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

Transmissions hydrauliques — Règles générales et exigences de sécurité relatives aux 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 4413 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 4413:1998), which has been technically revised, specifically with regards to the following:

a) integration of ISO 4413:1998 and EN 982:1996;

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 provisions 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 hydraulic fluid power systems, power is transmitted and controlled through a liquid under pressure within an enclosed circuit.

In the past, ISO 4413 was intended to provide assistance in the understanding between the supplier and the purchaser. This edition of ISO 4413 now includes, in addition, general requirements for the engineering of a hydraulic system and safety requirements that support the essential health and safety requirements of the European Machinery Directive.

Equivalent requirements for pneumatic systems are defined in ISO 4414.

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

1 Scope

This International Standard specifies general rules and safety requirements for hydraulic fluid power systems and components used on machinery as defined by ISO 12100:2010, 3.1. It deals with all significant hazards associated with hydraulic fluid power systems and specifies the 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 hydraulic 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.

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 4021, *Hydraulic fluid power — Particulate contamination analysis — Extraction of fluid samples from lines of an operating system*

ISO 4406, *Hydraulic fluid power — Fluids — Method for coding the level of contamination by solid particles*

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

ISO 6149-1, *Connections for hydraulic fluid power and general use — Ports and stud ends with ISO 261 metric threads and O-ring sealing — Part 1: Ports with truncated housing for O-ring seal*

ISO 6149-2, *Connections for hydraulic fluid power and general use — Ports and stud ends with ISO 261 metric threads and O-ring sealing — Part 2: Dimensions, design, test methods and requirements for heavy-duty (S series) stud ends*

ISO 6149-3, *Connections for hydraulic fluid power and general use — Ports and stud ends with ISO 261 metric threads and O-ring sealing — Part 3: Dimensions, design, test methods and requirements for light-duty (L series) stud ends*

ISO 6162-1, *Hydraulic fluid power — Flange connectors with split or one-piece flange clamps and metric or inch screws — Part 1: Flange connectors for use at pressures of 3,5 MPa (35 bar) to 35 MPa (350 bar), DN 13 to DN 127*

ISO 6162-2, *Hydraulic fluid power — Flange connectors with split or one-piece flange clamps and metric or inch screws — Part 2: Flange connectors for use at pressures of 35 MPa (350 bar) to 40 MPa (400 bar), DN 13 to DN 51*

ISO 6164, *Hydraulic fluid power — Four-screw, one-piece square-flange connections for use at pressures of 25 MPa and 40 MPa (250 bar and 400 bar)*

ISO 10763, *Hydraulic fluid power — Plain-end, seamless and welded precision steel tubes — Dimensions and nominal working pressures*

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 16874, *Hydraulic fluid power — Identification of manifold assemblies and their components*

ISO 17165-1, *Hydraulic fluid power — Hose assemblies — Part 1: Dimensions and requirements*

ISO 23309, *Hydraulic fluid power systems — Assembled systems — Methods of cleaning lines by flushing*

IEC 60947-5-5, *Low-voltage switchgear and controlgear — Part 5-5: Control circuit devices and switching elements — Electrical emergency stop device with mechanical latching function*

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
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)

4 List of significant hazards

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

5 General rules and safety requirements

5.1 General

5.1.1 When designing hydraulic 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 hydraulic 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, system and the environment shall be considered.

5.2 Basic requirements for the design and specification of hydraulic systems

5.2.1 Selection of components and piping

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 cause 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 supplier's instructions and recommendations, unless testing or field experience validates other components, applications or installations. Operator manuals for mobile machinery may exclude operation in certain situations.

5.2.1.3 It is recommended that, wherever practicable, components and piping made in conformance with recognized International Standards 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 a system or the rated pressure of any part of the system if the excessive pressure can cause a hazard.

Any system or part of a system that can be disconnected and sealed so that trapped fluid can be subject to a pressure increase or decrease (e.g. due to the change in a load or the fluid temperature) shall include means for limiting the pressure if the change 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-compensator pump controls, may be used to limit main system operating pressure, provided these means ensure safety under all operating conditions.

5.2.2.3 Systems shall be designed, constructed and adjusted to limit 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 Means shall be provided to prevent unacceptable pressure build-up where high external loads are reflected on actuators.

5.2.3 Mechanical movements

In stationary industrial machinery, 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 hydraulic systems, the expected noise shall be taken into account, and noise generation shall be minimized at its source. Depending on the application, measures shall be taken to minimize the risks caused by noise. Airborne, structure-borne and liquid-borne noise shall be considered.

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

5.2.5 Leakage

If leakage (internal or external) occurs, it shall not cause a hazard.

5.2.6 Temperature

5.2.6.1 Operating temperature

The full range of operating temperatures for the system or any component shall not exceed the specified limits at which they can safely be used.

5.2.6.2 Surface temperature

Hydraulic systems shall be designed to protect persons from surface temperatures that exceed touchable limits by either location or guarding, see ISO 13732-1. When such protection is not possible, proper warnings shall be provided.

5.2.7 Operational and functional requirements for hydraulic systems

The following specifications for operation and function shall be defined:

a) working pressure range;

b) working temperature range;

c) type of fluid being used;

d) working flow-rate range;

e) lifting provisions;

f) emergency, safety and energy isolation requirements;

g) painting or protective coating.

Annex B (informative) provides forms and checklists to facilitate the gathering and recording of this information for stationary machinery. These forms and checklists may also be useful to record those specifications that apply to hydraulic systems used in mobile machinery.

5.3 Additional requirements

5.3.1 Site conditions and operating environment

Site conditions and operating environment that affect the requirements of hydraulic systems used in stationary industrial machinery shall be defined. Annex B (informative) provides forms and checklists to facilitate the gathering and recording of this information, which may include:

a) ambient temperature range of the installation;

b) humidity range of the installation;

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

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

e) protection for electrical circuits and devices;

f) atmospheric pressure;

g) sources of contamination;

h) sources of vibration;

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

j) required reserves, e.g. flow, pressure and volume;

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

l) available cooling and heating media and capacities;

m) requirements for the protection of persons and the hydraulic system and its components;

n) legal and environmental limiting factors;

o) other safety requirements.

Annex B may also be useful to record those environmental conditions that apply to the specification of a hydraulic system used in mobile machinery. The individual forms in Annex B are also available in a separate revisable electronic format.

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

5.3.2.1 Replacement

To facilitate maintenance, means should be provided or components and piping fitted so that their removal from the system for maintenance

a) minimizes the loss of fluid;

b) for stationary machinery only, does not require the draining of the reservoir;

c) does not necessitate an otherwise needless disassembly of adjacent parts.

5.3.2.2 Maintenance requirements

The system shall be designed and constructed so that components and piping that require adjustment or maintenance are located where they are accessible and can be safely adjusted and serviced. Where these requirements are not feasible, maintenance and service information shall be provided; see 7.3.1.1 g) and n).

5.3.2.3 Lifting provisions

All components, assemblies or piping having a mass greater than 15 kg should have provision(s) for lifting by means of lifting devices.

5.3.2.4 Installation

Components should be installed so that they are accessible from a safe working position (for example, ground-level or working platform).

5.3.2.5 Use of standard parts

5.3.2.5.1 Commercially available parts (keys, bearings, packings, seals, washers, plugs, fasteners, etc.) and part configurations (shaft and spline sizes, port sizes, mountings, mounting surfaces or cavities, etc.) should be selected and coded in accordance with accepted International Standards.

5.3.2.5.2 Within a hydraulic system, ports, studs, and connectors should be limited to the minimum number of standard series possible. All port connections should be in accordance with ISO 6149-1, ISO 6149-2 and ISO 6149-3 for threaded port connections, or ISO 6162-1, ISO 6162-2 or ISO 6164 for four-screw flange port connections.

NOTE When using more than one type of ISO standard threaded port connection [e.g. ISO 1179 (all parts), ISO 9974 (all parts) and ISO 11926 (all parts)] in a system, there is a strong possibility of incompatible intermixing between some stud ends from one connection series and some ports from a different connection series, causing leakage and severe failure of the connection system. Ports and stud ends that conform to ISO 6149-1, ISO 6149-2 and ISO 6149-3 are marked such that they are identifiable.

5.3.2.6 Seals and sealing devices

5.3.2.6.1 Materials

Seal and sealing device materials shall be compatible with the fluid used, adjacent materials and their working conditions and environment.

5.3.2.6.2 Replacement

Component design shall facilitate servicing and replacement of seals and sealing devices, if such servicing and replacement is intended.

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 hydraulic systems for transportation and where an incorrect reconnection can cause a hazard, the piping and corresponding connections shall be clearly identified. The identification shall correspond to the data on all appropriate documentation.

5.3.4.2 Packaging

All parts of the hydraulic 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 Sealing and protection of openings

Exposed openings in hydraulic systems and components, in particular tubes and hoses, shall be protected during transportation either by being sealed or 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.

5.3.4.4 Handling facilities

Transport sizes and masses shall be consistent with the handling facilities available at the purchaser's premises (e.g. lifting tackle, passageways, ground loading); see B.1.5. If necessary, the hydraulic system shall be designed such that it can be easily disassembled into subassemblies.

5.4 Specific requirements for components and controls

5.4.1 Pumps and motors

5.4.1.1 Mounting

Hydraulic pumps and motors shall be mounted or installed so that

a) they are accessible for maintenance;

b) no shaft misalignment is introduced as a result of the duty cycle, temperature variations or applied weight loadings;

c) induced axial and radial loads are within rated limits for the pumps and motors and any drive components used;

d) all fluid connections are correctly connected; all pump shafts rotate in the correct direction as marked and intended; all pumps deliver fluid from inlet to discharge; and all motor shafts rotate in the correct direction relative to the direction of fluid flow;

e) vibration is adequately damped.

5.4.1.2 Couplings and mountings

5.4.1.2.1 Drive couplings and mountings shall be capable of continuously withstanding the maximum torque that can be generated at the pump or motor under all conditions of intended use.

5.4.1.2.2 Drive couplings shall be provided with a suitable protective guard when the coupling area can be accessible during operation of the pump or motor.

5.4.1.3 Rotational speed

Rotational speed shall not exceed the specified limits.

5.4.1.4 Drains, air bleeds and auxiliary ports

Drains, air bleeds and similar auxiliary ports shall be installed so that they do not allow ingress of air into the system. They shall be designed and installed such that back pressure does not exceed the pump or motor manufacturer's recommendations. If high-pressure air bleeds are used, they shall be installed so as to minimize the hazard to persons.

5.4.1.5 Pre-filling of housings

Where the housings of hydraulic pumps and motors require pre-filling with fluid prior to start up, a readily accessible and marked means for pre-filling shall be provided and be located to ensure that air is not trapped in the housings.

5.4.1.6 Working pressure range

If there are any restrictions on the working pressure range at which the pump or motor may be used, these shall be defined in the technical data; see Clause 7.

5.4.1.7 Installation

Hydraulic pumps and motors shall be installed so that

a) through the arrangement and selection of piping connections external leakage is prevented; tapered pipe threads or connection mechanisms that require sealing compounds shall not be used;

b) loss of prime or case lubrication is prevented during periods of inactivity;

c) pressure at the pump inlet port is not less than the minimum specified by the pump supplier for the operating conditions and the system fluid used;

d) they are either protected from predictable external damage, or suitably guarded if a hazard results.

5.4.2 Cylinders

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 at any position; see ISO/TS 13725.

5.4.2.2 Dimensioning

The design of cylinders shall take account of the maximum loads and pressure peaks that are expected.

5.4.2.3 Mounting ratings

All load ratings shall take account of the mounting types.

NOTE Cylinder rated pressures reflect only the capability of the pressure-containing envelope and not the force transmitting capability of mounting configurations.

5.4.2.4 Loading by position stop

When a cylinder is used as a position stop, the cylinder shall be sized and the mounting selected on the basis of the maximum loading induced by the machine member restrained.

5.4.2.5 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., while in use.

5.4.2.6 Unintended pressure intensifications

Means shall be provided in the system for preventing unintended pressure intensifications caused by differences in effective cylinder areas from exceeding rated pressure limits.

5.4.2.7 Mounting and alignment

Cylinders should preferably be mounted so that load reaction occurs along the cylinder centreline. The mounting shall minimize the following:

a) excessive deformation of the cylinder structure from either push or pull loading;

b) application of side or bending loads;

c) rotational velocities of cylinder pivot mountings that can necessitate continuous external lubrication.

5.4.2.8 Mounting location

Mounting surfaces shall not distort cylinders, and allowance shall be made for thermal expansion. Cylinders shall be mounted to enable ease of access for maintenance, adjustment to cushioning devices and complete unit replacement.

5.4.2.9 Mounting fasteners

Mounting fasteners for cylinders and accessories shall be designed and installed to accommodate all predictable forces. Foot-mounted cylinders can impose a shear force on the cylinder mounting bolts. If this shear load is of concern, cylinders that have a means to absorb the shear load should be considered. The mounting fasteners shall be adequate to absorb the turning moments.

5.4.2.10 Cushions and deceleration devices

When internal cushioning is used, the cylinder shall be designed to take into account the effects of load deceleration.

5.4.2.11 Adjustable stroke end stops

Means shall be provided to prevent loosening of adjustable external or internal stroke end stops.

5.4.2.12 Piston stroke

The stroke lengths, including tolerances, if not specified in the relevant International Standard, shall be specified, depending on the application of the hydraulic system.

NOTE ISO 6020-1, ISO 6020-2, ISO 6020-3, ISO 6022 and ISO 16656 specify tolerances on stroke lengths.

5.4.2.13 Piston rods

5.4.2.13.1 Material, finish and protection

Piston-rod material and finish shall 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.

5.4.2.13.2 Assembly

For assembly purposes, piston rods with threaded ends shall be provided with devices to apply counter forces; see ISO 4395. Pistons shall be positively locked to piston rods.

5.4.2.14 Maintenance of sealing devices and wear parts

Sealing devices and other wear parts that are intended to be serviced should be easily replaceable.

5.4.2.15 Air bleeding

5.4.2.15.1 Location of air bleeds

Cylinders on stationary industrial machinery shall be mounted so that they are self-bleeding, or accessible external air bleeds shall be provided. Where practical, cylinders shall be installed with air bleeds uppermost. Where these requirements are not feasible, maintenance and service information shall be provided; see 7.3.1.1 g), n) and r).

5.4.2.15.2 Air vent ports

Cylinders with air-filled chambers shall have their air-vent ports designed or positioned to avoid hazards. It shall be possible to vent air from cylinders without hazards.

5.4.3 Gas-loaded accumulators

5.4.3.1 Information

5.4.3.1.1 Information that is permanently marked on accumulators

The following information shall be permanently and legibly marked on accumulators:

a) name and/or logo of manufacturer;

b) date of manufacture (month/year);

c) manufacturer's serial number;

d) total shell volume, expressed in litres;

e) allowable temperature range, T_S, expressed in degrees Celsius;

f) permissible maximum pressure, P_S, expressed in megapascals (bar);

g) test pressure, P_T, expressed in megapascals (bar);

h) number of notified body (if applicable).

The place and method of stamping shall not reduce strength. If space is not available to provide all of this information on the accumulator, the information shall be provided on tags that are permanently attached to the accumulators.

NOTE Additional information can be required by local regulations.

5.4.3.1.2 Information that is given on, or on a label attached to, accumulators

The following information shall be given either on accumulators or on a label on accumulators:

a) name and brief address of the manufacturer/supplier;

b) product identification of the manufacturer/supplier;

c) warning note, to read: "**Caution — Pressurized vessel. Discharge pressure prior to disassembly!**";

d) gas-charge pressure;

e) warning note, to read: "**Use only *X***" where ***X*** is the pre-charge medium, e.g. nitrogen.

5.4.3.2 Requirements for hydraulic systems with gas-loaded accumulators

Hydraulic systems that incorporate gas-loaded accumulators shall automatically vent the accumulator liquid pressure or positively isolate accumulators (see 5.4.7.2.1), when the system is shut off. In special situations where pressure is required after the machine is shut down or the energy potential of hydraulic accumulators does not represent any hazards (e.g. clamping devices), it is not necessary to comply with the venting or isolating requirements. Gas-loaded accumulators and any associated pressurized components shall be applied within the rated limits of pressure, temperature and environmental conditions. Protection against excessive pressure on the gas side can be required in special circumstances.

5.4.3.3 Installation

5.4.3.3.1 Mounting position

If damage to components and connectors in a gas-loaded accumulator system can cause a hazard, they shall be suitably protected.

5.4.3.3.2 Support

Gas-loaded accumulators and any associated pressurized components shall be supported in accordance with the instructions of the accumulator supplier.

5.4.3.3.3 Unauthorized alterations

Gas-loaded accumulators shall not be modified by machining, welding or any other means.

5.4.3.4 Discharge rate

Gas-loaded-accumulator discharge rates shall be related to the demands of the intended service but shall not exceed the manufacturer's rating.

5.4.4 Valves

5.4.4.1 Selection

Valve types shall be selected to take into account correct function, leak tightness, maintenance or adjustment requirements, and resistance against foreseeable mechanical and environmental influence. Surface-mounted

and/or cartridge valves should be preferred in systems used in stationary industrial machinery. When isolation valves are required (e.g. to fulfil the requirements of 5.4.3.2 and 5.4.7.2.1), only valves that are qualified by their manufacturer for this safety application shall be used.

5.4.4.2 Mounting

When mounting valves, the following shall be considered:

a) independent support from their associated fluid piping or connector;

b) access for removal, repair or adjustment;

c) effects of gravity, impact and vibration on the valve;

d) sufficient clearance for wrench and/or bolt access and electrical connections;

e) means to avoid incorrect mounting;

f) prevention of damage by a mechanical operating device;

g) orientation to prevent accumulation of air or to allow bleeding of air, as applicable.

5.4.4.3 Manifolds

5.4.4.3.1 Surface finish and flatness

Valve-mounting-surface flatness and finish of the manifold shall be in accordance with the valve manufacturer's recommendations.

5.4.4.3.2 Distortion

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

5.4.4.3.3 Mounting

Manifolds shall be securely mounted.

5.4.4.3.4 Internal passages

Internal passages should have cross-sectional flow areas sufficiently large to minimize unintended pressure drops. 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 be dislodged and cause malfunction of and/or damage to other components, including seals and packings.

5.4.4.3.5 Identification

Manifold assemblies and their components shall be labelled for reference in accordance with ISO 16874. When this is not possible, the identification shall be provided by other means.

5.4.4.4 Electrically operated valves

5.4.4.4.1 Electrical connections and solenoids

5.4.4.4.1.1 Electrical connections

Electrical connections shall be in accordance with appropriate standards (e.g. IEC 60204-1 or manufacturer standard) and be designed with the suitable protection class (e.g. in accordance with IEC 60529).

5.4.4.4.1.2 Solenoids

Solenoids shall be selected (e.g. cyclic rate, temperature rating, voltage tolerance) so that they are capable of operating the valves at the specified conditions.

5.4.4.4.1.3 Manual or other overrides

If it is necessary to operate an electrically operated valve when electrical power is not available, it shall be provided with means for an override. Overrides shall be designed or selected so that the risk of inadvertent operation is minimized; and they should reset when the override control is removed, unless otherwise specified.

5.4.4.5 Adjustments

When valves permit adjustments of one or more parameters, the following provisions should be incorporated, as appropriate:

a) means for securing the adjustment;

b) means for locking the adjustment, if required to prevent unauthorized change; or

c) means for preventing adjustment beyond a safe range.

5.4.5 Fluids and conditioning components

5.4.5.1 Fluids

5.4.5.1.1 Specification

5.4.5.1.1.1 Fluids should be described in accordance with recognized International Standards. The manufacturer of the component or system shall define the proper hydraulic fluid by the type and the technical data or, if this is impossible, by the trade name of the hydraulic fluid's manufacturer.

5.4.5.1.1.2 When selecting a hydraulic fluid, consideration shall be given to its electrical conductivity.

5.4.5.1.1.3 Where a fire hazard exists, consideration shall be given to the use of a fire-resistant fluid.

5.4.5.1.2 Compatibility

All components in contact with the hydraulic fluid used shall be compatible with this hydraulic fluid. Additional precautions shall be taken in cases in which problems can arise due to incompatibility of the fluid with

a) protective finishes and other fluids associated with the system, for example paints, process and/or service fluids;

b) construction and installation material that can be in contact with spilled or leaking fire-resistant fluid, for example electrical cabling, other service supplies and products;

c) other hydraulic fluids.

5.4.5.1.3 Cleanliness level of fluids

The cleanliness level of hydraulic fluids, expressed in accordance with ISO 4406, shall be suitable for the most contaminant-sensitive component in the system.

NOTE 1 Commercial hydraulic fluids might not exhibit the required cleanliness level when delivered.

NOTE 2 Contamination of the fluid can affect the electrical conductivity of the fluid.

5.4.5.2 Reservoirs

5.4.5.2.1 Design

The reservoir or combination of communicating reservoirs

a) shall contain all the fluid that can flow from the system during normal operation or maintenance in accordance with the intended use;

b) shall maintain the fluid level at a safe working height and allow sufficient fluid access to supply lines during all operating cycles and operating attitudes;

c) shall allow adequate space for thermal expansion and air separation;

d) for hydraulic systems in stationary industrial machinery, shall be installed either over a pan, or equivalent device, of suitable capacity and configuration in order to effectively collect major accidental spillage from the reservoirs [see also 5.2.5 and 5.3.1 n)], or over an impermeable area;

NOTE Design requirements in these cases can be subject to national legal provisions.

e) should be able to provide passive cooling to control the system fluid temperature; when passive cooling is not sufficient, active cooling shall be provided; see 5.4.5.4;

f) should provide a slow recirculating velocity that allows for the release of entrained air and the precipitation of heavy contaminants;

g) should separate the return fluid from pump inlet lines by baffles or other means; if baffles are used, they shall not prevent thorough cleaning of the reservoirs;

h) for hydraulic systems in stationary industrial machinery, should be provided with bottom-supporting legs or members to raise the reservoir a minimum of 150 mm above the floor to facilitate handling, draining and heat dissipation. A minimum of four legs or supporting members of sufficient area should be provided for foundation anchoring and levelling.

If the fluid reservoir is of the pressure-sealed type, the special requirements of that type of unit shall be considered.

5.4.5.2.2 Construction

5.4.5.2.2.1 Spillage

Provisions shall be made to prevent spilled fluid from returning directly to the reservoir.

5.4.5.2.2.2 Vibration and noise

Care shall be taken to prevent excessive structure-borne vibration and airborne noise, particularly when components are mounted in or directly to the reservoir.

5.4.5.2.2.3 Top

The reservoir top

a) shall be positively fastened to the reservoir body;

b) shall, if removable, be designed to prevent the ingress of contaminants;

c) should be designed and constructed to avoid the formation of areas that collect and trap external solid and fluid contaminants and waste.

5.4.5.2.2.4 Configuration

The reservoir configuration shall satisfy the following requirements.

a) Suction lines shall be sized so that the pump inlet characteristics are in accordance with the design requirements.

b) Suction lines shall be located so that adequate fluid supply is maintained at the minimum operating fluid level and that entrainment of air and the formation of vortices in the fluid are eliminated, if not otherwise required.

c) Return lines to the reservoir should discharge below the minimum operating fluid level.

d) Return lines to the reservoir shall discharge at the lowest practical velocity and promote the desired fluid circulation pattern within the reservoir. The reservoir circulation shall not promote the entrainment of air.

e) Any cut-out in the reservoir shall be effectively sealed.

f) The reservoir should be designed to minimize resuspension of settled contaminants in the system fluid.

g) Removable fasteners inside the reservoir should be avoided or be secured against unintended loosening.

5.4.5.2.2.5 Maintenance

Maintenance provisions shall fulfil the requirements specified below.

a) Access covers that can be removed and replaced by one person shall be provided on reservoirs on stationary industrial machinery. The covers shall provide access to all internal areas for cleaning and inspection; alternative inspection means, e.g. an endoscope, are allowed.

b) Suction strainers, return diffusers and other replaceable internal reservoir components shall be easily accessible for removal or cleaning.

c) Reservoirs shall have means that they can be easily emptied in the assembled position;

d) Reservoirs on stationary industrial machinery should be shaped to allow complete draining in the assembled position.

5.4.5.2.2.6 Integrity

Reservoirs shall be designed to provide adequate structural integrity when they

a) are filled to maximum capacity with the system fluid;

b) are subjected to positive and negative pressures caused by the withdrawal or return of fluid at rates required by the system under all foreseeable conditions;

c) support mounted components;

d) undergo transport.

If lifting points are provided on the reservoir for transporting the hydraulic system, the supporting structure and attaching provisions shall be sufficiently robust to withstand the maximum expected handling force, including foreseeable impact and jerk, with no detrimental effect. The means of attachment shall be sufficiently strong and elastic to maintain secure restraint of the system parts mounted on, or attached to, the reservoir during handling and transport, with no damage or permanent deformation.

Pressure-sealed reservoirs shall be adequately designed for their maximum internal pressure during intended use.

5.4.5.2.2.7 Corrosion protection

Any internal and external corrosion protection shall take into account detrimental foreign contaminants, e.g. condensed water (see also 5.4.5.1.2).

5.4.5.2.2.8 Equipotential bonding

If required, equipotential bonding (e.g. grounding) shall be provided.

5.4.5.2.3 Accessories

5.4.5.2.3.1 Sight glasses and fluid-level sensors

Reservoirs shall be equipped with a fluid level indicator (e.g., sight glass) that

a) shall be permanently marked with system fluid high and low levels;

b) shall be fitted so that they are clearly visible during filling;

c) should have additional marks as appropriate for specific systems;

d) for fluid level sensors, shall be capable of indicating the actual fluid level and the specified limits.

5.4.5.2.3.2 Filling points

All filling points for fluids shall be clearly and permanently marked. Filling points should be fitted with sealed and captive covers to prevent the ingress of contaminants when closed. Contamination during filling shall be prevented by filtration or other means. Where this requirement is not feasible, maintenance and service information shall be provided; see 7.3.1.1 i).

5.4.5.2.3.3 Air intake

Means (e.g. air breather filters) shall be provided to ensure that air entering reservoirs has a cleanliness level compatible with the system requirements, taking into account the environmental conditions. If the air breather filter contains a changeable filter element, it should be equipped with a device that indicates when the filter requires servicing.

5.4.5.2.3.4 Water separators

If a water separator is provided, an indicator that signals when maintenance is required shall be installed; see 5.4.8.5.

5.4.5.3 Filtration and fluid conditioning

5.4.5.3.1 Filtration

Filtration shall be provided to maintain the required cleanliness level of the hydraulic fluid (see 5.4.5.1.3), expressed in accordance with ISO 4406. If the required cleanliness level cannot be achieved with a main filter system (i.e. pressure or return line filter), a separate off-line filtration system may be used.

5.4.5.3.2 Location and sizing of filters

5.4.5.3.2.1 Location

Filters shall be located in pressure, return and/or auxiliary circulation lines as necessary to achieve the cleanliness level of the hydraulic fluid required by the system.

5.4.5.3.2.2 Maintenance

All filter assemblies shall be equipped with a device that indicates when the filter requires servicing. The indication shall be readily visible to the operator or maintenance personnel; see 5.4.8.5. When this requirement is not feasible, scheduled filter replacement shall be addressed in the operator manual; see 7.3.1.1 i) and q).

5.4.5.3.2.3 Accessibility

Filters shall be installed where they are readily accessible and adequate space shall be allowed for replacing filter elements.

5.4.5.3.2.4 Sizing

The filter shall be selected such that the initial differential pressure recommended by the filter manufacturer is not exceeded at the intended flow rate and maximum fluid viscosity. The maximum flow rate in a return line filter can be greater than the maximum pump flow rate, due to the effects of cylinder area ratios and decompression.

5.4.5.3.2.5 Differential pressure

A filter assembly whose element cannot withstand without damage the maximum differential pressure in its part of the system shall be equipped with a filter bypass valve. Contamination in the bypass flow downstream from a filter in a pressure line shall not cause a hazard.

5.4.5.3.3 Suction lines

Filtration on pump suction lines is not recommended and should not be used for main system filtration; see B.2.11. The use of inlet screens or strainers can be accepted.

5.4.5.4 Heat exchangers

5.4.5.4.1 Application

Heat exchangers shall be used when passive cooling cannot control the system fluid temperature within the permissible limits or if precise control of fluid temperature is required.

5.4.5.4.2 Liquid-to-liquid heat exchangers

5.4.5.4.2.1 Application

Liquid-to-liquid heat exchangers shall be applied so that the fluid circulation paths and flow velocities are within the manufacturer's recommendations.

5.4.5.4.2.2 Thermal controls on stationary industrial machinery

Thermal controls on stationary industrial machinery shall be applied to the coolant side of the heat exchanger to maintain the desired hydraulic fluid temperature and to minimize the coolant flow required.

Cooling-medium control valves should be on the input line. Shut-off valves shall be provided in the cooling medium lines for maintenance.

5.4.5.4.2.3 Cooling medium

The cooling medium and its properties shall be specified. The heat exchanger shall be protected from corrosion caused by the cooling medium.

5.4.5.4.2.4 Drain

Provisions shall be made for draining both circuits of heat exchangers.

5.4.5.4.2.5 Temperature measuring points

Temperature-measuring points should be available for both hydraulic fluid and cooling media. Measuring points should include provisions for permanent installation of sensors and for service without loss of fluid.

5.4.5.4.3 Liquid-to-air heat exchangers

5.4.5.4.3.1 Application

Liquid-to-air heat exchangers shall be applied so that flow velocities are within the manufacturer's recommendations.

5.4.5.4.3.2 Air supply

An adequate supply of air and its cleanliness shall be considered; see B.1.5.

5.4.5.4.3.3 Air exhaust

Exhaust of air shall not cause a hazard.

5.4.5.5 Heaters

5.4.5.5.1 When heaters are used, the dissipated power density shall not exceed the fluid manufacturer's recommendations. If a heater is in direct contact with the hydraulic fluid, a low-fluid-level interlock should be provided.

5.4.5.5.2 Thermal controls should be applied to maintain the desired hydraulic fluid temperature.

5.4.6 Piping

5.4.6.1 General requirements

5.4.6.1.1 Dimensioning

Piping system conductor sizes and routing shall be designed taking into account the estimated fluid velocities, pressure drops and cooling requirements in all parts of the system under all anticipated operating conditions. It shall be assured that fluid velocity, pressure and temperature can be maintained within design limits throughout the system during all intended uses.

5.4.6.1.2 Use of connections

The number of separable connections in the piping system should be kept to a minimum, e.g. by use of bent tubing in preference to elbow connectors.

5.4.6.1.3 Piping layout

5.4.6.1.3.1 Tubes (i.e., rigid conductors) should be used. Hoses may be used if required for mechanical reasons, e.g. accommodation of movements of parts, damping of vibration or reduction of noise.

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

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

5.4.6.1.3.4 Every connection to piping should be sufficiently accessible to permit tightening with a torque wrench without, insofar as feasible, disturbing adjacent piping or equipment. Design attention is particularly necessary where piping terminates in a cluster of connectors.

5.4.6.1.4 Piping mounting and identification

Incorrect connections that can cause a hazard shall be avoided by identification of the tubes and hoses or by some other means.

5.4.6.1.5 Connector sealing

Tube connectors and hose fittings that use elastomeric seals should be used.

5.4.6.1.6 Pressure rating of connectors

Connectors shall have a rated pressure not less than the maximum working pressure of the portion of the system in which they are used.

5.4.6.2 Tube requirements

Tubing should be made of steel, unless other materials are agreed upon in writing; see B.2.14. Nominal working pressures for metric steel tubing with outside diameters up to and including 50 mm can be calculated in accordance with ISO 10763.

5.4.6.3 Support of tubes

5.4.6.3.1 Tubes shall be securely supported.

5.4.6.3.2 Supports shall not damage the tubes.

5.4.6.3.3 Pressure, vibration, wall thickness, noise emission and routing shall be considered.

5.4.6.3.4 Recommended approximate spacing of tube supports is given in Figure 1 and Table 1.

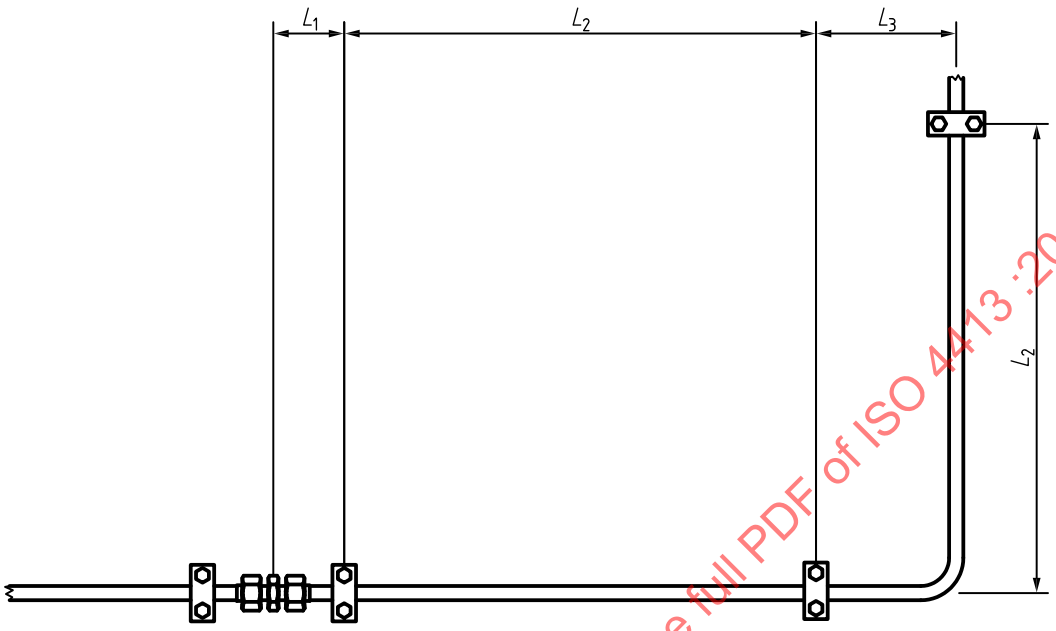

Figure 1 — Dimensions related to spacing of tube supports

Table 1 — Recommended approximate spacing of tube supports

Dimensions in millimetres

Outside diameter of tube	Recommended approximate spacing of tube support		
	From a connection	Between supports on a straight run	From a bend
d	L_1	L_2	L_3
$d \leqslant 10$	50	600	100
$10 < d \leqslant 25$	100	900	200
$25 < d \leqslant 50$	150	1 200	300
$d > 50$	200	1 500	400

5.4.6.4 Foreign matter

Before installation, the sealing surfaces and internal surfaces of piping shall be free of any visible detrimental foreign matter such as scale, burrs, swarf, etc. For certain applications, to improve safe and reliable operation of the system, stricter limits, involving also microscopic foreign matter in hose assemblies, may apply. In these cases, detailed specifications on maximum acceptable built-in solid contamination and procedures to assess it shall be specified.

5.4.6.5 Hose assemblies

5.4.6.5.1 General requirements

Hose assemblies shall

a) be constructed from hoses that have not been previously used in operation as part of another hose assembly and that fulfil all performance and marking requirements given in appropriate standards;

b) be marked in accordance with ISO 17165-1;

c) be delivered by the hose manufacturer, together with a recommendation on the maximum storage time;

d) not be used at working pressures that exceed the hose-assembly manufacturer's recommended maximum working pressure;

e) be specified, taking into consideration shock, pressure surges and flow restriction at both ends, to avoid, for example, possible damage to the hose lining.

NOTE Hose assembly installation and protection guidance are given in ISO/TR 17165-2.

5.4.6.5.2 Installation

Installation of hose assemblies shall

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

b) minimize torsional deflection of the hose during installation and use;

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.

5.4.6.5.3 Protection against failure

5.4.6.5.3.1 When failure of a hose assembly can constitute a whiplash hazard, the hose assembly shall be restrained or shielded by suitable means. If this is not possible because of intended machine movements, information on the residual risks shall be given.

The information on residual risks may be used by the machine manufacturer for risk analysis and definition of necessary measures, e.g. technical measures or instructions.

5.4.6.5.3.2 If the failure of a hose assembly can constitute a fluid-ejection hazard or fire hazard, it shall be shielded by suitable means. If this is not possible because of intended machine movements, information on the residual risks shall be given.

The information on residual risks may be used by the machine manufacturer for risk analysis and definition of necessary measures, e.g. technical measures or instructions.

5.4.6.6 Quick-action couplings

5.4.6.6.1 Applications that require the connection or disconnection of quick-action couplings under pressure should be avoided. When such applications are unavoidable, quick-action couplings designed to connect or disconnect under pressure shall be used and detailed instructions for the operator shall be provided; see also 5.2.2.1.

5.4.6.6.2 Uncoupled quick-action coupling halves in a system under pressure shall be capable of either containing the full system pressure or being suitably capped.

5.4.7 Control systems

5.4.7.1 Unintended movement

Control systems shall be designed to prevent unintended hazardous movement and improper sequencing of actuators. This applies to all phases of the operation.

5.4.7.2 System protection

5.4.7.2.1 Unexpected start-up

Systems on stationary industrial machinery shall be designed to facilitate positive isolation from energy sources and also to facilitate dissipation of the fluid pressure in the system in order to prevent unexpected start-up. In hydraulic systems, this can be done, for example, by

— mechanical locking of isolation valves to the shut-off position, and dissipation of pressure from hydraulic systems when the isolation valve is closed;

— isolation of the electrical supply; see IEC 60204-1.

5.4.7.2.2 Control or energy supply

Hydraulic components that are controlled electrically, pneumatically and/or hydraulically shall be selected and applied so that failure of the control or energy supply does not cause a hazard. Whatever the type of control supply or energy used (e.g. electrical, hydraulic, pneumatic or mechanical), 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).

5.4.7.2.3 Internal fluid drainage

Means shall be provided to prevent the system fluid from draining back into the reservoir when the system is switched off if such drainage can cause a hazard.

5.4.7.3 Control system components

5.4.7.3.1 Adjustable control mechanisms

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

5.4.7.3.2 Stability

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

5.4.7.3.3 Tamper resistance

5.4.7.3.3.1 Pressure and flow control valves or their enclosures shall be fitted with devices to discourage unauthorized alteration of pressure or flow rate if such alteration can cause a hazard or malfunction.

5.4.7.3.3.2 Means shall be supplied for locking the setting of adjustable components or of locking their enclosures, if changes or adjustment can cause a hazard or malfunction.

5.4.7.3.4 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.

5.4.7.3.5 Manual set-up controls

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

5.4.7.3.6 Two-hand controls

Two-hand controls shall conform to the requirements of ISO 13851 and be such that the operator is not exposed to hazards caused by machine movements.

5.4.7.3.7 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 reliably moves to or maintains a defined position (e.g. through spring biasing or a detent).

5.4.7.4 Control systems in open- and closed-loop control circuits

5.4.7.4.1 Override systems

Where actuators are controlled in open- or closed-loop control circuits and a malfunction of the control system can result in the actuators causing a hazard, then means shall be provided to maintain or recover control or stop the motion of these actuators.

5.4.7.4.2 Additional devices

Actuators on stationary industrial machinery that are controlled in open- or closed-loop control circuits shall have means to hold or move the actuator to a safe state if unintended movement can cause a hazard.

5.4.7.4.3 Filters

An additional full-flow filter without bypass and with a readily accessible filter-clogging indicator should be installed in the supply line of, and close to, a servo or proportional valve if a valve malfunction caused by contaminant can create a hazard. The collapse pressure rating of the filter element shall exceed the system maximum working pressure. Blockage of fluid flow by filters without a bypass shall not create a hazard.

5.4.7.4.4 Flushing of the system

The system and fluid should be cleaned to achieve a stabilized cleanliness level within the manufacturer's specifications before systems with actuators that are operated in open- or closed-loop control circuits are commissioned. Unless otherwise agreed, flushing of the assembled system shall be in accordance with ISO 23309.

5.4.7.5 Other design considerations

5.4.7.5.1 Monitoring of system parameters

Where changes in system operating parameters can signal a hazard, clear identification of those parameters, together with the signal value or change in value for each of them, shall be included in the information for use. Reliable means for monitoring those parameters shall be provided in the system.

5.4.7.5.2 Test points

It is recommended that sufficient and suitable test points be provided to adequately monitor system performance. Test points installed in hydraulic systems to verify pressure shall

a) be accessible;

b) have a safety cap that is permanently attached to minimize the ingress of contamination;

c) be designed to ensure safe and rapid engagement of the measuring instrument at the test point at maximum working pressure.

5.4.7.5.3 System interactions

Operating conditions in one system or part of a system shall not affect operation of any other system or part in a way that can cause a hazard.

5.4.7.5.4 Control of multiple devices

Where a system has more than one interrelated automatically and/or manually controlled device and where failure of any of these devices can cause a hazard, protective interlocks or other safety means shall be provided. These interlocks shall interrupt all related operations in a planned safe sequence and time and shall include reset provisions for each related operation, provided that such interruption does not of itself cause damage or a hazard. Reset provisions should require checks for safe position and conditions before restart.

5.4.7.5.5 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 time lapse control, on its own, could cause a hazard.

5.4.7.6 Location of controls

5.4.7.6.1 Protection

Controls shall be designed or installed in such a way that adequate protection is provided against

a) malfunction and predictable damage;

b) high temperature;

c) corrosive atmosphere;

d) electromagnetic interference.

5.4.7.6.2 Accessibility

Controls shall be easily and safely accessible. The results of the adjustment should be readily visible. Controls on stationary industrial machinery should be a minimum of 0,6 m or a maximum of 1,8 m above the working floor unless size, function or piping method requires alternative location.

5.4.7.6.3 Manual controls

The location and mounting of manual controls shall

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

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.

5.4.7.7 Emergency stop devices for stationary industrial machinery

5.4.7.7.1 General

5.4.7.7.1.1 When there is a hazard (for example a fire hazard) that can affect an extended machinery set or entire area that includes a hydraulic system, one or more emergency stop devices (e.g. an emergency stop button) shall be provided. At least one emergency stop device shall be remotely located.

5.4.7.7.1.2 Hydraulic systems shall be designed so that operation of an emergency stop device does not result in a hazard.

5.4.7.7.2 Features of emergency stop devices

Emergency stop devices shall conform to the requirements specified in ISO 13850 (function) and IEC 60947-5-5 (device).

5.4.7.7.3 System restart after emergency stop

Restarting a system after an emergency stop or emergency return shall not cause damage or a hazard.

5.4.8 Diagnostics and monitoring

5.4.8.1 General requirements

Provisions for diagnostic testing and condition monitoring should be made to facilitate preventive maintenance and trouble-shooting. Where changes in system operating parameters can signal a hazard, clear identification of those parameters, together with the signal value or change in value for each of them, shall be included in the information for use. See 5.4.7.5.1 and 5.4.7.5.2 for related information.

5.4.8.2 Pressure measurement and verification

Suitable pressure gauges shall be used to measure pressure. Pressure peaks and damping shall be taken into account, and pressure gauge protectors should be used, if necessary. Test points installed in hydraulic systems to verify pressure shall

a) be accessible;

b) have a safety cap that is permanently attached to minimize the ingress of contamination;

c) be designed to ensure safe and rapid engagement of the measuring instrument at the test point at maximum working pressure.

5.4.8.3 Fluid sampling

A means of obtaining a representative fluid sample in accordance with ISO 4021 should be provided to allow for checking fluid cleanliness conditions. If a sampling valve is provided from a high-pressure line, a label warning of a high-pressure jet hazard shall be installed, such that it is clearly visible at the sampling position, and the sampling valve shall be shielded.

5.4.8.4 Temperature sensing

A temperature-sensing device should be installed in the reservoir. In some applications, it can be useful to install an additional temperature-sensing device in the hottest part of the system.

5.4.8.5 Contamination control

Means should be provided to show when a filter or separator requires servicing; see 5.4.5.2.3.4 and 5.4.5.3.2.2. An alternative is regular, scheduled servicing as outlined in the operator's manual.

6 Verification of safety requirements and acceptance testing

The hydraulic 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 unintended leakage on any component other than slight wetting insufficient to form a drop on any cylinder rod after multiple cycles.

NOTE Because a hydraulic system might not be a complete machine, many verification procedures cannot be carried out until the hydraulic system is incorporated into the machine. Functional testing will then have to be carried out after assembly, by arrangement between the supplier and purchaser.

The results of verification by inspection and testing shall be documented, and the following information shall also be included in the report:

— type and viscosity of the hydraulic fluid used;

— temperature of the hydraulic fluid in the reservoir, after the temperature has stabilized.

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 and shall be supplied in an agreed format.

7.2 Final information for systems on stationary industrial machinery

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) instructions to assemble the system or any sub-systems to the machine;

g) hydraulic fluid material safety data sheets, if the manufacturer supplies the system filled with fluid.

7.3 Maintenance and operating data

7.3.1 General data

7.3.1.1 All hydraulic systems shall be provided with the necessary maintenance and operating data (including data relating to trial runs and commissioning), in an agreed format. This includes any of the following that are applicable:

a) working pressure range;

b) working temperature range;

c) type of fluid being used;

d) flow rate;

e) start-up and shut-down procedures;

f) any required depressurizing instructions and identification of those parts of the system that are not depressurized by the normal venting device;

g) adjustment procedures;

h) external lubrication points, the type of lubricant required and the intervals to be observed;

i) location of sight glasses or displays of fluid-level indicators or sensors, fill points, drains, filters, test points, strainers, magnets, etc., that require scheduled maintenance;

j) type, technical data and required cleanliness level of the fluid, expressed in accordance with ISO 4406;

k) instructions for fluid maintenance and filling volume;

l) advice on the safe handling and disposal of fluids and lubricants;

m) cooling-medium flow rate, maximum temperature, permissible pressure range required for adequate cooling, and draining instructions for maintenance;

n) maintenance procedures for unique assemblies;

o) observations on testing and change intervals for hydraulic accumulators and hoses; see 5.4.6.5;

p) list of recommended spare parts;

q) recommended maintenance or overhaul intervals for those components that require scheduled maintenance;

r) procedures for removing air from components.

7.3.1.2 Standard parts (for example threaded fasteners, dowel pins or O-ring seals) used in hydraulic fluid power components may be identified with the part numbers assigned by the suppliers of the components or with the standard part designations used in International Standards for the parts.

7.3.2 Requirements for systems with gas-loaded accumulators

7.3.2.1 Warning label

7.3.2.1.1 For hydraulic systems that contain one or more accumulators whose warning labels are not visible when installed on the machine, an additional warning label reading "**CAUTION – System contains accumulator(s)**" shall be applied in a visible location on the system, as described in B.1.6. Duplicate information shall be provided on the circuit diagram.

7.3.2.1.2 If isolation of the liquid pressure in a gas-loaded accumulator is required by design when the system is shut off, information for safe servicing shall be referenced on all components or assemblies still pressurized and placed in a visible location thereon.

7.3.2.1.3 All sub-systems that remain under pressure after isolation of the machine from its power supply shall be provided with clearly identified unloading valves, and a warning label drawing attention to the necessity of depressurizing those sub-systems before any setting or maintenance activity on the machine.

7.3.2.2 Maintenance information

The following information shall be given

a) Gas precharge: the main routine service that a gas-loaded accumulator is likely to require is the checking and adjustment of gas precharge pressure. Pressure checks and adjustments shall be carried out using the method and apparatus recommended by the accumulator manufacturer, taking into consideration that the precharge pressure depends on the gas temperature. Care shall be taken not to exceed the rated pressure of the accumulator during checks and adjustments. After any check or adjustment, there shall be no leakage of gas.

b) Removal from system: before removing gas-loaded accumulators, the liquid pressure in the accumulator shall be reduced to atmospheric pressure, i.e., depressurized condition.

c) Gas-loaded accumulator maintenance data: maintenance, overhaul and/or replacement of component parts shall be carried out only by suitably skilled people, in accordance with a written maintenance procedure and using parts and materials certified as produced to the current design specification.

   Before disassembly of the gas-loaded accumulator commences, the accumulator shall be fully depressurised on both liquid and gas sides.

7.3.3 Requirements for safety related parts of control systems

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 If 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 by the supplier and shown, if practicable, in a permanent and readily visible form on all components:

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

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

c) rated pressure;

d) symbols in accordance with ISO 1219-1 oriented in such a way that the positions and controls represented agree directionally with the movement of the operating device, and with all ports correctly identified.

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

7.4.2 Components and hose assemblies within a system

7.4.2.1 Each component and hose assembly in the hydraulic 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.

7.4.3 Ports and conductors

7.4.3.1 Component ports, power take-off points, test ports, bleed points and drain outlets 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 hydraulic 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).

7.4.4 Valve-control mechanisms

7.4.4.1 Valve-control mechanisms and their functions should 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 hydraulic and related electrical circuit diagram, it shall be identified in the same way on both circuit diagrams.

7.4.5 Internal devices

Cartridge valves and other functional devices [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.

7.4.7 Direction of pump and motor shaft rotation

The direction of rotation of pump and motor shafts shall be clearly and distinctly identified if a mismatch can cause a hazard.

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:

"Hydraulic systems and their components are in accordance with ISO 4413:2010, *Hydraulic fluid power — General rules and safety requirements for systems and their components.*"

Annex A
(informative)

List of significant hazards

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

Hazard		Relevant subclauses in		Other relevant standards
No.	Type	ISO 12100:2010	this International Standard	
A.1	Mechanical hazards: — shape; — relative location of moving parts; — mass and stability (potential energy of elements); — mass and velocity (kinetic energy of elements); — inadequate mechanical strength; — accumulation of potential energy by — elastic elements, — liquids or gases, — vacuum.	See Table B.1, 1	5.2.1, 5.2.2, 5.2.3, 5.2.5, 5.3.2.2, 5.3.1, 5.3.2.1, 5.3.4, 5.4.1, 5.4.2, 5.4.3, 5.4.4, 5.4.6, 5.4.5.2, 7.3, 7.4.1	—
A.2	Electrical hazards	See Table B.1, 2	5.3.1, 5.4.4.4.1, 5.4.5.2.2.8, 5.4.7.2.1, 5.4.7.2.2	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	5.2.6.1, 5.2.6.2, 5.3.1, 5.2.7, 5.4.5.4.2	ISO 13732-1
A.4	Hazards generated by noise	See Table B.1, 4	5.2.4, 5.3.1, 5.4.5.2.2.2	ISO/TR 11688-1
A.5	Hazards generated by vibration	See Table B.1, 5	5.2.3, 5.3.1, 5.4.5.2.2.2	—
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	5.4.2.15.2, 5.4.5.1.2, 7.2, 7.3.1	—
A.8	Hazards generated by neglect of ergonomic principles in the design of machines	See Table B.1, 8	5.3.1, 5.3.2.1, 5.3.2.2, 5.3.2.3, 5.3.2.4	—
A.9	Slipping, tripping and falling hazards	See Table B.1, 1, 9	5.2.5, 5.3.1, 5.3.2.2, 5.3.2.6, 5.4.6.1.4, 5.4.7.6.2,	—
A.10	Fire or explosion hazards	See Table B.1, 3	5.2.5, 5.3.1, 5.3.2.6, 5.4.5.1.1, 5.4.6.5.3	—

Table A.1 (*continued*)

Hazard		Relevant subclauses in		Other relevant standards
No.	Type	ISO 12100:2010	this International Standard	
A.11	Hazards generated by failure of energy supply, breakdown of machinery parts and other functional disorders	5.4 b), 6.2.11	5.3.1, 5.4.7	—
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	5.4.4.4.1, 5.4.7	—
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	5.2.2, 5.2.5, 5.2.7, 5.4.1.3, 5.4.2.6, 5.4.6.5.3, 5.4.6.6	ISO/TR 17165-2
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	5.4.7	ISO 13849-1
A.11.4	Errors of fitting	6.4.5	5.3.1, 5.3.2, 5.3.4, 5.4.1.1, 5.4.3.3, 5.4.4.2, 5.4.6, 7.4	—
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	5.4.7.2.3	—
A.12.2	Safety signs and signals	6.2.8 g), 6.4.3	5.4.3.1, 7.3, 7.4	—
A.12.3	All kinds of information or warning devices	6.4.3, 6.4.4	5.4.5.3, 5.4.5.2.3, 5.4.7.5.1, 7.4	—
A.12.4	Energy supply disconnecting devices	6.3.5.4	5.4.3.2, 5.4.7.2.1, 7.3	—
A.12.5	Emergency devices	6.3.5, 6.2.11	5.4.4.4.1	ISO 13850
A.12.6	Essential equipment and accessories for safe adjustment and/or maintenance	6.2.15, 6.3	5.3.2.2, 5.4.2.11, 5.4.7.3	—

Annex B
(informative)

Form for collecting hydraulic system and component data to ensure conformance with ISO 4413

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

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 Applicable standards, codes and laws (in addition to ISO 4413)

Document number	Title of document	Edition	Source

B.1.5 Site or operating environment conditions; see 5.3.1

Minimum ambient temperature: ..... °C

Maximum ambient temperature: ..... °C

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

Airborne contaminant level: .....

Normal atmospheric pressure
(for systems in stationary machinery) ..... kPa (..... bar)

Electrical network details
(for systems in stationary machinery) Voltage: ..... V ± V

Frequency: ..... Hz

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

Phase: .....

Available air supply:
(for systems in stationary machinery) ..... $m^3\ min^{-1}$ ..... MPa (..... bar)

Cooling water supply: Flow rate: .....L min^{-1} Inlet temperature..... °C
(for systems in stationary machinery) Pressure: ..... MPa (..... bar)

Available heating media and capabilities: .....

Available steam supply:
(for systems in stationary machinery) Delivery rate: .....kg/hr at a temperature of: ..... °C

at pressure of: ..... MPa (.....bar)

Quality: .....%

Other utilities:
(for systems in stationary machinery).....

.....

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

Vibration exposure: .....

Maximum vibration levels and frequencies (if known)

Level 1: .....

Frequency 1 ..... Hz

Level 2: .....

Frequency 2 ..... Hz

Level 3: .....

Frequency 3 ..... Hz

Fire or explosion hazard: .....

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

.....

.....

Special access or mounting requirements: .....

.....

.....

Requirements for the protection of persons and the hydraulic system and its components: .....

.....

.....

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

.....

.....

B.1.6 System requirements; see 5.2.7

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

Maximum fluid working temperature: .....°C

Minimum fluid working temperature: .....°C

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

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

Type of fluid to be used: .....

Maximum fluid contamination level: ...../...../..... (expressed in accordance with ISO 4406)

Maximum pump flow rate: ..... L min^{-1}

Duty cycle: .....

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

System reliability requirements (e.g., MTTF): .....

Lubrication requirements: .....

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

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

Painting or protective coating requirements: .....

Labeling: .....

Maximum noise level requirements: .....

B.2 Component requirements

B.2.1 Pumps; see 5.4.1

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

B.2.2 Motors; see 5.4.1

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

B.2.3 Cylinders; see 5.4.2

Item number	Type	Rated pressure MPa (bar)	Bore mm	Piston rod diameter mm	Stroke mm	Speed $mm \cdot s^{-1}$ min.	Speed $mm \cdot s^{-1}$ max.	Applicable standards	Supplier