

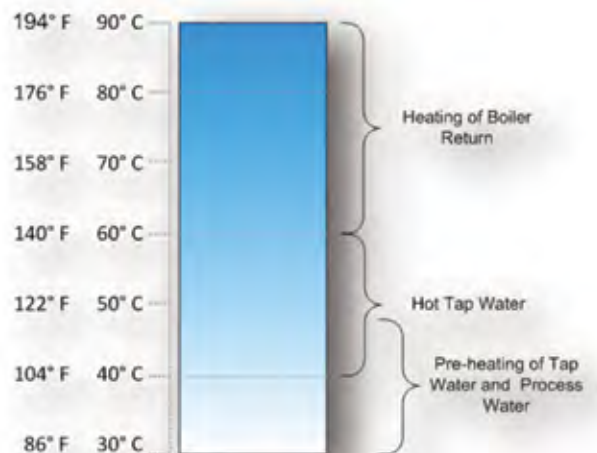
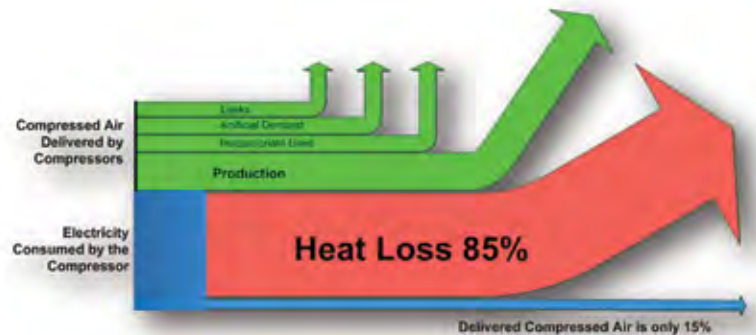
HEAT RECOVERY AND COMPRESSED AIR SYSTEMS

BY FRANK MOSKOWITZ FOR THE COMPRESSED AIR CHALLENGE®



Having a fundamental understanding of how your plant's compressed air system works and what forces influence it will help you improve its performance. The overall efficiency of a compressed air system can be as low as 10–15%. The figure below shows two main components of inefficiency — one is from the wasted air due to losses through leaks, artificial demand and inappropriate uses, the other is due to heat of compression. With some basic understanding, as much as 90% of this heat can be recovered for use in your operation.

It's simple physics that compressing air gives off heat. The heat energy is concentrated in the decreasing volume of air. To maintain proper operating temperatures, the compressor must transfer excess heat to a cooling media before the air goes out into the pipe system. As much as 90% of that heat can be recovered for use in your operation. If you can supplement or replace the electricity, gas or oil needed to create hot water for washrooms, or direct warm air into a workspace, warehouse, loading dock or entryway, the savings can really add up. The possibilities to recover this waste heat via hot air or hot water are good. The return on investment for energy recovery is usually as short as one to three years. In addition, energy recovered by means of a closed loop cooling system (for water-cooled compressors) is **advantageous to the compressor's** operating conditions, reliability and service life due to an equal temperature level and high cooling water quality to name but a few.



Fundamentals of Compressed Air Systems WE

The Compressed Air Challenge® (CAC®) is pleased to announce that the Winter 2010 session of **Fundamentals of Compressed Air Systems WE** (web-edition) is coming soon. Led by our experienced instructors, this web-based version of the popular **Fundamentals of Compressed Air Systems** training uses an interactive format that enables the instructor to diagram examples, give pop quizzes and answer students' questions in real time. Participation is limited to 25 students. Please visit www.compressedairchallenge.org to access online registration and for more information about the training.



If you have additional questions about the new web-based training or other CAC® training opportunities, please contact the CAC® at info@compressedairchallenge.org or call 301-751-0115.

The temperature level of the recovered energy determines the possible application areas and thereby, the value.

This diagram illustrates some of the typical application areas for energy recovery available from the compressors cooling water in different temperature ranges. In the highest temperature levels (from oil-free compressors) the degree of recovery is the greatest. The highest degree of efficiency is generally obtained from water-cooled installations, where the compressor discharge cooling water can be connected directly to a continuous-process heating requirement. For example, the heating boilers' return circuit. Surplus energy can then be effectively utilized all year round. Most new compressors from the major suppliers can be adapted to be supplemented with standard equipment for recovery.

"Compressors are better at producing heat than compressed air," says Tom Taranto of Data Power Services.

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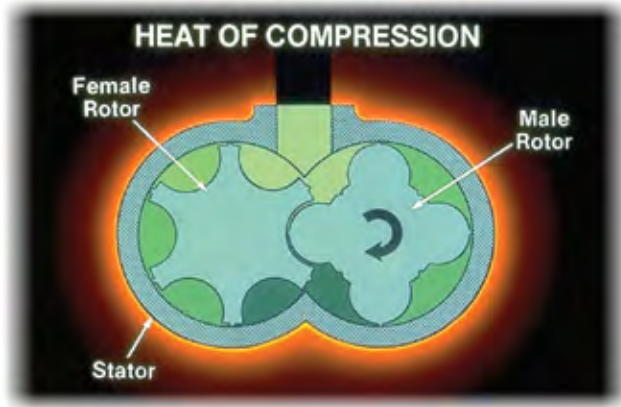
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HEAT RECOVERY AND COMPRESSED AIR SYSTEMS



Heat Recovery with Air-Cooled Lubricant Injected Rotary Screw Compressors

Air-cooled, packaged, rotary screw compressors are very amenable to heat recovery for space heating or other hot air uses. Ambient atmospheric air is heated by passing it across the system's aftercooler and lubricant cooler, where it extracts heat from both the compressed air and the lubricant that is used to lubricate and cool the compressor. This is relatively low-temperature heat (under 100 °F) and is therefore pretty limited in its application.

As a rule, approximately 50,000 British thermal units (BTU) per hour of energy are available for each 100 cfm of capacity (at full load). This value is based on 80% recoverable heat from the compressor and a conversion factor of 2,545 BTU/bhp-hr. Air temperatures of 30–40 °F above the cooling air inlet temperature can be obtained. Recovery efficiencies of 80–90% are common. Caution should be applied if the supply air for the compressor is not from outside and the recovered heat is used in another space, because this can cause a decrease in the static pressure in the cabinet or room and reduce the efficiency of the compressor. A decrease in static pressure or “negative pressure” has the same effect as throttling the inlet of the compressor, which changes the compression ratio, thus reducing efficiency. If outside air is used, some return air may be required to avoid damaging the compressor with below freezing air.

Because packaged compressors are typically enclosed in cabinets and already include heat exchangers and fans, the only system modifications needed are the addition of ducting and possibly another fan to handle the duct loading and to eliminate any back pressure on the compressor cooling fan. These heat recovery systems can be modulated with a simple, thermostatically controlled hinged vent. When heating is not required — such as in the summer months — the hot air can be

ducted outside the building. The vent can also be thermostatically regulated to provide a constant temperature for a heated area. Hot air can be used for space heating, industrial drying, preheating aspirated air for oil burners or any other application requiring warm air.

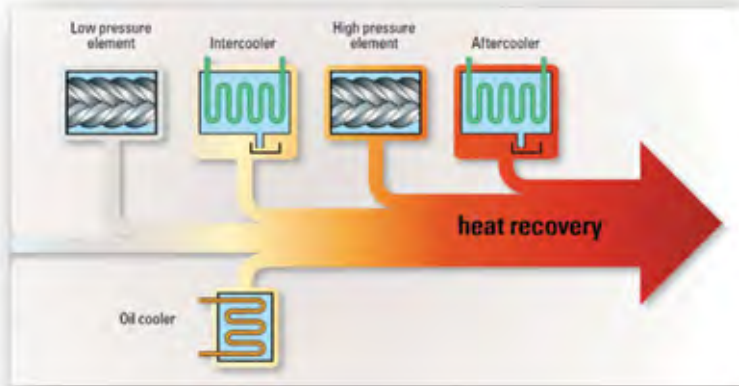
Energy recovery from air-cooled compressor installations will not always give heat when it is required and perhaps not in sufficient quantities. The quantity of recovered energy will vary if the compressor has a variable load. In order for recovery to be possible, a corresponding energy requirement is needed, which is normally met through an ordinary system supply. Recovered energy is best utilized as additional energy to the ordinary system, so that the available energy is always utilized when the compressor is running.

Heat Recovery with Water-Cooled Lubricant Injected Compressors

Heat recovery for space heating is not as common with water-cooled compressors because an extra stage of heat exchange is required and the temperature of the available heat is lower. Because many water-cooled compressors are quite large, however, heat recovery for space heating can be an attractive opportunity. Recovery efficiencies of 50–60% are typical. With water-cooled, lubricant-injected rotary screw compressors using a heat exchanger, it is possible to extract waste heat from the lubricant coolers and produce hot water. (Because of the possibility of a tube failure, a double-wall lubricant cooler is often recommended.) Depending on design, heat exchangers can heat non-potable (gray) or potable water. When hot water is not required, the lubricant is routed to the standard lubricant cooler.

Hot water can be used in central heating or boiler systems, industrial cleaning processes, plating operations, heat pumps, laundries or any other application where hot water is required. Heat exchangers also offer an opportunity to produce hot air and hot water, and enable the operator some ability to vary the hot air/hot water ratio.

The key to the value of heat recovery is that there must be a thermal match between the heat recoverable and needed, and an hourly match between when it's produced and needed. The installation cost must also be considered. Just because there is heat available does not mean that it is economical to recover it. Often on small units, it just doesn't pay to spend a lot of money on heat recovery systems — there just aren't enough BTUs there. Also, a heat bypass system should still be installed for times when the air compressor is running and the heat is not needed.



Heat Recovery with Engine-Driven Compressors

Engine-driven compressors have the same kind and volumes of low-grade heat available off the air end, but there is also a higher-temperature option off the engine. Depending on the size of the engine, it is even possible to generate low-pressure steam off the exhaust. Engine jacket water is available at 180–220 °F. A general rule of thumb is that 30% of the gas input energy is available as high-temperature heat. If the application temperature is low enough, up to 90% of the input energy could be recovered.

A typical engine-driven air compressor requires about 11,000 BTUs/horsepower input. Therefore, a 200 hp unit would require about 2.2 million BTUs input and the heat recovery potential would be at least 660,000 BTUs. That is comparable to a small boiler, running the same hours as the air compressor. Larger industrial-grade engines (greater than 250 hp) can have gas inputs as low as 7,500 BTUs/hp.

Heat Recovery with Water-Cooled Oil-Free Compressors

Oil-free rotary screw compressors offer a much better opportunity for heat recovery. As is typical with all compressors, the input electrical energy is converted into heat. Discharge temperatures from the low- and high-pressure elements can be over 300 °F. This heat appears at the low-pressure and high-pressure compression elements, the oil cooler, the intercooler and the aftercooler. Some manufacturers offer built-in energy recovery systems, which circulate cooling water through all four of these components and, as a result of the heat transfer, can yield hot water at up to 194 °F.

CAC Qualified Instructor Profile

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Mr. Frank Moskowitz has an extensive background, with more than 30 years of experience in plant engineering. He has a degree in mechanical engineering and education, including the refrigeration, electrical and plumbing trades. For the past 20 years, Frank has been an associate of Draw Professional Services, primarily in the auditing, consulting, training and system design fields. His specialty consists of compressed air systems (oil-flooded and oil-free), vacuum systems, contaminate removal, system design and energy management. Frank is a Compressed Air Challenge® instructor for the Fundamentals and Advanced levels of training, an AIRMaster+ instructor and a Department of Energy (energy-savings) expert on compressed air systems. Frank is also vice-chair for ASME Standard EA-4-2010 “Energy Assessment for Compressed Air Systems” and is a member of International Standards Organization (ISO) technical committee for air compressors and compressed air systems energy management TC118/SC6/WG4.



The instructors featured here are available to lead a Compressed Air Challenge seminar at your facility. Visit www.compressedairchallenge.org for more information.

HEAT RECOVERY AND COMPRESSED AIR SYSTEMS

Calculating Energy Savings

When calculating energy savings and payback periods for heat recovery units, it is important to compare heat recovery with the current source of energy for generating thermal energy, which may be a low-price fossil fuel, such as natural gas. The equations in the text box below illustrate the annual energy and costs savings available by recovering heat for space heating from an air-cooled, rotary screw compressor. Applications where the existing heater is less than 85% efficient will see proportionally higher savings.

These equations appear in the CAC® “Best Practices for Compressed Air Systems.” (This 325-page manual is available at the CAC® bookstore)

Annual Energy Savings (BTU/yr)=

0.80 x Compressor bhp x 2,545 BTU/bhp-hour x hours of operation

Example: A 100 hp compressor running two shifts, 5 days per week

$(0.80) \times (100 \text{ bhp}) \times (2,545 \text{ BTU/bhp-hour}) \times (4,160 \text{ hours per year}) = 846,976,000 \text{ BTU per year}$

Where:

0.80 is the recoverable heat as a percentage of the unit's output

2,545 is a conversion factor

Cost Savings (\$/yr) =

$([\text{Energy Savings in Btu/yr}]/[\text{Btu/unit fuel}] \times [\$/\text{unit fuel}])/\text{Primary Heater Eff}$

Example: Waste heat will be displacing heat produced by a natural gas forced-air system with an efficiency of 85%

$([846,976,000 \text{ BTU per year}]/[100,000 \text{ BTU/therm}] \times [\$0.40/\text{therm}])/0.85 = \$3,986 \text{ per year}$

* Cost of operating an additional fan for duct loading has not been included.

Source: Compressed Air Challenge


Conclusion

Your compressed air system represents an excellent source for heat recovery and could improve the efficiency of the system overall.

Improving the performance of your compressed air system reduces your plant-wide energy costs. It can reduce downtime, increase your production throughput, lower your scrap rate, improve product quality and create longer equipment life.

You can find much more information on improving plant compressed air system performance and regaining the lost energy at www.compressedairchallenge.org.

This web site provides details on the Compressed Air Challenge®, a voluntary collaboration of industrial compressed air users, compressed air equipment manufacturers, distributors and their associations, compressed air consultants, state research and development agencies, organizations for efficient energy use and power utilities.

This group has one purpose in mind — helping you obtain and enjoy the benefits of improved performance of your compressed air system. 

Frank Moskowitz
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