Heat recovery from air compressors

Air compressors are widely used in industrial applications to compress air from ambient conditions; that can be humid and at 1 bar absolute, to most popularly 6 bar and dried from entrapped moisture. Compression is either by piston type or screw-type compressors, whereby the air molecules are squeezed, consequently increasing the compressed air temperature up to 60°C. The friction also increases the lubrication oil temperature as high as 80°C, which must be cooled down for efficiency.

A well-known fact is that a massive **72% to 90% of the electrical energy used by air compressors is released as waste heat**. This heat, if not recovered, is thrown out to the atmosphere and wasted, where at the same time, there can be a boiler burning fossil fuels to heat water or generate the steam needed for different processes in the plant. Sadly, the waste heat from the compressor is released to the atmosphere by an open/closed cooling tower or where not available can be an air cooler.

Typically, there are two in built heat exchangers to exchange the heat which can either be shell and tubes, brazed plate heat exchangers for their compactness or gasketed plate heat exchangers (GPHE) for their ease of cleaning and compactness. The choice will depend on the manufacturer of the compressor.

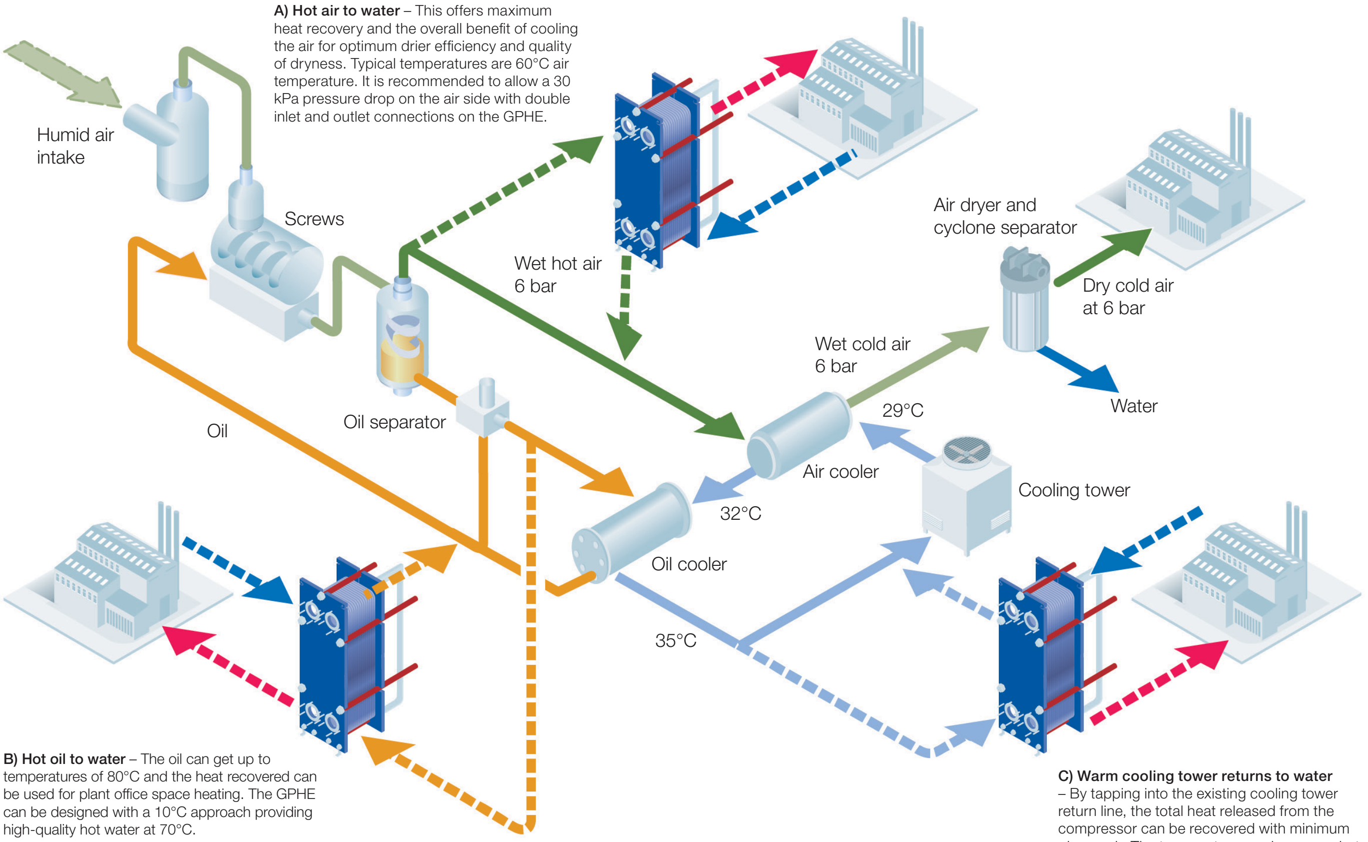
Benefits of heat recovery

Recovering waste heat from air compressors not only has environmental benefits in sustainability, reducing carbon emissions and monetary savings, helping plant profitability but also improves the dryness quality of the air that has just been compressed. For the dryer located after the air cooler, needs to further cool the air down to 3°C to remove the moisture that is inherent in the humid air intake. Heat recovery savings are also in the extended life of power tools and other air-operated equipment, as *moist compressed air* is a significant problem at points of usage

The diagram below shows a typical compressor working. For previously installed and operating air compressors heat recovery is still possible not having to remove or replace the existing coolers. If the compressor is cooled with an open cooling tower, all the above alternatives in heat recovery will provide extra savings as below:

- Free up cooling tower capacity
- Savings in water with less water evaporation
- Reduction in tower water treatment costs
- Reduced electricity costs with tower fan operation
- Less make up water usage, hence less $CaCO_3$ in the system avoiding build-up.

A) Hot air to water – This offers maximum heat recovery and the overall benefit of cooling the air for optimum drier efficiency and quality of dryness. Typical temperatures are 60°C air temperature. It is recommended to allow a 30 kPa pressure drop on the air side with double inlet and outlet connections on the GPHE.



B) Hot oil to water – The oil can get up to temperatures of 80°C and the heat recovered can be used for plant office space heating. The GPHE can be designed with a 10°C approach providing high-quality hot water at 70°C.

C) Warm cooling tower returns to water – By tapping into the existing cooling tower return line, the total heat released from the compressor can be recovered with minimum pipe work. The temperature can be somewhat lower and mixed compared to options A and B; however, this is the simplest and cheapest way to recover.

Solutions for sustainability

How to identify potential savings
Model numbers typically refer to the installed motor power. A model XXX 72 YY would mean a 72 kW power consumption. This compressor can provide between 4-13 bar compressed air depending on the need, with a varying proportional compressed air volume of 8.8 to 6.4 normal m³/min. The equipment weight is approximately 1.5 tonnes.

Example:
The running cost of a compressor consuming 72 kW of electricity for 24 hours a day is 1,173 euro per month (72 kW x 24 hr x 0.1 euro/kWh = 1,173 euro). The produced heat is 80% of this power consumed and is released to the atmosphere as waste heat which can be recovered.

Heat recovered from the compressed air or lubricating oil can produce hot water that can be used for a multitude of applications in a plant:

- Heating of office or production facilities
- Preheating hot water boiler feed
- Preheating steam boiler feed
- Hot water for cleaning
- Hot water for bathing & showers
- Use in production processes
- Supply to district heating network

Of the 72 kW of electrical motor power driving the screws, we can assume 80% is heat rejection which will be 72 x 80% = 57.6 kW

Most of the heat is absorbed into the lubricating oil and not the compressed air. The proportion is close to 90/10. Heat in the oil in the above example is approximately 52 kW and the compressed air is only 6 kW (compressed air is not a worthwhile investment for heat recovery).

Heat recovery

Oil to heating circuit

Lubricating oil:	95/90/85°C → 65/60/55°C
Heating water:	80/75/70°C ← 50/45/40°C

Oil to tap water

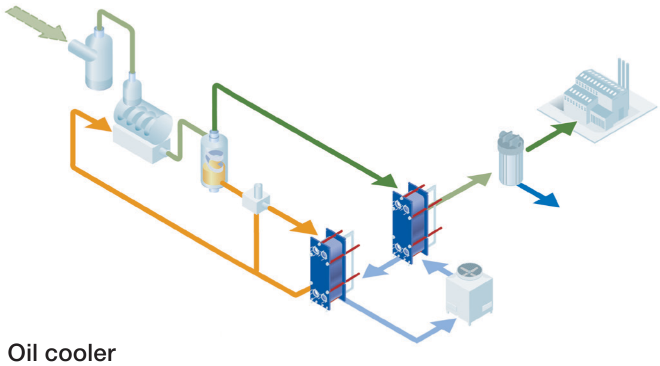
Lubricating oil:	95/90/85°C → 65/60/55°C
Heating water:	80/75/70°C ← 30/25/20°C ***

*** Keep the exit temperature on the oil above 50°C in order to maintain desired physical properties of viscosity and lubrication, with good automation.

- With the compressor located inside the plant room, the GPHE can be partially installed inside the cabinet or protruding slightly from the cabinet.
- With replacement, existing heat exchangers can be removed.
- With heat recovery, it is advisable to keep the installed heat exchangers, which need to be used when heat recovered is not used and cooling done with existing systems.

A protective shroud can be installed over the plate pack for the compressed air cooler to prevent leakage to surroundings.

Replacing a shell-and-tube or brazed heat exchanger



Oil cooler
Assume worst case temperatures for oil and cooling tower water.

Lubricating oil:	85°C → 55°C
Cooling tower water:	35°C ← 29°C (or local conditions)

Air cooler
Compressed air is typically expressed in volumetric flow as Nm³ /min. We must assume the air is with some moisture which we can disregard.

Compressed air:	60°C → 40°C
Cooling tower water:	31°C ← 29°C (or local conditions)

Manufacturers literature will show the amount of compressed air flow per model of compressor, as minimum and maximum flow.

The more the compressed air is cooled the better, as this will help drying the air at the dryer, which reduces the air temperature to 3°C with refrigerant, drains the water via a cyclone separator and is reheated with incoming air, ultimately available to the user at 25-35°C and dry from moisture.

▼ PRACTICAL TIPS

When selecting GPHEs for compressor oil cooling to recover heat, Oil ISO VG 46 properties can be used as a general guide.
Its properties are such that at 15°C the density is 0.86 kg/dm³, and at 40°C the viscosity of the oil is 40 centipoise.