EFFICIENT COMPRESSED AIR SYSTEMS

HOW TO SAVE ENERGY, REDUCE COSTS AND HELP THE ENVIRONMENT

2 COMPRESSED AIR - EFFICIENT UTILISATION

Equipment selection and system design play an important role in lowering the costs of producing compressed air (see Efficient Compressed Air Systems 1. Compressed Air Selection and Efficient Production). However, purchasing an efficient system is not all there is to saving energy and money. Ensuring that installed systems are running as efficiently as possible can allow you to make great gains.

LEAKS

Leaks can be a significant source of wasted energy in an industrial compressed air system and may be costing you much more than you think. Audits typically find that leaks can be responsible for between 20-50% of a compressor's output making them the largest single waste of energy. In addition to being a source of wasted energy, leaks can also contribute to other operating losses:

- Leaks cause a drop in system pressure. This can decrease the efficiency of air tools and adversely affect production
- Leaks can force the equipment to cycle more frequently, shortening the life of almost all system equipment (including the compressor package itself)
- Leaks can increase running time that can lead to additional maintenance requirements and increased unscheduled downtime
- Leaks can lead to adding unnecessary compressor capacity

Therefore, proactive leak detection and repair can have a significant effect on your business. Table 1 lists the estimated amount of air leaks for a system operating at a pressure of 700 kPa, for 2000 hours per year and the energy wasted.

Table 1. Air Leakage And Annual Energy Wastage By Equivalent Hole Diameter

Equivalent hole diameter (mm)	Quantity of air lost in leaks (l/s)	Annual energy waste (kWh)	Annual cost of leaks ($ AUD)
0.4	0.2	133	$13
0.8	0.8	532	$53
1.6	3.2	2,128	$213
3.2	12.8	8,512	$851
6.4	51.2	34,040	$3,404
12.7	204.8	136,192	$13,619

The first step is to be able to distinguish between base leakage and minimum usage. End-uses such as instrumentation or agitation systems, which need to operate 24 hours a day, can sometimes be confused with leakage. There are several methods that can be used to measure the level of compressed air leakage.

For compressors that use start/stop controls, the method involves starting the compressor when there are no demands on the system, that is when all the air-operated end-use equipment is turned off. Air escaping through the leaks will cause pressure drops, which in turn will make the compressor load and unload. Measurements to determine the average time it takes to load and unload can then be taken. Total leakage expressed in terms of the percentage of compressor capacity lost can be calculated as follows:[1]

$$\text{LEAKAGE } (\%) = [(T \times 100)/(T+t)]$$

WHERE T = ON-LOAD TIME AND

t = OFF-LOAD TIME

In systems without on/off controls leakage, can be estimated if there is a pressure gauge downstream of the receiver. This method requires an estimate of total system volume, including any air receivers, air mains, and piping that are downstream of the receiver isolating valve (V, in cubic metres). The system is then run at normal operating pressure (P_1). You will then need to record the time (T) it takes for the system to drop to a lower pressure (P_2), which should be a point equal to about one-half the operating pressure. Leakage can be calculated as follows:

$$\text{LEAKAGE } (m^3/s) = (V \times (P_1-P_2)/T(\text{SECS})$$

WHERE: V TOTAL SYSTEM VOLUME IS CUBIC METRES

P_1 AND P_2 ARE IN BAR(g)

T IS IN SECONDS

[1] UK Department of Environment Transport and Regions, Good Practice Guide 126, 1994

You can estimate the annual cost of the leakage by using the formula:[2]

0.4 X (COST PER KWH IN $) X (NO. OF HOURS RUN PER YEAR) X (LEAKAGE RATE IN LITRES/SEC)

A well-maintained system should have a leakage level less than 10%. These tests should be carried out quarterly as part of a regular leak detection and repair program.

Leakage can come from any part of the air compressor system and the sources can be numerous. The most common problem areas are:

- Couplings, hoses, tubes, and fittings
- Pressure regulators
- Open condensate traps and shut-off valves
- Pipe joints, disconnects, and thread sealants
- Air cooling lines permanently left open
- Air using equipment left in operation when not needed

Air leaks are almost impossible to see so other methods must be used to locate them. The simplest method is to inspect the plant during a quiet time. Listen for pipe work or tool leaks and examine hoses and couplings for air tightness. Alternatively, a reliable but time consuming method is to apply soapy water with a paint brush to suspect areas and watch for bubbles. However, the most comprehensive way to detect leaks is to use an ultrasonic acoustic detector that can recognize the high frequency hissing sounds associated with air leaks. These portable units consist of directional microphones, amplifiers, and audio filters, and usually have either visual indicators or earphones to detect leaks.

When looking for leaks you should investigate the following:

CONDENSATE TRAPS	Check if automatic traps are operating correctly and avoid bypassing.
PIPE WORK	Ageing or corroded pipe work.
FITTINGS AND FLANGES	Check joints and supports are adequate. Check for twisting.
MANIFOLDS	Check for worn connectors and poorly jointed pipe work.
FLEXIBLE HOSES	Check that the hose is moving freely and clear of abrasive surfaces. Check for deterioration and that the hose has a suitable coating for the environment eg oily conditions. Is the hose damaged due to being too long or too short?
INSTRUMENTATION	Check connections to pneumatic instruments such as regulators, lubricators, valve blocks and sensors. Check for worn diaphragms.
PRESS AND DROP HAMMERS	Use a flow meter at the feeding points to check for internal leaks. Internal leaks are expensive to fix but can be responsible for up to 80% of demand.
PNEUMATIC CYLINDERS	Check for worn internal air seals.
FILTERS	Check drainage points, ill fitting bowls, and contaminated bowls.
TOOLS	Check hose connections and speed control valve. Check air tools are always switched off when not in use.

When inspecting the plant a system of tagging identified leaks will assist in timely repair. Staff can also use tagging if they observe leakages during day to day operation. Stopping leaks can be as simple as tightening a connection or as complex as replacing faulty equipment such as couplings, or pipe sections. Leaks can also be caused by bad or improperly applied thread sealant. Select high quality fittings, disconnects, hose, tubing, and install them properly with appropriate thread sealant. Equipment no longer in use should be isolated with a valve in the distribution system. Leakage is an ongoing issue with new leaks able to occur at any time. Therefore, to minimise the costs to your business, it is important the tasks of detecting and repairing leaks is carried out at least every 6 months.

PRESSURE DROP AND RETICULATION SYSTEM

Pressure drop is a term used to describe any reduction in air pressure that occurs after it leaves the compressor until it reaches the point of use. Pressure drop occurs as the compressed air travels through dryers, separators, filters, piping etc. While some loss in pressure is to be expected, a properly designed system should have a pressure drop below 10% of the compressor's discharge pressure. Pressure drop should be measured from the receiver tank output to the point of use.

Unnecessary pressure drop leads to supply pressure being increased to compensate for the losses. Excessive pressure drop will result in poor system performance and excessive energy consumption. Elevating system pressure to compensate for pressure drop can increase unregulated uses such as leaks, open blowing and production applications without regulators or with wide open regulators. Seeking ways to reduce pressure drop rather than increasing discharge pressure or adding additional compressor capacity will be far more efficient and beneficial to the system.

Any type of obstruction, restriction or roughness in the system will cause resistance to air flow and cause pressure drop. System components should be selected based upon air flow rate and air temperature. The manufacturers often supply pressure drop information for each component under these conditions. The incorrect sizing of pipes can result in excessive pressure drop. Air should travel at a velocity of approximately 6-10m/s– the higher the velocity the higher the pressure drop[3]. To calculate the velocity determine the free air delivery (i.e., the volume of air delivered per second, which should be stated on the compressor) and the cross sectional area of the pipe (3.14 x radius^2). Then divide the volume by the area as shown in the formula below:

VELOCITY (m/s) = VOLUME (m^3/sec)/AREA OF PIPE(m^2)

Other areas within the system that typically have problems with pressure drop include the aftercooler, lubricant separators, and check valves.

Minimizing pressure drop requires a systems approach in design and maintenance of the system. Air treatment

2 UK Energy Efficiency Best Practice Programme – Guide 41

3 UK Department of Environment Transport and Regions, Good Practice Guide 126, 1994

components, such as aftercoolers, moisture separators, dryers, and filters, should be selected with the lowest possible pressure drop at specified maximum operating conditions. When installed, the recommended maintenance procedures should be followed and documented. Additional ways to minimize pressure drop are as follows:

- Properly design the distribution system. For example, minimise bends in the piping, reduce the distance the air travels
- Operate and maintain air filtering and drying equipment to reduce the effects of moisture, such as pipe corrosion
- Select aftercoolers, separators, dryers and filters that have the lowest possible pressure drop for the rated conditions
- Specify pressure regulators, lubricators, hoses, and connections that have the best performance at the lowest pressure

When purchasing components work with suppliers to ensure that products most efficiently meet the desired specifications for the air pressure required taking into account all of the system characteristics.

AIR INLET TEMPERATURE

Providing cooler air to the compressor at intake can provide good savings. If air is drawn from a cool, dry source, rather than from a hot compressor house, the system will operate more efficiently. Experience shows that using cooler outside air rather than hot compressor room air can save up to 6% of compressor power. Generally for every 3^0C reduction in inlet temperature there is a 1% reduction in energy usage[4]. For example, if an air compressor operating for 2000 hours per year with an electricity tariff of 10 c/kWh reduced the compressor inlet temperature by as little as 6°C, the annual cost saving could be as much as $A4,600. Ducting outside air directly into the compressor inlet, especially from a cool shaded area, (typically the southern side of the building) is a very cheap way to save on compressed air costs. The payback for this type of installation is commonly between 2 and 5 years.

4 Sustainable Energy Development Authority NSW, Energy Savings Manual, 2000

SERVICE

Compressed air systems require periodic maintenance to operate at peak efficiency and minimize unscheduled downtime. An inadequate service routine can have a significant impact on energy consumption causing lower compression efficiency, air leakage, or pressure variability. Poorly maintained equipment can lead to high operating temperatures, poor moisture control, and excessive contamination. Most problems are minor and can be corrected by simple adjustments, cleaning, part replacement, or the elimination of adverse conditions. Compressed air system maintenance is similar to that performed on cars; filters and fluids are replaced, cooling water is inspected, belts are adjusted, and leaks are identified and repaired.

At a minimum all equipment in the compressed air system should be maintained in accordance with manufacturers' specifications. Manufacturers provide inspection, maintenance, and service schedules, which are designed to protect equipment and should be followed. However, in many cases, sizeable efficiency and economic benefits can be gained by undertaking a more vigorous maintenance program with more frequent inspections.

Some of the key maintenance areas are:

COMPRESSOR PACKAGE	The compressor and intercooling surfaces need to be kept clean. Fans and water pumps should also be inspected to ensure that they are operating at peak as performance. Check system for compressor and motor lubricant leaks and cleanliness.
INLET FILTER CARTRIDGES	Inspect and clean or replace. Inlet filters and inlet piping should be maintained at least as per manufacturer's specifications, taking into account the level of contaminants in the facility's air.
DRAIN TRAPS	Clean out debris and check operation periodically.
COMPRESSOR LUBRICANT LEVEL	Inspect daily and top-off or replace as per manufacturer specifications. Change lubricant filter as per manufacturer specifications.
AIR LUBRICANT SEPARATOR	Change as per manufacturer specifications, or when pressure drop exceeds acceptable level.
LUBRICANT SELECTION	The compressor lubricant and lubricant filter need to be changed as per manufacturer's specification. Lubricant can become corrosive and degrade both the equipment and system efficiency. For lubricant-injected rotary compressors, the lubricant serves to lubricate bearings, gears, and intermeshing rotor surfaces, acts as a seal and removes most of the heat of compression.
BELT CONDITION	Check belts for wear and check/adjust tension as per manufacturer specifications.
OPERATING TEMPERATURE	Verify that operating temperature is as per manufacturer specification.
AIR LINE FILTERS	Replace particulate and lubricant removal elements if pressure drop occurs. Inspect all elements at least annually regardless of pressure drop indication.
WATER COOLING SYSTEM	For water-cooled systems, check water quality (especially pH and total dissolved solids), flow, and temperature, and clean/replace filters and heat exchangers as per manufacturer specifications.
SYSTEM LEAKS	Check lines (especially joints), fittings, clamps, valves, hoses, disconnects, regulators, filters, lubricators, gauge connections, and end-use equipment for leaks.
COMPRESSOR DRIVE	Lubricate and clean electric motors. Poor maintenance will waste energy, and may cause failure before its expected lifetime.

By periodically benchmarking the system, tracking power, pressure, and flow, you can evaluate if the system is operating properly and being well maintained. If power use at a given pressure and flow rate goes up, the system's efficiency is degrading. This type of testing will also let you know if the compressor is operating a full capacity, and if the capacity is decreasing over time. When installing a new system record these specifications at the initial set-up when first operating properly.

REPLACEMENT PARTS

When purchasing replacement parts it is important not just to consider the price of the part but its suitability for the job. Replacement parts not provided by the original manufacturer need to be verified as having equivalent specifications to the original part. This is especially true when purchasing valves, piston rings, rotary screw elements and air oil separators. Incorrectly matched replacement parts are a common cause of low efficiency and the money saved by buying a cheaper part is quickly overrun by increased energy costs. Also, the use of non- original manufacturer provided parts may void the warranty conditions and expose the user of the compressed air system to increased legal liability in the event of the replacement part being unsafe.

ANALYSIS AND MEASUREMENT SERVICES

Many companies, including leading suppliers, now provide analysis and measurement services to assist with the design, implementation and operation of your compressed air system as efficiently and cost effectively as possible. These companies can assist in assessing your 'true' demand for compressed air, selecting appropriate components or designing maintenance schedules.

CHECK LIST	
Leaks	
	Measure losses due to leakage and calculate cost of leaks
	Determine Source of leaks
	Repair leaks
	Establish a strategy for reporting/detecting leaks
Air Inlet Temperature	
	Duct outside air to reduce air inlet temperature
Pressure Drop	
	Determine the size of pressure drop
	Ensure correct sizing of pipes
	Select components with low pressure drop
	Design system to minimise pressure drop
	Carry out thorough cleaning of dryers and filters
Service	
	Service equipment to manufacturers specifications as a minimum
	Develop a maintenance plan taking into account your plants particular conditions
Replacement Parts	
	Only use genuine parts
Analysis and Measurement Services	
	Your supplier or consulting companies can provide services to assist you streamline your compressed air system

If you would like more information contact:

Air and Mine Equipment Institute of Australasia
www.amei.com.au
email: info@amei.com.au

For up-to-date telephone details please check the AMEI website

ACKNOWLEDGEMENTS:

AMEI acknowledges the support of the Australian Greenhouse Office