



## **Heat Recovery from Industrial Compressed Air Systems**

By CAGI Promotional Subcommittee

The rise in energy prices is an unwelcome reality in today's manufacturing and business environment. And while the rate of price increases for natural gas, heating oil and electricity may vary from year to year, the upward trajectory is clear. Energy cost reduction strategies are vital to staying competitive.

Related considerations are protection of the environment and the focus on sustainable growth. Some industries are under increasing pressure to reduce their carbon footprint, and many companies are proactively taking steps to do so.

With manufacturing plants and other facilities doing what they can to streamline their operations and improve efficiencies, facility engineers face the challenges of optimizing the energy efficiency of their operations and extracting as much productivity out of every unit of energy consumed and paid for.

### **Compressed Air as an Energy Source**

One important way operational efficiencies can be increased is by harnessing heat from compressed air systems, which make up a significant share of industrial energy consumption.

The law of thermodynamics and the principle of the conservation of energy tell us that energy isn't created or destroyed; it can only change form. The air that enters a compressor at atmospheric pressure has a base level of energy content. After the compression process increases the air pressure and raises its temperature, the energy becomes available for transfer. The heat must be removed to maintain proper compressor operating temperatures and to cool the compressed air to make it suitable for plant use.

The heat generated by compressed air systems can be a very good source of energy savings. In fact, nearly all (96%) of the electrical energy used by an industrial air compressor is converted into heat. (The balance remains in the compressed air or radiates from the compressor into the immediate surroundings.)

Too often, that heat is simply ejected into the ambient environment through the compressor cooling system. But here's the good news: Nearly all this thermal energy can be recovered and put to useful work and significantly lower a facility's energy costs. Some uses of recovered energy from compressed air systems:

- Supplemental space heating
- Makeup air heating
- Boiler makeup water preheating
- Industrial process heating
- Water heating for showers, bathrooms, etc.
- Heating process fluids
- Heating food and beverage products
- Heat-driven chillers

### **Heat Recovery with Rotary Screw Compressors**

The most common compressor equipment found in manufacturing plants is the air-cooled, lubricated rotary screw design. The amount of heat recovered using these systems will vary if the compressor has a variable load. But in general, very good results will be achieved when the primary air compressor package is an oil-injected rotary screw type design.

Oil-less rotary screw compressors are also well-suited for heat recovery activities. As with other compressor systems, the input electrical energy is converted into heat. Because they operate at much higher internal temperatures than fluid injected compressors, they produce greater discharge temperatures (as high as 300°F or even greater).

### **Warm Air Applications**

Capturing warm air is easily accomplished by ducting the air from the compressor package to an area that requires heating. The air is heated by passing it across the compressor's aftercooler and lubricant cooler. This extracts heat from the compressed air as well as the lubricant, improving both air quality and extending lubricant life.

By integrating standard HVAC ductwork and controls, warm exhaust air from compressors can be channeled to remove or provide heat in the compressor room and adjacent areas. Typical uses include:

- Heating for warehouses or storerooms
- Heating for production areas and workshops
- Drying air for paint spraying
- Air curtains
- Pre-heating combustion air to improve efficiency

Nearly all current models have cabinets that channel airflow through the compressor, and many current designs exhaust warm out the top of the unit. This simplifies adapting compressors for space heating to the installation of ducting and (sometimes) a supplemental fan to handle duct loading and eliminate back pressure on the compressor cooling fan.

Space heating can be regulated easily using thermostatically controlled, motorized louver flaps for venting, thereby maintaining consistent room temperature by making continuous adjustments

to the heating air flow. This also means that when heating is not required, the hot air can be ducted outside the building to reduce cooling costs.

### **Water/Fluid Heating**

Rejected heat can also be used to heat water or other process fluids. It can be done with either air-cooled or water-cooled compressors, although the best efficiencies are usually obtained from water-cooled compressor installations where discharge cooling water is connected directly to a continuous process heating application such as a heating boiler's return circuit for year-round energy savings.

The key to heat recovery effectiveness with water-cooled compressors is attaining a "thermal match" between the heat being recovered and the heat that is needed on a regular (hourly) basis.

*Plate heat exchangers* offer a cost-effective way to capture heat from the rotary screw compressor and utilize it to heat water for diverse processes such as electroplating, chemical processing and laundry services.

*Fail-safe heat exchangers* provide additional protection against contamination of process water or fluids by the compressor cooling fluid. This makes them more suitable for heating applications in the food and pharmaceutical industry sectors – as well as for heating potable water.

Some compressor manufacturers offer built-in heat recovery heat exchangers as options. In some cases, they are fully integrated inside the compressor cabinet and require very little onsite engineering.

### **Energy Savings ... and More**

Most process applications in production facilities can benefit from heat recovery from compressed air systems throughout the year, not just during the cold-weather months. In most space heating applications heat is required during three seasons. And during the warmer months, removing the heat of compression will make the compressor room temperatures much more comfortable. Maintaining proper ambient conditions will also improve compressor efficiency and facilitate air treatment. Moreover, controlling operating temperatures will extend compressor air equipment life.

Current energy costs make an investment in heat recovery systems highly attractive. However, when attempting to calculate energy savings and payback periods for heat recovery efforts, it's important to compare heat recovery with the current source of energy for generating thermal energy, such as relatively lower-cost natural gas.

Generally, the larger the system the faster the payback, but payback on heat recovery also depends on the amount of rejected heat that can be used, and the cost of the alternative energy source. After factoring in the installation cost, it's possible that smaller systems will not provide enough recoverable BTUs of energy to make the investment worthwhile.

Naturally, higher energy savings will be realized when the alternative heating source is an older, less efficient technology. Investing in newer, more efficient equipment may be more cost effective. Many heaters are now operating at ~85% efficiency or better, and thus compressor heat recovery activities will result in relatively less annual energy savings.

Beyond energy savings, an important argument can also be made that heat recovery activities benefit the environment. After all, substantial energy savings also mean a reduction in the carbon footprint of a plant. As energy policies and regulations continue to evolve in the United States and other countries, these considerations are only expected to become more important.