Our Planet, Our People.

Sustainability in compressed air technology

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Overview

Environmental responsibility is an increasing priority among users of air compression systems. Socially and ecologically responsible processes help to ensure a sustainable future for the earth and the people who call it home.

Sustainability factors in choosing an air compression system

Energy efficiency, maintenance requirements, heat exchange and air quality are important sustainability factors. A sustainable air compression system performs well at relatively low temperatures, with minimal air leakage and pressure drops, therefore producing more compressed air for less energy.

Diagram 1: Efficient use of energy is not only important for the environment, but is also becoming an economic necessity

Type of compressor

While piston compressors remain the most common type in many industries, a screw compressor may be the preferred option where sustainability and efficiency are priorities. The percentage of operation time without excessive wear and risk of overheating, known as the allowable duty cycle, of a piston compressor is around 60 to 70 percent. This results in frequent shutdown for cooling, increased wear and tear and operation over a wide pressure band. It also requires an oversized system to meet demand during cooldown periods. By contrast, rotary systems typically have a 100 percent allowable duty cycle and can therefore run continuously.

A piston compressor usually has a larger footprint. This, combined with higher noise volume, oil carry-over and vibration, usually necessitates external installation. More materials are therefore required, and performance may be impacted. Conversely, more options are available for positioning a rotary system, allowing maximum performance and a location with optimal ventilation.

An additional consideration is internal operating temperature. A piston compressor can operate at 150 to 200°C, while an oil cooled rotary system runs at significantly lower temperatures of around 75 to 95°C.

Minimising leakage and pressure drop

With air compression already accounting for up to 30% of a facility's energy consumption, leakages can have significant environmental consequences. Pressure drop also compromises sustainability by reducing the efficiency of air compression. Pipe diameter, materials and system design can all influence leakage and pressure drop.

Pipe diameter has a major impact on compressed air system performance. For example: A system with a 7.5kW motor delivering compressed air of 1m³ per minute would have a 0.5 bar pressure drop through 100 metres of straight metal pipe of 20mm diameter. By contrast, pressure drop would be only 0.13 bar with a 25mm diameter pipe in the same conditions.

Material quality and maintenance is another important consideration. Plastic piping materials, while often cheaper, are more susceptible to breakage, increasing the likelihood of leakages. Additionally, interior surfaces may deteriorate and abrade, which increases pressure drop. More durable piping materials are recommended for sustainability of the system and to minimise leakage.

Design plays a key role in system sustainability. An efficient system will have minimal turns, sufficient bracing for piping that hangs from walls or ceilings, and flexible fittings between components to minimise vibration. A well-designed system will also take future expansion into account by using the largest feasible piping diameter at the time of installation: upgrading an existing system is much more resource-efficient than replacing a system when user needs increase.

Exhaust heat reuse

Heat recovery can make an enormous difference to energy efficiency. Up to 96 percent of the drive energy supplied to a compressor is available for reuse. Exhaust heat can be sent directly into ducts for heating nearby rooms, with thermostatic control enabling consistent temperatures.

Exhaust heat can also be used for drying processes, hot air curtains, or preheating burner combustion air for heating systems. Compressor heat can also be fed into hot water systems using plate heat exchangers. The heat exchanger is connected to the compressor's cooling circulation system and transfers energy from the warm coolant to the water. Depending on the intended use case for the heated water, fail-safe heat exchangers may be used in conjunction with plate heat exchangers. Using these heat exchangers, up to 76 percent of the installed compressor power can be used for heating purposes without additional energy consumption, while the compressor is operating under full load.

"Heat recovery allows the heat generated by the compression process to be used elsewhere, such as space or water heating, without additional energy consumption"

Moisture control

Around 140 litres of condensate is produced by an average compressed air system over 24 hours. If the air is not dried following the compression process, condensation can accumulate in the downstream equipment, reducing the system's lifespan. Saturation capacity of the air increases with higher ambient temperatures, bringing more vapour into the compressor. Some systems may not be designed for hot Australian summers, so it's important to select a drying method with capacity to operate reliably during peak temperatures.

Drying is an energy-intense process, so the air inlet temperature at the dryer should be as low as possible to maximise efficiency. Aftercoolers, used in some systems such as screw and piston compressors, cool the compressed air to near-ambient temperature and lower its pressure dew point before it enters the dryer.

Refrigerated air dryers are usually sufficient for ISO 8573-1: 2010 Class 4 compressed air requirements. A refrigerated dryer lowers the pressure dew point of the compressed air to around 3°C. Older refrigerated dryers use 404A, which has a Global Warming Potential (GWP) rating of 3,922 – one of the highest of any refrigerant on the market. Newer dryers, however, use R-513A which, with a GWP of 631, is much more environmentally friendly. Modern refrigeration dryers also include cycling control, adapting energy usage according to changing operating conditions.

While a desiccant dryer can bring pressure dew points down to -70°C for those with Class 1 compressed air requirements, users considering sustainability will note its high energy demand. A combination system, such as Kaeser's Hybritec, uses refrigeration to cool the pressure dew point to 3°C, then desiccants to cool to around -40°C. Since the air is pre-dried, the energy use is notably reduced.

Oil-free compressors may not need refrigerant dryers at all. With more heat generated than in oil-filled machines, a heat of compression dryer can use the heat exchangers of the second compression stage as regeneration air coolers. This full-flow regeneration uses the heat that is already produced, eliminating additional energy demands.

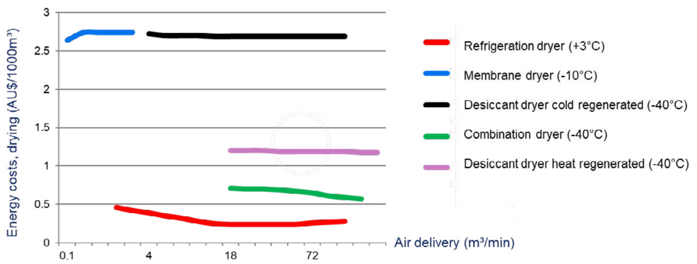

Diagram 2: Selecting the correct dryer type and pressure dew point for the application can significantly lower energy costs.

Waste oil management

During compressed air generation, significant volumes of oil-contaminated condensate is produced. Modern solutions integrate advanced filtration technologies and automated monitoring to provide a cost-effective and environmentally responsible approach to oil/water separation. This not only prevents contamination of downstream components but also extends system longevity and reduces maintenance demands.

Investing in these innovations ensures compliance with environmental requirements while delivering long-term operational benefits. Advanced filtration systems should employ long-lasting filter materials that extend service life and minimise waste. The use of advanced filter media within the separator allows for high retention efficiency while maintaining a compact footprint. Additionally, the containing the entire oil volume within the filter cartridge avoids contamination during maintenance activities thus contributing to a safer and more environmentally responsible operation. By reducing the volume of waste requiring specialised disposal, businesses can achieve significant cost savings over time.

For optimal performance, oil/water separation systems should incorporate intelligent monitoring features. These systems continuously monitor filter saturation and operational status, alerting maintenance personnel when replacements are required. This proactive approach minimises downtime, reduces unnecessary filter changes and ensures ongoing environmental compliance. In the event of a failure (e.g. a power outage), the system must be able to continue to operate as a conventional gravity separator, ensuring uninterrupted operation without leakages to the environment.

Condensate flow path, from entering the pressure relief chamber (1) to the discharge water outlet (9)

Diagram 3: Separation of oil and condensate allows for appropriate disposal of waste as well as preventing contamination of waterways

Industry 4.0: Smart efficiency

Smart technology systems can substantially increase energy efficiency. A smart control system can optimise the air compressor to find the energy/efficiency 'sweet spot,' facilitating more compressor activity at peak periods and conserving energy when it is not required.

Using real-time analysis, an AI-powered remote monitoring system can identify compressed air usage pattern, leaks, faults and inefficiencies. This allows for timely maintenance to avoid unscheduled downtime. It also ensures that the user is not bound to pre-existing part replacement schedules: parts are replaced only when needed, thus minimising unnecessary waste.

An optimised compressor system can reduce CO^2 emissions by up to 73 percent compared with a non-optimised one, amounting to an annual saving of 139.7 tons of CO^2. With energy costs accounting for up to 70 percent of total expenses, an efficient system also significantly reduces the lifetime costs of the system.

> Sustainability factors into all aspects of the compressed air industry, from manufacture and packaging to installation and ongoing use.

Selecting a compressed air equipment vendor

The United Nations has set 17 goals for social, economic and environmental sustainability. Commitment to caring for people and the planet in the air compression industry aligns with several of these goals. Selecting a vendor that offers products which not only operate extremely cost-efficiently and in the most eco-friendly manner, but also consume as few valuable environmental resources as possible during production, sales and service, is an important step towards sustainability.

Manufacture

A sustainable manufacturing process uses resources efficiently, minimises waste and takes advantage of modern renewable energy options. LED lighting, effective building insulation and adsorption cooling cycles are examples of efficient energy use. Further, renewable electricity sources such as solar power, wind farms and waste-to-energy incinerators can provide reliable energy supply to a manufacturing plant, thus reducing or even eliminating the production of greenhouse gases.

Considerate use of resources creates a minimum of waste. Material purchasing should be calculated to avoid over-supply and excessive disposable packaging, and scrap can be recycled or re-purposed. When waste is unavoidable, thoughtful disposal such as the use of oil-water separators to keep oils and contaminants from waterways can reduce environmental harm.

Packaging and supply

Petrochemical-based packaging materials such as polystyrene foam and plastic bubble wrap contribute to the proliferation of microplastics in the environment, emit greenhouse gases in their manufacture, and add to landfill. Plastic packaging that is not disposed of correctly also pollutes waterways and damages ecosystems.

Manufacturers should aim to eliminate plastic packaging and consider reusable, compostable and recyclable options. These may include materials that can be returned to the supplier for reuse, or those that can be added to kerbside recycling. Compostable products, where available, should be compliant with Australian Standards 4736 (industrial compost) or AS 5810 (domestic compost).

Practical examples of sustainable packaging materials include die-cut packaging made from honeycomb cardboard, biodegradable bubble wrap alternatives, and paper-based packing tape. Many sustainable packaging options are also light in weight, thus minimising carbon emissions in transportation.

According to the Department of Infrastructure, the transport sector is Australia's third-largest source of greenhouse gas emissions. Use of electric vehicles in delivery fleets, powered by renewable energy, significantly reduces carbon emissions. Where fully carbon-neutral transport is not feasible, carbon credits can be purchased from certified providers to offset emissions.

Ancillary services

Optimal functionality is essential for sustainability. Improving the compressed air system starts with an air audit to identify basic compressed air use, followed by an air demand analysis (ADA). ADA can identify issues and provide customised recommendations to ensure an efficient system that is fit for purpose.

It is estimated that half the compressed air generated in a typical system is lost through leaks, artificial demand and suboptimal design. A system may therefore be mistakenly perceived as insufficient, with the user seeking unnecessary upgrades. Advice is recommended before changes to a compression system, as ADA often identifies inefficiencies that can be rectified without the need for expansion or replacement.

For example, enabling consistent pressure and optimised run time can ensure that performance matches demand. This prevents systems being over-specified and therefore using more energy than required. Quality air compression at a consistent pressure also reduces maintenance requirements and minimises downtime.

When maintenance is required, the use of quality parts ensures greater functionality and a longer product lifespan, keeping energy costs and breakdowns to a minimum. Oil changes can also be reduced through sample testing, and EPA-approved oil recycling companies can be engaged for safe disposal. Carbon emissions can therefore be reduced by not only maximising efficiency but also reducing the need for production, supply and delivery of parts and by recycling waste products.

Social responsibility

A sustainable company considers people as well as carbon emissions. The health and wellbeing of staff can be optimised through comprehensive work health and safety systems that minimise the risk of accident or injury, and through the promotion of healthy lifestyles by providing exercise equipment or recreational facilities.

Companies should also ensure that staff receive quality education and training, and provide avenues for innovation and leadership to ensure maximal career satisfaction. Equitable employment opportunities and consistent pay rates can help to move a company towards gender equality and inclusion.

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