (\text{cost/kW/month}) \times (\% \text{ demand reduction})\]

\[
= (20 \text{ hp}) \times (0.746 \text{ kW/hp}) \times (1/0.88) \times (12 \text{ months/year}) \times ($4.50/\text{kW/month}) \times (3/5) \\
= $549.33/\text{year}
\]

(The percent demand reduction is taken to be $3/5 = 60\%$ based on the assumption that no more than two machines will run at the same time for the 30 minute demand averaging interval.)

energy savings = \[(\text{motor capacity}) \times (0.746 \text{ kW/hp}) \times (1/\text{efficiency}) \times (6.5 \text{ h}) \times (250 \text{ days/year}) \times (\text{cost/kWh})\]

\[
= (20 \text{ hp}) \times (0.746 \text{ kW/hp}) \times (1/0.88) \times (6.5 \text{ h}) \times (250 \text{ days/year}) \times ($0.02915/\text{kWh}) \\
= $803.12/\text{year}
\]

Total electricity savings = ($549.33 + $803.12)/\text{year} = $1352.45/\text{year}

Gas cost = \[(6500 \text{ ft}^3/\text{min}) \times (8.5 \text{ h}/\text{day}) \times (60 \text{ min/h}) \times (100 \text{ heating days/year}) \times (0.075 \text{ lb/ft}^3) \times (0.24 \text{ Btu/lb}) \times (65-45^\circ \text{F}) \times (1/0.7) \times ($3.50/10^6 \text{ Btu})\]

\[
= $596.70/\text{yr}
\]

Gas savings from reduced heat loss = \[(\text{air volume flow rate}) \times (\text{operating hour reduction}) \times (60 \text{ min/h}) \times (\text{heating days/year}) \times (\text{air density}) \times (\text{specific heat of air}) \times (\text{temperature difference}) \times (1/\text{eff}) \times (\text{gas cost})\]

\[
= (6500 \text{ ft}^3/\text{min}) \times (8.5 - 2) \text{ h/day} \times (60 \text{ min/h}) \times (100 \text{ days/year}) \times (0.075 \text{ lb/ft}^3) \times (0.24 \text{ Btu/lb}) \times (65-45^\circ) \times (1/0.7) \times ($3.50/10^6 \text{ Btu}) \\
= $456.30/\text{year}
\]
• **Total Cost Savings:**
  
  \[
  \text{Total annual cost savings} = \text{electricity cost savings} + \text{gas cost savings}
  \]
  \[
  = \$456 + \$1352
  \]
  \[
  = \$1808
  \]

**Implementation Cost Data:**

- Speed control: $1500
- Programmable controller: 550
- Electric dampers (5 at $65): 325
- Wire, switches: 50
- Installation (estimate): 300

**Implementation Cost:** $2725

**Simple Payback Period:**

\[
\text{SPP} = \frac{\text{implementation cost}}{\text{annual savings}} = \frac{\$2725}{\$1808/\text{year}} = 1.5 \text{ years}
\]

This EMO is also quite cost-effective.

### 12.5 TWENTY-FIVE COMMON ENERGY MANAGEMENT OPPORTUNITIES

Through our combined energy management experiences with over 200 manufacturing plants and a review of the literature, we have found that a number of energy management opportunities (EMOs) have been used time after time. The astute energy manager must become familiar with these opportunities and be ready to apply them (as well as others) in energy management work.

Twenty-five of these common changes are summarized below. Most are process modifications, but a few are lighting and space conditioning oriented. The order of listing is not significant; the order would change depending on whether one were listing by frequency of occurrence, amount of savings, financial return on investment, etc.

1. **Switch to energy-efficient lamps.** Switch existing lamps to the energy-efficient ones, such as 34-watt energy-efficient fluorescent lamps for conventional 40-W ones, or replace T-12 lamps with T-8 or T-10 lamps.
2. **Switch to energy-efficient light sources.** Change to more efficient sources usually requiring fixture changes. Change from incandescent lights to fluorescent or from mercury vapor or fluorescent to high-pressure sodium for in-plant lighting, a very frequent conversion.

3. **Use night setback-setup.** Turn temperatures up or down at night when needs are reduced. Examples include large ovens that cannot be turned off, large refrigeration units where night operations involve less infiltration (fewer people going in and out), and space conditioning.

4. **Turn off equipment.** Turn off exhaust fans, ovens, motors, or any other equipment when not needed.

5. **Move air compressor intake to cooler locations.** Move air intakes from hot equipment rooms to cooler (often outside) locations. Efficiency improvements are large and paybacks attractive.

6. **Eliminate leaks in steam and compressed air systems.** Steam and compressed air leaks are very expensive and should be fixed. Technology exists for repairing leaks without shutting the equipment down. Night audits (when noise is minimized) often turn up large numbers of these leaks.

7. **Control excess air.** As shown earlier, careful control of combustion air can lead to significant energy savings.

8. **Optimize plant power factor.** Depending on the utility billing schedule and the company’s power factor, large savings may be available through power factor improvement.

9. **Insulate bare tanks, vessels, lines, and process equipment.** Good savings are often available through insulation of process lines and tanks. Condensate return lines and tanks are often not insulated.

10. **Install storm windows, doors, and weather stripping.** Although these are often difficult to justify, sizable savings are sometimes available. This is especially true for large glass exposures in cold climates.
11. *Use energy-efficient electric motors.* When replacement is necessary or for new applications, energy-efficient motors can usually be justified. Electric utilities often provide rebates to customers who replace standard motors with energy-efficient models.

12. *Preheat combustion air.* Recuperators can save large amounts of energy and money. Sometimes they are highly cost effective.

13. *Reduce the pressure of compressed air and steam.* If the pressures have been overdesigned, a reduction will not harm the process. In such cases, large savings are possible.

14. *Insulate walls, ceilings, roofs, and doors.* Industrial plants are frequently poorly insulated. Insulation in dropped ceilings, on roofs or walls, and doors may be cost-justified.

15. *Recover heat from air compressor.* Larger air compressors reject large amounts of heat through air or water cooling. Proper design can allow this waste heat to be used for space conditioning in the winter and to be exhausted in warm weather. Sometimes the payback is very attractive.

16. *Insulate dock doors.* Plastic strips, dock bumpers, vestibules, or air screens all help block infiltration through large dock doors. If the space is heated and/or air-conditioned, the savings can be very large.

17. *Install economizers on air conditioners.* In some areas of the country, economizers can be very attractive. They allow the optimum use of outside air in air conditioning. Sometimes outside air can be used and the air conditioner turned off.

18. *Use radiant heat.* Sometimes infrared heaters can be used to spot-heat rather than heat entire areas. Infrared heat (like the sun) warms objects and people but not space. The payback can be very attractive.

19. *Return steam condensate to the boiler.* Returning hot condensate can yield dramatic savings in energy, water, and water conditioning costs. Return lines should probably be insulated.
20. *Change product design to reduce energy requirements.* Product redesign can often reduce the energy necessary in heat treating, cleaning, coating, painting, etc.

21. *Explore waste heat recovery for space exhaust systems.* Large amounts of exhaust in buildings that are heated and/or air-conditioned offer the potential for waste heat recovery.

22. *Install devices to improve heat transfer in boilers.* Turbulators and other devices designed to reap more energy out of the combustion process are often very cost effective.

23. *Reschedule operations to reduce peak demand.* Sometimes simple changes in equipment scheduling can dramatically reduce demand charges.

24. *Cover open heated tanks.* Covering open heated tanks can often lead to big energy savings. Floating balls, cantilevered tops, and rubber flaps have all been used as covers.

25. *Spot-ventilate or use air filters.* In welding areas or other areas where large amounts of ventilation are required, spot ventilation can often reduce the amount needed. Also, electrostatic or other types of air filters can sometimes allow reuse of the air. Savings are especially large if the space is heated and/or air-conditioned.

### 12.6 SUMMARY

This chapter has provided a suggested procedure for process improvement that is based on the industrial engineering concept of work simplification. It has also provide a detailed presentation of electric motor and drive system efficiency improvements. These are particularly important because of the large quantity of energy used in business and industry by electric motors. Some case studies of process energy management were also presented. The reader should not consider these examples as typical results but should use them as a starting point for potential analysis. Because process energy management can be intricate and complex, the energy manager must understand the entire process system and consider all of the impacts of any proposed changes.
Table 12-2. Mean frequency of occurrence of dry bulb temperature (°F) with mean coincident wet bulb temperature (°F) for each dry bulb temperature range.

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<th>Temperature range (°F)</th>
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<th>July</th>
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<td>Observ./ h, G_p</td>
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<td>02 10 18</td>
<td>02 10 18</td>
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<td>09 17 01</td>
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Table 12-2. (Continued)

Cooling Season

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Table 12-2. (Continued)

Cooling Season

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Table 12-2. (Continued)

Cooling Season

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Table 12-3. Enthalpy data [Btu • hr/lbm (air)]

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### May

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\(\Delta h\) = h_{(30–h)}
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10.5  

112.6
## September

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<th>Hours</th>
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## October

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<th>Hours</th>
<th>1 lbm (air)</th>
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Process Energy Management

Total \( \frac{\text{Btu} \sum h}{\text{lbm (Air)}} \)

March 6,209.5
April 5,472.4
May 1,877.4
June 300.7
July 10.5
August 112.6
September 1,130.4
October 4,603.4
November 6,141.6
25,858.5

\( \frac{\text{Btu} \sum h}{\text{lbm (Air)}} \)

REFERENCES


BIBLIOGRAPHY


