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Pneumatic fluid power — General rules and safety requirements for systems and their components

Transmissions pneumatiques — Règles générales et exigences de sécurité pour les systèmes et leurs composants

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Contents

Page

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 4414 was prepared by Technical Committee ISO/TC 131, *Fluid power systems*, Subcommittee SC 9, *Installations and systems*.

This third edition cancels and replaces the second edition (ISO 4414:1998), which has been technically revised, specifically with regards to the following:

a) integration of ISO 4414:1998 and EN 983:1996;

b) integration of safety requirements to comply with the European Machinery Directive 2006/42/EC;

c) updating of safety requirements, taking into account International Standards on machine safety.

Introduction

This International Standard is a type B standard as defined in ISO 12100. The stipulations of this International Standard can be supplemented or modified by a type C standard. For machines that are covered by the scope of a type C standard and that have been designed and built in accordance with the provisions of that standard, the provisions of that type C standard take precedence over the provisions of this type B standard.

In pneumatic fluid power systems, power is transmitted and controlled through air or a neutral gas under pressure within a circuit.

The application of pneumatic fluid power systems requires a thorough understanding and precise communication between the supplier and purchaser. This International Standard was prepared to assist that understanding and communication and to document many of the good practices learned from experience with pneumatic systems.

Use of this International Standard assists in

a) identifying and specifying the requirements for pneumatic systems and components;

b) identifying respective areas of responsibility;

c) designing systems and their components to comply with specific requirements;

d) understanding the safety requirements of a pneumatic system.

Equivalent requirements for hydraulic systems are defined in ISO 4413.

Pneumatic fluid power — General rules and safety requirements for systems and their components

1 Scope

This International Standard specifies general rules and safety requirements for pneumatic fluid power systems and components used on machinery as defined by ISO 12100:2010, 3.1. It deals with all significant hazards associated with pneumatic fluid power systems and specifies principles to apply in order to avoid those hazards when the systems are put to their intended use.

NOTE 1 See Clause 4 and Annex A.

The significant hazard noise is incompletely dealt with in this International Standard.

NOTE 2 Noise emission depends especially on the installation of pneumatic components or systems into machinery.

This International Standard applies to the design, construction and modification of systems and their components, also taking into account the following aspects:

a) assembly;

b) installation;

c) adjustment;

d) uninterrupted system operation;

e) ease and economy of maintenance and cleaning;

f) reliable operation in all intended uses;

g) energy efficiency; and

h) environment.

This International Standard does not apply to air compressors and the systems associated with air distribution as typically installed in a factory, including gas bottles and receivers.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 1219-1, *Fluid power systems and components — Graphic symbols and circuit diagrams — Part 1: Graphic symbols for conventional use and data-processing applications*

ISO 1219-2, *Fluid power systems and components — Graphic symbols and circuit diagrams — Part 2: Circuit diagrams*

ISO 5598, *Fluid power systems and components — Vocabulary*

ISO 11727, *Pneumatic fluid power — Identification of ports and control mechanisms of control valves and other components*

ISO 12100:2010, *Safety of machinery — General principles for design — Risk assessment and risk reduction*

ISO 13850, *Safety of machinery — Emergency stop — Principles for design*

ISO 13851, *Safety of machinery — Two-hand control devices — Functional aspects and design principles*

ISO 14118, *Safety of machinery — Prevention of unexpected start-up*

IEC 60529, *Degrees of protection provided by enclosures (IP code)*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 5598 and ISO 12100 and the following apply.

3.1
commissioning
procedure by which a system is formally accepted by the purchaser

3.2
emergency control
control function that brings a system to a safe condition

3.3
function plate
surface that contains information describing either the performance of a manually operated device (e.g. ON/OFF, forward/reverse, left/right, up/down) or the status of a function performed by the system (e.g. clamp, lift, advance)

3.4
neutral gas
non-combustible gas that has properties similar to air and does not react to the effects of pressure and/or temperature in a manner different from air

3.5
purchaser
party that stipulates the requirements of a machine, equipment, system or component and judges whether the product satisfies those requirements

3.6
supplier
party that contracts to provide the product(s) to satisfy the purchaser's requirements

4 List of significant hazards

Table A.1 lists significant hazards associated with the use of pneumatic fluid power in a machine.

5 General rules and safety requirements

5.1 General

5.1.1 When designing pneumatic systems for machinery, all intended operations and use of systems shall be considered. Risk assessment, e.g. in accordance with ISO 14121-1, shall be carried out to determine the foreseeable risks associated with systems when they are used as intended. Reasonably foreseeable misuse shall not cause hazards. The risks identified shall be eliminated by design and, where this is not practicable, safeguards (first preference) or warnings (second preference) against such risks shall be incorporated, in accordance with the hierarchy established in ISO 12100.

NOTE This International Standard provides requirements for components of fluid power systems; some of these requirements are dependent on the hazards associated with the machine in which the system is installed. Therefore, the final specification and construction of the pneumatic system could need to be based on risk assessment and agreement between purchaser and supplier.

5.1.2 The control systems shall be designed in accordance with the risk assessment. This requirement is met when ISO 13849-1 is used.

5.1.3 The prevention of damage to the machine, systems and the environment shall be considered.

5.1.4 Deviations from this International Standard shall be agreed to in writing between the purchaser and supplier. Attention should be drawn by the purchaser and/or the supplier to applicable national and local codes or laws.

5.2 Basic requirements for the design and specification of pneumatic systems

5.2.1 Component selection

5.2.1.1 All components and piping in the system shall be selected or specified to provide for safety in use, and they shall operate within their rated limits when the system is put to its intended use. Components and piping shall be selected or specified so as to ensure that they can operate reliably under all intended uses of the system. Particular attention shall be paid to the reliability of components and piping that can create a hazard in the event of their failure or malfunction.

5.2.1.2 Components and piping shall be selected, applied and installed in accordance with the manufacturer's recommendations.

5.2.1.3 It is recommended that wherever practicable, components and piping made in accordance with recognized International Standards should be used.

5.2.2 Unintended pressures

5.2.2.1 All related parts of the system shall be designed or otherwise protected against foreseeable pressures exceeding the maximum working pressure of the system or the rated pressure of any part of the system if the excessive pressure can cause a hazard.

5.2.2.2 The preferred means of protection against excessive pressure is one or more pressure-relief valves located to limit the pressure in all related parts of the system. Other means, such as pressure regulators, may be used, provided these means satisfy the application requirements.

5.2.2.3 Systems shall be designed, constructed and adjusted to minimize pressure surges and fluctuations. Pressure surges and fluctuations shall not cause hazards.

5.2.2.4 Loss of pressure or pressure drop shall not expose persons to a hazard and should not damage the machinery.

5.2.2.5 All pneumatic components shall vent into a non-hazardous area with a connection to the atmosphere.

5.2.2.6 Means shall be provided to prevent unacceptable pressure build-up where high external loads are reflected on actuators.

5.2.3 Mechanical movements

Mechanical movements, whether intended or unintended (e.g. effects from acceleration, deceleration or lifting/holding of masses), shall not result in a situation hazardous to persons.

5.2.4 Noise

In the design of pneumatic systems, the expected noise shall be taken into account. Depending on the application, measures shall be taken to minimize the risks caused by noise. Airborne noise and structure-borne noise shall be considered.

NOTE For the design of low-noise machinery and systems, see ISO/TR 11688-1.

5.2.5 Leakage

Leakage (internal or external) shall not cause hazards.

5.2.6 Operational and functional requirements for pneumatic systems

The following specifications for operation and function shall be defined:

a) working pressure range;

b) working temperature range;

c) type of gas to be used (e.g., air, nitrogen or other neutral gas);

d) cycle rates;

e) duty cycle;

f) service life of components;

g) sequence of events;

h) filtration and lubrication, including identification of components not to be lubricated;

i) lifting provisions;

j) emergency, safety and energy isolation requirements;

k) painting or protective coating;

l) lubricant compatibility with components.

Annex B provides forms and checklists to facilitate the gathering and recording of this information. These forms and checklists can also be useful to record those specifications that apply to pneumatic systems used in mobile machinery. The individual forms in Annex B are also available in a separate revisable electronic format.

5.2.7 Control or energy supply

Whatever the type of control or energy supply used (e.g., electrical, pneumatic), the following actions or occurrences (whether unexpected or intentional) shall not create a hazard:

a) switching the supply on or off;

b) reducing the supply;

c) cutting off the supply;

d) restoring the supply (unexpectedly or intentionally).

5.2.8 Positive isolation from energy sources

The system shall be designed to facilitate positive isolation from energy sources (see ISO 12100:2010, 6.3.5.4). In pneumatic systems, this can be done, for example, by

— isolating the supply with a suitable shut-off device, which should be lockable, and shall be accessible without causing a hazard, or isolating and dissipating pressure from the system with a suitable shut-off device(s) having a pressure-release feature, which can need to be lockable;

— releasing or supporting mechanical loads when the system is depressurized;

— isolating the electrical supply (see IEC 60204-1:2009, 5.3).

The system shall facilitate dissipation of the fluid pressure.

Precautions should be taken when the supply is reinstated after isolation or depressurization.

5.2.9 Location of components and controls

The system shall be designed and constructed so that components and controls are located where they are easily accessible for use, adjustment and maintenance without causing hazard.

5.2.10 Unexpected start-up

In order to prevent unexpected start-up, precautions shall be taken in accordance with ISO 14118.

5.2.11 Uncontrolled actuator movement

If rapid opening of the shut-off valve can produce uncontrolled movement of actuators, a soft-start/slow-start valve shall be incorporated.

5.2.12 Airborne hazardous substances

Systems shall be so designed, constructed and/or equipped that airborne hazardous substances are minimized.

5.3 Additional requirements

5.3.1 Site conditions and operating environment

Site conditions and operating environment shall be defined. Annex B provides forms and checklists to facilitate the gathering and recording of this information, which may include

a) ambient temperature range of the installation;

b) ambient humidity range of the installation;

c) atmospheric pressure;

d) specification of pneumatic supply available, such as pressure, flow capability, pressure dew point, nominal filtration rating, and oil carry-over;

e) available utilities, e.g. electricity, water, waste;

f) electrical network details, e.g. voltage and its tolerance, frequency, available power (if limited);

g) protection for electrical circuits and devices;

h) sources of contamination;

i) sources of vibration;

j) possible severity of a fire, explosion or other hazard and availability of related emergency resources;

k) unusual environmental or geographical conditions, e.g. altitude, ultraviolet radiation;

l) requirements for safeguarding;

m) space required for access, use and maintenance as well as the location and mounting of components and systems to ensure their stability and security in use;

n) legal and other environmental limiting factors (e.g. noise emission level);

o) other safety and special requirements.

5.3.2 Installation, use and maintenance of components, piping and assemblies

5.3.2.1 Replacement

Components, piping and assemblies should be installed so that they can be easily replaced without dismantling other parts of the machine.

5.3.2.2 Lifting provisions

All components, assemblies or piping having a mass greater than 15 kg should have provision(s) for lifting (see ISO 12100:2010, 6.3.5.5).

5.3.3 Cleaning and painting

5.3.3.1 During external cleaning and painting of machinery, sensitive materials shall be protected from incompatible liquids.

5.3.3.2 During painting, areas that should not be painted (e.g. piston rods, indicator lights) shall be covered and the coverings removed afterwards. After painting, all warnings and safety related markings shall be visible and legible.

5.3.4 Preparation for transportation

5.3.4.1 Identification of piping

Whenever it is necessary to dismantle pneumatic systems for transportation, the piping and corresponding connections shall be clearly identified. The identification shall correspond to, and not conflict with, the data on any appropriate drawings.

5.3.4.2 Packaging

All parts of the pneumatic system shall be packaged for transportation in a manner that preserves their identification and protects them from damage, distortion, contamination and corrosion.

5.3.4.3 Protection of openings

Exposed openings in pneumatic systems and components, in particular tubes and hoses, shall be protected during transportation either by being sealed or by being stored in an appropriately clean and closed container. Male threads shall be protected. Any protective device used shall be of the type that prevents reassembly until it is removed.

5.4 Specific requirements for components and controls

5.4.1 Air motors and semi-rotary actuators

5.4.1.1 Protection

Air motors and semi-rotary actuators shall be mounted where they are protected from predictable damage, or be suitably guarded. Rotating shafts and couplings shall be guarded to prevent hazard to personnel.

5.4.1.2 Mounting

The mounting of air motors and semi-rotary actuators on, or related to, their drive assemblies shall be sufficiently rigid to ensure adequate alignment at all times and to accommodate the applied torque. Protection against inadvertent damage from end and side forces should be considered.

5.4.1.3 Load and speed considerations

The starting and stall torques, the effect of load variations, and the kinetic energy of the moving load shall be considered in the application of air motors and semi-rotary actuators.

5.4.2 Cylinders

NOTE Many cylinder designs are intended for a specific type of industry or application. These include rotary, rotating, rodless, cable, welded, foundry, air bag, etc.

5.4.2.1 Resistance to buckling

Attention shall be given to stroke length, loading and cylinder mountings in order to avoid bending or buckling of the cylinder piston rod in any position.

5.4.2.2 Loading and overrunning

Adequate structural and/or pressure-sustaining strength shall be provided for applications where overrunning or sustained and/or impact loads are encountered. Cushioning is recommended to avoid impact when using the cylinder ends as a positive stop.

5.4.2.3 Mounting ratings

Mounting attachments shall be selected for the required load. Mountings and their supporting structures shall be designed for the maximum expected loads at any position within the stroke.

5.4.2.4 Resistance to shock and vibration

Any attachment mounted on or connected to a cylinder shall be assembled in such a way that resists loosening caused by shock, vibration, etc. in use.

5.4.2.5 Mounting fasteners

Mounting fasteners for cylinders and accessories shall be designed and installed to accommodate all predictable forces. The mounting fasteners shall be adequate to absorb turning moments.

5.4.2.6 Alignment

Mounting surfaces shall be designed to prevent distortion of cylinders when installed. Cylinders shall be mounted in such a way that avoids unintended side loads during operation.

5.4.2.7 Adjustable stroke end stops

If stroke length is determined by external stroke end stops, means shall be provided for locking adjustable stroke end stops.

5.4.2.8 Piston rod material, finish and protection

Piston rod material and finish should be selected to minimize wear, corrosion and foreseeable impact damage. Piston rods should be protected against foreseeable damage from dents, scratches, corrosion, etc. Protective covers may also be used.

5.4.2.9 Air vent

Single-acting piston-type cylinders shall have air vent ports designed and/or positioned to avoid hazards to persons when displaced air is exhausted.

5.4.3 Valves

5.4.3.1 Selection

Valve type and method of mounting shall be selected to ensure correct function, adequate leak tightness and resistance against foreseeable mechanical and environmental influences.

5.4.3.2 Mounting

When mounting valves, the following shall be considered:

a) independent support from their associated piping or connector and ability to remove the valve with a minimum of disturbance to piping;

b) means of avoiding incorrect mounting on the valve base, e.g. mounting-bolt pattern, port identification or other identification;

c) effects of gravity, impact and vibration on the main elements of the valve, to minimize the probability of an inadvertent shift or destruction of parts of the valve;

d) avoidance of the influence of back pressure, which can affect functioning and safe use when stacked or manifold valves or common exhaust lines are used;

e) sufficient clearance for wrench and/or bolt access for removal, repair or adjustment of the valve and any related electrical connections.

5.4.3.3 Manifolds

5.4.3.3.1 Surface flatness and finish

Manifold surface flatness and finish shall be in accordance with valve supplier's recommendations.

5.4.3.3.2 Distortion

Manifolds shall not malfunction due to distortion when operated within the intended range of operating pressures and temperatures.

5.4.3.3.3 Mounting

Manifolds shall be rigidly and securely mounted.

5.4.3.3.4 Internal passages

Internal passages, including cored and drilled holes, shall be free from detrimental foreign matter, such as scale, burrs, swarf, etc., that can restrict flow or that can be dislodged and cause malfunction of and/or damage to any component, including seals and packings.

5.4.3.4 Valve control mechanisms and related operating devices

5.4.3.4.1 Mechanically and manually operated valves

Mechanically and manually operated valves shall be installed so that they cannot be damaged by foreseeable operating forces.

5.4.3.4.2 Electrically operated valves

5.4.3.4.2.1 Electrical connections

Electrical connections to a supply shall be in accordance with appropriate standards, e.g. IEC 60204-1. For hazardous operating conditions, the appropriate degree of protection (e.g. explosion-proofing, water-proofing) shall be employed.

5.4.3.4.2.2 Terminal block housing

Where terminal blocks and housings are specified on the valves, the terminal block housings shall be constructed with the following:

a) appropriate degree of protection, in accordance with IEC 60529;

b) adequate space for permanently located terminals and the terminal cable, including an additional length of cable;

c) captive fasteners for the electrical access cover to prevent loss, e.g. screws with retaining washers;

d) suitable securing device for the electrical access cover, e.g. a chain;

e) cable connections with strain relief.

5.4.3.4.2.3 Solenoids

Solenoids shall be selected (e.g., cyclic rate, temperature rating) so that they are capable of operating the valves reliably at minimum and maximum voltage, including the appropriate degree of protection in accordance with IEC 60529.

The temperature rise on the surface of the solenoid shall be considered. Measures, by location or guarding, shall be taken to protect persons from surfaces when temperatures exceed touchable limits. If this is not possible, warning labels shall be used; see ISO 13732-1.

5.4.3.4.2.4 Manual override

If it is necessary to operate an electrically operated valve for safety or other reasons when electrical control is not available, then it should be fitted with manual override facilities. These shall be designed or selected so that they cannot be operated inadvertently, and they shall reset when manual control is removed unless otherwise specified.

5.4.3.5 Pressure-relief valves

Pressure relief valves shall be located near a component or piping whenever pressures in excess of the rated pressure of that component or piping are possible.

5.4.3.6 Quick-exhaust valves

Quick-exhaust valves shall be installed such that exhausting air does not cause a hazard to personnel.

5.4.3.7 Flow-control valves

Flow-control valves should be located on or near the cylinder ports.

5.4.3.8 Three-position valves

Systems that use three-position valves, particularly those with a closed centre position, should be analyzed to determine if leakage from the system and/or leakage through a valve can result in undesired effects, such as unexpected cylinder movement.

5.4.4 Air-preparation components

5.4.4.1 General

To ensure required air quality, an air-preparation unit shall be installed at the entry point of the pneumatic system. Additional air-preparation units may be installed in sub-systems as necessary.

Air preparation units should be located as close as practicable to the device being protected and shall be readily accessible for maintenance.

NOTE The selection of air-preparation units depends on flow and pressure requirements at the point of use.

5.4.4.2 Filtration

5.4.4.2.1 General

Means shall be provided to remove detrimental solid, liquid and gaseous materials from the system.

5.4.4.2.2 Nominal filtration rating

The degree of filtration shall be consistent with the requirements for the components and environmental conditions.

5.4.4.2.3 Deterioration of filter performance

If deterioration of filter performance, which is sometimes indicated by increasing pressure drop across a filter, can lead to a hazardous situation, clear indication of such deterioration shall be given.

5.4.4.2.4 Provisions for maintenance

Filters and separators shall be capable of being cleaned and drained or replaced without disturbing the piping. Filters with removable or replacement elements shall be provided, where applicable. The filter element rating shall be identifiable if more than one rating is available.

5.4.4.2.5 Drains

Water drains should be used to drain air-line filters and separators, preferably of the automatic type. Where required, drains shall be protected from damage caused by freezing. Environmental and safety issues shall be considered when collecting and disposing waste fluids.

5.4.4.3 Lubrication

5.4.4.3.1 Application

Lubricants shall not be supplied to any component that does not require additional lubrication.

5.4.4.3.2 Compatibility of lubricating fluids

Where necessary, appropriate lubricating fluids shall be specified for use in systems. Such fluids shall be compatible with all components, elastomers, plastic tubing and flexible hoses in the system.

5.4.4.3.3 Lubricators

When lubrication is required, a lubricator(s) should be located close to and above the device being lubricated. Where it is not practicable to locate the lubricator above the device being lubricated, recirculating or injection type lubricators should be used. Lubricators shall be located to allow easy access for filling.

When necessary, lubricators shall have drains to remove water that has collected in the bottom of the lubricator bowl.

5.4.4.4 Air drying

5.4.4.4.1 Where a reduction of water-vapour content is required, an air dryer shall be used. The type of air dryer used depends on the environment and system requirements.

5.4.4.4.2 The air dryer shall be sized to deliver the required air flow rates at the specified pressure dew point.

5.4.4.5 Shielding of air preparation components

5.4.4.5.1 To protect personnel from the hazard of non-metallic bowl failures on filters, separators, filter-regulators and lubricators when the product of the rated pressure and the volume of the empty bowl is greater than 100 kPa·l (1 bar·l), the bowl should be capable of being shielded.

5.4.4.5.2 To avoid the possible failure of plastic bowls in certain environments, or where shielding is not being used, metal bowls shall be used.

5.4.5 Piping and fluid passages

5.4.5.1 General requirements

5.4.5.1.1 The design and selection of piping materials shall take into account site conditions.

5.4.5.1.2 The flow rate through piping should not create hazards due to temperature change or pressure drop.

5.4.5.1.3 Variations in the flow rate should be minimized by avoiding sudden changes in internal diameters of piping.

5.4.5.1.4 In order to optimize response time, the length of the piping between actuators and their directional control valves should be kept to a minimum.

5.4.5.1.5 To minimize energy losses, the number of connections should be kept to a minimum.

5.4.5.2 Piping layout

5.4.5.2.1 Piping should be designed to discourage its use as a step or ladder. External loads should not be imposed upon the piping.

5.4.5.2.2 Piping shall not be used to support components where they can impose undue loads on the piping. Undue loads can arise from component mass, shock, vibration and pressure surges.

5.4.5.3 Piping identification, location and mounting

5.4.5.3.1 Piping should be mounted to minimize installation stresses, should be located to protect against foreseeable damage, and should not restrict access for adjustment, repairs or replacement of components.

5.4.5.3.2 Piping should be identified or located in such a manner that it is not possible to make an incorrect connection that can cause a hazard or malfunction.

5.4.5.4 Foreign matter

Conductors, connectors, and fluid passages, including cored and drilled holes, shall be free from detrimental foreign matter, such as scale, burrs, swarf, etc., that can restrict flow or can be dislodged and cause malfunction of and/or damage to any component, including seals and packing.

5.4.5.5 Support of tubes

5.4.5.5.1 Tubes shall be securely supported.

5.4.5.5.2 Supports shall not damage the tubes or reduce the flow.

5.4.5.5.3 Table 1 gives recommendations for the maximum distance between tube supports.

Table 1 — Recommended maximum distance between tube supports

Nominal tube outside diameter mm	Recommended maximum distance between tube supports m
$\leqslant$ 10	1
$>$ 10 and $\leqslant$ 25	1,5
$>$ 25 and $\leqslant$ 50	2
$>$ 50	3

5.4.5.6 Piping between assemblies

Where the machine is constructed of separated assemblies, a rigidly mounted bulkhead-type terminal device or terminal manifold should be used to support the piping and provide connection for each end of the piping lengths between assemblies.

5.4.5.7 Piping across access ways

Piping runs across access ways shall not interfere with the normal use of the access way. They should be located either below or well above the floor level, and in accordance with site conditions. These piping runs shall be readily accessible, rigidly supported, and where necessary, protected from external damage.

5.4.5.8 Quick-action couplings

Quick-action (quick-release) couplings shall be selected and installed so that when they are being coupled or uncoupled,

a) the coupling shall not couple or uncouple in a hazardous manner;

b) compressed air or particles shall not be expelled in a hazardous manner;

c) a controlled pressure-release system shall be provided where a hazard may exist.

5.4.5.9 Hose assemblies

5.4.5.9.1 General requirements

Hose assemblies shall

a) be constructed from hoses that have not been previously used in operation as part of another hose assembly;

b) be provided with a recommendation on the maximum storage time and storage conditions supplied by the hose manufacturer;

c) be used within the hose manufacturer's recommended pressure ratings;

d) be selected for its electrical conductivity or non-conductivity in applications where this characteristic can lead to a hazard.

5.4.5.9.2 Installation

Installation of hose assemblies shall

a) have the minimum length necessary to avoid sharp flexing and straining of the hose during the component operation; hoses should not be bent with a radius smaller than the specified minimum bending radius;

b) minimize torsional deflection of the hose during installation and use, e.g. as the result of a rotating connector jamming;

c) be located or protected to minimize abrasive rubbing of the hose cover;

d) be supported, if the weight of the hose assembly can cause undue strain.

5.4.5.10 Removal of piping

Piping should be removable without disturbing components that are mounted separately from the piping and without using special tools.

5.4.5.11 Failure of hose assemblies and plastic piping

5.4.5.11.1 When failure of a hose assembly or plastic piping constitutes a whiplash hazard, it shall be restrained or shielded by suitable means. In addition, an air fuse for compressed air should be mounted.

5.4.5.11.2 When the failure of a hose assembly or plastic piping constitutes a fluid ejection hazard, it shall be shielded by suitable means.

5.4.6 Control systems

5.4.6.1 Unintended movement

In all phases of operation, control systems shall be designed to prevent unintended hazardous movement and improper sequencing of actuators, particularly vertical and inclined motions.

5.4.6.2 Pressure regulation

5.4.6.2.1 Control shall be provided to maintain the system pressure within safe limits, e.g., where pressure regulators are used in pneumatic circuits for safety, they should be of the self-relieving type; see 5.2.2.2 and 5.2.2.4.

5.4.6.2.2 A relieving-type pressure regulator that is not designed to be a safety component shall not be the sole device to prevent excess pressure where its relief capability is inadequate.

5.4.6.2.3 The required accuracy of pressure regulation and flow rate characteristics for the application determines the type of regulator used (see ISO 6953-1).

5.4.6.3 Adjustable control mechanisms

5.4.6.3.1 Pressure and flow control valves shall be constructed to permit adjustment within their ratings. Adjustment beyond these ratings can be possible; the ratings are not maximum adjustable limits.

5.4.6.3.2 Adjustable control mechanisms shall hold their settings within specified limits until reset.

5.4.6.3.3 The required accuracy of pressure regulation and flow rate characteristics for the application determines the type of regulator used; see ISO 6953-1.

5.4.6.4 Stability

Pressure and flow control valves shall be selected so that changes in actual pressure, actual temperature or load do not cause a malfunction or a hazard.

5.4.6.5 Tamper resistance

Pressure and flow control valves or their enclosures shall be fitted with tamper-resistant devices (e.g. key lock on a pressure regulator) where an unauthorized alteration to pressure or flow can cause a hazard or malfunction.

5.4.6.6 Manual control levers

The direction of movement of manually operated levers shall not be confusing; for example, moving a lever up should not lower the controlled device; see IEC 61310-3.

5.4.6.7 Manual set-up controls

If manual control is provided for setting up, this control shall be safely designed and have priority over automatic controls in the set-up mode.

5.4.6.8 Two-hand controls

If two-hand controls are provided, they shall be designed and applied in accordance with ISO 13851.

5.4.6.9 Safe position

Any actuator required to maintain its position or to adopt a specific position for safety in the event of a control system failure shall be controlled by a valve that is held in or switched back to the safe position (e.g. by spring tension or comparable physical principle).

NOTE To leave the safe position, pressure or force is necessary; see ISO 13849-2:2003, Table B.2.

5.4.6.10 Control systems with servo or proportional valves

5.4.6.10.1 Override systems

Where actuators are controlled by servo or proportional valves and malfunction of the control system can result in the actuators causing a hazard, means shall be provided to maintain or recover control, or stop the motion, of these actuators.

5.4.6.10.2 Additional devices

Actuators whose speed is controlled by servo or proportional valves shall have means to hold or move the actuator to a safe position if unintended movement may cause a hazard.

5.4.6.11 Monitoring of system parameters

Where changes in the system operating parameters can constitute a hazard, clear indication of the system operating parameters, e.g. temperature, pressure, shall be provided.

5.4.6.12 Control of multiple devices

Where there is more than one interrelated automatically and/or manually controlled device on the machine, and where failure of any of these devices can cause a hazard, protective interlocks or other safety means shall be provided. Where practicable, these interlocks should interrupt all operations, provided that such interruption does not of itself cause a hazard.

5.4.6.13 Control of sequencing by position sensing

Sequencing by position sensing shall be used wherever practicable and shall always be used when a sequencing malfunction of a pressure or a time-lapse control, on its own, can cause a hazard or damage.

5.4.6.14 Location of controls

5.4.6.14.1 Manual controls

The location and mounting of manual controls shall

a) place the control within reach of the operator's normal working position;

b) not require the operator to reach past rotating or moving devices to operate the control;

c) not interfere with the operator's required working movements;

d) be designed, selected and located so that an operator is not exposed to hazards.

5.4.6.14.2 Enclosures and compartments

The size of enclosures, compartments, doors and covers and the arrangement of the control devices within shall provide adequate room for maintenance and ventilation.

5.4.6.15 Emergency controls

The system shall incorporate an emergency stop in accordance with ISO 13850, or emergency control.

5.4.7 Diagnostics and monitoring

5.4.7.1 Pressure measurement

5.4.7.1.1 Pressure-measuring instruments should be selected with a pressure-measuring range such that the maximum working pressure of the system does not exceed 75 % of the maximum scale value for steady-state pressure or 65 % of the maximum scale value for cyclic pressure.

5.4.7.1.2 Where pressure-measuring instruments are included as permanent items in a system, they shall be protected from rapidly fluctuating pressure.

5.4.7.2 Electrical supply indicators

Electrical devices should be incorporated to indicate the state of the electrical signal to individual components.

5.4.8 Pneumatic silencers

Pneumatic silencers shall be used where the sound pressure level caused by exhausting air is above that permitted by applicable codes and standards. The use of exhaust-port silencers in themselves shall not create a hazard. Silencers should not create detrimental back pressure.

5.4.9 Seals and sealing devices

Seals and sealing devices

a) shall not be adversely affected by air, moisture, temperature, fluids or lubricants used;

b) shall be compatible with adjacent contact materials;

c) shall be stored in accordance with the supplier's recommendations;

d) shall be used within the limits of their shelf life;

e) should be tested under conditions as close as possible to those of the actual application prior to being specified for production use.

5.4.10 Receivers and surge tanks

When receivers and surge tanks are incorporated in a system (apart from the plant supply system), the following requirements shall be taken into consideration:

a) sufficient capacity to provide the pressure stability required;

b) design, construction and labelling in accordance with applicable regulations;

c) provision of correct pressure measurement, if necessary;

d) provision for a drain and protection from freezing when the location allows collection of condensate;

e) venting or pneumatic pressure isolation when air supply is shut off.

   If pressure is isolated, a lockable manual shut-off valve shall be provided to maintain pressure in the surge tank. If venting of the receiver or surge tank is necessary, a manual vent shall be provided, and an appropriate service warning label shall be permanently installed on the component.

6 Verification of safety requirements and acceptance testing

The pneumatic system shall be subjected to a combination of inspection and testing to verify that

a) the identification of systems and components conforms to the system's specifications;

b) the connection of components in the system complies to the circuit diagram;

c) the system, including all safety components, functions correctly;

d) there is no audible leakage, with the exception of functional air consumption, after the system is subjected to the maximum pressure that can be sustained under all conditions of intended use; leakage in a pneumatic system should be overcome by the observance of proper installation procedures.

NOTE Because a pneumatic system might not be a complete machine, many verification procedures cannot be carried out until the pneumatic system is incorporated into the machine.

The results of verification by inspection and testing shall be documented.

7 Information for use

7.1 General requirements

Information for use shall be in accordance with ISO 12100:2010, 6.4, as far as applicable.

7.2 Final information

The following documents, conforming to the system as finally accepted, shall be provided

a) final circuit diagrams in accordance with ISO 1219-2;

NOTE ISO 1219-2 provides a method for creating unique identification codes; see 7.4.2.1.

b) parts list;

c) general arrangement drawing;

d) maintenance and operating instructions data and manuals; see 7.3;

e) certificates, if required;

f) assembly instructions;

g) lubrication fluid or grease material safety data sheets, if supplied with the system.

7.3 Maintenance and operating data

7.3.1 An instruction handbook describing system operation and maintenance, including the required maintenance and operating data in accordance with ISO 12100:2010, 6.4, for all pneumatic equipment, including piping shall be provided.

NOTE It is generally expected that these requirements are dealt with by the system provider.

These data shall clearly

a) describe start-up and shut-down procedures;

b) give any required depressurizing instructions and identify those parts of a system that are not depressurized by the normal venting device(s);

c) describe adjustment procedures;

d) indicate external lubrication points, the type of lubricant required and intervals to observe, and whether or not the lubricator(s) can be filled under pressure;

e) locate drains, filters, test points, etc., that require regularly scheduled maintenance;

f) state maintenance procedures for unique assemblies;

g) list recommended spare parts;

h) provide a recommendation on hose-assembly maintenance requirements.

7.3.2 For service or replacement of components in safety-related parts of control systems, information shall be provided relating to service life and mission time.

NOTE When ISO 13849-1 is applied, this information can be necessary to maintain the designed performance level.

7.4 Marking and identification

7.4.1 Components

7.4.1.1 The following particulars shall be provided and be shown, if practicable, in a permanent and readily visible form on all components:

a) manufacturer's or supplier's name and/or brand mark;

b) manufacturer's or supplier's product identification;

c) rated pressure;

d) symbols in accordance with ISO 1219-1, with all ports correctly identified in accordance with ISO 11727; these symbols should be oriented to correspond to the physical assembly.

NOTE It is generally expected that these requirements are dealt with by the system provider.

7.4.1.2 Where lack of available space would result in lettering too small to be legible, information may be provided on supplementary literature such as instruction/maintenance sheets, catalogue sheets or accessory tags.

7.4.1.3 For air motors, the direction of rotation shall be indicated. For filters, lubricators and regulators, the direction of flow shall be indicated.

7.4.1.4 Optional information that can be given either on the component or in supplementary literature as described in Table 2.

Table 2 — Additional information that can be given on components and/or in supplementary literature

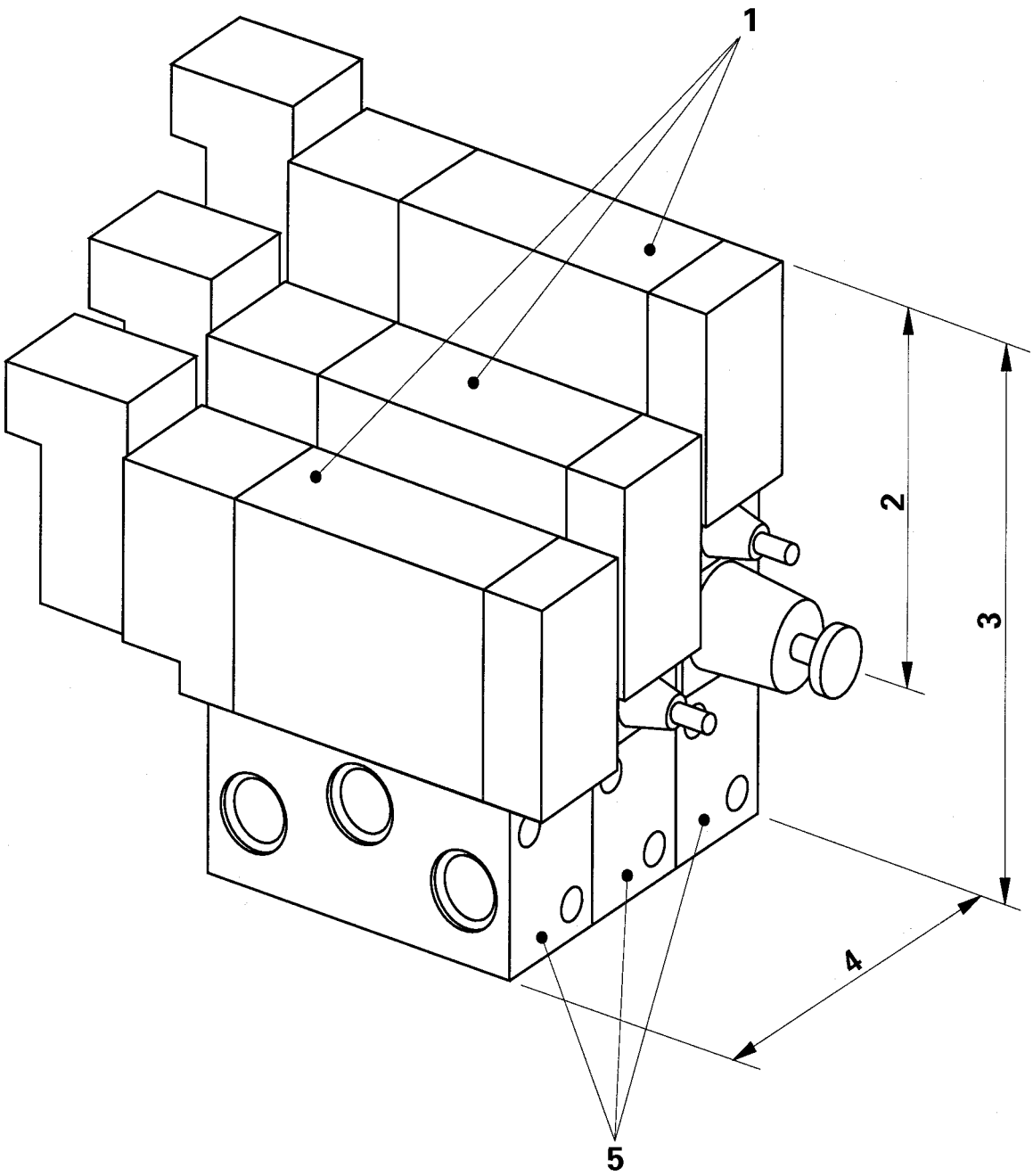
Component	Required information	Optional information[a]	Remarks
Air motors	—	Free-air consumption	—
Rotary actuators	Angle of rotation	—	—
	Displacement	—	—
Cylinders	Cylinder bore	—	—
	Length of stroke	—	—
Solenoids	Voltage	—	—
	a.c. frequency or V·A, d.c. power	—	—
	—	Protection classification (IP rating)	In accordance with IEC 60529
Directional control valves	Working pressure range	—	Can substitute for rated pressure
	Port size	—	—
Pressure switches	Working pressure range	—	Can substitute for rated pressure
	Pressure differential range	—	—
	Voltage and current-carrying capacity of switch	—	—
	—	Protection classification (IP rating)	In accordance with IEC 60529
Filters	Nominal filtration rating	—	See ISO 5782-1.
	Port size	—	—
Pressure regulators	Port size	—	See ISO 6953-1.
	—	Range of pressure adjustment	—
Lubricators	Port size	—	See ISO 6301-1.
	—	Minimum flow required to operate	—
	—	Lubricant valve adjustment direction	—

[a] Temperature ratings for all components are optional.

7.4.2 Components within a system

7.4.2.1 Each component and hose assembly in the pneumatic system shall be given a unique identification code; see 7.2 a). This identification code shall be used to identify the components and hose assemblies on all parts lists, general arrangement drawings and/or circuit diagrams. It should be clearly and permanently marked on the installation adjacent to, but not on, the component or hose assembly.

7.4.2.2 The order and orientation of stack valves should be clearly indicated adjacent to, but not on, the stacked valve assembly; see Figure 1.



Key

1 individual valves
2 stacked valve assembly
3 station
4 manifold assembly
5 individual ganged manifold bases

NOTE The figure shows a complete manifold assembly of three stations. Two of the stations have a stacked valve assembly on the manifold base; the remaining station has only one valve on the manifold base.

Figure 1 — Example of a stacked valve assembly

7.4.3 Ports and conductors

7.4.3.1 All ports shall be clearly and distinctly identified. All identifiers shall match those on the circuit diagram.

7.4.3.2 If mismatching is not avoided by any other means, the conductors that connect the pneumatic system to other systems shall be clearly and distinctly identified and correspond to the data in related documentation.

One of the following possibilities for the identification of conductors, based on the data of the circuit diagram may be used:

a) marking by use of the identification number of the conductors;

b) marking of conductor ends by use of component and port identification, either

- local-end connection marking, or
- both-end connection marking;

c) marking of all conductors and their ends by a combination of a) and b).

7.4.3.3 The following particulars shall be provided on the hose and be shown in a permanent and readily visible form:

a) manufacturer's or supplier's name and/or brand mark;

b) date of manufacture (year/quarter);

c) rated pressure;

d) nominal inside diameter (optional).

NOTE It is generally expected that these requirements are dealt with by the hose manufacturer.

7.4.3.4 The following particulars shall be provided on the plastic tube and be shown in a permanent and readily visible form:

a) manufacturer's or supplier's name and/or brand mark;

b) date of manufacture (year/quarter);

c) nominal outside diameter (optional).

NOTE It is generally expected that these requirements are dealt with by the plastic tube manufacturer.

7.4.4 Valve control mechanisms

7.4.4.1 Valve control mechanisms and their functions shall be clearly and permanently identified with the same identification used on the circuit diagram.

7.4.4.2 When the same electrical valve control mechanism (e.g., a solenoid and its attaching plugs or cables) is shown on a pneumatic and related electrical circuit diagram, it shall be identified in the same way on both circuit diagrams.

7.4.5 Internal devices

Valves and other functional devices [e.g., orifice plugs, passages, shuttle valves, non-return (check) valves, etc.] located within a manifold, mounting plate, pad or connector shall be identified adjacent to their access openings. Where access openings are located under a component or components, identification shall, if practicable, be provided adjacent to the concealed component and marked "**CONCEALED**". Where this is not possible, the identification shall be provided by other means.

7.4.6 Function plate

A function plate should be provided for each control station and located where it can be easily read. It shall be clearly understood and provide positive identification of each system function controlled. Where this is not possible, the identification shall be provided by other means.

8 **Identification statement** (reference to this International Standard)

It is strongly recommended to manufacturers who have chosen to conform to this International Standard that the following statement be used in test reports, catalogues and sales literature:

"Pneumatic systems and their components are in accordance with ISO 4414."

Annex A
(informative)

List of significant hazards

Table A.1 — List of significant hazards associated with the use of pneumatic power in a machine

Hazard		Relevant subclauses in		Other relevant standards
No.	Type	ISO 12100:2010	this International Standard	
A.1	Mechanical hazards — shape; — approach of a moving element to a fixed part; — mass and stability (potential energy of elements); — mass and velocity (kinetic energy of elements); — inadequate mechanical strength; — accumulation of potential energy by — elastic elements (springs), — liquids or gases, — vacuum; — leakage.	See Table B.1, 1	5.2.1, 5.2.2, 5.2.3, 5.2.5, 5.2.8, 5.2.11, 5.3.1, 5.3.2, 5.3.4.1, 5.4.1.1, 5.4.2.1, 5.4.2.2, 5.4.2.3, 5.4.2.4, 5.4.3, 5.4.4.2.3, 5.4.4.5, 5.4.5.2, 5.4.5.3, 5.4.5.4, 5.4.5.7, 5.4.5.8, 5.4.5.9, 5.4.5.11, 5.4.6.3, 7.3, 7.4.1	—
A.2	Electrical hazards	See Table B.1, 2	5.2.8, 5.3.1, 5.4.3.4.2.1	IEC 60204-1
A.3	Thermal hazards resulting in burns and scalds, by a possible contact of persons, by flames or explosions and also by the radiation of heat sources	See Table B.1, 3	5.3.1, 5.4.3.4.2.3	ISO 13732-1
A.4	Hazards generated by noise	See Table B.1, 4	5.2.4, 5.3.1, 5.4.3.6, 5.4.8, 6	ISO/TR 11688-1
A.5	Hazards generated by vibration	See Table B.1, 5	5.3.1, 5.4.2.4, 5.4.3.1, 5.4.3.2 c)	
A.6	Hazards generated by radiation — electromagnetic fields	See Table B.1, 6	5.3.1	IEC 61000-6-2 IEC 61000-6-4
A.7	Hazards generated by materials and substances	See Table B.1, 7	5.2.12, 5.3.1, 5.4.2.9, 7.2	—
A.8	Hazards generated by neglect of ergonomic principles in the design of machines	See Table B.1, 8	5.2.9, 5.3.2, 5.4.6.7	—
A.9	Slipping, tripping and falling hazards	See Table B.1, 9	5.3.1, 5.4.5.7	—

Table A.1 (*continued*)

Hazard		Relevant subclauses in		Other relevant standards
No.	**Type**	**ISO 12100:2010**	**this International Standard**	
A.10	Fire or explosion hazards	See Table B.1, 3	5.2.12, 5.3.1, 7.2	—
A.11	Hazards generated by failure of energy supply, breaking down of machinery parts and other functional disorders	5.4 b), 6.2.11	5.2.1, 5.2.2, 5.2.5, 5.2.7, 5.4.6.9, 5.4.6.10	—
A.11.1	Failure of energy supply (of energy and/or control circuits): — variation of energy; — unexpected start; — prevention from stopping if the command has already been given; — falling or ejecting of moving parts or pieces held by the machinery; — impeded automatic or manual stopping; — protection device remains not fully effective.	5.4 b), 6.2.11	5.2.7, 5.2.8, 5.2.10, 5.3.1, 5.4.3.4.2.3, 5.4.3.4.2.4	—
A.11.2	Unexpected ejection of machine parts or fluids	See Table B.1, 1; 6.2.10, 6.2.11.1, 6.2.11.5, 6.3.2.1	5.3.1, 5.4.5.8, 5.4.5.11	—
A.11.3	Failure, malfunction of control system (unexpected start up, unexpected overrun)	See Table B.1, 1; 6.2.11.1, 6.2.11.2, 6.2.11.4, 5.4	5.2.7, 5.2.8, 5.2.10, 5.4.6.2, 5.4.6.9, 5.4.6.10, 5.4.6.13,	ISO 13849-1
A.11.4	Errors of fitting	6.4.5	5.3.1, 5.3.2, 5.3.4.1, 5.4.3.2 b), 5.4.5.3, 7.4.2	—
A.12	Hazards caused by temporarily missing and/or incorrectly positioned safety related measures/means, for example	6.3		—
A.12.1	Starting and stopping devices	6.2.11, 6.2.12	5.2.7	—
A.12.2	Safety signs and signals	6.2.8 g), 6.4.3	7.3	—
A.12.3	All kinds of information or warning devices	6.4.3, 6.4.4	5.4.4.2.3, 5.4.6.5, 5.4.7, 7.4	—
A.12.4	Energy supply disconnecting devices	6.3.5.4	5.2.7, 5.2.8, 7.3	—
A.12.5	Emergency devices	6.3.5, 6.2.11	—	ISO 13850
A.12.6	Essential equipment and accessories for safe adjusting and/or maintaining	6.2.15, 6.3	5.2.9, 5.4.1.1, 5.4.2.7, 5.4.5.11, 5.4.4.5, 5.4.6.3, 5.4.6.4	—

Annex B
(informative)

Form for collecting pneumatic system and component data to ensure conformance with ISO 4414

(Click here to access revisable electronic version of this annex.)

☐ Original ☐ Revised Revision number: ..... Revision date: .....

Purchase inquiry number: ..... Purchase order number: ..... Date issued: .....

B.1 General requirements

B.1.1 Description of equipment

.....

.....

.....

B.1.2 Commissioning

Location: .....

Date: .....

B.1.3 Names and contact information of parties involved

Purchaser

Company name: .....

Primary contact person: .....

Address: .....

Telephone: .....

Telefax: .....

E-mail: .....

Supplier

Company name: .....

Primary contact person: .....

Address: .....

Telephone: .....

Telefax: .....

E-mail: .....

B.1.4 Delivery location

Company name: .....

Division (if applicable): .....

Address: .....

B.1.5 Pneumatic system

☐ ISO 4414:2010, *Pneumatic fluid power — General rules and safety requirements for systems and their components*

☐ Supplementary agreements attached.

☐ Company pneumatic standard: .....

☐ Plant or division supplement: .....

☐ Other standards and codes: .....

Document number	Title of document	Edition	Source

B.1.6 Fluid (air) characteristics; see 5.2.6

Maximum supply pressure: .....kPa (..... bar)

Minimum supply pressure: .....kPa (..... bar)

Maximum flow rate: ..... L (ANR) s^{-1} at ... kPa (… bar)

☐ Supply available

☐ Supply to be provided

Type of compressor lubricant: .....

Nominal filtration rating: .....

Maximum pressure dew point: .....°C

B.1.7 Site or operating environment conditions; see 5.3.1

Altitude: ..... m

Normal atmospheric pressure: ..... kPa (..... bar)

Humidity range of the installation: ..... % relative humidity (if known)

Minimum ambient temperature: .....°C

Maximum ambient temperature: .....°C

Airborne contaminant level: .....

Ambient noise level: ..... dB

Floor surface: ☐ wood block ☐ reinforced concrete ☐ other: .....

Electrical network details

Voltage: ..... V ± V

Frequency: ..... Hz

Available power (if limited): ..... W

Phase: .....

☐ AC ☐ DC

Other utilities: .....

Waste disposal: .....

Vibration exposure: .....

Maximum vibration levels and frequencies (if known)

Level 1: .....

Frequency 1: ..... Hz

Level 2: .....

Frequency 2: ..... Hz

Level 3: .....

Frequency 3: ..... Hz

Emergency, safety and energy isolation requirements: .....

Other special legal and/or safety requirements: .....

.....

.....

.....

.....

.....

Requirements for the protection of persons
and the pneumatic system and its components:

☐ Fencing around machine

☐ Cabinet locks

☐ Control component locks

☐ Other: .....

Protection for electrical devices: ..... IP (in accordance with IEC 60529)

Fire or explosion hazard: .....

Available handling facilities
(e.g. lifting tackle, passageways, ground loading): .....

Special access or mounting requirements: .....

.....

.....

B.1.8 Final information; see 7.2

Preliminary for approval use		Description	Final received by system delivery date	
Copies	Reproducible		Copies	Reproducible
☐	☐	Pneumatic system circuit diagram	☐	☐
☐	☐	Electrical system circuit diagram	☐	☐
☐	☐	Pneumatic parts list	☐	☐
☐	☐	Sequence of operation	☐	☐
☐	☐	Sequence/time chart	☐	☐
☐	☐	Piping layout	☐	☐
☐	☐	Floor layout	☐	☐
☐	☐	Foundation drawings	☐	☐

Original drawing(s) to be forwarded upon completion of order to: .....

☐ Drawing(s) to include field changes.

Drawing(s) to be supplied in following format(s): ☐ electronic ☐ paper – rolled ☐ paper – folded

Purchaser's assigned drawing number(s): .....

Purchaser's associated equipment drawing number(s): .....

B.1.9 System requirements; see 5.2.6

Maximum working pressure: ..... kPa (..... bar)

Maximum fluid operating temperature: ..... °C

Minimum fluid operating temperature: ..... °C

Extreme temperature range
(for start-up or intermittent operation): ..... to ..... °C

Maximum surface temperature exposed to persons: ..... °C

Duty cycle: .....

Service life of system (e.g., hours, cycles, etc.): .....

Lubrication requirements: .....

Component and/or system lifting provisions: .....

Painting or protective coating requirements: .....

Labelling: .....

Maximum noise level requirements: .....

Emergency, safety and energy isolation requirements: .....

B.2 Component requirements

B.2.1 Air motors and semi-rotary actuators; see 5.4.1

Item number	Type	Shaft speed min^{-1}	Displacement cm^3	Rated pressure kPa (bar)	Applicable standards

B.2.2 Cylinders; see 5.4.2

Item number	Type	Rated pressure kPa (bar)	Bore mm	Piston rod diameter mm	Stroke mm	Applicable standards	Supplier
Double-acting							
Single-acting							
Other							

B.2.3 Directional control valves; see 5.4.3

This category includes solenoid operated, air pilot operated, mechanically operated, manually operated, non-return (check), shuttle and other types.

Item number	Type	Rated pressure kPa (bar)	Rated flow rate $l \cdot min^{-1}$	Applicable standards	Supplier

B.2.4 Quick-exhaust valves; see 5.4.3

Item number	Type	Rated pressure kPa (bar)	Rated flow rate $l \cdot min^{-1}$	Applicable standards	Supplier

B.2.5 Miscellaneous valves; see 5.4.3

This category includes flow control, lockout, two-hand non-tie-down, press clutch safety, pressure relief, sequence, time-delay and slow-start/soft-start types.

Item number	Type	Rated pressure kPa (bar)	Rated flow rate $l \cdot min^{-1}$	Applicable standards	Supplier

B.2.6 Air preparation components; see 5.4.4

Filters (particulate, coalescing or vapour-removal type)
☐ with manual drains ☐ with automatic or semi-automatic drains

Item number	Type	Rated pressure kPa (bar)	Rated flow rate $l \cdot min^{-1}$	Applicable standards	Supplier

Regulators (relieving or non-relieving type) ☐ with pressure gauge ☐ without pressure gauge

Item number	Type	Rated pressure kPa (bar)	Control pressure range kPa (bar)	Maximum temperature °C	Applicable standards	Supplier

Lubricators

Item number	Type	Rated pressure kPa (bar)	Maximum temperature °C	Applicable standards	Supplier

Filter-regulators and filter-regulator-lubricator (FRL) units
☐ combine where practical ☐ keep units separate

B.2.7 Piping; see 5.4.5

Plastic piping ☐ not permitted

☐ permitted below.....kPa (.....bar)

Item number	Material	Maximum rated pressure kPa (bar)	Applicable standards	Supplier
Plastic piping, including tubes, connectors and supports				
Rigid piping, including tubes (steel and copper), connectors, supports, rotating joints, valve mounting manifolds, circuit manifolds				
Flexible piping, including hoses and hose fittings				

B.2.8 Auxiliary compressors

Item number	Type and description	Pressure kPa (bar)	Applicable standards	Supplier

B.2.9 Accessories

This category may include receivers, silencers, pressure switches, gauges, quick-action couplings, etc.

Item number	Type and description	Rated pressure kPa (bar)	Applicable standards	Supplier

B.2.10 Other components

Item number	Type and description	Applicable standards	Supplier

B.2.11 Component reliability

Where component reliability is required for safety-related parts of control systems, ISO 19973 can be useful. The system supplier may request the following information from the component manufacturer.

Item number	Component	MTTF[a]	B10 life[b]

[a] MTTF is the characteristic life for a Weibull distribution.

[b] B10 life may be specified for either the median life or the 95 % confidence level.

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[3] ISO 3746, *Acoustics — Determination of sound power levels of noise sources using sound pressure — Survey method using an enveloping measurement surface over a reflecting plane*

[4] ISO 5782-1, *Pneumatic fluid power — Compressed-air filters — Part 1: Main characteristics to be included in suppliers' literature and product marking requirements*

[5] ISO 6301-1, *Pneumatic fluid power — Compressed-air lubricators — Part 1: Main characteristics to be included in supplier's literature and product-marking requirements*

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[9] ISO 13849-1, *Safety of machinery — Safety-related parts of control systems — Part 1: General principles for design*

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[18] IEC 61000-6-4, *Electromagnetic compatibility (EMC) — Part 6-4: Generic standards — Emission standard for industrial environments*

[19] IEC 61310-3, *Safety of machinery — Indication, marking and actuation — Part 3: Requirements for the location and operation of actuators*

ICS 23.100.01

Price based on 37 pages