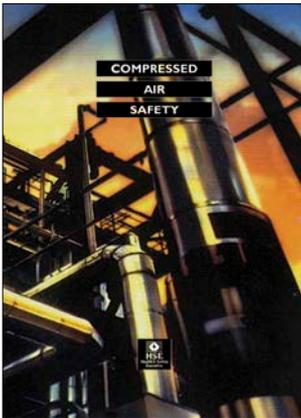


Compressed air safety



HSG39 (Second edition)
Published 1998

This book aims to promote the safe use of compressed air and describes the many ways in which compressed air can be dangerous as well as how to minimise the risk of such dangers occurring.

It is aimed at designers, manufacturers, installers, users and others concerned with or responsible for health and safety at work.

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Introduction

- 1 This guidance booklet aims to promote the safe use of compressed air by giving advice to designers, manufacturers, installers, users and others concerned with or responsible for health and safety at work. It was originally produced in 1990 during a rapidly changing situation in Europe arising from the preparation for the single market and was further revised under the 'Review of Regulations and Guidance' undertaken by the Health and Safety Executive (HSE) in 1996.
- 2 There are many ways in which compressed air can be dangerous, for example:
 - (a) it can enter body orifices such as the mouth, ears and anus, causing severe and often fatal injuries;
 - (b) at high pressure it can penetrate the skin;
 - (c) particles or oil carried in an air jet can damage the eyes;
 - (d) oil-coke deposits in a system can spontaneously ignite and cause an explosion;
 - (e) vessels containing compressed air, even at comparatively low pressure, can explode violently once their integrity is lost; and
 - (f) dirty or 'wet' air can lead to corrosion and blocked valves which may make the system unsafe.
- 3 This booklet explains how to minimise the likelihood of such problems, but it does not give specific advice on air separation plant, the pneumatic transportation of materials through pipelines or the supply of respirable air. Reference in this guidance booklet to a particular standard does not preclude using an equally effective alternative standard.

Compressor plant

Groups of compressors

- 4 For the purposes of this booklet compressors are divided into three groups: small, medium and large.
- 5 A small compressor delivers up to 40 litres per second of free air and/or has a power input of no more than 15 kW. Such compressors may be mobile or fixed and may be supplied as packaged units. A typical one would comprise a reciprocating compressor driven by an electric motor on top of or alongside an air receiver.
- 6 A medium compressor delivers between 40 and 300 litres per second of free air and/or has a power input of between 15 and 100 kW.
- 7 A large compressor delivers more than 300 litres per second of free air and/or has a power input of more than 100 kW.
- 8 Many medium and large compressors are supplied as packaged units. A typical one would comprise a compressor, air intake filter, motor and air cooler, all on a common bed frame with factory-connected piping and factory-installed electrical controls and wiring. It could be enclosed in a sheet metal housing treated with soundproofing material to reduce noise levels.
- 9 Using a packaged unit has a number of advantages; it simplifies foundation work, reduces installation time and provides a properly engineered and adequately guarded assembly of components in a compact space. However, the user is still responsible for siting the system so that incoming air is as dry and free from contaminants as site conditions allow. Both the air entering the compressor plant and the delivered air **must** be as dry, clean and cool as possible. Advice on siting is given in paragraphs 60 to 67.

Hazards

- 10 The major hazard associated with compressors is overpressurisation, which may arise from:
 - (a) a blocked outlet or some other restriction to flow;
 - (b) failure of automatic controls combined with low air consumption;
 - (c) compressor malfunction, eg overspeeding;
 - (d) an external fire near the pressure system; and
 - (e) overheating and the build-up of carbonaceous deposits, both of which can lead to fires or explosions. Although they are rare, fires and explosions can also occur as a result of oil or oil vapour being ignited in the pressure system.
- 11 Dirty or 'wet' air can cause a system to fail eg by causing fine particles of debris to agglomerate, blocking safety related valves.

General information and advice

- 12 Standards for the safe design, construction, installation and operation of many types of stationary compressor are set out in BS 6244 *Code of practice*

for stationary air compressors. It specifies requirements to help minimise compressor accidents and defines general safety practices. BS EN 1012 Parts 1 & 2 cover *Compressors and vacuum pump safety requirements*.

NOTE: It is important that records are amended following modifications to plant and pipework.

Precautions

- 13 Transmission machinery eg 'V' belts, pulleys and other dangerous parts, should be guarded to prevent access, see BS 5304 *Code of Practice for Safety of machinery*.

Safety valves

- 14 On all medium or large multi-stage positive displacement compressors a safety valve should be fitted between each stage and, where appropriate, in the inter or after cooler circuit.
- 15 Where an isolating valve is installed in the discharge pipework between the compressor and receiver, the pipework on the compressor side of the valve should be protected by a suitable safety valve that complies with BS 6759, Part 2 *Specification for safety valves for compressed air or inert gases* and is installed to BS 6244, clause 21, unless the system has been designed to withstand the maximum pressure that can be generated. (This valve is in addition to the air receiver safety valve.) On small fixed and small and medium transportable compressor units, where the outlet of the compressor is directly connected without shut-off or non-return valves to an air receiver to which no other source of pressure is attached, one safety valve on the air receiver is sufficient.

Pressure indication

- 16 An accurately calibrated air pressure gauge with a readily visible appropriate scale-reading should be provided after each stage of compression. However, on small two-stage compressors this is not required after the first stage of compression, but a suitable tapping to enable a test device to be fitted should be provided. Gauges should be constructed to comply with BS EN 837-1 Part 1- *Bourdon tube pressure gauges- Dimensions, metrology, requirements and testing* and installed to comply with BS EN 837-1 Part 2 *Selection and installation recommendations for pressure gauges*.
- 17 On medium and large reciprocating compressors with forced feed lubrication systems it is important that a gauge is provided in the appropriate position to indicate oil pressure.

Thermal protection

- 18 To minimise the risk of overheating, large compressors should be provided with a suitable thermal protective device as near as practicable to the last stage discharge valve or, where there is more than one valve, at a common point of discharge which would automatically shut down the compressor when a predetermined temperature is exceeded. **Note - where automatic compressor shut-down may adversely affect the safety of pressure-dependent systems, additional high temperature warning devices may be required so that action can be taken prior to automatic shut-down.**
- 19 On large two-stage compressors a thermal protective device should also be provided as near as possible to the first-stage discharge valve. Large compressors with three or more stages would require a separate device for each stage.

- 20 For medium and large air-cooled compressors protective devices should be provided to monitor general compressor overheating which may be caused by cooling-fan failure or the fouling of cooling surfaces.
- 21 Oil-flooded rotary compressors should have an automatic shut-down device to prevent the temperature of the compressed air from exceeding a safe limit.

Coolant protection

- 22 If the compressor is water cooled, a thermostat should be provided to the cooling water outlet or water return to the radiator header tank to shut down the compressor when the water temperature exceeds the manufacturer's recommended maximum. Where the thermostat device does not give 'no water' or 'no flow' protection, a water flow detection device should also be provided. Sufficient good quality cooling water is required to cool all parts of the system and inhibit blockages and corrosion. The supply may require protection against freezing in low temperatures.

Lubricant protection

- 23 On medium and large compressors a pressure-sensing device should be provided to shut down the compressor and activate visible and audible alarms if the lubricating oil pressure drops below the manufacturer's recommended minimum. Gravity-feed lubrication systems should be fitted with a level sensing device. A thermal sensing device should be fitted to set off an alarm and shut down the compressor if the oil in the crank case, sump or scavenge systems exceeds the temperature specified by the lubricant manufacturer. There can be safety advantages to using synthetic ester-based oils for lubricating compressors.

Explosion protection

- 24 If components run hot, or oil coke deposits spontaneously ignite, there may be an explosion. BS 6244 describes the chemistry of such conditions and explains how oil coke deposits can be prevented. To reduce the explosion risk on medium and large compressors, a fusible plug can be fitted on the underside of the pipe between the compressor and the receiver as close as is practicable to the compressor. When ordering such a plug, users will need to provide the following information for the manufacturer:
- (a) maximum design working pressure;
 - (b) maker and grade, or closed flashpoint of the oil used for cylinder lubrication;
 - (c) maximum design outlet temperature of air; and
 - (d) bore of outlet pipe from compressor.

- 25 Fusible plugs are generally available for pressure up to 340 bar (5000 psi). As an additional precaution regular inspections of the compressor should be carried out (see paragraphs 142 to 170).

Air inlet/outlet monitoring

- 26 A water manometer or other pressure-indicating device should be fitted to each inlet air filter on large compressors. The device measures the pressure drop across the filter, indicating how clean it is. It is recommended, where it is reasonably practicable to do so, that such devices be fitted to small and medium compressors.

Other instrumentation

- 27 On medium and large compressors consideration should be given to fitting temperature reading or recording instruments to indicate:

- (a) air temperature at:
 - (i) the inlet to the compressor;
 - (ii) the outlet from the first stage of compression, near to the discharge valve;
 - (iii) the inlet to the last stage of compression;
 - (iv) the outlet from the last stage of compression, near to the discharge valve; and
 - (v) the outlet from the after cooler
- (b) oil temperature at:
 - (i) the crank case; or
 - (ii) with forced feed and scavenge lubrication system, the point where the oil leaves the crank case;
- (c) water temperature at:
 - (i) the inlet to each cooling circuit (except on radiator-cooled sets); and
 - (ii) the outlet from each cooling circuit.

It is important that the user and manufacturer discuss whether such instruments are needed.

Air inlet/outlet control

- 28 The inlet valve can either be designed so that it cannot be used in a partially open position, or be fitted with visible and audible warnings that indicate whether the valve is fully open or closed during plant operation. The valve operation is normally automatic except when required for starting up the compressor. Oil-flooded rotary compressors have built-in self-regulating inlet throttles. Constant speed compressors should be provided with suitable control gear so that the amount of air delivered can be controlled to suit demand.
- 29 Figure 1 shows an illustration of a large compressor installation and the positions at which safeguards are required or recommended. It is unlikely that any installation will require all the safeguards indicated. The final requirement will depend on relevant statutory requirements, the degree of supervision the installation will receive and the local environment.

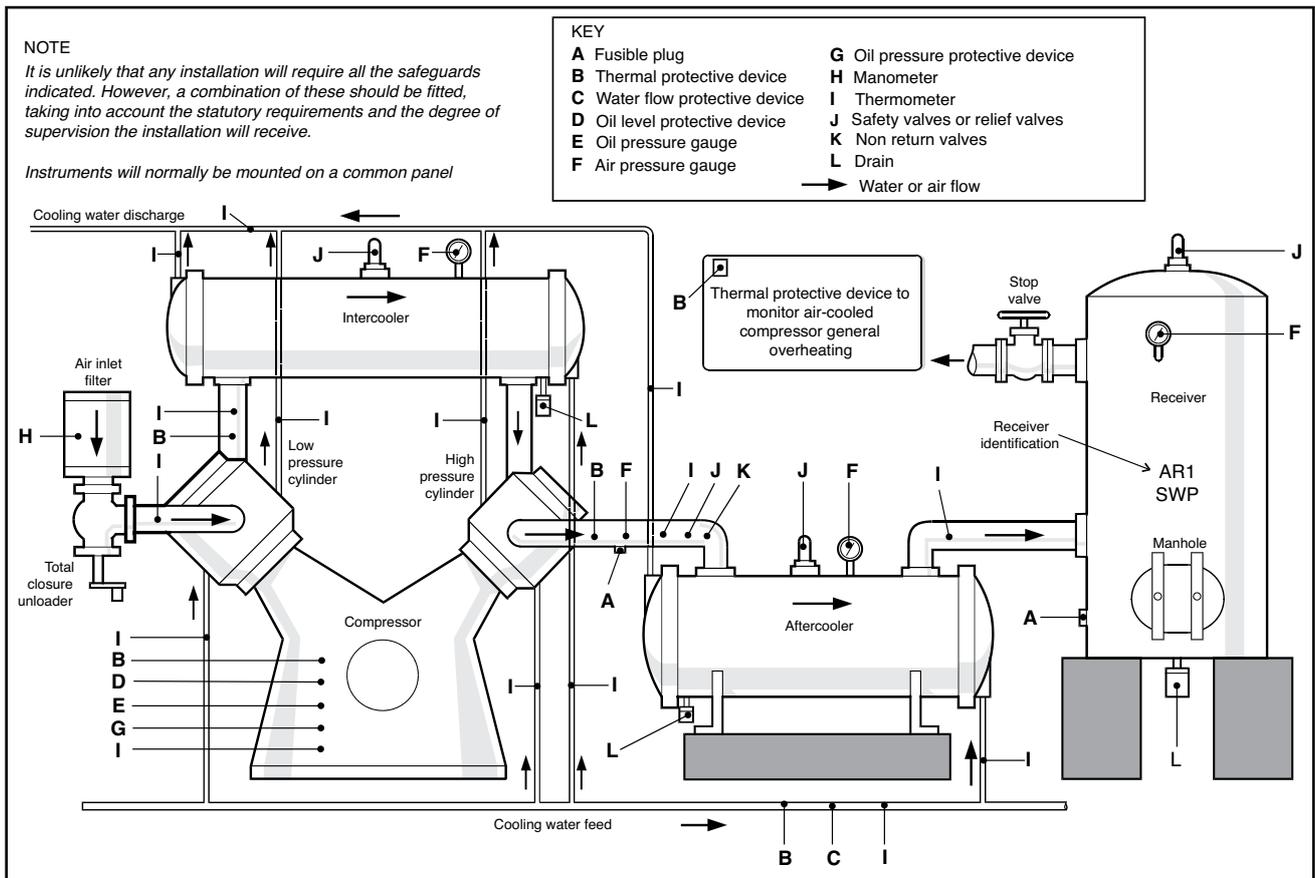


Figure 1 Illustration of a large compressor installation showing the position at which safeguards are required or recommended

Air receivers

Statutory requirements

- 30 Both manufacturers and users should be familiar with the statutory requirements applying to compressed air systems and air receivers. These are principally contained in the Pressure Systems and Transportable Gas Containers Regulations 1989. Additional recommendations are given in the Approved Code of Practice *Safety of pressure systems*.
- 31 In premises where the air receivers must be cleaned and examined at regular intervals and for air receivers with a value of pressure times volume greater than 250 bar litres, the nature and frequency of the examination must be contained in a written scheme of examination. The written scheme of examination drawn up or certified by a competent person will normally specify a period between examinations of 24 to 48 months.
- 32 When connected to an air compressing plant a receiver should either be constructed to withstand the compressor's maximum pressure safely, or be fitted with a safety valve and a pressure-reducing valve to prevent the receiver's safe working pressure from being exceeded. When providing a safety valve and pressure gauge for a set of air receivers that are interconnected and collectively supplied through a single pipe, they may be treated as one receiver, provided that:
 - (a) any reducing valve or other suitable appliance is provided in the single supply pipe; and
 - (b) there is no means of isolating any interconnecting pipework.
- 33 The receiver should be fitted with a suitable safety valve complying with BS 6759, Part 2 or similar equivalent standard and adjusted so that air is allowed to escape as soon as the safe working pressure has been exceeded. It is essential that the valve is capable of discharging more air than the system can supply to the receiver.
- 34 The receiver should be fitted with a correct pressure gauge complying with BS 1780 or similar equivalent standard and which indicates pressure in bar, lbf/sqin, or other suitable units.
- 35 There should be a suitable appliance, either manual or automatic, for draining the receiver. It is recommended that manual drain valves should be full bore and straight through, to minimise any build-up of debris which could prevent tight shut off. Automatic drain valves should have adequate capacity for liquid discharge, be designed to minimise debris build-up and have a manual override to check performance. A strainer positioned immediately upstream of the valve will help prevent debris build-up. Protection against freezing of valves will be required in low temperature conditions.
- 36 A receiver should have a suitable manhole, handhole or other means (as determined by the relevant standards, for example BS EN 286-1 *Specification for simple unfired pressure vessels designed to contain air or nitrogen* and BS 5169 *Specification for fusion welded steel air receivers*) to enable the interior to be thoroughly cleaned and inspected.

- 37 A receiver should be clearly marked, in a conspicuous position, with its safe working pressure and other relevant information required by the Pressure Systems and Transportable Gas Containers Regulations 1989. The details should be clearly visible on the vessel or a plate attached to it.
- 38 A receiver should be readily distinguishable. This can be achieved by painting on identification markings or by affixing a manufacturer's plate, giving the name of the manufacturer, serial number etc.

Hazards

- 39 The main hazard is that the vessel may explode because its safe working pressure has been exceeded or because its ability to withstand pressure has been reduced through corrosion fatigue or internal coke fires for example.

General information and advice

- 40 All new air receivers should conform to BS EN 286-1 or BS 5169, where applicable, or to a standard providing equal integrity.

Precautions

- 41 To determine the required capacity, the compressor output and demand pattern need to be taken into account. As a guide, this will be between six and ten times the free air output of the compressor at normal pressure (litres/second). Many users try to save on initial cost and make the mistake of buying a receiver that is too small.
- 42 The drain valve, safety valve, examination holes and manholes need to be accessible.
- 43 The scale of any gauges needs to be clearly visible.
- 44 On large compressor systems the air receiver should be fitted with a fusible plug conforming to BS 1123, Part 1. If a fire breaks out nearby, the plug will help to prevent an explosion by guarding against:
- (a) the air temperature rising to the compressor lubricating oil flashpoint; or
 - (b) an explosion occurring below the designed working pressure because of lost integrity owing to heat.
- 45 Welded-on brackets are often used to mount compressor-motor combinations onto air receivers. Where this is the case, welding should be to the specification and approval of the air receiver manufacturer. It should not be carried out indiscriminately because the welder may unwittingly weaken the receiver. Mounting brackets should be designed and fitted in accordance with the applicable air receiver standard. It is good practice to weld mounting brackets onto intermediate reinforcing plates rather than directly to the air receiver.

Coolers

Hazards

- 46 Many aftercoolers are pressure vessels and the associated hazards are similar to those of air receivers (see paragraph 39).

General information and advice

- 47 Cooling plays an important part in the supply of good quality compressed air. Intercoolers and aftercoolers lower the temperature of the compressed air. These coolers are usually water or atmospheric air cooled. With very small air compressors the function of the aftercooler (ie the lowering of the dewpoint of the compressed air) is performed by the air receiver. For other cases a separate aftercooler will normally be necessary.

Precautions

- 48 Air-cooled coolers usually rely on a good circulation of external air over the heat exchanger surface to ensure effective transfer of heat. There should be adequate space available around these heat exchangers to allow effective cleaning of all surfaces. The cooling air inlets and outlets should not be obstructed by loose equipment, materials etc or by any subsequently erected building. Where possible the air inlet should be sited on the north side of the building.
- 49 It is recommended, particularly at medium and large compressors, that aftercoolers are fitted to the discharge side immediately after the compressor. These are frequently provided with separators to remove oil and moisture from the air.
- 50 A condensate separator with an automatic drain valve should be provided at a suitable drainage point at the cooler's compressed air outlet. Protection against freezing of the valve will be required in low temperature conditions.
- 51 Where a fluid is used as the cooling medium, a coolant drain valve should be fitted and the cooling circuit protected against corrosion. There should be some way of measuring the inlet and outlet temperatures of the compressed air and of the coolant.

Air dryers

Hazards

- 52 The hazards associated with the shells of large dryers designed on the tube-in-shell principle are similar to those of an air receiver (for information on hazards see paragraph 39). A secondary hazard, should an air dryer not function properly, is that moisture-laden air can cause a safety system to fail.

General information and advice

- 53 Air dryers are sometimes desirable where pipe runs have to be routed outside buildings or where the compressed air is used outside buildings eg for operating valves. Where exceptionally dry air is needed, eg for purging double glazing units, air dryers are essential. There are two main types: refrigerant and desiccant. Further classification can be found in BS 6754 *Specifications and testing of compressed air dryers*.

Refrigerant

- 54 Refrigerant air dryers can usually reduce the dewpoint of the compressed air to 2° C. This prevents condensation from forming in the distribution pipes where the ambient temperature exceeds 2°C. This may be suitable even where short runs of pipe are routed in the open air, provided they are properly insulated.

Desiccant

- 55 Desiccant dryers can reduce the pressure dewpoint of the compressed air to very low levels, exceptionally, as low as -100°C but normally, between -20°C and -40° C. The reduction in the pressure dewpoint of compressed air should be closely related to the requirements of the plant or equipment installed. A desiccant dryer normally consists of two chambers that both contain desiccant - one on stream, the other being regenerated. An automatic inlet valve directs air from the compressor to each chamber in turn, thus ensuring a constant supply of dry air.
- 56 Positioning of the air dryer will depend on the customer's particular requirements, but will be either immediately between the aftercooler and receiver (where fitted) or immediately after the receiver. Where the need for exceptionally dry air represents only a small percentage of the total compressed air used, a dryer may be located immediately upstream of the particular plant where the dry air is needed.

Precautions

- 57 The chambers of air dryers are pressure vessels and should conform with BS 5500 *Specifications for unfired fusion-welded pressure vessels* or to a standard providing equal integrity. If means are provided for isolating the dryer (and it is good practice to provide means of isolation for all equipment), either the chambers should be constructed to withstand the maximum pressure that can be generated by the compressor or a suitable pressure reducing valve and a safety valve should be fitted to prevent the safe working pressure of the chambers from being exceeded.

- 58 Where there is no means of isolating the dryer from a suitable safety valve, eg on the receiver, and where non-return valves are fitted to the dryer outlet (to protect it from stored energy in the system), no safety valves are needed.
- 59 Some dryers regenerate the desiccant simply by passing a proportion of the drier air through it. Others use heater coils embedded in the desiccant. This latter type should be equipped with a thermal protective device that can detect any temperature rise above the thermostat setting. Excessive temperature rises due to thermostat failures have been known to lead to oil mist explosions.

Installation of compressors

- 60 Small compressor installations may easily be overlooked, especially if sited in a separate enclosure outside the working area, and consequently may not receive proper maintenance (see paragraph 146-158). The design of large installations will need to incorporate adequate access and suitable lifting equipment to facilitate maintenance. If normal lighting is likely to be inadequate, local lighting should be provided so that the working area is adequately lit. Consideration should also be given to compressor specifications if they are to be installed in possible hazardous areas, e.g. in garage pits where a flammable atmosphere may be present.

Precautions

Small compressors

- 61 Where possible the compressor unit should be mounted at ground level and/or in an area big enough to allow for inspection and maintenance.
- 62 Any platform used for access or as a place of work should be big enough for a person to stand safely on it, and have guard rails and toe boards.
- 63 The unit should not be mounted on a plant structure where there is excessive vibration.
- 64 Small units used to supply workshops and similar installations should be sited where they are accessible and physically protected against damage from material, tools and equipment. Where the risk of damage is high they should, where possible, be installed in separate rooms adjacent to the main building (see paragraphs 60 and 67).

Medium and large compressors

- 65 Where users are responsible for on-site system design and installation they should follow the manufacturer's instructions carefully. Medium and large compressors should be located in a position (usually permanent) best suited for the purpose and with access for ease of maintenance. This means that the compressor, including its prime mover, air receiver, cooler etc. should be:
- (a) near the centre of the load to minimise pipe runs;
 - (b) housed in a building that is insulated or heated to keep the ambient temperature above freezing;
 - (c) provided with adequate ventilating air to prevent overheating, and sited so that the intake of moisture is minimised; and
 - (d) sited away from dusty atmospheres and provided with adequate facilities for draining of condensate.
- 66 There should be some means of controlling airborne dust and contaminants in the vicinity of the compressor. The air intake should be provided with an efficient filter.

Noise

- 67 Compressor noise is one of the most common noise problems associated with the workplace and is potentially damaging. Reference should be made to the Prevention of Damage to Hearing from Noise at Work Regulations,

enacted on 1 January 1990, and the associated guides 1 and 2 and 3 to 8. Where noise from compressors is likely to cause exposure to hazardous levels of noise, this should be included in the noise assessment (required under the Noise at Work Regulations 1989) and the assessment should indicate the degree of noise reduction required to reduce the exposure to safe levels. Compressors should be supplied with noise emission information. If this is not the case, purchasers should request this information which can be used in the assessment. Noise control measures, if required, include the following:

- (a) siting the compressor away from work areas;
- (b) providing the compressor with an acoustic enclosure(the need for access and removal for maintenance will need to be addressed);
- (c) providing anti-vibration mountings;
- (d) the fitting of or improving the performance of silencers;
- (e) access to enclosures provided for compressors should only be permitted to persons wearing suitable and effective ear protection.

68 *HSE Guidance note PM 56* gives information and advice about nozzle design to reduce noise.

Main line systems

- 69 This section deals with the system of pipes, valves and fittings from the source of the supply to the point of application or control.

Hazards

- 70 Inadequately sized and designed systems can lead to the operating units being starved of air, causing machine malfunction. Repeated malfunctions may tempt operators to adopt unsafe practices to overcome any problems. Badly designed pipe runs and lack of isolation valves may expose maintenance staff to unnecessary risks. Some grades of plastic pipework are not recommended for use in compressed air installations and designers are advised to consult manufacturers when selecting materials.
- 71 Incorrect maintenance of non-metallic bowls used on filters, traps, separators and lubricators can lead to explosions. It is important to ensure that all lubricants used to replenish lubricators are compatible with the lubricator bowl and the equipment to be lubricated. Attention is drawn to BS 6005 *Specification for moulded transparent polycarbonate bowls used in compressed air filters and lubricators*, regarding installation, use and maintenance of units fitted with polycarbonate bowls.

General information and advice

- 72 Compressed air systems invariably grow. It is important to take into account any foreseeable expansion of the system, and generous allowance should be made on the size of piping provided. The cost of installing a 50 mm diameter pipe is little more than a 25 mm one, any difference being in the cost of material. However, flow capacity of a 50 mm pipe is four times that of a 25 mm one and using the larger size ensures better performance and facilitates future additions to the system at little extra cost. As a general guide the pipe size would be such that the pressure drop between the receiver and the most remote take off points would not exceed 5% of the required supply pressure with a maximum of 0.3 bar (4 psi). The pipe size for initial main runs in any system would not normally be less than the output port of the compressor.
- 73 There are two main types of compressed air system; single line and ring main. Figures 2 and 3 show typical layouts, with positions indicated for various valves, drains, filters, air line lubricators and pressure gauges.
- 74 Users should keep a schematic drawing of the air system showing pipe runs, intended direction of air flow, and the positions of fittings such as valves, drains, etc. The drawings should be amended when modifications or additions are made to the system. Any graphic symbols used should comply with BS ISO 1219 *Fluid power systems and components. Graphic symbols and circuit diagrams*.

Precautions

Pipe-runs

- 75 The route of the pipe run and the position of valves and operating points should be safe and convenient for those who will use and maintain the system.

- 76 The pipe route itself should not present a hazard or obstruct access and should be routed away from any areas where it may be vulnerable to mechanical damage.
- 77 There should be adequate and sufficient access ways, working platforms and clearance space provided to enable the compressed air system to be operated and maintained without exposing anyone to unnecessary risk.
- 78 Pipe runs should have a slight fall in the direction of air flow, and drainage valves should be fitted at the lowest point, in such a way that moisture and air can be discharged safely. A drain valve should be fitted at the bottom of vertical pipe runs. Sections of pipe and valves that may have water in them and may be exposed to frost should be suitably insulated. **Note: receiver drains generally have a heavier duty than normal pipe run drains-see paragraph 35.**
- 79 Pipe runs should be secured by brackets or other supports installed at appropriate intervals to support the pipe system such that each removable section is self-supporting and the remaining pipe is stable after removal. To allow for expansion, particularly at the compressor/receiver discharge or on straight runs exposed to sunlight or heat from the process, suitable and adequate expansion devices should be fitted; eg bellows, loop bends, flexible pipes. BS 3974:Parts 1-3 *Specification for pipe supports* gives details of suitable methods.

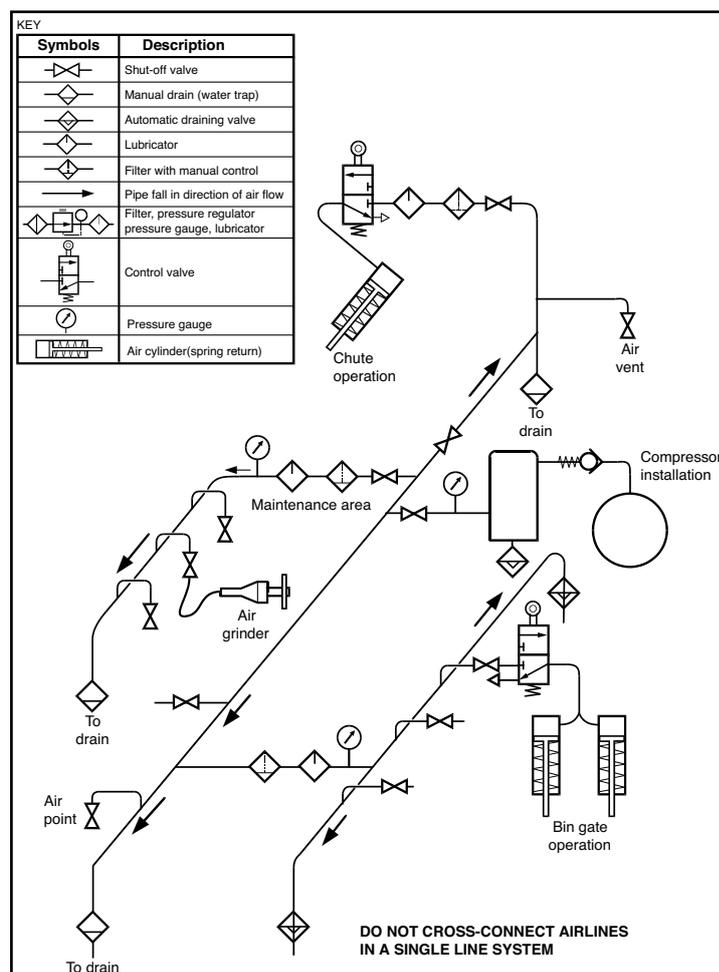


Figure 2 Single line system - typical layout

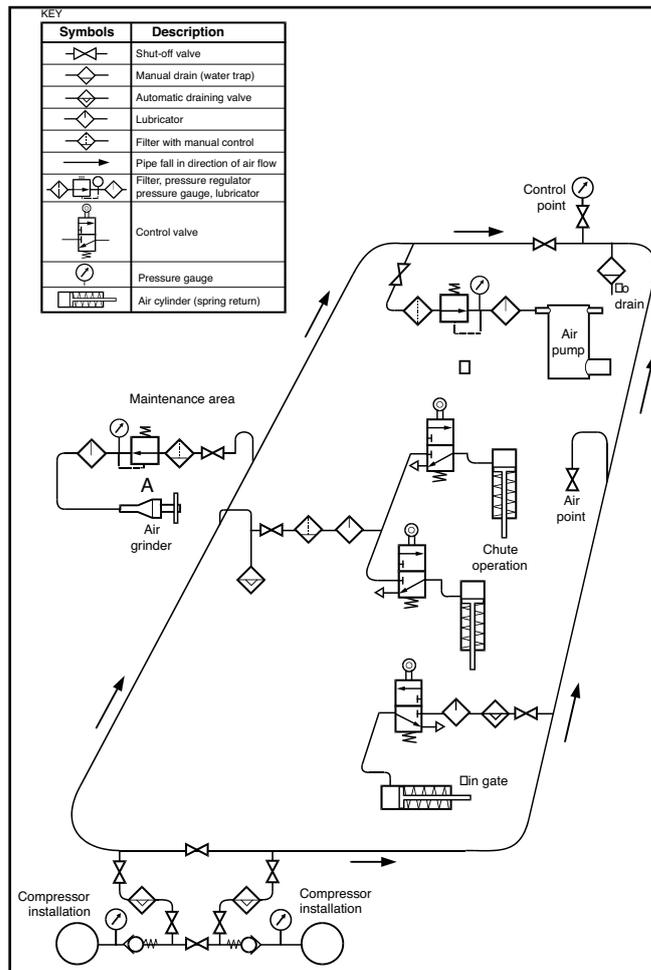


Figure 3 Ring main system - typical layout

- 80 Piping and associated fittings connected between the compressor and air receiver should be easy to clean. If carbon deposits build up in such pipework there may be an explosion (see paragraph 24).
- 81 All outlet points should, where practicable, be taken from the top of the pipe run, and a stop valve or self-venting ball valve (where necessary complete with handle) should be provided adjacent to the connection point. The connection point at any outlet should be arranged horizontally or face downwards; upward facing connection points invariably fill with dirt and prompt the bad practice of blowing out before use. Outlet points should be provided at convenient places for all routine activities which require compressed air. They should be positioned so that hoses attached to them will not cross or obstruct the normal access to the workplace, and can be connected without the need for climbing.
- 82 Pipe runs should be identified by painting the pipe light blue (BS colour reference 20.E.51) in accordance with BS 1710. Where applicable the risk of coupling up to the wrong compressed gas supply can be further reduced by the use of non-interchangeable connections (see also paragraph 100).
- 83 Stop valves should be provided and positioned so that the complete pipework system can be isolated from the compressed air supply. All branch lines of subsections of the system should also have stop valves fitted to allow

separate isolation. Where appropriate each valve should have a facility to be locked in the closed position.

- 84 For ring mains or systems with dual supply, stop valves must be provided which enable each individual air supply to be isolated from the pipework system. This arrangement of stop valves will allow safe operating procedures to be adopted during maintenance of the system and ancillary equipment.
- 85 Where air cannot be vented from the system or any part of the system through the normal outlets, valves should be fitted for this purpose. The valves specified should be suitable for the application. In most cases three-port valves or self-venting ball valves are the most suitable type for isolating and venting; these valves should be arranged so that when the supply is shut off, the downstream part of the air system is vented through the exhaust port of the valve and provision made to lock the valve in this position.
- 86 Where valves are grouped, or where the purpose or location of the valve is not obvious, a notice should be provided indicating the position and/or purpose of the valve.
- 87 Lever operated stop valves can be inadvertently moved to the open position. During maintenance they should be either locked in the closed position or the lever handle should be removed.

Filters, traps, separators and lubricators

- 88 Filtration and lubrication to a standard of cleanliness appropriate to end usage are necessary. Air line lubricators should be provided for operations which involve air tools, air cylinders or air control valves; they should be positioned after the stop valve and after any filter or separator. In both cases it is essential that filters and lubricators are positioned after and adjacent to a stop valve to allow safe service and maintenance. They should not be fitted into ring mains where the direction of air flow is not controlled but into the branch lines leading from them. High standards of filtration will be required for instrument control or in the electronics industry. Ultra-high efficiency filtration will be required in hospitals and the pharmaceutical, foodstuffs preparation and brewing industries, and appropriate filters, traps or separators should be fitted. Where extremely clean or sterile air is required specialist equipment suppliers should be consulted. Precautions should be taken against the ingress of dirt and other contaminants from the surrounding area through careful siting of the compressor. The use of exhaust port filters should be considered.
- 89 In most cases these components will have either metallic or transparent plastic bowls (usually polycarbonate or polyamide), which have good impact strength. The properties of the materials may however be adversely affected by solvents, alcohols, cleaning solutions or synthetic lubricants and maintenance in accordance with manufacturers' recommendations is essential. (NB Useful guidance for polycarbonate bowls is provided in BS 6005 *Specification for moulded transparent polycarbonate bowls used in compressed air filters and lubricators*.) It is therefore essential that cleaning of polycarbonate bowls is carried out with clean rags, and that material likely to be contaminated with diluted soluble oils should be avoided. Where possible, filters, separators and lubricators should be positioned so that the risk of accidental damage to any non-metallic bowls is minimised. Even subsequent minor knocks may lead to damaged bowls exploding. It is good practice to shield all non-metallic bowls and manufacturers should ensure that such bowls can be shielded. Specific requirements for filters, traps, separators and lubricators are discussed in paragraphs 104, 105 and 109.

Pressure regulators

- 90 Where it is necessary to protect equipment from overpressurisation, pressure regulators should be provided and set to maintain a constant safe downstream pressure. An air pressure gauge should be provided on the outlet side. Depending on the level of risk created by overpressurisation all adjustable controls should have some form of tamper-resistant protection. Where the risk is low, a simple snap action lock should suffice. As the risk increases, greater security against unauthorised adjustment is needed. Consideration should be given to using models incorporating positive internal stops or positive means of locking. For very high risks, non-adjustable models may be the best answer; alternatively the adjustable items may be sited in lockable enclosures with the key kept by a responsible person.
- 91 A pressure relief valve (safety valve) or other suitable overpressure protective device should be fitted and set to relieve if the safe working pressure of the equipment or vessel is exceeded. The relief valve should be positioned so that if the valve discharges, the risk to personnel is minimised.

Portable pneumatic equipment

Statutory requirements

- 92 The Pressure Systems and Transportable Gas Containers Regulations 1989 and the Provision and Use of Work Equipment Regulations 1992 set out the duties of users and owners of portable pneumatic equipment.
- 93 The Personal Protective Equipment at Work Regulations 1992 set out what eye protection is needed for certain processes using compressed air.
- 94 Under the Management of Health and Safety Regulations 1992 and the Health and Safety at Work Act 1974 employers have a responsibility to train their staff. Further advice on training is given in paragraphs 171 to 173.

Hazards

- 95 Both blow guns and hand held tools are usually connected to a length of flexible hose which during the course of its life will be subject to mechanical damage and considerable flexing. This damage and/or flexing particularly at connection points can cause the hose to rupture. This can lead to sudden discharges of compressed air and may cause unsupported lengths of hose to 'whip' and 'snake' dangerously.
- 96 The practice of using blow guns for removing swarf, powdered materials etc from components and from machinery is widespread throughout industry. There are a number of hazards connected with the use of blow guns including:
 - (a) *eye injuries* - at air line pressures the air causes swarf or other particles to move at high velocity creating a serious hazard to the eyes of the operator or anyone nearby;
 - (b) *other injuries* - injuries have been caused by discharging guns with the nozzle held close to the skin. Very serious injuries, sometimes fatal, have occurred when the nozzle of the gun has been pointed towards the anus, even at some distance from it. Many of the injuries occur when clothing is dusted down and because of this compressed air should never be used for cleaning clothing; instead vacuum cleaners with brush type heads are recommended. Others are the result of horseplay (see also paragraphs 172 and 173);
 - (c) *dust explosions* - there has been at least one serious explosion of a dust cloud when a blow gun was used to remove flammable dust;
 - (d) *toxic hazards* - the use of compressed air for cleaning toxic material can result in the dispersal of the material into the air;
 - (e) *noise* - blow guns frequently produce high noise levels.

General information and advice

- 97 By following the advice in the previous sections a clean, dry air supply should be safely generated and distributed to all outlet points. The type of equipment to be connected to the outlet point will determine what extra precautions, if any, will be required. The most common range of devices will be air or blow guns, portable tools or pneumatic powered machinery. Each has its own particular requirements.

Precautions

Flexible hoses

- 98 When selecting a flexible hose, users should take into account the site conditions, including temperatures, oils and pressures to which it will be subjected. Where lubricating oil is present in pipelines, a grade of hose resistant to that particular oil must be used. A synthetic based grade of hose should be used for mineral oils and a natural based grade for vegetable oil. Where fire and explosion risks may be present, the use of fire-resistant anti-static (FRAS) hoses should be considered. The manufacturer's advice should always be followed.
- 99 Heavy, medium and light grades of hose are available. Where hoses are used for semi-permanent distribution of compressed air, for example in quarries, construction sites, shipyards, farmyards, garage forecourts etc, heavy grades should be used. Medium and light grades are used for general purposes such as fixed pneumatic machinery and pneumatic cylinders, small power tools and portable equipment. Hoses used with hand-held power tools should be light and flexible (but suitable for the duty).
- 100 Tubes and hoses used to connect cylinders to their control valves are available in a variety of colours to make fault finding and maintenance easier (see paragraph 143). They should be neatly run and adequately secured. If the failure of a flexible hose would be hazardous it should be further restrained or shielded.
- 101 Coupling a portable tool to the outlet point is usually achieved by use of a quick-acting connector. The connector should be designed so that when disconnected it automatically seals the air pressure on the upstream side and slowly vents the air pressure on the downstream side. For all hoses above 10 mm bore, more than 10 m long or subject to a pressure exceeding 7 bar, the connector should have a self-venting socket which releases the downstream pressure before disconnection is possible. Alternatively, a plug with a controlled venting action should be used. These safety features prevent inadvertent tool operation and uncontrolled whipping of the hose when its inlet end is uncoupled from the socket. Another way of reducing 'whipping' or 'snaking' is to fit emergency shut-off valves, hose rupture valves or air fuses as close as practicable to the connector. The valves will close or reduce flow to a very low level in the event of excessive air-flow conditions caused by a failure of the hose (see also paragraph 83 about fitting of isolation valves). The same requirement could be necessary when using plastic tubing.
- 102 Similar requirements for quick-acting connectors apply to most percussive and vibrating air tools, which may be fixed or hand held. If a quick-acting coupling socket is fitted at the hose end adjacent to the tool, the plug should not be screwed directly into the inlet port but should be fitted onto a short isolation hose (0.5 to 1.5 m long), thus isolating the plug and socket from the tool vibrations.
- 103 Where hoses are used to suspend tools, the load strength of hose and couplings should be at least five times the suspended load.

Blow guns

- 104 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 tamper-proof pressure regulator set at a reduced pressure from the normal 80 psi airline supply. Models are available commercially which incorporate an air curtain designed to provide a protective shroud around the nozzle. Although

not completely safe, these designs significantly reduce the risk of eye injury and the dangers from close skin contact. If designed correctly such nozzles can often help to prevent the operator from being subjected to excessive noise. Because air is vented directly into the atmosphere, clean dry air is essential and lubricators should not be used. Blow guns can exhaust significant quantities of air and place extra loading on the compressor system. In view of this and the attendant risk arising from use of blow guns, their use should be considered carefully with a view to using alternative means for cleaning down machinery or components.

Portable tools

- 105 Pressure regulators should be used to reduce the pressure to the optimum value for the safe and efficient use of the equipment. This value should be clearly marked on the tool. Filters and lubricators should be fitted in the supply pipe as shown at 'A' in Figure 3. To prevent over-speeding, tools with air motors should incorporate a governor or throttle. There should be available an easily accessible means of isolating the air supply from the tool. European Standard pr EN 792 *Hand-held non electric power tools-Safety* covers design of drills, grinders, nibblers, polishers etc. It is poor practice to pull portable tools using the hose or use it as a means of access by climbing on to suspended hose . Old damaged hose should not be used to make up fresh hose assemblies.

Pneumatic powered machinery

Hazards

- 106 The hazards normally associated with powered machinery are equally applicable to pneumatic powered machinery and suitable safeguards are necessary as described in BS EN 982 *Safety requirements for fluid power systems and their components-Pneumatics* and BS 5304 Code of Practice *Safety of machinery*.
- 107 Unlike liquid fluid power media, compressed air is elastic (compressible), and because of this, additional hazards can arise from stored energy and actuators under load (see paragraphs 138 to 141). This hazard requires particular consideration when the machinery is fitted with interlocking guards. Interlocking systems are covered in paragraphs 129 to 137 of this booklet.

General information and advice

- 108 Where pneumatically powered machinery is connected to the outlet point this should be by means of conventional connectors, eg compression or push-in, push-on connectors with a shut-off valve. Plastic tubing made from PVC or nylon is widely used, in particular for piping up pneumatically operated machines employing pneumatic cylinders and valves. Compression or push-in, push-on, connectors of various types can be used with the tubing which is suitable for connecting to vibrating and moving parts by forming loops which absorb the vibration or movement, but, as for flexible hoses (Para 98) it is always necessary to consider site conditions when applying plastic tubing. The specification for nylon tubing is given in BS 5409, Part 1. **Note: To prevent errors during installation and maintenance, all component parts should be clearly identified. The identification should correspond to the data on the circuit diagram.**
- 109 The machine should have its own filter, pressure regulator, pressure gauge and lubricator set, as shown at Part B of Figure 3. With this arrangement, optimum conditions for the operation of the particular machine can be set without affecting any other equipment connected to the supply. If the filter, pressure regulator, pressure gauge and lubricator set are properly maintained (see paragraphs 160 to 170), wear on seals in actuators and valves will be limited and the machinery should perform correctly and efficiently. The likelihood of malfunctions, which could lead to unintended operation, will also be reduced.

Precautions

- 110 To a large extent the design features needed will depend on how the machine will be used. However, paragraphs 111 to 141 outline some basic requirements for machine and circuit design.
- 111 All components used in the machine design, including connecting hoses, should be able to withstand safely the maximum possible air main pressure. The maximum safe working pressure of the machine should be clearly, prominently and permanently marked on the machine.

- 112 All components should be protected against over-pressurisation by the provision of pressure relief valves unless the components can withstand the compressor's maximum pressure and will not be subjected to unacceptable pressure build up due to high external loads.
- 113 The machine should be designed and constructed so that any components which require adjustment or regular maintenance are easily and safely accessible.
- 114 Supply or control system failure should not cause a hazard. To ensure that such a possibility is minimised, the effects of gravity, impact or vibration should be considered. For this reason, valves controlling actuators should be mounted with the main spool horizontal. In addition, any actuators that have to adopt a specific position for safety if the supply or control system fails should be controlled by a valve which is spring biased (mono-stable) to the safe position.
- 115 If the machine is to be provided with an emergency control it should, without delay, stop or set moving parts to whichever position provides maximum safety. The emergency control should be of the mushroom head type, coloured red, prominently located and readily accessible to the operator. Where an operator has to work from more than one position it may be necessary to provide additional emergency controls. Operation of the emergency control should not of itself create a hazard.
- 116 Where air is discharged to the atmosphere during the normal course of operation of the machine, and this causes workers to be exposed to high levels of noise, some method of reducing the worker's exposure should be considered. Components should be located, or shielded, so that operators are not subjected to air blast from exhaust ports. If silencers are fitted, these should be designed to create minimum back pressure and should be compatible with water and any lubricants used. Alternatively an exhaust hose can be fitted so that the air is discharged well away from workers, for example under a factory roof (see HSE Guidance Note PM56 *Noise from pneumatic systems*).

Actuators

Hazards

- 117 Where linear actuators are used, special attention should be given to stroke length, loading and the methods of mounting the cylinder to avoid buckling of the piston rod and excessive side loading which could lead to piston rod bearing and seal wear. Where shear forces on fixing screws are likely to be excessive, the cylinder mounting should also be keyed or dowelled in position. Alternatively, fitted bolts may be used.
- 118 Repeated shockloads on cylinder endcaps can eventually cause either the cylinder or the piston rod assembly to fail, which could lead to serious injury. Most cylinder manufacturers can supply cylinders with built-in cushioning designed to reduce speed at stroke extremities, thus bringing the machine component to a shockless stop. Equally hazardous is the potential for piston and rod to separate. Cylinder manufacturers should ensure that pistons are positively locked to the piston rod.

General information and advice

- 119 The function of the actuator determines the precautions necessary for a safe design. If the purpose is to impart motion to a load which is otherwise supported, the problem will be different from those for an actuator designed to lift or lower a load. Cylinders designed to clamp pose yet another problem.

Precautions

- 120 For any actuators imparting motion, smooth action is preferable and cushioning is desirable. If the cylinders are double-acting there may be occasions, eg at start-up or following an emergency, when the cylinder is pre-exhausted, causing the actuator to accelerate rapidly when air is first introduced to the cylinder. Where this is likely to cause a hazard a soft start arrangement should be introduced in the supply line to the machine. This will initially restrict the flow rate until a certain predetermined pressure has been reached.
- 121 Linear actuators with magnetic pistons and integral mounted reed switches or proximity switches for signalling control valves are now popular. This is largely due to the comparative cheapness of using electric or micro-electronic control together with cost and space savings from not needing to install independent mechanically actuated trips. Safeguarding pneumatically powered machines where the control circuit is electrical requires extra caution to ensure that the risk of injury is minimised if either the electric or pneumatic power supply fails. Reed switches may malfunction in areas subjected to high vibration levels or electromagnetic fields.
- 122 Actuators designed for lifting or supporting loads may collapse dangerously if the supply fails. The machine should have spring-applied mechanical scotches to support the load whenever movement is not required. In certain instances mechanical scotches may be impracticable. As a safety back up a normally closed, air to open, spring return valve in the cylinder supply line could be used.

- 123 Supply failure to clamping cylinders can lead to a hazard by releasing the component prematurely. This can be overcome by using single acting cylinders where the return spring applies the clamping force (see paragraph 127), or the use of two control valves will temporarily keep the cylinder pressurised (see figures 4 and 5). But care should be taken in using this design as even a small leak could affect the integrity of the system.

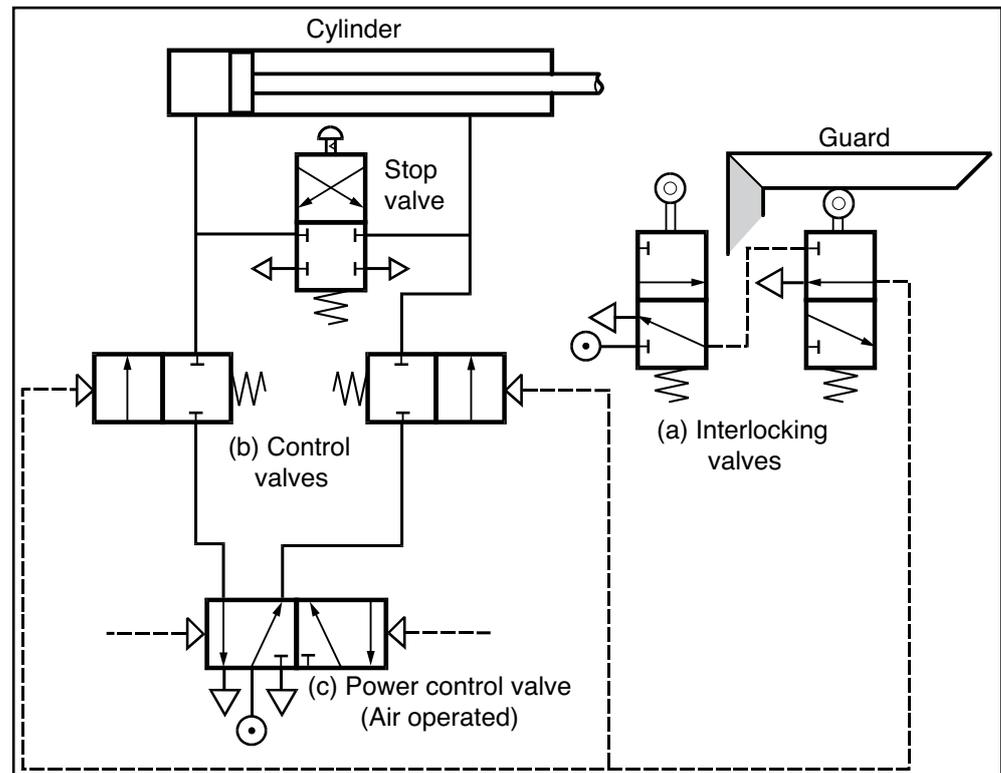


Figure 4 Single control system interlocking with piston arrest and hold (guard open)

Note: Figures 4 - 19 illustrate principles only, and they are not intended to provide all the information needed to construct a safe working system.

- 124 Machines incorporating several actuators may require them to be set in a certain position before the machine is first used, and subsequently, after the emergency control or interlocking guards have been operated. Re-positioning may be possible without re-establishing the pneumatic supply, but these cases will be in the minority. In all other cases re-positioning is best achieved by providing manual override controls. Such controls should be of the two hand type ie designed so that the two controls are placed, separated and protected to prevent spanning with one hand only, being operated with one hand and another part of the body, or being readily bridged. It should not be possible to set the actuators in motion unless the two controls are operated within approximately 0.5 seconds of each other. Movement of the actuators should be arrested, or where appropriate returned, immediately one or both controls are released. BS EN 574 *Two Hand Control Devices* covers functional aspects and principles for design of this type of control.

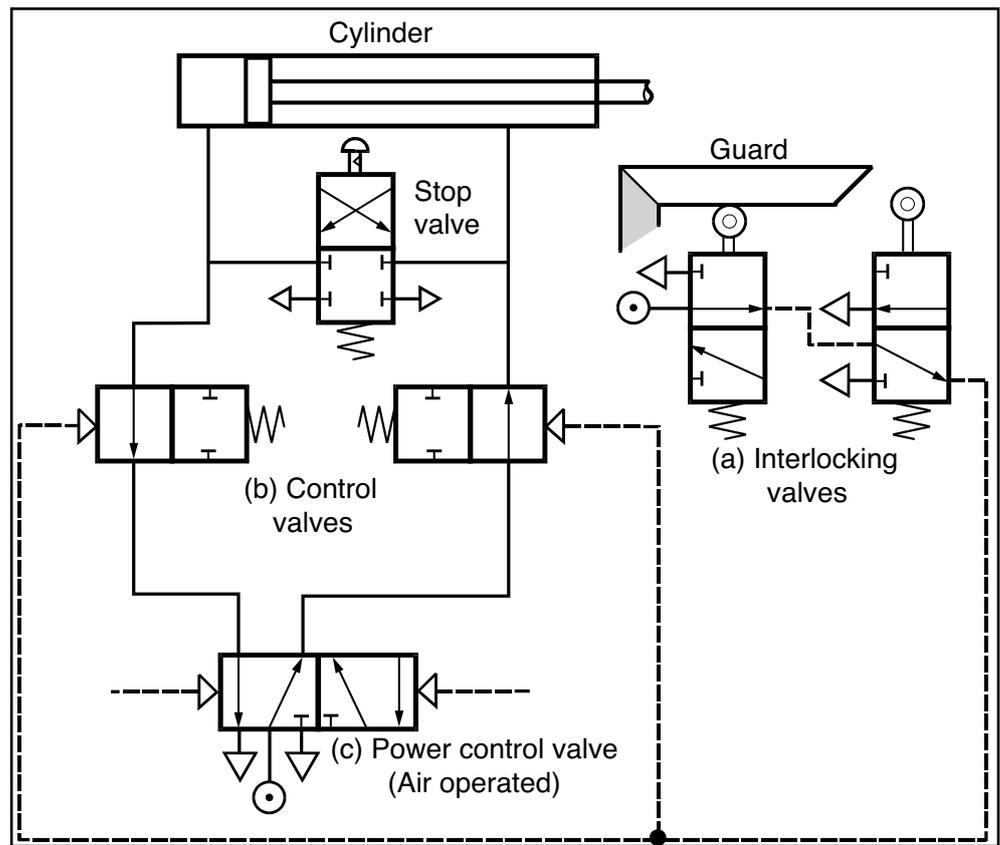


Figure 5 Single control system interlocking with piston arrest and hold (guard closed)

Interlocking methods and circuit design

General information and advice

- 125 The method used for interlocking should be commensurate with the risk. The higher the risk the higher the integrity of the interlocking system should be.
- 126 Principles for design and selection of interlocking devices associated with guards are given in EN 1088 and BS 5304. General principles for application are given in BS EN 983 *Safety of Machinery- Safety requirements for fluid power systems and their components-Pneumatics*.
- 127 On pneumatic machinery, because the power medium is compressible and normally exhausted to atmosphere, the safety circuit design is not straightforward as for other power media. However, the basic aims for interlocking remain the same and, where possible, the power supply should be interrupted by the guard operated interlocking device and any residual system pressure exhausted to atmosphere. In this condition any cylinders will be pre-exhausted and alternative arrangements in the system design will be necessary where any cylinders are required to be under constant load (see paragraph 122). In addition, particular precautions may be necessary when reinstating the supply to pre-exhausted cylinders if rapid acceleration is undesirable. To avoid the need to maintain supply pressure to cylinders required to be under constant load, such as those operating clamps or supports, alternative features should be considered, such as single-acting cylinders, or spring applied mechanical scotches. Cylinders fitted with rod locks, the locking action of which is triggered by loss of air supply, may also be used to prevent uncontrolled movement.
- 128 Signal air lines should be kept to a minimum length to facilitate rapid exhaust pressure decay. Where this is not practicable and pilot signals exhausting to the atmosphere retain sufficient pressure levels to operate main control valves (even after a guard has been opened), additional interlocking devices should be provided which prevent opening of the guard until it is safe to do so. When 3-position valves are used in safety circuits, where practicable the centre position should provide a supply-sealed-only condition (outlets vented) because an all-ports-sealed centre position can result in stored energy in the actuator, leading to unintended movement if piping is disconnected.

Interlocking systems

Single control system interlocking

- 129 The basic elements of single control system interlocking (see Figures 4 and 5) are:
- (a) an interlocking valve or position switch operated by the guard;
 - (b) interposed control valves, electromechanical relays and/or solid-state switching devices, if any; and
 - (c) an air operated, solenoid operated or solenoid actuated air operated valve, controlling power to the drive.

- 130 Any of these elements, or the piping or wiring interconnecting them, can fail and cause danger, so they should be chosen to provide the maximum degree of reliability. The greater the number of devices incorporated in the system, the lower its inherent reliability, so interposing devices should be avoided if possible.

Dual control system interlocking

- 131 The basic elements are similar to those employed in single control system interlocking. Where the possibility of common mode failure needs to be minimised different control power media should be used and kept separate except for necessary interconnections for cross monitoring (where provided), and connection to the supply.
- 132 Such systems can be entirely pneumatic (see Figures 15 and 16), or hybrid for example one system, pneumatic and one system, electric (see Figures 17 and 18). This latter arrangement may be particularly appropriate where cylinders with magnetic pistons and integral reed switches or proximity switches are used. In both systems the output of the power controlling devices should be connected so that either can stop hazardous movement of the machinery, irrespective of the condition of the other. Where the circuit is such that a single failure is not self-revealing eg the actuator continues to operate, the integrity of the dual control system can be improved by cross monitoring (shown also in Figures 17 and 18).

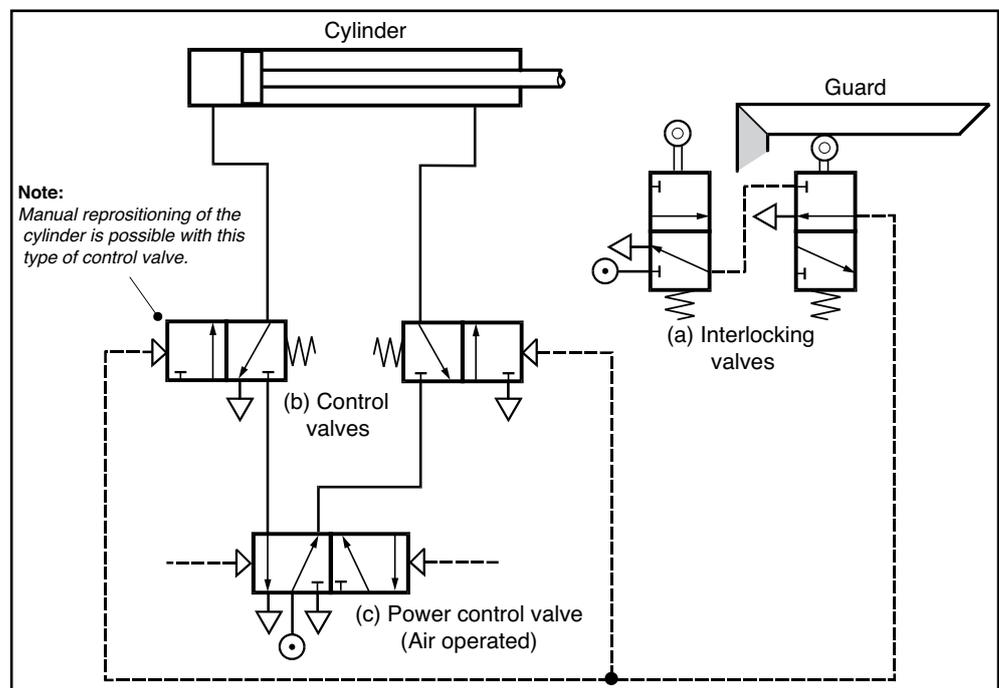


Figure 6 Single control system interlocking with piston arrest (guard open)

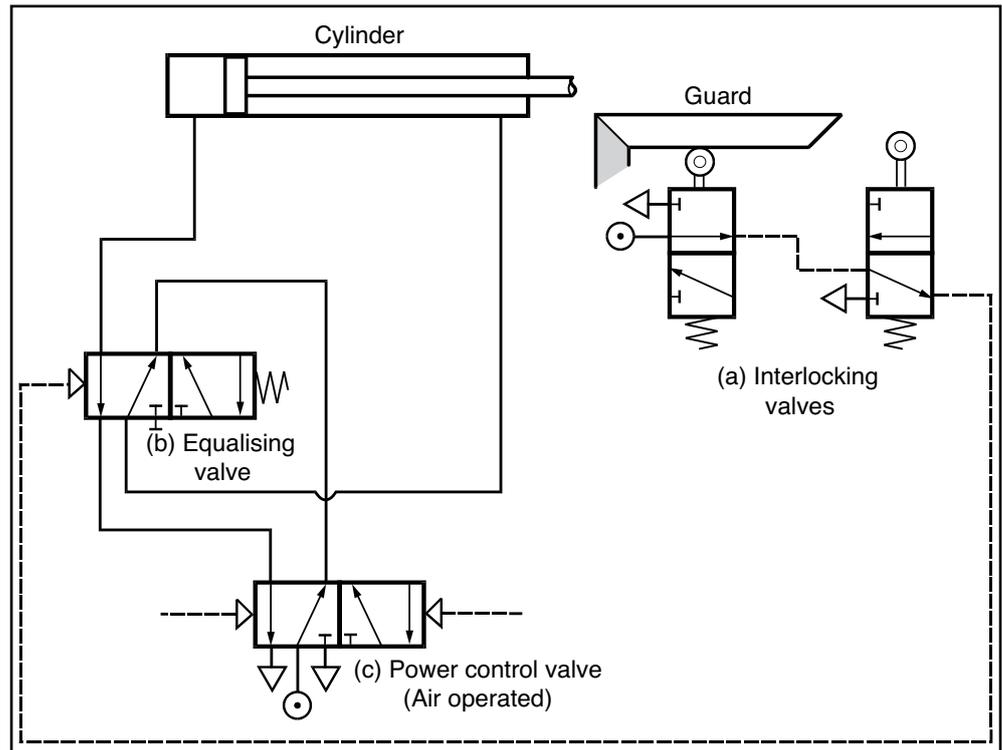


Figure 9 Use of an equalising valve - control interlocking (guard closed)

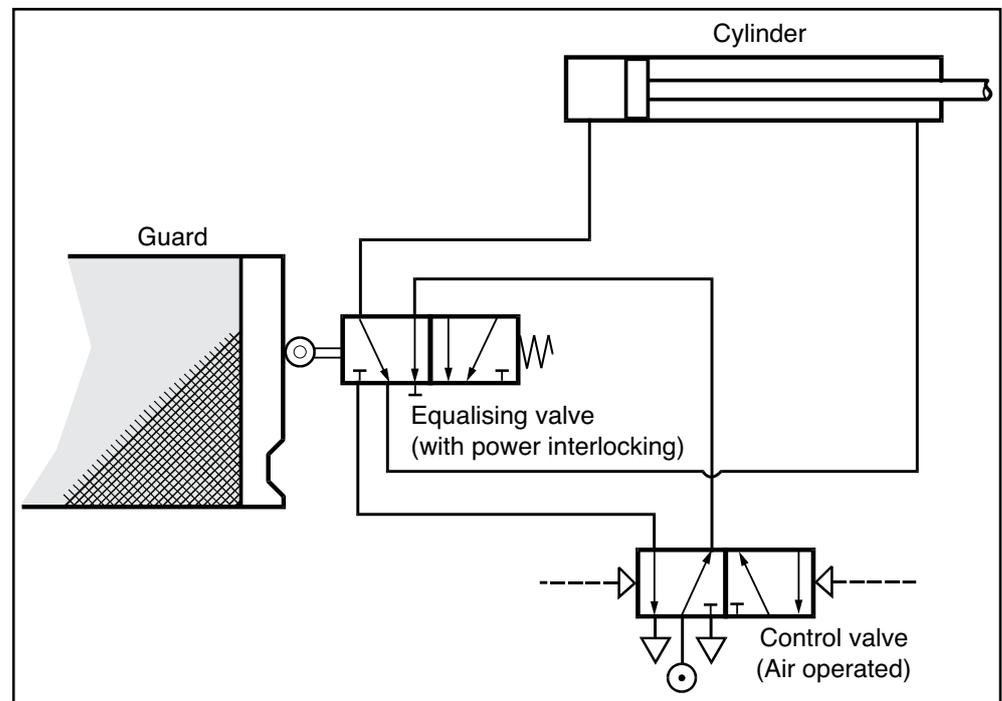


Figure 10 Use of an equalising valve - power locking (guard open)

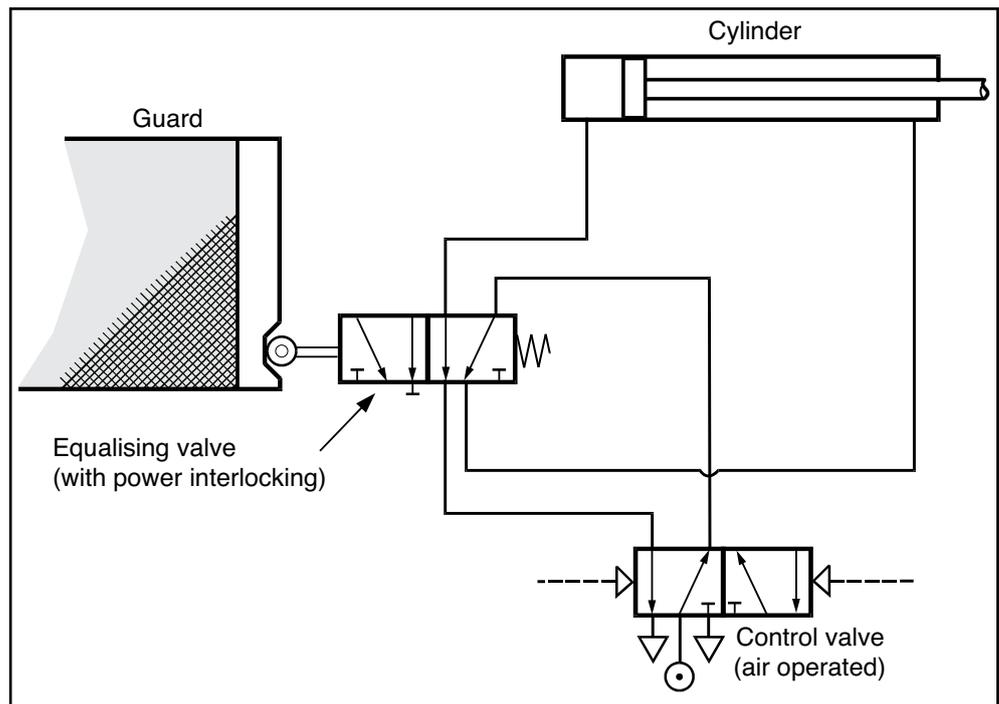


Figure 11 Use of an equalising valve - power locking (guard closed)

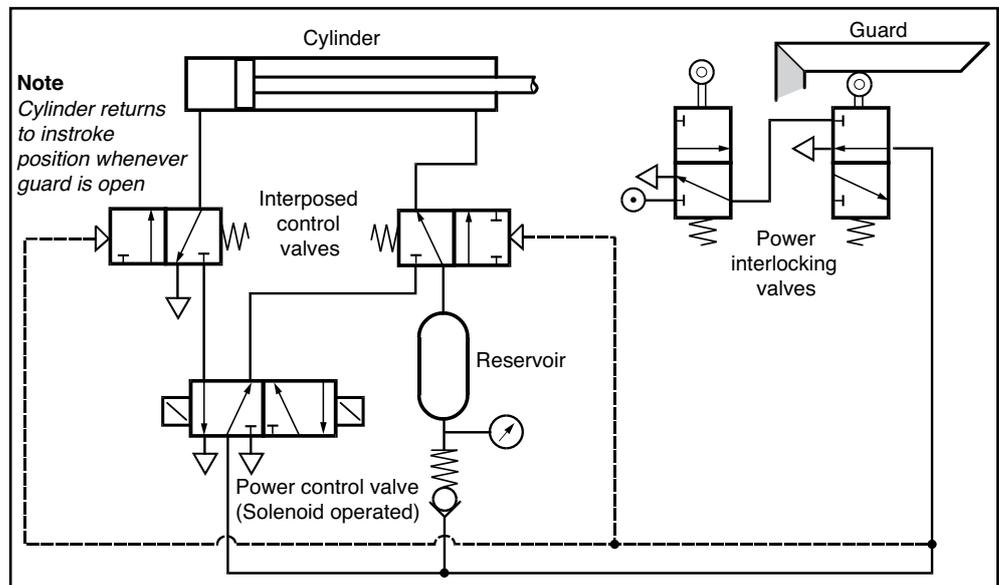


Figure 12 Use of a reservoir - power interlocking (guard open)

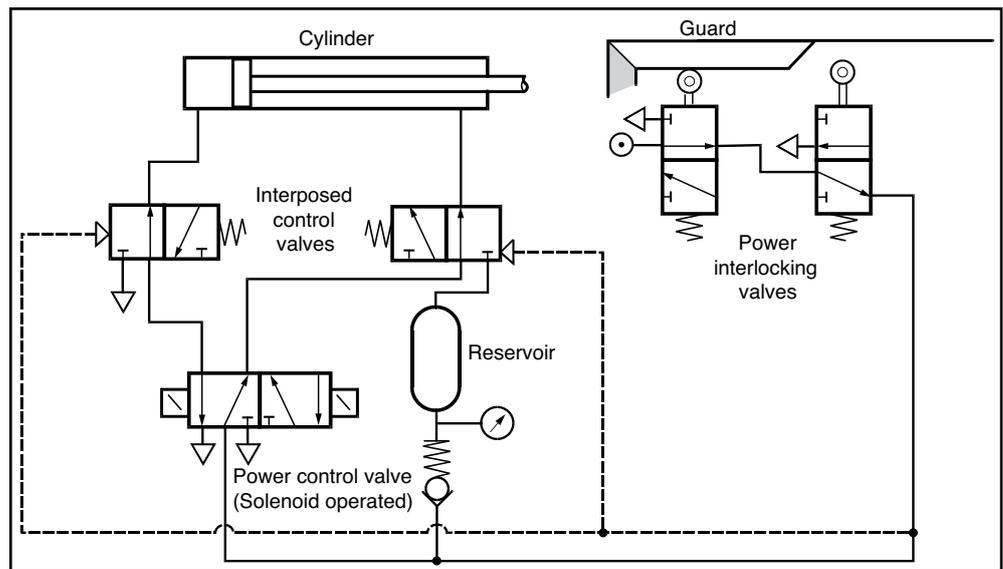


Figure 13 Use of a reservoir - power interlocking (guard closed)

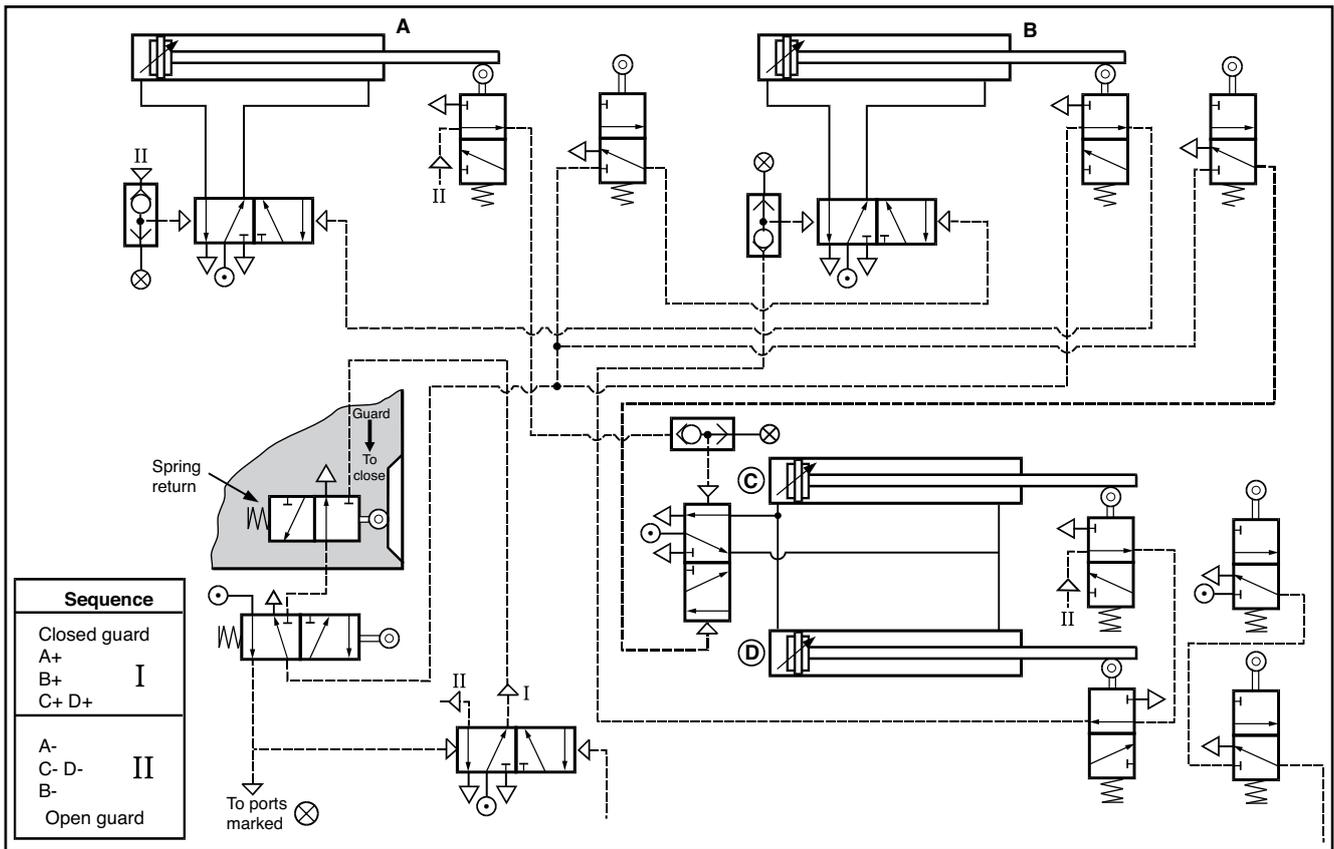


Figure 14 Control system interlocking from complex sequence

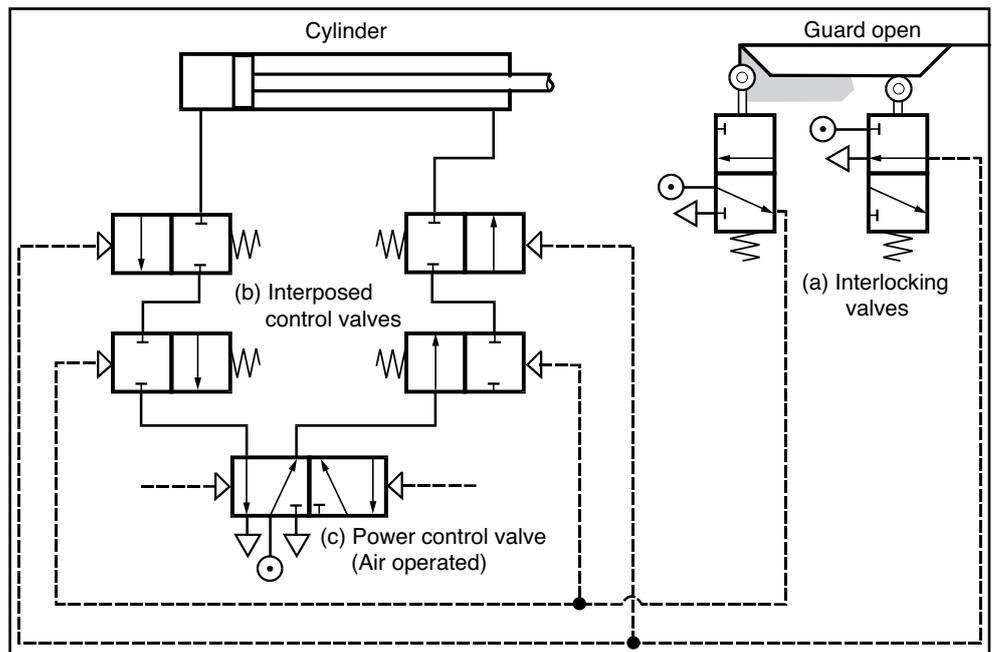


Figure 15 Dual control system interlocking without cross-monitoring, both channels pneumatic (guard open)

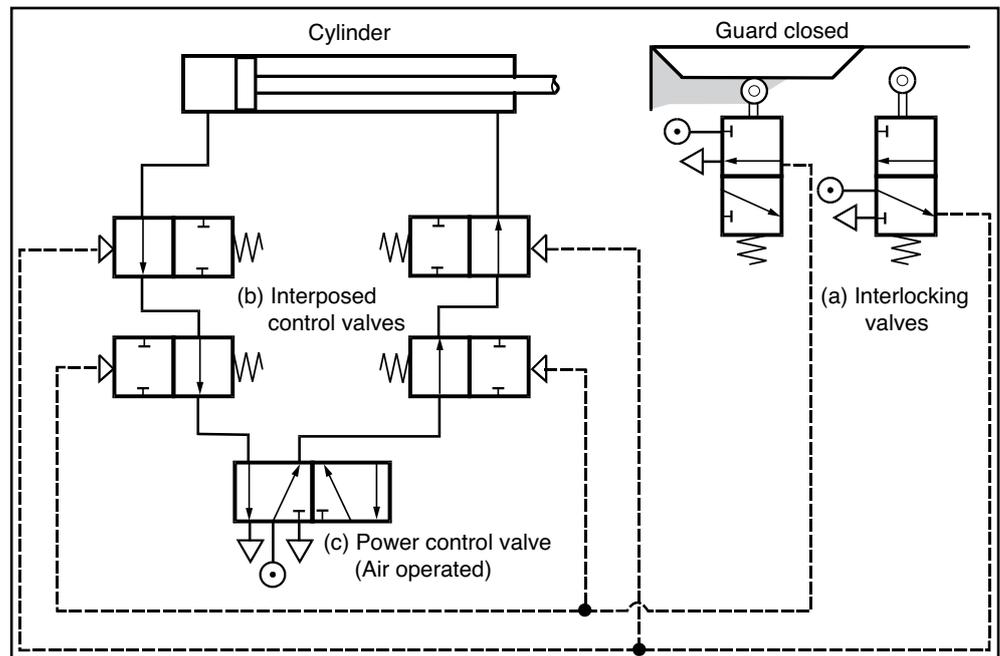


Figure 16 Dual control system interlocking without cross-monitoring, both channels pneumatic (guard closed)

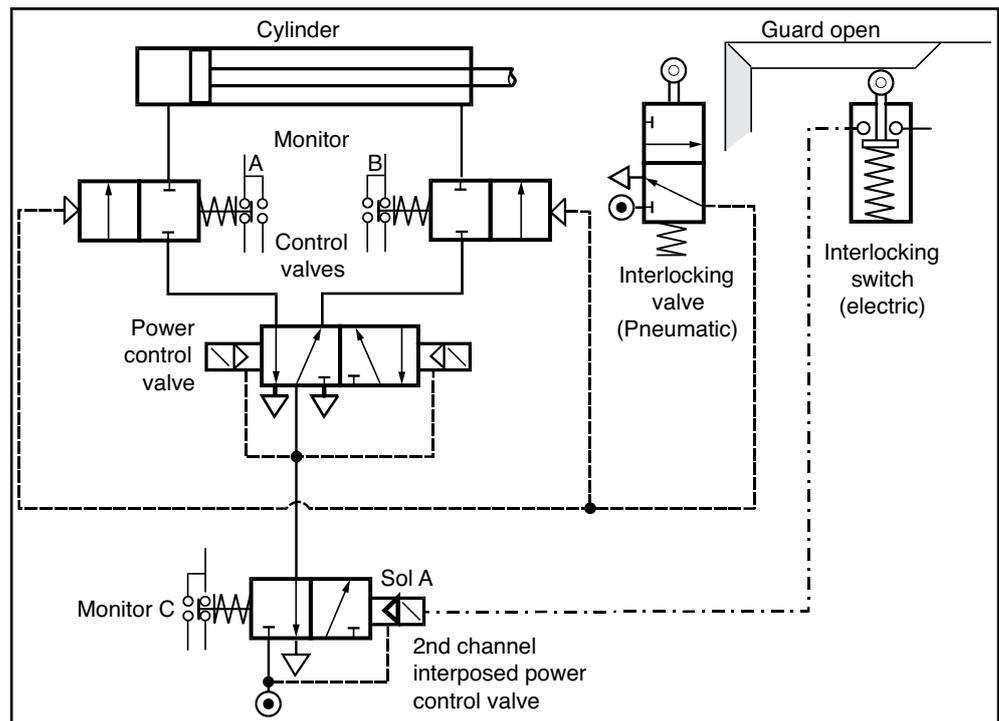


Figure 17 Dual control interlocking, one control channel pneumatic and one electric, with electric cross monitoring (guard open)

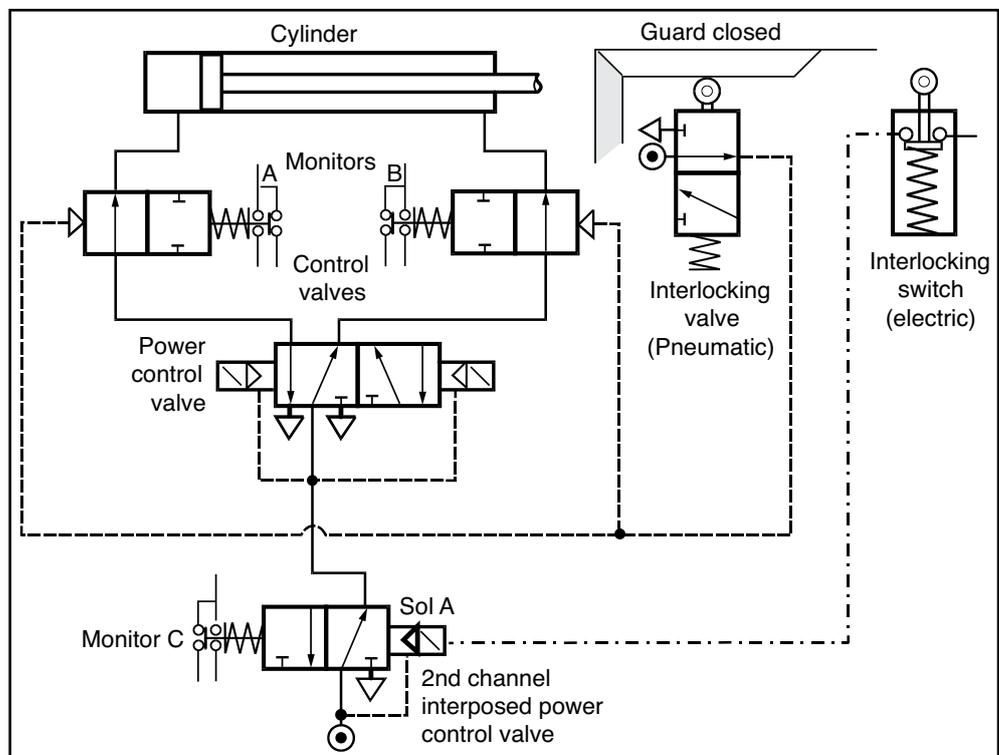


Figure 18 Dual control interlocking, one control channel pneumatic and one electric, with electric cross monitoring (guard closed)

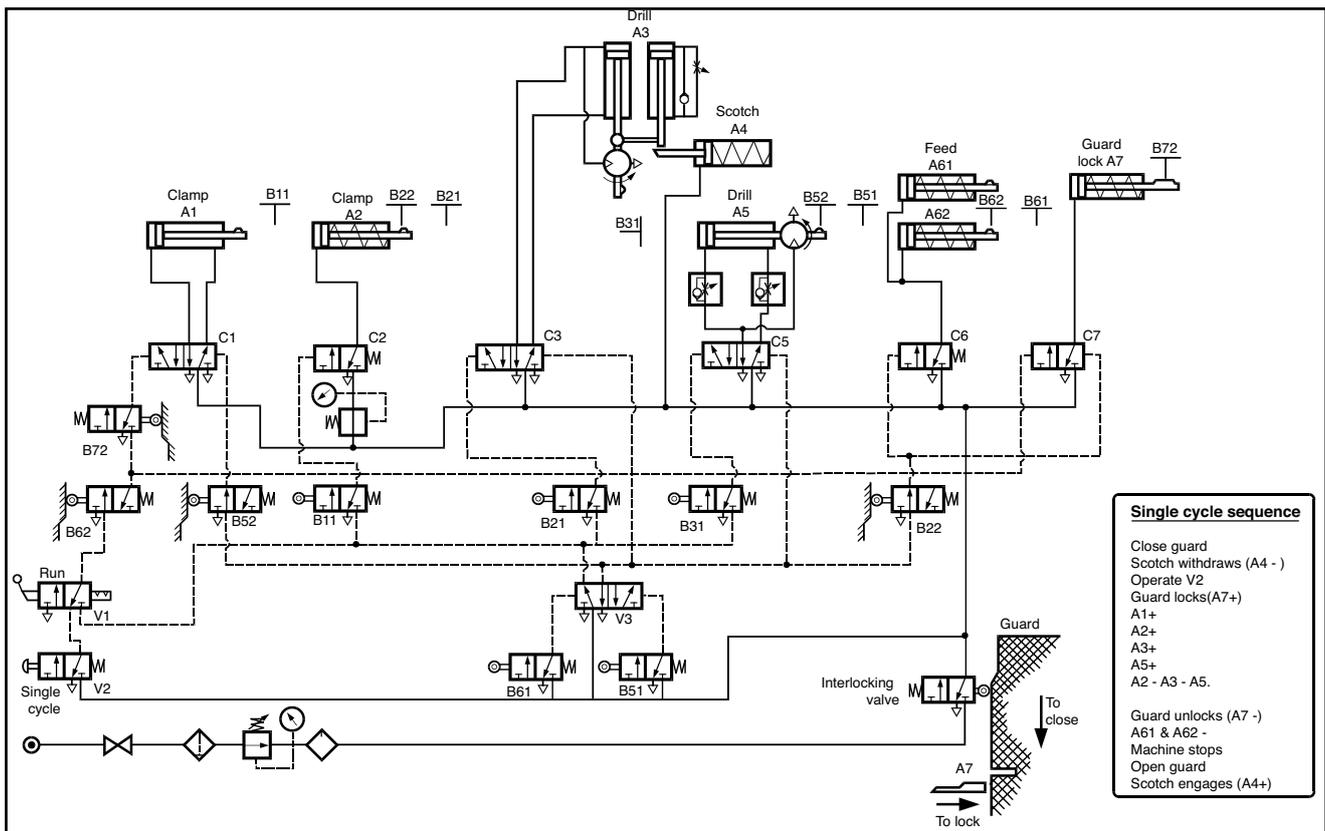


Figure 19 Guard operated power interlocking with scotch to prevent drill falling under gravity. Also fitted with guard lock to prevent inadvertent opening

Power interlocking

- 133 Power interlocking is achieved by direct mechanical action of a valve in the main air supply in series with the actuator. The mechanical action may be direct from guard movement (see Figures 10 and 11) via a linkage, by a captive key or a trapped key.
- 134 Interlocking by means of air isolation and exhaust may cause difficulties on machinery which relies on the air supply to keep heavy articles suspended or components clamped in position. Similarly, where complex machinery is designed to perform a series of functions in sequence automatically (see Figure 14), air isolation and exhaust interlocking could lead to the need for potentially dangerous, extensive manual re-setting of actuators and sequencing valves. For these reasons, power system methods of interlocking are not normally practicable for complex air operated machinery and hence control system interlocking of the pilot signals has to be used.
- 135 Where practicable, however, power system interlocking of complex systems is better than single control system interlocking, provided the power interlocking valve and the arrangements between the guard and valve are of similar or higher integrity than the control system interlocking. In addition, any machinery parts which are supported by compressed air and which would fall under gravity when the air is isolated and exhausted should be automatically scotched while the guard is open.
- 136 Such precautions are shown in Figure 19, the layout of which is in line with BS ISO 1219-2 recommendations. Hazards arise from actuators A1, A2, A3 and A5, which need safeguarding. Also, A3 operates vertically and will

fall under gravity when air supply, through the guard operated interlocking valve, is exhausted. The circuit has thus been arranged so that, with the guard open, A3 is scotched using a single acting cylinder. Once the guard is closed the scotch withdraws and the guard is locked so that the sequence cannot be broken by inadvertently opening the guard. The complete single cycle sequence is indicated in Figure 19, where it can be seen that the guard unlocks to allow manual feeding if necessary. Continuous cycling can be effected by operating the valve labelled 'run'. If, during use, a malfunction occurs requiring the guard to be opened, this can only be achieved by shutting the stop valve in the main air supply line.

- 137 All these problems highlight the need for the machine designer to consider carefully the overall system design to ensure that the interlocking arrangements are effective. Although in many cases interlocking the pilot signals rather than the power supply may be the only practical solution (see Figure 14), this should be a last resort only.

Circuit design

Piston arrest

- 138 Where it is necessary just to arrest the movement of a piston when a guard is open, this can be achieved by using either two three-port, two-position valves (see Figures 6 and 7) or an equalising valve (see Figures 8 to 11). If an equalising valve is used the piston may not stop immediately, but it will seek an equilibrium position whereby forces on both sides of the piston are equal. The circuit in Figure 6 will allow manual repositioning of the piston without disconnecting pipes (depending on the friction in the system). Neither of these techniques is suitable for clamping or supporting applications.

Piston arrest and hold

- 139 Where, for safety reasons, the piston must be arrested and held in position, two two-port control valves can be used (see Figures 4 and 5). The piston will seek an equilibrium position before coming to rest. However, a hazard could arise if connections to the cylinder are broken to subsequently override the locked position. Air exhausting through the broken connection could allow air under pressure on the opposite side of the piston to expand, thereby causing movement which could lead to injury.

Overriding locked position

- 140 Where the locked condition must be overridden while the guard is open, a two-port stop valve can be added to the circuit (see Figures 4 and 5). This would normally have blocked ports but by depressing the stop valve both sides of the cylinder are opened to atmosphere, enabling the piston to be moved manually.

Predetermined position

- 141 It may be necessary to ensure that pistons adopt a predetermined safe position in the event of power supply failing. Again the use of single acting cylinders may be possible but an alternative is to use a reservoir and nonreturn valve arrangement (see Figures 12 and 13). It is important to ensure that where reservoirs are used they are of sufficient capacity to ensure that the piston does not stall in an unsafe position.

Inspection and maintenance

Statutory requirements

- 14 2 There are specific statutory requirements for the examination and maintenance of pressure systems including air receivers (see paragraph 30). In addition to the specific requirements, general requirements are set out in Section 2(2)(a) of the HSW Act and PUWER: employers must provide and maintain plant and systems of work that are, so far as is reasonably practicable, safe and without risks to health. The following advice is aimed at assisting employers to carry out this duty.

Hazards

- 143 Fault finding on pneumatic machinery can be hazardous if it is not properly planned. The machine design should incorporate means of minimising the need for trial and error methods of locating a fault. Further assistance can be given to fault finding by incorporating diagnostic techniques which indicate the area of a fault (see also paragraph 100).

General information and advice

- 144 The efficient safe running of a compressed air system relies on cleanliness, filtration, cooling and lubrication. The best way of achieving these four conditions is to operate the plant in accordance with the operator's manual and to draw up and follow a written schedule of maintenance work which can be revised in the light of experience. This is a form of safe system of work. The written schedule should identify areas for attention, how often attention should be given and the responsibilities of those who carry out and supervise the work (see paragraphs 146 and 147).
- 145 The frequency of inspection depends very largely on the circumstances and environment in which the plant is used. The frequency stated in this Booklet should therefore be taken as a guide only and adjusted to suit particular installations in the light of operational experience.

Maintenance of compressors and ancillary plant

Supervision and procedures

- 146 Small compressor units are easily overlooked, especially if sited in a separate enclosure outside the working area. Particular care is needed to see that regular maintenance, inspection and testing is carried out. Procedures should be laid down and records kept.
- 147 The user should nominate a responsible person to supervise the proper operation and maintenance of the compressor plant in line with the manufacturer's instructions.
- 148 This person should regularly check that all instructions regarding operation and maintenance are properly followed and that the compressor, its accessories and safety devices are kept in good working order. The responsible person should also make sure that maintenance work is carried out only by adequately trained staff.

- 149 Although there are statutory requirements covering some aspects of maintenance, the following additional maintenance procedures are recommended to minimise the likelihood of hazards occurring.

Daily

- 150 The compressing plant should be kept as clean and free from oil deposits as possible.
- 151 A daily routine check should be carried out on reciprocating compressors. The check should, where applicable, include the following:
- (a) the cooling water should be visually checked to make sure that it is circulating properly by observing the flow outlet or flow indicator;
 - (b) the level of the oil in the crank chamber should be checked using a dipstick, level gauge or other device. Any excessive usage of lubricating oil should be investigated;
 - (c) the oil pressure should be checked;
 - (d) the oil feed to the cylinders should be checked to make sure that it is adequate but not excessive. Oil consumption should be recorded, as excessive consumption can often lead to explosions downstream of the compressor;
 - (e) the outlet air pressure and temperature should be checked;
 - (f) the compressor performance should be checked eg by listening for any unusual noises during running;
 - (g) any defects found should be rectified and a record kept; and
 - (h) at the end of each day any accumulation of oil and water should be drained from the air receiver, the intercooler, the aftercooler and main supply pipes.

Checks mainly directed to reciprocating compressors

Weekly

- 152 Each week the safety valves (where design allows) should be checked by easing them by hand.

600 hours

- 153 After each 600 hours of running:
- (a) the quality of oil in the crank case should be checked and, according to the manufacturer's recommendations, replaced if necessary; and
 - (b) the condition of the inlet air filters should be checked and thoroughly cleaned or replaced. The interval between successive replacements will be determined by local circumstances but is, to a certain extent, controlled by the capacity of the filter and the cleanliness of the atmosphere in the vicinity. Where oil wetted viscous filters are used, spare units should be provided and excess oil should be drained from the filter units for at least four to eight hours before the units are replaced, except where the manufacturer advises otherwise.

Six-monthly

- 154 Where oil coke deposits are liable to occur, the explosion risk can be reduced by carrying out six-monthly inspections of the delivery ports and pipework and cleaning as required. The period between inspections can be modified in the light of experience gained from operating a particular installation.

2000 hrs or annually

- 155 After each 2000 hours of running or annually (whichever is the sooner):
- (a) in the case of oil lubricated compressors, the delivery valves, ports and all the pipework, vessels and fittings between the delivery port and that point in the system at which the air temperature can be confidently expected to be below 80°C, should be inspected. Any carbonaceous deposit should be effectively removed;
 - (b) fusible pellets or complete plugs should be replaced;
 - (c) the condition of protective devices should be checked and tested to determine that they operate correctly;
 - (d) the intercooler and aftercooler sections should be cleaned;
 - (e) the radiator should be drained and washed out;
 - (f) the output control gear should be cleaned and inspected; and
 - (g) the air receiver should be thoroughly cleaned and examined internally.

Precautions

- 156 All maintenance work, other than routine checks to filters designed for cleaning in-service, should be undertaken only when the compressor has been stopped, disconnected and locked off from the power supply and all internal pressure dissipated. Other precautions may also be necessary: for example, the compressor may have to be scotched to prevent movement of the mechanism.
- 157 Under no circumstances should flammable liquids be used for cleaning. Appropriate safety precautions should be taken against any toxic vapours liberated during usage of any cleaning or degreasing liquids.
- 158 An open flame should never be used for inspecting the interior of a compressor, pressure vessel or pipework.

Maintenance of air powered equipment

- 159 Dirty and 'wet' air and worn components are among the most common causes of hazards associated with air powered equipment.

Supervision and procedures

- 160 The user should nominate a responsible person to supervise the regular inspection and maintenance of the equipment. Where the equipment is extensive, some form of written system of planned maintenance should be used and records of tests, repairs and modifications kept.
- 161 In addition to any maintenance required by statutory requirements, the following maintenance procedures are recommended.

Daily

- 162 The system should be checked for leaks and repairs carried out as necessary.
- 163 At the end of each day any accumulation of water should be drained from the drain points. The drain valves should be inspected to make sure that they are not choked with sediment.

Weekly

- 164 At the end of each week, air line lubricators should be topped up as necessary with the correct grade of oil and checked to ensure that they are providing adequate but not excessive lubrication. Filters should be checked and those that are clogged or causing unacceptable flow restrictions should be replaced.
- 165 Similarly, on machines which require pressure regulation below mains pressure, the pressure regulator should be checked to make sure that it has not been tampered with and that the correct pressure is maintained.

Monthly

- 166 All hoses which are subject to flexing and/or mechanical damage should be inspected for signs of cracking or deterioration and replaced as necessary. Particular attention should be paid to areas adjacent to couplings.

Three monthly

- 167 Every three months machines with interlocking guards should be checked to make sure that all interlocking valves are firmly secured and operated positively by their cams. Check that wear in any linkages or valve operating mechanisms is not so excessive that the valve is in danger of malfunctioning.

Six monthly

- 168 Every six months all stop valves should be checked. Check that access to the valve has been maintained, that the handle is in position, that it will shut off the air supply and that it will open fully and operate freely.

Precautions

- 169 Before any pressurised components are dismantled they should be effectively isolated from all pressure sources and completely vented to atmosphere. Precautions should also be taken to guard against the possibility of injury through sudden release of trapped springs.
- 170 When components, especially valves, are found to be worn and service kits of seals are used to rebuild them, care should be taken to check thoroughly the function of the rebuilt valve before placing it in the equipment. For convenience, manufacturers of service kits often include enough seals to service a range or family of valves, although not all the seals in the kit are required for each valve. Incorrect seal replacement can completely alter the valve's function and if replaced in the equipment could present a serious hazard. Manufacturers should supply clear instructions on how to use such service kits properly and supervisors should ensure that this information is passed on to the person carrying out the maintenance.

Training

Statutory requirements

- 171 Section 2(2)(c) of the HSW Act and *Management Regulations and Regulations 8 & 9 of the Provision and Use of Work Equipment Regulations (PUWER)* requires every employer to provide such information, instruction, training and supervision as is necessary to ensure, so far as is reasonably practicable, the health and safety at work of their employees. Sections 7 and 8 of the HSW Act place responsibilities on employees to take reasonable care to co-operate with employers and not to interfere with or misuse anything provided for their safety.

Hazards

- 172 All those who, in the course of their work, need to use compressed air must be properly trained. Many accidents would be avoided if adequate training was provided. It is probably because compressed air supplies are so commonplace, being found at most garage forecourts, for example, that employers falsely believe that training in their use is unnecessary.

Precautions

- 173 Supervisors and workers including maintenance personnel must be given proper training in safe working practices. The training should stress the hazards associated with compressed air (see paragraph 2) and should highlight the following points:
- (a) compressed air should never be used for cleaning clothing; vacuum cleaners with brush type heads are permissible. For other cleaning operations special nozzles designed to provide low pressure, high volume may be used with care (see paragraphs 96b and 104);
 - (b) horseplay with compressed air is extremely dangerous and is strictly forbidden. Employers should note that young people in particular may require special supervision to make sure that they behave properly;
 - (c) when using compressed air tools the exhausting air should be directed away from the body;
 - (d) compressed air should never be used near a naked flame;
 - (e) any defects in equipment should be reported at once; and
 - (f) safety and monitoring devices should never be misused or abused.

Further information

The following five publications are produced by the European Committee on Manufacturers of Compressors, Vacuum Pumps and Pneumatic Tools (PNEUROPE):

Safety recommendations for the use and operation of portable air compressors
London

Safety recommendations for the use and operation of stationary air compressors
London

Pneumatic tools - safety in operation London

Safety recommendations for the use and operation of portable pneumatic tools
London

Recommendations for the proper use of hand held and hand operated pneumatic tools London 1986

British Compressed Air Society (BCAS) produces: *Guide to the selection and the installation of compressed air services* London, 4th edition ISBN 0 905608 02X and *A guide to compressor noise reduction* London, under revision

European Oil Hydraulic and Pneumatics Committee (CETOP) *Hydraulic and pneumatic systems circuit diagrams* London

(PNEUROP, BCAS and CETOP publications are available from the British Compressed Air Society, 33/34 Devonshire Street, LONDON W1N 1RF)

Royal Society for the Prevention of Accidents (ROSPA) *Beware compressed air* Birmingham, (IS 303) (available from: ROSPA, Cannon House, The Priory, Queensway, BIRMINGHAM B4 6BF)

British Aggregate Construction Materials Industry *Compressed Air Safety* London (available from: British Aggregate Construction Materials Industry, 25 Lower Belgrave Street, LONDON SW1 OLS)

British Coal Reciprocal air compressors (surface and underground) (NCB codes and rules series) Doncaster (available from: British Coal, HQ Mining Department, The Lodge, South Parade, Doncaster DN1 2DX)

British and European Standards

- BS 1041: *Temperature measurement*
- BS 1041: *Part 2 Expansion thermometers (in seven parts)*
- BS 1041 *Section 2.1:1992 Guide to selection and use of liquid-in-glass thermometers*
- BS 1041: *Part 3: 1969 Industrial resistance thermometry*
- BS 1041: *Part 4:1992 Thermocouples*
- BS 1041: *Part 5: 1992 Radiation pyrometers*
- BS 1041: *Part 7: 1988 Guide to selection and use of temperature/time indicators*
- BS 11 23: *Part 1: 1987 Safety valves, gauges, gas and fusible plugs for compressed air or inert installations: code of practice for installations*
- BS 1710: *1991 Specification for identification of pipelines and services*
- BS 1704: *1992 Specification for solid stem general purpose thermometers*
- BS 1780: *1992 Specification for bourdon tube pressure and vacuum gauges*
- BS 2917-1 *1993 / ISO 1219-1 Specification for graphic symbols used on diagrams for fluid power systems and components*
- BS 3974: *Specification for pipe supports (in three parts)*
- BS 3974: *Part 1: 1974 Pipe hangers, slider and roller type supports*
- BS 3974: *Part 2: 1978 Pipe clamps, cages, cantilevers, and attachments to beams*
- BS 3974: *Part 3: 1980 Large bore, high temperature marine and other applications*
- BS EN 286 *Part 1: 1991 Specification for simple unfired pressure vessels designed to contain air or nitrogen*
- BS EN 292 *Part 1: 1991 Safety of machinery: Basic concepts, general principles for design. Basic terminology, methodology*
Part 2: Technical principles of specifications

- BS EN 983 1996 *Safety of Machinery- Safety requirements for fluid power systems and their components-Pneumatics*
- BS EN 1012-1 1997 *Compressors and vacuum pumps-Safety requirements Part 1 Compressors*
- BS EN1012-2 1997 *Compressors and vacuum pumps-Safety requirements Part 2 Vacuum pumps*
- BS EN 837 Part 1 *Bourdon tube pressure gauges-Dimensions, metrology, requirements and testing*
Part 2 *Selection and installation recommendations for pressure gauges*
- BS ISO 1219 -1995 *Fluid power systems and components. Graphic Symbols and circuit diagrams*
- BS 4575: 1987 Part 2: *Code of practice for pneumatic equipment and systems*
1988 Part 3: *Fluid Power Transmission and Control Systems*
- BS 4862: 1983 *Mounting dimensions of single rod double 10 bar pneumatic cylinders*
- BS 4862: Part 1: 1983 *Specification for cylinders up to 25 ml bore*
- BS 5118: 1980 *Specification for general purpose rubber hoses for compressed air*
- BS 5169: 1992 *Specification for fusion welded steel air receivers*
- BS 5304: 1988 *Code of practice. Safety of machinery*
- BS 5409: *Specification for nylon tubing*
- BS 5409: Part 1: 1976 *Fully plasticized nylon tubing types 11&12 for use primarily in pneumatic installations*
- BS 5500: 1994 *Specification for unfired fusion welded pressure vessels*
- BS 5791: *Glossary of terms for compressors, pneumatic tools and machines*
- BS 5791: Part 1 1990 *General*
- BS 5791: Part 2 1990 *Compressors*
- BS 5791: Part 3 1990 *Pneumatic tools and machines*
- BS 6005: 1997 *Specification for moulded transparent polycarbonate bowls used in compressed air filters and lubricators*
- BS 6066: 1986 *Specification for thermoplastics hoses for compressed air*
- BS 6244: 1982 *Code of practice for stationary air compressors*
- BS 6754: 1986 *Specifications and testing of compressed air dryers*
- BS 6759: *Safety valves*
- BS 6759: Part 1: 1984 *Specification for safety valves for steam and hot water*
- BS 6759: Part 2: 1984 *Specification for safety valves for compressed air or inert gases*
- BS 7226: 1989 *Methods of test for performance of inlet air cleaning equipment for internal combustion engines and compressors*

British Standards are available from:

BSI Sales and Customer Services
389 Chiswick High Road
Chiswick
London W4 4AC
Tel 0181 996 7000
Fax 0181 996 7001

Health and Safety Executive publications

Pneumatic nailing and stapling guns

1979, (Guidance note, plant and machinery/PM 17), ISBN 0 11 883192 5

Noise from pneumatic systems

1985, (Guidance note, plant and machinery/PM 56), ISBN 0 11 883529 7

Safety in pressure testing

1992 (Guidance note, general series/GS 4) ISBN 0 7176 0811 5

Safety of pressure systems. Pressure Systems and Transportable Gas Containers Regulations 1989 Approved Code of Practice COP37 1990 ISBN 0 11 885514 X

A guide to the Pressure Systems and Transportable Gas Containers Regulations 1989 ISBN 0 11 885516 6

Legal requirements

Supply of Machinery (Safety) Regulations 1992 (as amended 1994)
ISBNs 0-11-025719-7 & 0-11-045063-9

Provision and Use of Work Equipment Regulations 1992 (as amended 1997)

Management of Health and Safety at Work Regulations 1992

Mines and Quarries Act 1954, HMSO, ISBN 0 10 850389 5

Personal Protective Equipment Regulations 1992

Health and Safety at Work etc Act 1974, chapter 37, HMSO, ISBN 0 10 543774 3

Electricity at Work Regulations 1989

The Pressure Systems and Transportable Gas Containers Regulations 1989 (SI 1989 No 2169), HMSO, ISBN 0 11 098169 3

The future availability and accuracy of the references listed in this publication cannot be guaranteed.

Further information

For information about health and safety, or to report inconsistencies or inaccuracies in this guidance, visit www.hse.gov.uk/. You can view HSE guidance online and order priced publications from the website. HSE priced publications are also available from bookshops.

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The Stationery Office publications are available from The Stationery Office,
PO Box 29, Norwich NR3 1GN Tel: 0870 600 5522 Fax: 0870 600 5533
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