Compressed Air Energy Efficiency

An Online Continuing Education Course for Engineers

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Compressed Air Energy Efficiency

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Overview

Compressed air is widely used for industrial purposes due to its various technological advantages such as high operating speed, force, accuracy, and safe handling. Despite these advantages, compressed air systems consume considerable amounts of energy. It takes about 8 hp of electrical energy to produce 1-hp-worth of work with compressed air. Here is some food for thought:

As a good approximation, a typical compressor produces:

4 cubic foot per minute (CFM) per 1 motor hp (horsepower)

Where:

1 hp = 0.746/0.9 = 0.829kW

Therefore:

1 CFM = 0.207kW

And, at $0.05/kW-hr:

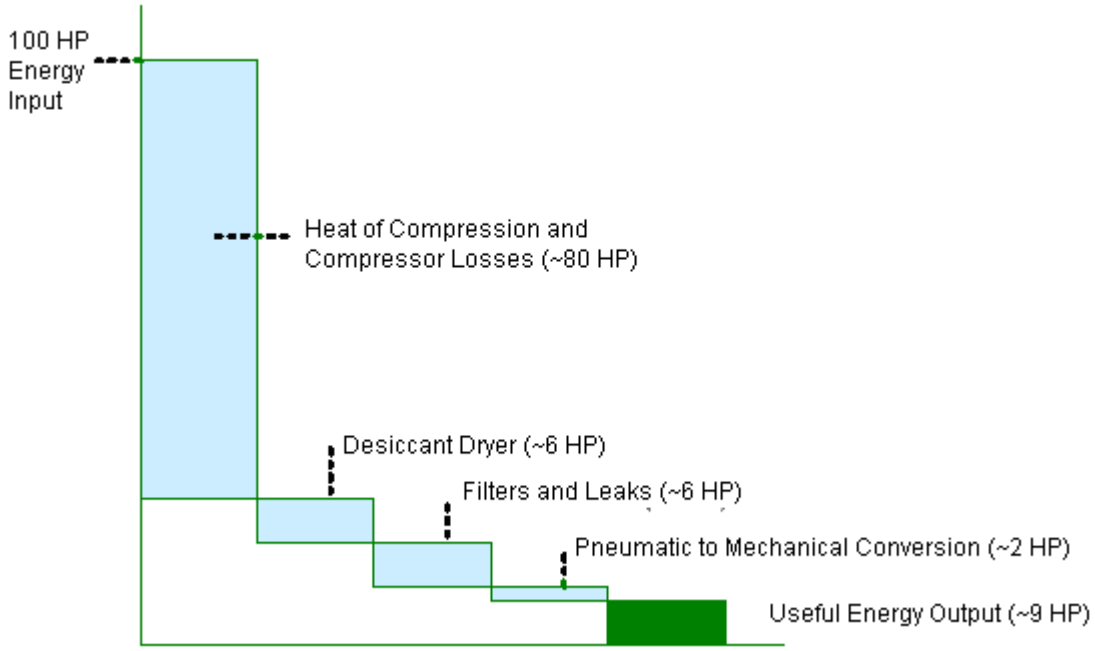
1 CFM = $0.0104/hr

Thus, 10 CFM over 8000 hours per year costs:

1 x 8000 x 0.0104 = $83.20

Approximately 90% of the energy to produce and distribute compressed air is lost.

The figure below illustrates the typical losses associated with producing and distributing compressed air. Assuming 100 HP energy input, approximately 91 HP ends up as losses, and only 9 HP as useful work.



Compressed Air Energy Input and Useful Energy Output

Certainly compressed air is the most expensive energy utility—the figure above shows that approximately 10% of useful energy only reaches the point of final use. Always question if compressed air is the most appropriate power source for an end use application. In many cases, you would be better off to use a direct drive electric tool instead of a compressed air driven one.

Most facilities can easily save 10-20% of their compressed air energy costs through routine maintenance such as fixing of air leaks, lowering air pressure, and replacing clogged filters. Even higher savings numbers can be gained by choosing better compressor control, adding storage receiver capacity, and upgrading air dryers and filters.

This course explains how the selection, control, and maintenance of compressed air plants can improve energy efficiency and reduce running costs.

SECTION 1: COMPRESSOR TYPES AND CONTROLS

Every compressed-air system begins with a compressor—the source of air flow for all the downstream equipment and processes. The main parameters of any air compressor are capacity, pressure, horsepower, and duty cycle. It is important to remember that *capacity* does the work; *pressure* affects the rate at which work is done. Both are independent—i.e., adjusting an air compressor's discharge pressure does not change the compressor's capacity.

There are two basic compressor types:

1. Positive-displacement, which includes reciprocating and rotary air compressors, and
2. Dynamic, which includes centrifugal and axial air compressors.

Reciprocating Air Compressors

Reciprocating air compressors are positive-displacement machines, which function by increasing the pressure of the air using a piston within a cylinder. There are three basic selection decisions that must be made about reciprocating compressors:

1. Single- or double-acting operation
2. Single- or multi-stage configuration
3. Air- or water-cooling option

In a ***single-acting*** compressor, the piston only compresses air in one direction of its stroke. In a ***double-acting*** model, the piston compresses air with both directions of its stroke. Obviously, because both strokes perform work, a double-acting compressor is more efficient (in moving a volume of air per input hp) than a comparable-size single-acting unit. However, they are also heavy and bulky, making them relatively expensive to install. They generally have more significant unbalanced forces, which combines with their size to require a special foundation and support.

A ***single-stage*** unit compresses air from inlet to discharge pressure in one operation. Usually single-stage operation is in pressure ranges of 95 psi or less. A ***multi-stage*** unit compresses from inlet to discharge pressure in two or more operations. Multiple-stage units are theoretically more efficient. They can cool down the air between stages reducing the work required to compress the

air. Usually two-stage operation is in pressure ranges of 100-175 psig and three-stage reciprocating units are generally used for pressures above 250 psig.

Air-cooled compressors, as the name implies, are cooled by ambient air. The compressor cylinder's heads are finned to provide increased cooling and heat transfer. Air-cooled units are generally designed for 50% to 75% duty cycles*, depending on the particular units and their application. In ***water-cooled*** compressors, integral water jackets surround the cylinders and heads. Heat transfer through the water is much more efficient than air.

Duty Cycle

Duty cycle is the percentage of time that the compressor motor is generally running under loaded conditions. In an application, at 50% duty cycle, and at 4 cfm/hp, a 32.65 cfm application will require a compressor capacity of 16.32 hp and NOT 8.16 hp [32.65 cfm ÷ 4 cfm/hp ÷ 50% duty cycle = 16.32 hp]. For a reciprocating compressor to be categorized as *continuous duty*, it is generally agreed that it must be double-acting and water-cooled.

Two primary control system types are available in reciprocating compressors: on/off control and load/unload control. Reciprocating compressors are designed as two-step (start/stop or load/unload), three-step (0%, 50%, 100%) or five-step (0%, 25%, 50%, 75%, 100%) control. These control schemes generally exhibit an almost direct relationship between motor power consumption and loaded capacity. Generally speaking, reciprocating air compressors have better unloading characteristics than screw compressors and are more suited to single compressor installations with fluctuating air demand.

Most air-compressor manufacturers promote the two-stage, single-acting compressor as the optimum machine for producing 100-psi class air—the base pressure level in most industrial plants. These compressors are available with oil-lubricated and oil-free cylinders.

Rotary Air Compressors

Rotary air compressors are positive displacement compressors and are most commonly used in sizes ranging from about 5 to 900 HP. Depending on the air purity requirements, rotary screw compressors are available as lubricated or dry (oil free) types.

1. **Oil-cooled rotary helical screw compressors:** This type of unit provides non-pulsating air in a range of 22 to 3,100 cfm. Two-stage rotary-screw compressors are frequently used in the 150- to 400-psia pressure range and offer advantages associated with lower compression ratio per stage. Reduced pressure differential

across the rotors minimizes blow-by and significantly reduces thrust-bearing loads. (Obviously two-stage units require two air ends, which increase the initial cost.)

The unique characteristic of this compressor is that it is cooled by oil. Oil injected into the air stream absorbs the heat of compression while it is being generated. The heated oil is then taken to an air- or water-cooled heat exchanger for cooling. Because the cooling takes place right inside the compressor, there are no hot spots inside the air end, no matter what the load on the compressor. In other words, oil-cooled rotary-screw compressors can run at full load and full pressure twenty-four hours a day, seven days a week.

Com ressors, oil-cooled rotary-scre

- timum level. As a result, out 180°F higher than
- carbon.
- ticularly in the larger le from compressors icant savings on floor
- E ning characteristics, it is riven models are c to 85 dB at one meter.
- Most models have fewer moving parts, and those parts run under more ideal conditions resulting in lower temperatures and less vibration.
- Fewer parts make it easier to stock them for the rotary designs, and the machines are easier to work on.

In summary, oil-cooled rotary-screw compressors offer users a continuous-duty source of compressed air in a neat, compact package that has low initial cost,