Energy Saving

The Norgren guide to saving energy in compressed air systems.

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Energy Saving in Compressed Air Systems

Compressed air is often wrongly assumed to be a cheap or even 'free' source of power. It is not.

A typical 1 000 cfm (500 litres/sec) installation will consume £20 000 of electricity in a year. During its lifetime energy represents 75% of the total cost of buying and running a compressor.

Numerous independent studies confirm that industry wastes around 30% of the compressed air it generates, equivalent to £6 000 in our typical 1 000 cfm installation.

The aim of this guide is to help the end user minimise wastage, by improving existing installed systems. It will highlight key areas for savings, and offer practical advice on an action plan.

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Leakage is the major source of energy loss in compressed air systems. A typical plant may lose 20% of its compressed air through poorly connected pipe joints, fittings, couplings etc. Fixing the leaks and introducing planned maintenance can produce substantial savings.

MISUSE   6

The second major wastage of compressed air is to use it as a power source just because it is available. There may be better alternatives for moving, drying or cleaning products.

Where compressed air is used selecting correct equipment such as nozzles and use of control circuits can minimise wastage.

OVER PRESSURISATION   7

A considerable saving both in energy and equipment life can be made by using devices at the minimum pressure required for the application rather than full line pressure. Simple use of pressure regulators offers very fast payback.

PRESSURE DROP   8

Loss in pressure due to blocked filter elements and undersized pipework can mean pressure starvation at the end of compressed air lines. The guide shows examples of how to choose and maintain equipment to minimise pressure drop in systems.

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Components fitted for safety reasons such as preset regulators and shut off valves can also help energy saving. This section reviews relevant parts of BS EN 983 and other standards linking them to energy issues.

GENERATION   12

The correct selection of control equipment to multiple compressor set ups, attention to inlet cooling and after treatment of the compressed air can realise good energy savings. Regular and correct maintenance of compressors, filters and driers is also vital.

ACTION PLAN AND FURTHER INFORMATION   14

A simple checklist for action and sources of further information.

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HOW TO USE THIS GUIDE

The process of air preparation has been the core of Norgren's business for over 70 years.

The guide reviews each of the major opportunities for energy saving so that you can take practical measures in your own plant.

Each section covers:
- What it is ?
- Where to look for savings
- What to note or measure
- How much does it cost ?
- What are the solutions ?
- How do we maintain good practice ?

Throughout the guide you will find detailed examples of how to calculate the savings potential indicated by.

These are based around a model factory 'Example Engineering', which has many of the problems commonly found in compressed air systems.

EXAMPLE ENGINEERING

The factory has installed compressor capacity of 1 500 cfm (750 litres/sec), and average demand of 1 000 cfm (500 l/s). It operates 24 hours per day, 7 days per week, for 50 weeks a year. Electricity costs 4,5p/kWh. At 75% compressor utilisation, total cost is £78 400 per year.

The basis for most of the calculations is the "wastage formula".
This costs flow at:
0,4 x hours x flow l/s x energy cost/kWh.
At Example Engineering, typical leakage is 20% and equals 100 l/s, which costs:
0,4 x 8 400 x 100 x £0,045 = £15 120.

The calculation examples in this guide are based on one section of the factory, the workshop area.

The workshop operates for 2 500 hours per year, but the ring main is pressurised all the time the factory is open. The total savings identified equal 30% of the air currently used by the workshop area.

WORKSHOP AREA
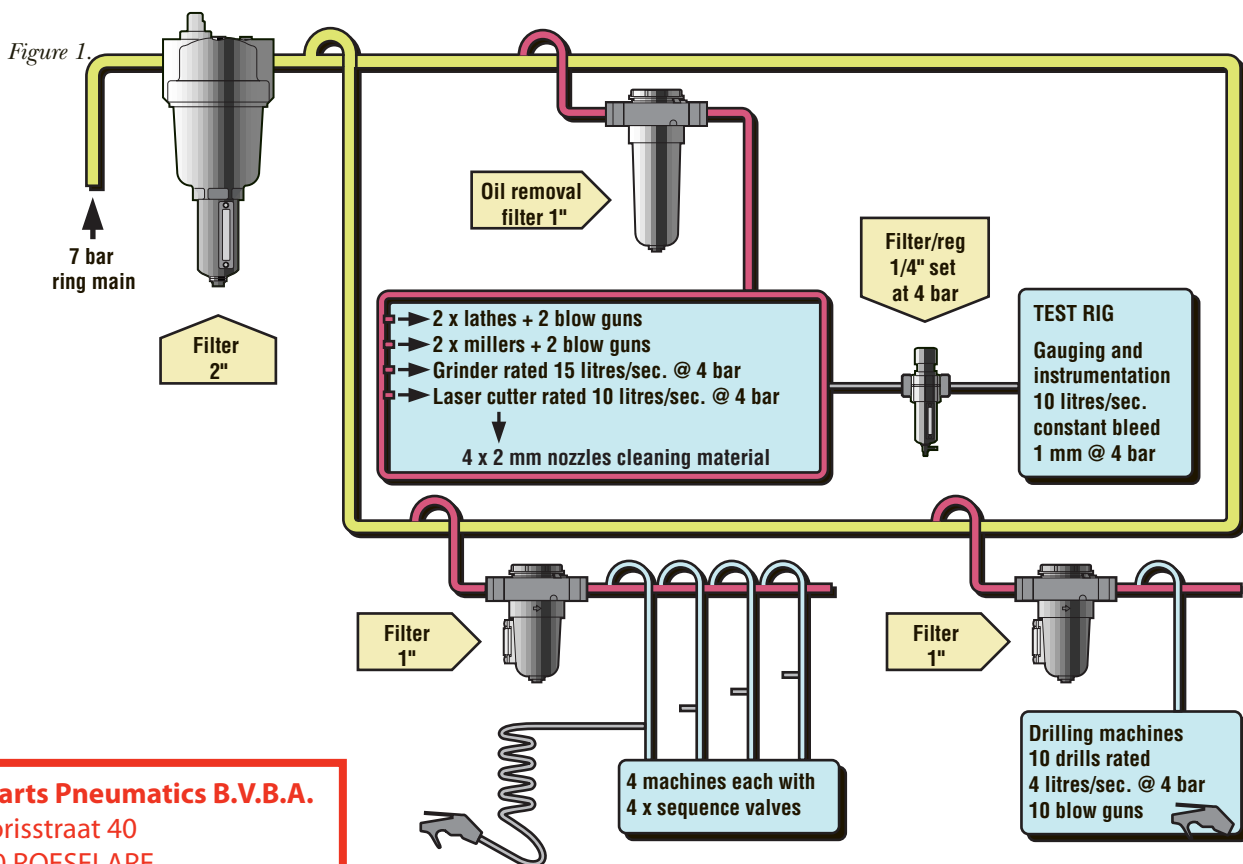
Figure 1.

7 bar ring main

Filter 2"

Oil removal filter 1"

Filter/reg 1/4" set at 4 bar

- 2 x lathes + 2 blow guns
- 2 x millers + 2 blow guns
- Grinder rated 15 litres/sec. @ 4 bar
- Laser cutter rated 10 litres/sec. @ 4 bar

4 x 2 mm nozzles cleaning material

TEST RIG
Gauging and instrumentation
10 litres/sec.
constant bleed
1 mm @ 4 bar

Filter 1"

Filter 1"

4 machines each with 4 x sequence valves

Drilling machines
10 drills rated
4 litres/sec. @ 4 bar
10 blow guns

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LEAKAGE

Leaks can be a significant source of wasted energy in an industrial compressed air system.

If compressed air were hydraulic fluid, leaks would be so visible that we would ensure their reduction. As it isl we accept a low level hiss in our work places as 'part of the job'

At a price which is roughly comparable to that of domestic gas, this attitude costs industry dearly.

It is estimated that leaks cost UK industry £20 million per annum.

In addition to being a source of wasted energy, leaks can also contribute to other operating losses. Leaks cause pressure loss in systems, which can mean pressure is too low to the application leading to more reject product. Frequently the generation capacity is increased to compensate, rather than simply fixing the leaks.

WHERE TO FIND LEAKS

Leaks occur everywhere !

- PIPEWORK
  Ageing pipework is a prime source of leaks. Replace any corroded pipework sections - for safety as well as energy saving.
- FITTINGS, FLANGES AND MANIFOLDS
  Large leaks are often found at connection points, both in the main distribution system and in off takes. Sometimes when several snap connectors are used together to form manifolds they can be a source of leakage due to worn connectors and poorly jointed pipe work.
- FLEXIBLE HOSES AND COUPLINGS
  Leaks can be caused by damage to hose due to abrasion by surrounding objects, deterioration of the hose material and strain on the joint because the hose is too long or too short.
- OLD COMPONENTS NOT MAINTAINED - SEALS START TO LEAK
  Check all pneumatic components eg old cylinders and regulators, for worn internal air seals which can cause large leaks.

- CONDENSATE DRAINAGE VALVES
  Large amounts of air can be lost when drain valves are stuck open or even left open intentionally. These can often be found in remote parts of the system where condensate collects.
- SYSTEMS LEFT PRESSURISED WHEN NOT IN USE
  Where subsystems have a large amount of leakage which cannot be avoided eg presses and drop hammers, isolate them from the air supply when not in use. Simple shut-off valves (figure 2), or electrically operated soft start dump valves (figure 3) offer cost effective ways to isolate leaky systems, or areas of a plant when not in use.

Figure 2.
Manual shut-off valve.

Figure 3.
Soft start dump valve used to isolate equipment, preventing leaks.

MEASURING THE LEAKAGE

You can measure the base leakage easily using one of several methods :

- Install a flowmeter and pressure transducer in the compressed air feeding main (after any receivers). Connect the output of the flowmeter and the pressure transducer to a chart recorder and take readings over a representative period of time. Measure the flow from the compressor when the system is not working eg at a weekend.
- Use a compressor of known capacity to pump the system up to normal operating pressure during non production hours. The compressor will unload at the operating pressure. As the system pressure drops due to leakage the compressor will load at its minimum running pressure. You can then estimate the leakage rate from the average loaded and unloaded times over a representative period.
- Pump the system up to pressure and measure the time taken for the pressure to decay to the lower limit. If you know the total volume of the piping network and the receivers, you can calculate the leakage rate.

Use a small flowmeter in branch lines to identify real problem areas.

But is it worth it ? How much do leaks really cost ?
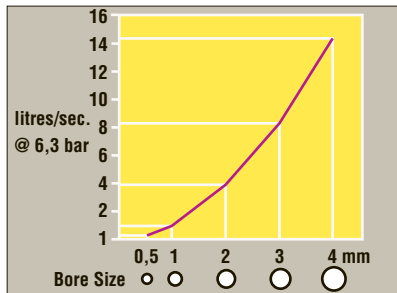
WHAT DOES IT COST ?

Figure 4.
Leakage rate for different hole diameters.

A single leak from a hole diameter 2 mm can cost £600 per year, in our workshop example. Use orifice flow chart (figure 19) to calculate leakage at different bore sizes and pressures.

REDUCING LEAKAGE

Set targets for leakage reduction. Publicise how much money the leakage is costing the organisation and how much you intend to save. Implement an ongoing maintenance programme - have 'leak' tags available and encourage their use.

Carry out a survey of the compressed air system. Inspect during quiet hours. Listen for pipework or tool leaks and examine hoses and couplings. Spray 'spotleak' on pipe joints and watch for bubbles.

The average leak will take around half a man hour to fix, and offer very quick payback.

Fixing the leaks will clearly save significant amounts of money, but how do we make sure they stay fixed ?

Implementing a site-wide awareness programme leads to long term savings on a big scale.

Dividing the site into areas, fitting air consumption meters and charging each area for its air usage will soon focus the attention of energy users. Targets can then easily be set to reduce energy loss due to leaks.
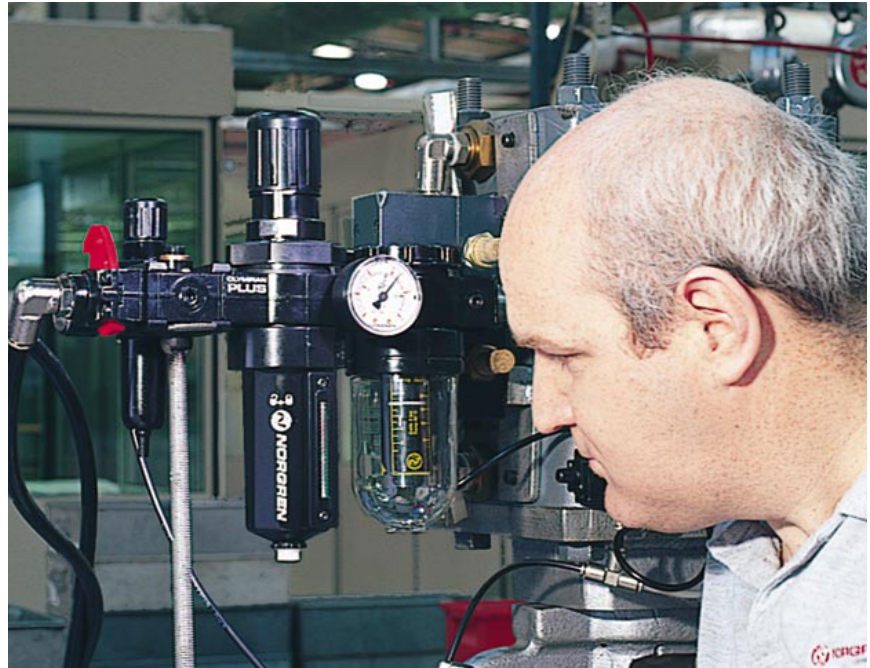
Figure 5.
Use a plug-in flow meter to measure leakage in machinery.

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LEAKAGE

After surveying the workshop area a number of leaks were found.

        1 x 2 mm leak @ 4 bar
and   11 x 1 mm leak @ 7 bar

Using the orifice flow table, that equates to 4,8 l/s and 11 x 1,2 l/s

        Total leaks = 18 l/s

Potential for saving

        0,4 x 8 400* x 18 x £0,045 = £2 722

* assumes system stays pressurised for 24 hours per day, 50 weeks per year.

Cost of solution:

Estimate 1/2 a man hour to fix each leak
        @ £15.00 per hour   = £90.00

Savings	Expense	Nett saving
£2 722.00	**£90.00**	**£2 632.00**

MISUSE

The second major wastage of compressed air is to use it as a power source just because it is available.

Some examples of this are inefficiently creating vacuum, ejecting faulty products and removing water/dirt/powder from products. There may be better alternatives for these applications. If compressed air is chosen the correct equipment and control must be employed to keep usage to a minimum.

WHERE TO FIND MISUSE

In an existing plant new misuses can often be seen by an increase in air demand and/or compressor running hours. To identify existing misuses all areas of the plant need to be surveyed, asking the question - is this an effective use of air ?

COSTING THE MISUSE

Where a process has air passing to atmosphere, such as rejection of under weight or faulty product in a canning process, a flowmeter can be installed in the line to measure the air usage. Then by using the wastage formula the cost of this process can be found.

RECOMMENDED PRACTICE

Another way to calculate costs is to use the exit orifice or nozzle diameter and the applied pressure to calculate the flow (see table, figure 19 orifice flow).

Where nozzles must be used, for example blowing loose flour off loaves of bread, then ensure that the distance between the exit nozzle and the product is as short as possible as this will allow the supply pressure to be reduced. The nozzle should be directed only at the area needed giving a cone (circular area) or fan spray (long narrow band) etc. Where a very long narrow area needs to be covered use nozzles in parallel to produce a curtain reducing the distance to the furthest point. Ensure the mains feed line to a number of nozzles is of sufficient diameter so as not to restrict the outlet flow.

Air saver nozzles can entrain, or accelerate air within their mechanism to produce the desired outputs with reduced supply pressures, giving savings of up to a twenty fold reduction in compressed air usage.

Finally where such solutions must be used ensure control valves and sensors are fitted to the system, so that flow only occurs when the product is at the application point, with no flow during the gaps between product on the conveyor, or at work breaks etc.

In some cases the solution is not to use compressed air. Dedicated air blowers or vacuum pumps may well prove more cost effective.

All such solutions can be costed and compared to the air usage/wastage and in almost every case savings can be made

Once misuse has been determined within a plant, ensure that when new processes are installed due consideration to the power source and its control are made.

Figure 6.
Blow gun with air saver nozzle

Figure 7.
Example of poor practice. Nozzle should be closer to the bread and of an air saver design. A control circuit is needed to stop air when no bread is under the nozzles. Consider local filtration and membrane dryer for high quality dry air.

MISUSE

Material is cleaned prior to being cut by the laser using 4 x 2 mm at line pressure.
4 x 2 mm nozzle presets   4 x 4,8 l/s at 7 bar
                                 4 x 1,81 l/s at 2 bar
Using the orifice flow table, figure 20.
So a reduction in pressure to 2 bar will give a flow saving of 11,96 l/s.

Potential for saving

0,4 x 8 400* x 11,96 x £0,045   = £1 808.00
* assumes no isolation valves and system is continually pressurised.

Cost of solution:

Fit one pressure regulator   = £18.00
Estimate 1/2 a man hour @ £15.00 per hour   = £7.50
Total   £25.50

Savings	Expense	Nett saving
£1 808.00	**£25.50**	**£1 782.50**

OVER PRESSURISATION

Many systems run at full line pressure with the only control being the pressure switch on the compressor.

Every item of pneumatic equipment has an optimum operating pressure and flow. Usage outside of these conditions will shorten the equipment life due to increased loading and wear, and will increase the running costs. A device running at 7 bar will consume twice as much air as it would at 3 bar.

IDENTIFYING OVER PRESSURISATION

The absence of pressure regulators in a system indicates that equipment is being used at excessive pressures. Savings can be realised in many areas, including air tools, control valves, clamping cylinders and on the return stroke of large double acting cylinders.

Where pressure regulators are present but outlet pressure is the same as the inlet, this often indicates poor lubrication with extra pressure being applied to overcome the friction slowing down the process. This is costly in extra wear and energy.

CALCULATING THE COSTS

All **air tools** are rated for their flow and optimum pressure. The air wastage can be calculated by using the pressure ratio (absolute), and then multiplying by the rated air flow i.e. consumption at 3 bar is 8 l/s at 7 bar his will be

$$\frac{(7+1)}{(3+1)} \times 8 = 16 \text{ l/s}$$

This can then be substituted into the annual wastage formula to calculate savings.

Double acting cylinders usually only do work on the out stroke (work stroke). When no work is being done or longer reset times are possible, the return stroke can be at a lower pressure. Where large bore, long stroke or multiple cylinder systems exist, considerable air savings can be made. Using a regulator to reduce return stroke

pressure can be a fast payback solution.

Consumption with reduced pressure return stroke for double acting cylinder can be measured using the formula

$$\text{Air saving} = \frac{0{,}7854 \times d^2 \times L \, (P1 - P2) \times 10^{-6}}{T \times 60}$$

d = cylinder diameter (mm)
L = stroke length (mm)
T = time for 1 stroke (sec)
P1 = applied pressure (bar) - outstroke
P2 = applied pressure (bar) - return stroke

Valves have a rated conductance C in litres/sec per bar absolute. Any flow saving is calculated by simply reducing the applied pressure. It is important to note the valve operating duration (i.e. time that flow occurs) to ensure that the correct flow saving is arrived at. Usually this figure is small but for multiple valve installations and/or rapidly cycling valves with long pipe runs the total saving can be significant.

Once over pressure examples have been identified within a factory, ensure that all new plant, processes and equipment are examined for optimum operating conditions and pressure control equipment prior to installation. This should be reflected in increased tool life as well as reduced energy costs.
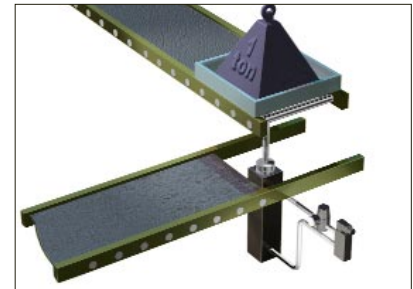

Figure 8.
Use of a regulator to reduce pressure on the return stroke of large bore cylinders saves energy.

OVER PRESSURISATION

10 air tools rated @ 4 bar
These drills are all supplied with 7 bar line pressure, and each is used on average for around 1 000 hours per year.
The air consumption of each drill at 4 bar is 15 l/s.

∴ at 7 bar each tool will be consuming: $\frac{8}{5} \times 15 = 24$ l/s

So by using a lower pressure there is a potential saving of 9 l/s per tool.
Over the total 2 500 hours of annual usage, the average flow saving =

$$\frac{1\,000}{2\,500} \times 9 = 3{,}6 \text{ l/s}$$

Potential for saving

0,4 x 2 500 x 3,6 x £0,045	= £1 620

Cost of solution:

Fit one pressure regulator per tool	= £18.00 x 10 = £180.00
1/2 man hour for fitting	
@ £15.00 per hour = 10 x £7.50	= £75.00
Total	£225.00

* calculations need to be done with absolute pressures – i.e. 1 bar higher than reading

Savings	Expense	Nett saving
£1 620.00	**£225.00**	**£1 395.00**

PRESSURE DROP

Pressure drop can be defined as 'the loss in a system of power available to do work'. In practice it is evidenced by low pressure in parts of the system. It is often compensated for by increasing generation pressure or turning up regulators.

The potential energy generated by compressing the air is dissipated through friction and heat losses as it is pushed through all the components of the system. We need therefore to design and maintain systems to minimise the amount of pressure drop. Every 1 bar of unnecessary pressure drop leads to an increase of 7% in generating costs. This means around £3 500 per annum to our typical factory.

The two main areas where pressure drop occurs are pipework and filtration.

PIPEWORK

Pressure drop occurs in pipework mainly as a result of friction of the air molecules with the surface of the pipe. If the pipe is too small for the volume of flow the velocity of the air will be very high and there will be a big loss in power.

Energy is also lost when there is a change in flow direction i.e. elbows, junctions and shut off valves. Simple pipe systems will minimise pressure drop.

How to calculate pressure drop in pipework:

Method 1

- Measure supply pressure.
- Measure the pressure at furthest point from supply.
- The difference is the system pressure drop.

Method 2

- Estimate the flow usage - eg. calculate the swept volume of working cylinders.
- Note the supply pressure and the diameter of the pipe.
- Use published normagraphs to arrive at the pressure drop.

Method 3

- Use a small flowmeter to measure the flow.
- Note the supply pressure and the diameter of the pipe.
- Use the tables on pages 14/15 to see whether flow is within recommended range.

RECOMMENDATIONS

Don't over flow the pipework. Keep velocity below 6 m/s in mains.

Simplify the pipework. Avoid elbows as a 90 degree elbow is equivalent to 1,6 m of straight pipe.

Fit 'low resistance' valves a full flow ball valve equates to 0,4 m of pipe, less than half the resistance of a gate valve.

FILTRATION

Filtration is an essential part of the conditioning in a compressed air system. If not protected from water, particles and degraded compressor oils, machines will quickly breakdown.

To keep pressure drop as small as possible:

Look for the right size filter unit

As with pipework if the filter unit is too small for the flow required then it will give a higher pressure drop. When new a general purpose filter should give no more than 0,1 bar pressure drop. Fitting a smaller filter is a false economy, as it will give higher initial pressure drop and also block more quickly because the surface area of the element is smaller.
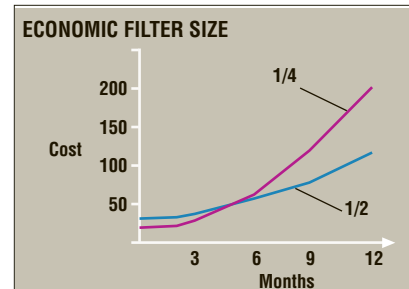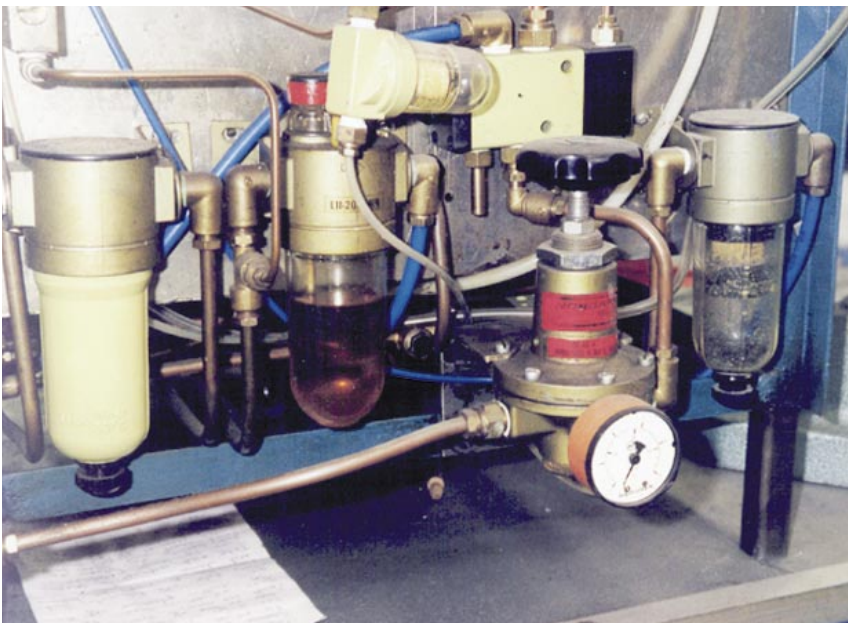
Figure 10.
Selecting the right size filter is important.

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Figure 9. Example of poor pipework on a production test rig.

![NORGREN]

Look for the right level of filtration

A very fine filter will have a greater resistance to flow than a coarse filter. Most air tools for example will only require filtration to around 40 micron. It makes sense therefore not to use a 5 micron or even a 0,01 micron filter in this application. See figure 21 for guidelines on quality of air needed for common applications.

Where applications needing higher grade filtration exist, place the higher grade filters as close to the application as possible. This ensures that the size of filter determined by the flow is as small as possible. Do not filter the whole of the air line or branch line to this standard, since this will increase the flow requirement, increasing the size of the filter, its purchase price, replacement element price and incur extra pressure loss for the whole of the system downstream of it.
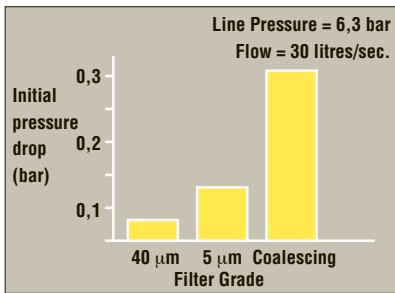
Figure 11.
The effect of filter grade on pressure drop.

Look for dirty filter elements
- check pressure drop indicators

After some time in service particles will be trapped within the filter media causing the element to become blocked. This means pressure is lost at the application. What usually happens at this stage is that the pressure is increased to compensate by turning up a regulator. Increasing the pressure increases the costs.

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An extra 0,35 bar of pressure drop in a line can cost as much as £400 per year.

Fitting pressure drop indicators - simple pneumatic or electrical - can indicate immediately when pressure drop is increasing. Changing the elements at this point means significant energy saving.
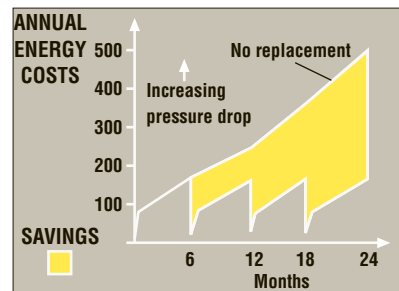

Figure 12.
Cost saving through regular element changes.

It is good practice to change the filter elements at regular intervals. This will ensure that energy wastage is kept to minimum and that correct air quality is delivered.

Any new plant should be installed with the right level of air quality in mind - instrument quality only where the application demands it.

Delivering very dry high quality air to all areas of the site is costly and should be avoided.

Figure 13.
Filters fitted with electrical and mechanical service indicators.

PRESSURE DROP

A 2" filter flowing 400 l/s @ 7 bar when new, pressure drop = 0,15 bar in 2 years this could increase to 0,4 bar
This extra 0,25 bar creates an extra power demand of 1,8 Kwh

Potential for saving

For 2 500 hours total extra power =
1,8 x 2 500 Kwh @ £0,045 per Kwh extra cost = £202.50

Cost of solution:

Replace filter element = £57.00
1/2 a man hour labour @ £15.00 per hour = £7.50

Savings	Expense	Nett saving
£202.50	£64.50	£138.00

9

How can Safety be an Energy Issue ?

In compressed air systems components fitted for valid safety reasons have a cost, however there are some that offer a payback resulting from the benefits gained in energy savings.

There are several documents that deal with safety of compressed air systems and pneumatic components. Some are international standards whilst others though not having legal status, offer best practice guidance from safety organisations and leading fluid power trade organisations.

BS EN 983 - LEAKS

'Leaks (internal or external) shall not cause a hazard'.

In systems where air pressure is used to maintain a load, such as in a press, braking or clamping application, a leak could potentially constitute a hazard.

BS EN 983 - FILTRATION

'Filter condition monitoring. If deterioration of filter performance could lead to a hazardous situation, clear indication should be given'.

A blocked filter, leading to reduced downstream pressure could have a similar effect to a leak in systems where the pressure is used to maintain loads.

Pressure drop indicators will show when the filter is blocking and needs changing. This also minimises energy costs by keeping pressure drop to an acceptable level.

BS EN 983 - TAMPER RESISTANT DEVICES

'Pressure and flow control devices or their enclosures shall be fitted with tamper resistant devices where an unauthorised alteration to pressure or flow can cause a hazard.'

Frequently pressure is increased to machines or systems in the hope that the increase will speed up the process. Usually there are other factors within the system

which will limit this and increasing the pressure will only increase the air consumption.

In some cases increasing the pressure can be unsafe such as when using pneumatic clamps. The force generated is calculated to clamp the component, any increase in that force may result in crushing of the component which may shatter or explode.

Simple tamper evident covers which can be padlocked can be fitted to regulators to ensure systems remain safe. Lockable shut off valves prevent someone accidentally turning off the air to a system, or turning on the air while a machine is being maintained creating a potential hazard.

Figure 14.
Use of a lockable tamper evident cover on a filter/regulator.

BS EN 983 - SOFT START DUMP VALVES

Machines should be designed so that at start up any moving components reach their working position in a safe manner. There must also be a safe way of releasing the system air very quickly when signalled.

Combined soft start dump valves achieve both these functions in one unit. They also have the added benefit that the signal can be linked to one power down operation which will isolate the machine when not in use. This means any leaks or constant bleed devices will not drain the main system.

HSG 39 - CORRECT USE OF BLOW GUNS

'Blow guns consisting simply of a reduced orifice in direct line with the supply hose can be extremely dangerous, unless preceded by a pre-set tamperproof pressure regulator set at a reduced pressure from the normal 80 psi air line supply.'

Blow guns are commonplace throughout industry and whilst most people are familiar with their use , the very real hazards they present are often not appreciated. As an example a pressure of 0,4 bar can penetrate human skin with possible fatal results if air gets into the bloodstream.

Many blow guns are operated at full line pressure and can even be 'home made' i.e. short pieces of copper tube with diameters up to 6 mm. This situation is clearly dangerous. A secondary concern is the sheer volume of air that is wasted.

Good practice would be a blowgun with built in side vents to prevent pressure build up if the nozzle becomes blocked, preceded by a small preset non adjustable regulator (see figure 15).

If reduced pressure presents problems with an operation such as cleaning swarf from a component, then blow guns with efficient nozzles can be used to entrain some atmospheric air. This equipment will provide a safe working situation with the added benefit that it will pay for itself very quickly in reducing air usage.
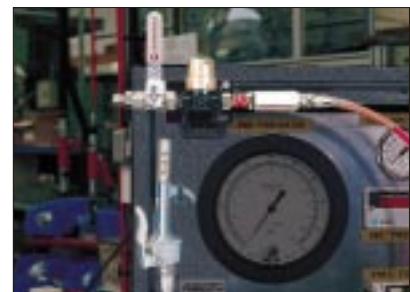

Figure 15.
Recommended arrangement for blow gun.

BS 6005 - 1997 SAFETY OF POLYCARBONATE BOWLS

Polycarbonate is commonly used for bowls on filters, filter-regulators and lubricators, offering clear visibility of bowl contents. However in an industrial environment it needs to be treated with some care. The standards says:

A.4.1.2 'Bowls which on visual inspection show signs of mechanical damage, cracking, or hazing should be replaced'.

A.4.1.3 'Bowls which have been contaminated with paint should also be replaced; they should not be cleaned'.

A.4.1.4 'All bowls which have been in service for 10 years should be replaced, even though they may appear acceptable by the visual inspection mentioned in A.4.1.2'

Whilst changing bowls which have any of the above problems will not directly save energy, it should be included in a maintenance plan which also checks the condition of filter elements and drains to reduce pressure drop and leaks.

Filters are notorious for being badly maintained and it is important to raise awareness of the safety implications of neglect of these units.

Figure 16.
Filter removed from a breathable air set in an automotive paint shop.

PUWER - ISOLATION FROM AIR SUPPLY

Regulation 19 'Every employer shall ensure that where appropriate work equipment is provided with suitable means to isolate it from its sources of energy'.

A variety of valves are available to help meet this requirement:
- ball valves
- shut off valves included in FRL units

Figure 17.
Lockable shut-off valve

- electrical operated control valves
- pneumatically operated control valves
Use of these has the added benefit that any leakage in the system downstream will not be continually draining the mains air supply.

AIR FUSE

The use of air fuses can also have an affect on energy saving. The device is designed to prevent pneumatic hoses whipping around, exhausting high pressure air in the event of a hose fracture. The fuse reduces the flow to atmosphere, so that only a very small amount of air escapes, compared to full line failure flow. Danger of injury from the hose is eliminated and energy wastage is minimised.

In situations where isolating valves and air fuses do not exist it would be necessary to bleed down the system, wasting all the compressed air before the hose failure could be repaired.

ENERGY & SAFETY 💸

18 blow guns with 4 mm hole, supplied with 7 bar line pressure.
Blow guns should be regulated to a lower pressure using the orifice flow table:

Flow through 4 mm @ 7 bar = 19 l/s
Flow through 4 mm @ 2 bar = 7 l/s
Potential flow saving per gun = 12 l/s

Gun is used for 300 hours per year (around 10 minutes in every hour)

Average saving per year = $\frac{300}{2\,500}$ x 12 = 1,4 l/s

Total for 18 blow guns = 25 l/s

Potential for saving

0,4 x 2 500 x 25 x £0.045 = £1 125.00

Cost of solution:

18 preset regulators = £306.00
1/2 man hour to fit each = £135.00
Total £441.00

Savings	Expense	Nett saving
£1 125.00	**£441.00**	**£648.00**

GENERATION

At best only 5% of the input energy to an air compressor remains in the air after it is compressed. This is due to the heat rejected by the compressor in its cooling systems.

Most compressor locations will contain the compressor, the treatment system and the control system. Each element of the compressor station, the installation and its maintenance has an effect on energy efficiency.

COMPRESSOR SIZE AND CONFIGURATION

The size and configuration of compressor is important in terms of energy efficiency.

Depending on the demand pattern it is normal to have the largest and most efficient machine on line to handle the base load and other machines coming on and off line to meet changes in demand.

Most modern installations use rotary compressors of the oil injected vane and screw types. When higher quality and larger volumes of air are needed oil free screw or centrifugal machines can be used and these usually have better efficiencies. (See figure 22)

Although not so popular for new applications, unless they are for special gases or high pressure, there are many piston machines still in operation. These machines particularly in the larger sizes have excellent efficiency and part load control.

Variable speed drives are becoming quite common as are two stage oil injected machines.

INSTALLATION

Cooling is most important with all compressors. The inlet air should be as cool as possible, ideally taken from a shaded outside location. In general a 4°C reduction in inlet temperature will give an improvement of 1% in efficiency.

A simple check on a compressors health is to measure the differences in temperature between the cooling medium

and the discharge air from the aftercooler.

For air-cooled compressors this should not exceed 15°C.

For water-cooled compressors this should not exceed 10°C.

If greater temperature differences are found the machines efficiency will be lower than design. The cooling systems should be improved.

Make sure all the feeding mains are correctly designed with flow velocities not greater than 6 metres per second. Use swept tees and long radius elbows at all pipe junctions.

Use electronic level sensing traps on all condensate collection points and ensure condensate recovery conforms to the regulations.

HEAT RECOVERY

Use the waste heat of compression for space heating, domestic water heating or process water. Large savings can be achieved by doing this.

MAINTENANCE

The way compressors are looked after in the field has a major impact on generation efficiency. Machines should always be maintained strictly in accordance with the manufacturers instruction book.

It is a false economy to run rotary vane and screw units past the manufacturers recommended compression element life cycle. Typically this is 24 000 hours with oil-injected machines and 40 000 hours for oil free machines.

Regularly inspect the intercooler pressure on two stage piston and screw compressor. This should be around 2 to 2,5 bar when the final discharge pressure is 7 bar. Any deviation shows stage imbalance giving poor efficiency.

Similarly check the pressure drop across the oil separator system.

If the maintenance of your compressor is conducted by a third party firm make sure you use a manufacturers accredited agent. Only use genuine spare

parts, items which are not of the original design or poorly refurbished will have a serious effect on energy efficiency. A small apparent saving in these areas can give a false economy in the long term.

CONTROL

Where a number of compressors, possibly of different types and sizes are used to meet varying air demands then a control system should be employed. This will optimise the number and mix of compressors to meet the demand, giving close pressure control with the most energy efficient mix of machines.

TREATMENT

Only treat the air to the minimum standard required. Refrigerated air dryers giving +3°C dewpoint and filters add 3% to the energy cost. Desiccant air dryers and filters giving -40°C dewpoint add between 8 and 15% to the running costs.

Use desiccant or membrane dryers at the point of use to save energy. Use dewpoint sensing controls with desiccant dryers.

Keep treatment system pressure losses to 0,5 bar. Size filters for the maximum flow, do not allow reduced flange sizes. Maintain filters regularly.

OPERATING PRESSURE

Establish the minimum acceptable pressure at the point of use and ensure the piping network is designed such that the pressure drop with the system on full load does not exceed 0,5 bar.

If possible reduce the generation pressure. A reduction of 1 bar can save 7% of the generation cost. Reduced pressure also reduces the unregulated air demand of the plant. A reduction from 8 bar to 7 bar will reduce the unregulated demand by around 12%.

Generation section kindly supplied by Eric Harding, Air Technology Ltd.

ACTION PLAN

- Measure System Flow Demand: methods
- Survey Factory In 3 Areas:
    compressor house
    ring main
    bays/point of use
- Focus In Each Area On:
    leaks
    misuse
    over pressure
    pressure drop
    safety issues
    locally measure usage if possible
- Having Identified Areas for Savings:
    cost out corrective action and payback
    implement
    check/flow pressure drop to validate measure
- Use Revised Flow Figures to Modify Control System for Compressors where necessary
- Implement Ongoing Preventive Maintenance and Periodic Re-audit (Leaks Come Back)

FURTHER SOURCES OF INFORMATION

Clean Compressed Air
Norgren's Guide to Effective Air Preparation
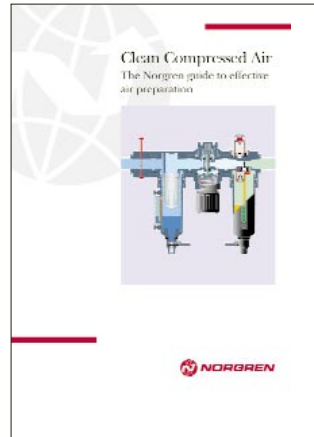
ETSU PUBLICATIONS

ETSU the energy efficiency branch of the Department of Environment Transport and Regions, offer a range of free publications on all aspects of energy saving. For compressed air information refer to:

Good Practice Guides

126	Compressing Air Costs
216	Energy Saving in the Filtration and Drying of Compressed Air
238	Heat Recovery from Air Compressors
241	Energy Savings in the Selection, Control and Maintenance of Air Compressors

Good Practice case studies

Various. Contact ETSU for details.
ETSU contact number 01235 436747.

Energy consumption guides

ECG 40	Compressing Air Costs:- Generation
ECG 41	Compressing Air Costs:- Leakage
ECG 42	Compressing Air Costs:- Treatment

OTHER PUBLICATIONS

HSG 39	Compressed Air Safety
BS 6005 1997	Specifications for Moulded Transparent Polycarbonate Bowls used in Compressed Air Filters and Lubricators
PUWER	Provision and Use of Work Equipment Regulations 1998

BS EN983 - 1996 Safety of machinery - safety requirements for fluid power systems and their components - pneumatics

A European Norm standard that supports the 'essential health and safety requirements' of the European Machinery Directive.

It identifies hazards which affect the safety of systems and their components when put to their intended use.

It is not a manufacturing standard so does not give guidance in the manufacturing of pneumatic components.

ISO 8573	Filtration

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![NORGREN]

Figure 19.

ORIFICE FLOW CHART

Orifice Size (hole)	litres/sec - ANR (dm³/s)				
(mm)	2 bar	4 bar	6 bar	7 bar	8 bar
0,2	0,02	0,03	0,04	0,05	0,06
0,3	0,04	0,05	0,10	0,11	0,12
0,5	0,11	0,19	0,26	0,30	0,39
1,0	0,45	0,73	1,05	1,20	1,35
1,5	1,02	1,70	2,37	2,69	3,05
2,0	1,81	3,05	4,20	4,80	5,40
3,0	4,00	6,77	9,46	10,81	12,16
4,0	7,27	12,04	16,82	19,16	21,67
5,0	11,35	18,83	26,32	30,00	33,82
6,0	16,34	27,16	37,82	43,32	48,65
8,0	29,16	48,15	67,30	76,90	86,50
10,0	43,32	75,30	105,10	120,10	135,10
15,0	102,10	169,90	236,60	269,90	304,00

Figure 20.

AIR QUALITY CLASSIFICATIONS ISO 8573

Quality Class	Dirt Particle Size in Microns	Water Pressure Dew-point °C (ppm vol.) at 7 bar g		Oil (including vapour) mg/m³
1	0,1	-70	(0,3)	0,01
2	1	−40	(16)	0,1
3	5	−20	(128)	1
4	15	+3	(940)	5
5	40	+7	(1 240)	25
6	—	+10	(1 500)	—

Figure 22.

COMPRESSOR EFFICIENCIES

Configuration	Capacity litres/sec	Specific Power Kwᵉ/50 l/s	Part Load Efficiency
Lubricated piston	2–25	24	Good
	25–250	20	Good
	250–1 000	17	Excellent
Oil-free piston	2–25	26	Good
	25–250	22	Good
	250–1 000	19	Excellent
Oil injected rotary vane and screw	2–25	24	Poor
	25–250	22	Fair
	250–1 000	19	Fair to good
Oil free toothed rotor and screw	25–25	20,5	Good
	250–100	18	Good
	1 000–2 000	18	Good
Oil-free centrafugal	250–1 000	21	Good
	1 000–2 000	18	Excellent
	Above 2 000	17	Excellent

Figure 21.

RECOMMENDED FILTRATION LEVELS.

Application	Typical Quality Classes	
	Oil	Dirt
Air agitation	1	3
Air bearings	2	2
Air gauging	2	2
Air motors	4	4
Brick and glass machines	5	4
Cleaning of machine parts	3	4
Conveying, granular products	2	4
Conveying, powder products	1	3
Foundry machines	4	5
Food and beverages	1	1
Hand operated air tools	5	5
Machine tools	5	4
Mining	5	5
Micro-electronics manufacture	1	1
Packaging and textile machines	5	3
Photographic film processing	1	2
Pneumatic cylinders	3	5
Pneumatic tools	5	4
Pneumatic tools (high speed)	4	3
Process control instruments	2	3
Paint spraying	1	1
Sand Blasting	4	5
Welding machines	5	5
General Workshop air	5	4

Figure 23.

FRICTION LOSS IN PIPE FITTINGS IN TERMS OF EQUIVALENT METRES OF STRAIGHT PIPE.

	8 mm	10 mm	15 mm	20 mm	25 mm	32 mm	40 mm	50 mm
Tee (straight through)	0,15	0,15	0,21	0,34	0,46	0,55	0,67	0,92
Tee (side outlet)	0,76	0,76	1,01	1,28	1,62	2,14	2,47	3,18
90° elbow	0,43	0,43	0,52	0,64	0,79	1,07	1,25	1,59
45° Elbow	0,15	0,15	0,24	0,30	0,38	0,49	0,58	0,73
Ball valve*	0,01	0,03	0,09	0,12	0,15	0,22	—	—

* Self exhausting – full open

Figure 24.

MAXIMUM RECOMMENDED FLOW * THROUGH ISO 65 MEDIUM SERIES STEEL PIPE.

Applied Gauge Pressure bar	Nominal Standard Pipe Size (Nominal Bore) – mm										
	6	8	10	15	20	25	32	40	50	65	80
	Approximate Pipe Connection – inch										
	1/8	1/4	3/8	1/2	3/4	1	1 1/4	1 1/2	2	2 1/2	3
0,4	0,3	0,6	1,4	2,6	4	7	15	25	45	69	120
1,0	0,5	1,2	2,8	4,9	7	14	28	45	80	130	230
1,6	0,8	1,7	3,8	7,1	11	20	40	60	120	185	330
2,5	1,1	2,5	5,5	10,2	15	28	57	85	170	265	470
4,0	1,7	3,7	8,3	15,4	23	44	89	135	260	410	725
6,3	2,5	5,7	12,6	23,4	35	65	133	200	390	620	14085
8,0	3,1	7,1	15,8	29,3	44	83	168	255	490	780	14375
10,0	3,9	8,8	19,5	36,2	54	102	208	315	605	965	14695

*Air flow rates in dm³/s free air at standard atmospheric pressure of 1 013 mbar.

General notes

The flow values are based on a pressure drop (ΔP) as follows:

10% of applied pressure per 30 metres of pipe   6 – 15 mm nominal bore inclusive

5% of applied pressure per 30 metres of pipe   20 – 80 mm nominal bore inclusive

Figure 25.

ADDITIONAL COSTS FOR TREATING COMPRESSED AIR

Pressure Dew-point °C	Dryer Type	Filtration	Added Cost Over Generation	Initial Cost
Typical 10	Membrane	Pre	10 - 15%	Low
3	Refrigerated	General purpose	3%	Medium
−40	Heatless desicant	Pre and after	8 - 15%	High
−40	Heated desicant	Pre and after	10 - 15%	High
−70	Heatless desicant	Pre and after	15 - 21%	High