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COMPRESSED AIR
ENERGY EFFICIENT EQUIPMENT TOOLKIT

CONTENTS AND PARTNERS

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INTRODUCTION

Compressed air systems serve many applications, including receiving, processing, bottling, and cleaning. They comprise compressors, motors, dryers, receivers, pipe/hose networks, and controls. Compressed air systems contribute 5-20% of the total site energy use, usually as electricity.

EQUIPMENT & PROCESSES

By using your equipment settings more efficiently you can reduce your energy consumption.

UPGRADE EQUIPMENT

You can evaluate what energy reduction benefits your organisation could gain from upgrading to more efficient equipment and/or adjusting combinations of equipment. Consider adopting a selection of the following opportunities according to available resources.

SELECT & PRIORITISE

Learn how to get the best from your equipment and processes and whether you need to upgrade.

COLLECT & CHECK

Learn how to collect data and engage with your suppliers.

OPTIMISE OPERATING SETTINGS

Compressor power decreases with decreasing discharge pressure (pressure measured at the point of leaving the compressor).

USE MINIMUM DISCHARGE PRESSURE

Reduce compressor power use by using the lowest required discharge pressure. Check compressor performance curves for more accurate estimates on potential savings.

POTENTIAL ENERGY SAVINGS

- For compressors operating at around 700kPa, every 100kPa decrease in pressure will reduce compressor power use by 8%. For compressor systems with a high proportion of unregulated end-uses (i.e. equipment using compressed air without a pressure regulator installed in the pipe/hose network), this percentage is even greater

OTHER BENEFITS

- More compressed air capacity for end-use equipment
- Lower maintenance costs
- Longer operating life of compressors system equipment

EQUIPMENT/MATERIAL

- None required

Use the lowest discharge pressure setting possible

Leakage is usually the largest source of energy waste associated with compressed air usage.

MAINTAIN COMPRESSOR SYSTEM AND REPAIR LEAKS

A proactive leak repair and maintenance program for the compressed air system involves:

- Regularly inspecting compressed air equipment, air pipes, bends and valves
- Checking to see that all air channels have proper physical supports to prevent leaks through excess stress
- Disconnecting or isolating any unused parts of the air distribution network or unused pressure regulators
- Consulting with staff who are on the plant floor and are most likely to notice changes in system performance

Regular preventative maintenance of compressed air system equipment should be conducted as per the equipment manufacturer's instructions. Some tasks for maintenance staff include:

- Checking for leaks
- Apply lubrication, including grease, and top-up and/or replace oil
- Clean and replace filters
- Correct any anomalies identified by indicator readings and set points
- Correct the tension of drive belts and replace worn belts
- Maintain the operation of valves, oil coolers, intercoolers, and aftercoolers
- Close condensate traps
- Check that compressor intake air is drawn from a cool space (e.g. outside) rather than a hot space (e.g. boiler room)
- Schedule or conduct major overhauls of compressors
- Ensure condensation can be removed swiftly from the distribution network, or does not occur

Pipe corrosion in the compressor system can increase friction and increase pressure-drop across the system, wasting energy. By maintaining filters and drying equipment (e.g. through changing drying filters at 8-10 psi drop per filter), friction is reduced in the system and energy efficiency is improved. For every 1 psi increase in air compressor pressure gained by periodic filter changes, air compressor energy use is reduced by about 0.5%.

POTENTIAL ENERGY SAVINGS

- Varies depending on the condition of the existing compressor system

OTHER BENEFITS

- Lower capital cost of compressor, which can be smaller if the pipe/hose network has less friction
- Lower maintenance costs
- Longer operating life of HVAC system equipment

EQUIPMENT/MATERIAL

- Maintenance equipment (e.g. lubricant, oil, steel brush, line leakage repair tools)
- Compressor leaks can normally be detected by the human ear, however smaller leaks in loud production environments may be harder – in this case, ultrasonic leak detection equipment can be used

(Table 1) Outline of potential cost/year for compressor line leaks.
Assumption: 700 kPa system, operating 2000 hrs/year, electricity costs 10 cents/kWh.

EQUIVALENT HOLE DIAMETER (SUM OF ALL LEAKS)	QUANTITY OF AIR LOSS PER LEAK (M3/YEAR)	COST OF LEAK ($/YEAR)
Less than 1mm	6,362	$95
From 1 to 3mm	32,208	$483
From 3 to 5mm	117,633	$1,764
Greater than 5mm	311,738	$4,675

REARRANGE THE COMPRESSOR SYSTEM

An air compressor needs to generate air-flow at a rate and pressure that meets the demands of the end-use and overcomes the friction and gravitational flow losses (pressure drop) in the pipe/hose network.

MINIMISE THE PRESSURE DROP OF THE PIPE/HOSE NETWORK

You can reduce pressure drop:

- A small increase in pipe/hose diameter will lead to a relatively large reduction in friction, and therefore, help to reduce flow losses. This is because pipe/hose friction is inversely proportional to the fifth power of internal pipe diameter for circular pipes. Since larger pipe/hose diameters carry air at lower pressure, they are less likely to develop leaks
- Internal pipe/hose roughness depends on the material and finish. Smooth, rigid pipes have much less friction than rough or flexible pipes and hoses and can therefore transfer air more efficiently
- Pipe/hose friction increases with increasing length. Pipe networks can be unnecessarily long due to bypass loops, bend components, bends in flexible hoses, and the location of the compressor and end-uses
- Each pipe/hose component adds friction losses. Eliminate bends and joins or keep them gradual (large radius) and use a minimal number of valves

'Ring system' pipe/hose arrangements use few bends which make them more efficient than other arrangements. They also allow for a lower compressor pressure by providing multiple supply lines to each end-use.

POTENTIAL ENERGY SAVINGS

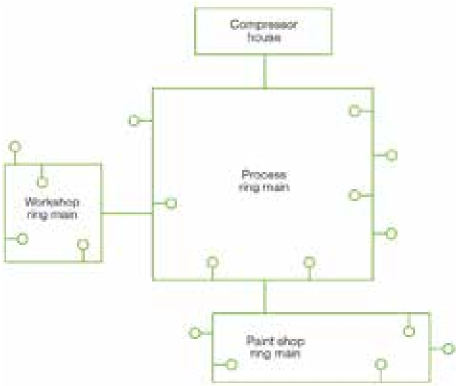
- Savings can be 3% of compressor power use (larger pipe/hose diameter only)

OTHER BENEFITS

- Lower capital cost of compressor, which can be smaller if the pipe/hose network has less friction
- Lower maintenance costs
- Longer operating life of HVAC system equipment

EQUIPMENT/MATERIAL

- Variable depending on choices made



Single main compressed air pipe layout with branch lines

Compressors operate more efficiently in cooler surroundings.

RELOCATE COMPRESSOR

Increase compressor efficiency by locating the compressor in areas that are cool, well ventilated, and out of direct sunlight (shaded, enclosure with reflective paint, or underground).

POTENTIAL ENERGY SAVINGS

- Savings vary depending on where the compressor is relocated

OTHER BENEFITS

- Lower maintenance costs
- Longer operating life of compressor

EQUIPMENT/MATERIAL

- Variable depending on choices made

INSTALL NEW AIR COMPRESSOR COMPONENTS

Air compressors use energy even on standby.

INSTALL CONTROLS TO OPERATE AIR COMPRESSORS ONLY WHEN REQUIRED

Decrease compressor power use by installing automatic control systems or time switches to turn compressors off when not required for long periods (such as outside of business hours).

POTENTIAL ENERGY SAVINGS

- Savings vary depending on choices made

OTHER BENEFITS

- Lower maintenance costs
- Longer operating life of compressors system equipment

EQUIPMENT/MATERIAL

- Control system

An example of a automatic control system

Replace internal cooling with external cooling.

REPLACE COOLING

The cooling of screw compressors is up to 5-10% more efficient with external oil coolers than with liquid-injection oil cooling (the direct injection of high-pressure liquid refrigerant into the compressor).

External oil coolers usually remove heat through the use of water or a refrigerant (usually ammonia) in a shell and tube heat exchanger on the oil circulation system.

POTENTIAL ENERGY SAVINGS

- Savings can be 3-15% of compressor power use, depending on the size of the screw compressors

OTHER BENEFITS

- Increased compressed air capacity by 5-10%
- Increased discharge temperature from 50°C to around 70°C, which is useful if a heat recovery system is installed on the compressor

EQUIPMENT/MATERIAL

- A water or refrigerant/thermosiphon oil cooler
- For a water oil cooler, a cooling water pipe between the evaporative condensers and the oil cooler
- For refrigerant/thermosiphon oil cooler, a refrigerant liquid-and-vapour return pipe between the liquid receiver and the oil cooler

External oil cooler

INSTALL NEW AIR COMPRESSOR COMPONENTS *CONT.*

Variable speed drives (VSDs) are well suited to compressors that operate at part-load for up to 95% of the time.

INSTALL A VARIABLE SPEED DRIVE ON AIR COMPRESSORS

At full load, VSDs are about 3% less efficient than constant speed drives and therefore should be avoided in situation where full loads operate most of the time.

VSDs constantly adjust the motor speed to match the air compressor output to the load profile. Even a small reduction in speed will lead to a relatively large reduction in power use.

A VSD eliminates the need for flow-control devices, such as valves and bypass loops. As a flow-on benefit, pressure drop in the pipe/hose network can then be reduced by removing unnecessary flow-control devices.

VSDs only reduce compressor power as well as the controls implemented. To find the best control method, you need an appropriate control signal and an iterative procedure to find the optimal settings.

Capital cost is $200-$500/kW, about the same as the motor, depending on the size number, and use patterns of the motor. The initial capital cost per kW decreases with increased motor size.

POTENTIAL ENERGY SAVINGS

- Savings can be 10-60% (20% average) of motor power use depending on size, number, and use patterns of the motor

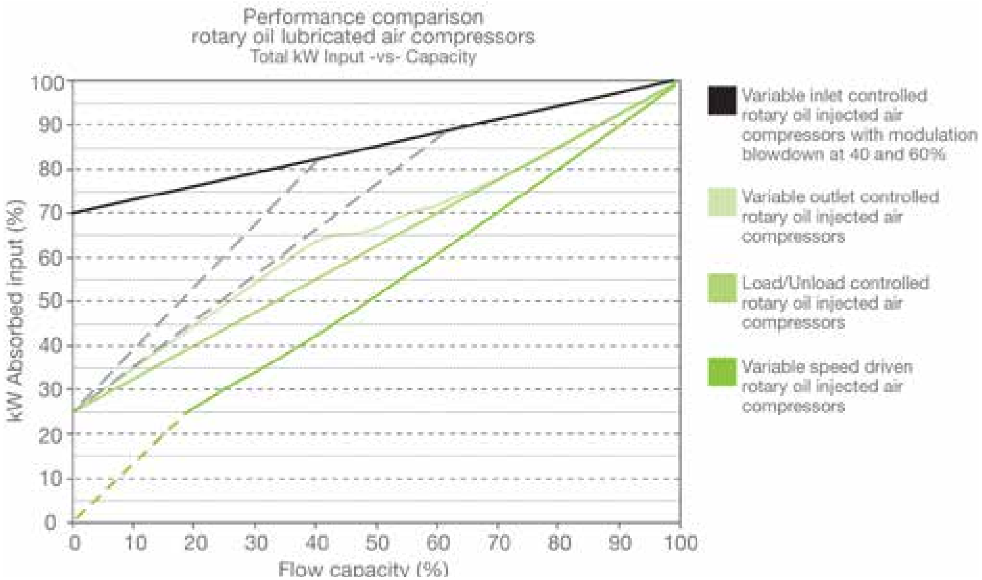
OTHER BENEFITS

- Lower maintenance costs
- Longer operating life of compressor system equipment

EQUIPMENT/MATERIAL

- VSD for each compressor
- Sufficient programming capability in the control system

Variable Speed Drive



Performance of an air compressor with and without a VSD

INSTALL NEW AIR COMPRESSOR COMPONENTS *CONT.*

Air compressors are more efficient when running at full load than at part load.

INSTALL AUTOMATED COMPRESSOR STAGING AND CAPACITY CONTROL

If the load varies, consider using multiple, smaller compressors so that all compressors can be used together at peak load, but a selection of compressors can be used at lesser loads. This strategy is suitable when the load is consistently above 50%.

Having compressors of different capacities allows you to match the compressor capacity with the required cooling load.

An automatic controller can turn compressors on and off as needed, usually resulting in only one small compressor operating at part-load. However, consider start up and shut down efficiency losses too. Ideally the logic used to control the compressors should be optimised, that is, set and fine-tuned across the full range of cooling loads and environmental conditions.

Capital cost is approximately $100,000 (2013). Capital cost depends on:

- Number of compressors
- Number of compressors that require VSDs

POTENTIAL ENERGY SAVINGS

Savings can be:

- 5% when installed on a partly-optimised compressor (most common)
- 15% when installed on a previously un-optimised compressor.

Savings depend on:

- Load profile
- Number, size and condition of compressors

OTHER BENEFITS

- Longer operating life of compressors

EQUIPMENT/MATERIAL

- Suction pressure transmitter (monitors negative pressure)
- Slide valve potentiometer (converts the valve position to a voltage signal) connected to the automatic controller for each screw compressor
- Capacity control solenoids for reciprocating compressors connected to the automatic controller
- VSDs on compressors
- Hardware and software control capability (to define the logic)

Automated compressor staging capacity controller

EQUIPMENT AND PROCESSES

Use the following table to select which energy efficiency opportunities your business would be interested in pursuing, as well next steps in terms of actions and responsibilities.

Tick the box if you plan to pursue an Energy Efficiency Option.

X	ENERGY EFFICIENCY OPTION	NEXT STEPS & TIMING	WHO RESPONSIBLE	NOTES
	Optimise operating settings			
	Use minimum discharge pressure			
	Maintain compressor system and repair leaks			

UPGRADE EQUIPMENT

Use the following table to select which energy efficiency opportunities your business would be interested in pursuing, as well next steps in terms of actions and responsibilities.

Tick the box if you plan to pursue an Energy Efficiency Option.

X	ENERGY EFFICIENCY OPTION	NEXT STEPS & TIMING	WHO RESPONSIBLE	NOTES
	Rearrange the compressor system			
	Minimise the pressure drop of the pipe/hose network			
	Relocate compressor			
	Install new air compressor components			
	Install controls to operate compressors only when required			
	Replace internal cooling with external cooling			
	Install a variable speed drive on air compressors			
	Install automated compressor staging and capacity control			

CHECKLIST TO ENGAGE WITH SUPPLIERS

By gathering the information suggested in this supplier checklist, you can build a complete picture of your equipment and energy uses.

This will help you to identify which actions are likely to benefit your business so that you can establish a business case to support decision making now and planning for the future. Some of the information you can collect within your own business resources, but some may need you the help of suppliers or experts (e.g. an energy audit).

Note: This checklist can be used by either the food business or the supplier.

DETERMINE THE END-USES OF YOUR COMPRESSED AIR SYSTEMS

CHECK THE FOLLOWING END-USES

Tick those that apply to your business

- ○ Processing
- ○ Bottling/packaging
- ○ Cleaning
- ○ Other

COMPILE A COMPRESSED AIR SYSTEM INVENTORY

COMPILE A LIST OF THE FOLLOWING EQUIPMENT

Tick those that apply to your business

- ○ Compressor: number, make, model, type, power rating (kW), flow rate (l/s), speed (rpm), operating pressure (kPa), number of compressor stages, and time in use (h/y)
- ○ Motor (if it is a separate unit): number, make, model, type, power rating (kW), efficiency (%), speed (rpm), and time in use (h/y)
- ○ Dryer: number, make, model, type, power rating (kW), flow rate (l/s), purge flow rate (l/s), pressure dew point (°C), pressure drop (kPa)
- ○ Pipes: diameter (m)
- ○ Hoses: diameter (m)
- ○ Valves: number, make, model, type
- ○ Other

CHOOSE AN APPROACH TO ESTIMATE TIME IN USE

Tick those that apply to your business

- ○ Record readings the hour-run meter (h) at regular intervals
- ○ Divide the hour-run meter reading (h) by the total time (h) that the air compressor has been installed
- ○ Compare the energy (kWh) and power readings (kW) (if the system has an electricity meter)
- ○ Examine electricity meter load profiles (kW)
- ○ Use existing control systems and manual procedures
- ○ Check control settings (if the system has controls)

CHECKLIST TO ENGAGE WITH SUPPLIERS *CONT.*

By gathering the information suggested in this supplier checklist, you can build a complete picture of your equipment and energy uses.

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ESTIMATE THE COMPRESSED AIR REQUIREMENTS

COMPILE A LIST OF THE FOLLOWING INFORMATION FOR EACH END-USE

Tick those that apply to your business

- ○ Air quality - pressure dew point (moisture) (°C), and dirt and oil concentration
- ○ Average flow rates (l/s) and maximum pressure (kPa) required now
- ○ Average flow rates (l/s) and maximum pressure (kPa) required in the future
- ○ Location of end-use
- ○ Operating times or events that require compressed air
- ○ Reason the end-use requires compressed air

CHOOSE AN APPROACH

Tick those that apply to your business

- ○ For an initial estimate of compressed air requirements of major end-uses, record the time of day and length of time (h) that the major end-uses use compressed air over a production cycle. This approach is convenient for end-uses with short demand cycles
- ○ For an initial estimate of the total compressed air requirement, record the readings of the outlet pressure gauge (kPa) at regular intervals over a production cycle. Use these readings with the 'pressure vs. flow' curve for the compressor (available from the manufacturer) to determine the corresponding flow rates (l/s)
- ○ For an initial estimate of the total compressed air requirement, install power demand analysers or power meters on the compressor and dryer to measure the power use (kW) over a production cycle. This data indicates times of peak and low load (kW)
- ○ If budget and time allow for a more accurate estimate of compressed air requirements, install metering and monitoring equipment, such as flow meters on the main compressed air branch lines, electronic pressure meters on the main lines, power meters on the compressor and dryer, and data-loggers. This approach provides a rich set of data on performance and assists in the diagnosis of problems

THIS LIST ENABLES YOU TO:

- Identify the end-uses that dominate the compressed air requirements
- Identify wasteful and unnecessary uses of compressed air
- Estimate the base and peak compressed air requirements, and the variation in compressed air, now and in the future
- Compare the current operating points of the compressor and dryer with the peak-efficiency points (rpm)

CHECKLIST ENGAGE WITH SUPPLIERS *CONT.*

By gathering the information suggested in this supplier checklist, you can build a complete picture of your equipment and energy uses.

This will help you to identify which actions are likely to benefit your business so that you can establish a business case to support decision making now and planning for the future. Some of the information you can collect within your own business resources, but some may need you the help of suppliers or experts (e.g. an energy audit).

Note: This checklist can be used by either the food business or the supplier.

ESTIMATE THE ENERGY USE OF YOUR EXISTING COMPRESSED AIR SYSTEMS

CHOOSE AN APPROACH

Tick those that apply to your business

- ○ Install a power demand analyser or a suitable meter to measure the average power (kW) of, or the energy (kWh) used by, the system over a test period
- ○ Install a clip-on ammeter to measure the instantaneous currents (A) of each of the three phases with the compressor running at the most common load. Calculate the average phase current (A). Repeat this process with the compressor at no load and at full load. Multiply the average phase currents (A) by the time (h) that the compressor runs at each load (kW)
- ○ For compressors with control systems, record energy use (kWh) readings weekly to determine annual energy use (kWh)

DETERMINE THE BUSINESS PARAMETERS OF THE COMPRESSED AIR SYSTEM

QUANTIFY OR QUALIFY THE FOLLOWING VALUES

Tick those that apply to your business

- ○ Energy price(s) ($/kWh; $/l petrol/diesel/fuel)
- ○ Capital budget ($)
- ○ Targets for running costs ($/y)
- ○ Required level of redundancy in the system
- ○ Acceptable payback period or return on investment
- ○ Acceptable level of risk for new technologies
- ○ Equipment constraints, such as: specific brands of motors, compressors, or dryers, specifications for electrical wiring, compatibility with existing infrastructure or floor space, and adaptability to future upgrades

If the existing equipment needs to be replaced, calculate the payback period (y) based on the extra (rather than total) costs ($) (if any) of the efficient equipment.

CONFIRM COMPRESSOR SYSTEM PERFORMANCE

CHECK THE FOLLOWING CONDITIONS

Tick those that apply to your business

- ○ The compressor meets the peak compressed air load (kW)
- ○ The compressor is optimised for the most common compressed air loads (kW)
- ○ The pipe/hose network has a pressure drop (kPa) of less than 10% of the compressor discharge pressure (kPa)
- ○ The air filter, oil filter, and oil separator are easily accessible

CHECKLIST TO ENGAGE WITH SUPPLIERS *CONT.*

By gathering the information suggested in this supplier checklist, you can build a complete picture of your equipment and energy uses.

This will help you to identify which actions are likely to benefit your business so that you can establish a business case to support decision making now and planning for the future. Some of the information you can collect within your own business resources, but some may need you the help of suppliers or experts (e.g. an energy audit).

Note: This checklist can be used by either the food business or the supplier.

SELECT A SERVICE PROVIDER

SELECT AN AIR COMPRESSOR SERVICE PROVIDER THAT CAN PROVIDE THE COMBINATION OF SERVICES THAT YOU SEEK

Tick those that apply to your business

- ○ Measurement and analysis of the compressed air requirements profile; and power (kW) of compressors, dryers, and end-uses
- ○ Reporting on equipment and process performance
- ○ Optimisation of the pumping system, including: optimisation of the control system, flow rates (l/s), and pressure levels (kPa), management of air leaks, minimisation of the compressed air requirements at end-uses, appropriate treatment of air and assessment of heat recovery potential
- ○ Design of a compressed air system that aims to minimise losses from the end-use to the compressor
- ○ Supply, service, and installation of compressed air system equipment (compressors, filters, drains, and pipes) for optimal energy efficiency (%)
- ○ Supply of spare parts, including shipping/transport
- ○ Guarantee of minimum efficiency (%) of the proposed system
- ○ Guarantee of maximum running costs ($/y) of the proposed system
- ○ Technical support and after sales service
- ○ In-house repairs and onsite service
- ○ Emergency service
- ○ Emergency rental compressors
- ○ Remote monitoring
- ○ Appropriate removal and disposal of old equipment
- ○ Other

NEGOTIATE A CONTRACT

DETERMINE YOUR PREFERRED TYPE OF CONTRACT

Tick those that apply to your business

- ○ Service contract - the supplier performs certain actions for a fixed price ($)
- ○ Energy performance contract - the supplier performs certain actions that meet certain levels of energy reduction (kWh) for a lower upfront price ($) and a share of the cost savings ($/y)

REFERENCES

The following references were used in the development of the *Compressed Air* section of the Food SA BCEEE toolkit. We encourage you to access these references as they may provide additional useful information for your business in evaluating energy efficiency opportunities.

Food SA's Your Guide to Sustainable Business in Food

AMEI (Air and Mine Equipment Institute of Australia): Efficient compressed air systems, www.amei.com.au/downloads/air_comp.pdf, www.amei.com.au/downloads/guide_1.pdf, www.amei.com.au/downloads/guide_2.pdf, www.amei.com.au/downloads/guide_3.pdf

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