Compressed Air System Economics

Office of Industrial Technologies

Delivering compressed air to a manufacturing facility is an expensive operation. Delivery requires costly equipment that consumes significant amounts of electricity and needs frequent maintenance. In spite of this, many facilities have no idea how much their compressed air systems cost on an annual basis, or how much money they could save by improving the performance of these systems.

Electricity costs are by far the largest expense of owning and operating a compressed air system. The initial cost for a 100-hp compressor is $30,000-$50,000, depending on the type of compressor and manufacturer, while annual electricity charges for the same system can reach $50,000. Added to this are annual maintenance costs, which can be 10% or more of the initial cost of the system.

This Fact Sheet presents a simple calculation to estimate annual electricity costs, and a more accurate calculation requiring electrical measurements.

Calculating Electricity Costs

Full-load Operation. Even if an air compressor is not separately metered, estimating annual electricity cost is simple. For more analysis techniques, see the AIRMaster software referenced in the *Resource and Tools* section, and/or call the Compressed Air Challenge™ number listed in the *Directory* section.

A Simple Calculation. The following data is needed for a quick calculation of electricity costs for a compressor operating at full-load:

C   Compressor motor nameplate rating (bhp),
C   Motor nameplate efficiency (or an estimate of efficiency),
C   Annual hours of operation (hrs/year), and
C   Cost of electricity ($/kWh).

Annual electricity costs can be calculated by inserting this information into the equation in the following text box:

Simple Calculation
(100 hp Compressor)

Annual Electricity Costs =
(Motor full-load brake horsepower) x (0.746 kW/hp) x (1/0.9) x (Annual Hours of Operation) x (Electricity Cost in $/kWh)

For example:

C   Motor full-load bhp = 100 hp
C   Annual hours of operation = 8,760 hours (3-shift, continuous operation)
C   Full Cost of electricity = $0.05/kWh

Annual electricity costs =
(100 hp) x (0.746 kW/hp) x (8,760 hours) x ($0.05/kWh)/0.9
 = $36,305

This equation assumes the electric motor driving the compressor is 90% efficient (the 90 in the 1/0.9 factor) -- a reasonable estimate for a

modern system larger than 50 hp. Newer energy-efficient motors may have even higher efficiencies, especially since the Energy Policy Act minimum motor efficiency levels went into effect in late 1997. If the system uses an older motor that has been rewound several times, or has a smaller motor, 80% efficiency (or the motor nameplate efficiency rating) should be used. For a more accurate assessment, add the horsepower ratings for the parasitic loads from any auxiliary motors to the compressor motor rating.

It should be noted that the common practice in the industry is to apply motors having a 15% continuous service factor and to use about two-thirds of this service factor. This means that a motor having a nominal nameplate rating of 100 hp may, in fact, be loaded to 110 bhp at compressor full capacity and pressure. This may not be expressed in the manufacturer=s sales literature, however, so engineering data sheets for the specific air compressor should be consulted. If the motor is running into the service factor, the higher horsepower estimate should be used instead of the nameplate horsepower rating.

A Calculation with Measurements. A

more accurate way to determine electricity consumption and costs involves taking electrical measurements of both full-load amps and volts. Motor full-load bhp and efficiency are not required for this calculation, although full-load power factor, which can be obtained from motor manufacturers, is. The calculation takes full-load amps, converts to full-load kW, and then multiplies by hours of operation and electricity

costs. A calculation is shown in the next text box.

More Detailed Calculation (100-hp Compressor with 30 Power)

Annual Electricity Costs =
[(Full-load amps)x(volts)x(1.732)x(power factor)]/1000
(Annual Hours of Operation) x (Electricity Cost in $/kWh)

For example:

C   Full-load amps = 115 amps
C   Voltage=460 volts
C   Full-load power factor = 0.85
C   Annual hours of operation = 8,760 hours (3-shift, continuous operation)
C   Cost of electricity = $0.05/kWh
•   Correction factor for 30 power= 1.732

Annual electricity costs =
((115 amps) x (460 volts) x (1.732) x (0.85) / 1000) x (8,760 hours) x ($0.05/kWh)
= $34,111

Part-load Operation. If the compressed air

system operates below full-load at times, and has a good control system, electricity costs will be less than if the compressor ran at full-load during all hours of operation. Estimate the percentage of time the compressor is running at full-load, and add the percentage as another multiplier in the equation shown previously. Repeat the calculation for the percentage of time the compressor is running unloaded (or at part-load) and include a factor to compensate for the reduced load on the motor (0.20 to 0.30 is a good estimate for unloaded operation for rotary screw compressors and 0.10 to 0.15 for reciprocating compressors -- 0.30 is used in the

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equation in the next text box). Add the two results for total energy costs.

For a more accurate calculation of energy costs for compressors running at part-load, create a number of "tiers" with the percentage of time running at different percentages of load. Manufacturers' data on energy consumption for the different percentages of load will be needed.

The following text box shows an example calculation taking into account unloaded operation.

Calculation with Part-Load Operation (100-hp Compressor)

Annual Electricity Costs =
[(Motor full-load brake horsepower) x (0.746 kW/hp) x (Annual Hours of Operation) x (Electricity Cost in $/kWh)] x [(Percent of time running fully loaded) + (0.30) x (Percent of time running unloaded)]

For example:

- Full load motor efficiency = 90%
- Motor full-load bhp = 100 hp
- Annual hours of operation = 8,760 hours (3-shift, continuous operation)
- Runs 65% of the time fully loaded, 35% of the time unloaded
- Unloaded operation consumes 30 percent of the electricity of fully loaded operation
- Cost of electricity = $0.05/kWh

Annual electricity costs =
[(100 hp) x (0.746 hp/kW) x (8,760 hours) x ($0.05/kWh) /0.9] x [0.65 + (0.30) x (0.35)]
 = $27,410

Remember, the calculations shown will only provide a good estimate of energy consumption, not an exact number.

Energy and Demand Charges -- Understanding Your Electricity Bill

The calculations shown previously use electricity rates stated in terms of dollars per kilowatt-hour ($/kWh). Electric utilities bill industrial customers using more complicated rate structures that typically include both energy ($/kWh) and demand charges ($/kW), and have different rates depending on the level of consumption or seasons. Demand charges are based on the peak demand for a given month or season and can have significant impacts on electricity costs for some customers. When the economic impacts of efficiency measures are calculated, the actual marginal cost of the electricity needs to be considered, taking into account energy and demand charges, seasonal rates, and different rates for different levels of consumption.

Pressure and Electricity Cost

High pressure air is more expensive to produce and deliver than low pressure air. For a system operating at around 100 psig, a rule of thumb is that every 2 psi in operating pressure requires an additional 1% in operating energy costs. In the system described in the first example shown, running the system at 110 psig instead of 100 psig would increase the energy costs by 5%, or $1,800 per year. See the Fact Sheet titled *Pressure Drop and Controlling System Pressure* for more information.

Savings From Performance Improvements

Due to the relatively low initial cost of the compressor when compared to lifetime electricity expenses, users should utilize life-cycle cost

analysis when making decisions about compressed air systems. In addition, a highly efficient compressed air system is not merely a system with an energy-efficient motor or efficient compressor design. Overall system efficiency is the key to maximum cost savings. Too often users are only concerned with initial cost and accept the lowest bid on a compressed air system, ignoring system efficiency.

Thorough analysis and design will be required to obtain an efficient system. Many compressed air system users neglect these areas, thinking they are saving money, but end up spending much more in energy and maintenance costs.

Following the steps outlined in the Sourcebook can lead to substantial energy savings for most compressed air systems. A system that has undergone numerous modifications and has only been maintained enough to keep it running can frequently achieve energy savings of 20-50% or more. For the 100-hp system described previously, this represents annual savings of $7,000-$18,000. Larger systems will have correspondingly greater energy savings.

Too many decisions regarding compressed air systems are made on a first-cost basis, or with an "if it ain't broke, don't fix it" attitude. To achieve optimum compressed air system economics, compressed air system users should select equipment based on life-cycle economics, properly size components, turn off unneeded compressors, use appropriate control and storage strategies, and operate and maintain the equipment for peak performance.