International Standard 5388

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION•МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ•ORGANISATION INTERNATIONALE DE NORMALISATION

Stationary air compressors — Safety rules and code of practice

Compresseurs d'air fixes — Règles de sécurité et code d'exploitation

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards institutes (ISO member bodies). The work of developing International Standards is carried out through ISO technical committees. Every member body interested in a subject for which a technical committee has been set up 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.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 5388 was developed by Technical Committee ISO/TC 118, *Compressors, pneumatic tools and pneumatic machines*, and was circulated to the member bodies in August 1978.

It has been approved by the member bodies of the following countries :

Australia	France	Netherlands
Austria	Germany, F.R.	Poland
Belgium	India	Romania
Brazil	Ireland	Sweden
Czechoslovakia	Korea, Dem. P. Rep. of	United Kingdom
Finland	Mexico	

The member bodies of the following countries expressed disapproval of the document on technical grounds :

South Africa, Rep. of
USA

Printed in Switzerland

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Stationary air compressors — Safety rules and code of practice

Section one : General

1 Scope and field of application

1.1 This International Standard establishes standards for the safe design, construction, installation and operation of stationary and skid-mounted air compressors for general use. It specifies requirements to help minimize compressor accidents and defines general safety practices for the field. Potential hazards associated with compressors are listed and detailed under the following headings in clause 6 :

a) improper lubrication;

b) inadequate cooling;

c) mechanical failures;

d) personal injury;

e) exposure to noise;

f) fires and explosions in the pressure system;

g) crankcase explosions;

h) incorrect installation, operation or maintenance.

This International Standard does not cover the prime movers, which are dealt with in other International Standards.

1.2 This International Standard is based on the requirement that the compressor components be designed in accordance with recognized good practice and applicable national standards.

1.3 This International Standard is intended to apply to stationary and skid-mounted air compressors for general use. However, the following types of compressor are specifically excluded :

a) compressors with a shaft input less than 2 kW;

b) compressors with an effective discharge pressure less than 0,5 bar (50 kPa);

c) compressors with an effective discharge pressure exceeding 50 bar (5 MPa);

d) compressors specifically supplying air for breathing, diving or surgery;

e) compressors used for air brake systems

f) ejectors.

2 References

ISO 508, *Identification colours for pipes conveying fluids in liquid or gaseous condition in land installations and on board ships.*[1)]

ISO 1000, *SI units and recommendations for the use of their multiples and of certain other units.*

ISO 1996, *Acoustics — Description and measurement of environmental noise — Part 1 : Basic quantities and procedures.*[2)]

ISO 1999, *Acoustics — Assessment of occupational noise exposure for hearing conservation purposes.*

ISO 2151, *Measurement of airborne noise emitted by compressor/primemover-units intended for outdoor use.*

ISO 2314, *Gas turbines — Acceptance tests.*

ISO 3046, *Reciprocating internal combustion engines : Performance.*

ISO 3448, *Industrial liquid lubricants — ISO viscosity classification.*

ISO 3864, *Safety colours and safety signs.*[3)]

ISO 3977, *Gas turbines — Procurement.*

1) At present at the stage of draft. (Revision of ISO/R 508-1966.)

2) At present at the stage of draft. (Revision of ISO/R 1996-1971.)

3) At present at the stage of draft. (Revision of ISO/R 408-1964 and ISO/R 557-1967.)

ISO 3989, *Acoustics — Measurement of airborne noise emitted by compressor units including primemovers — Engineering method for determination of sound power levels.* [1)]

IEC Publication 34, *Rotating electrical machines.*

IEC Publication 45, *Specification for steam turbines.*

3 Unit system

Throughout this International Standard, SI units are used. (See ISO 1000.) However, in accordance with accepted practice in the compressed air industry, the bar is used as the unit of pressure (1 bar = 10^5 Pa).

NOTE — Unless otherwise stated, the term pressure means effective (gauge) pressure.

4 Definitions

4.1 maximum allowable working pressure : The maximum operating air pressure which the manufacturer specifies for any service condition specified for the compressor or any part to which the term is referred, such as an individual stage or casing.

4.2 relief valve or safety valve set pressure : The pressure on the inlet side of a relief valve or safety valve when opening commences.

4.3 maximum allowable working temperature : The maximum compressed air temperature which the manufacturer specifies at any service condition specified for the compressor or any part to which the term is referred.

4.4 maximum expected outlet temperature : The highest predicted outlet air temperature resulting from any specified service condition including part-load operation.

4.5 maximum allowable compressor speed : The highest rotational frequency at which the manufacturer's design will permit operation, assuming overspeed and governor mechanisms are installed and operating.

4.6 trip speed : The rotational frequency at which the primemover is automatically tripped out.

4.7 surge limit : The limiting flow below which stable operation of a turbocompressor is not possible.

5 Compressor categories

Air compressors can be grouped into the following three categories from a lubrication viewpoint :

a) "Oil-free" compressors in which the air does not come into contact with the oil used to lubricate the machine, for example dynamic compressors, labyrinth compressors, diaphragm compressors or compressors with unlubricated piston rings.

b) Oil-lubricated compressors in which the moving parts in the compression chamber are lubricated with oil which is either specially injected for that purpose by a mechanical lubricator or is carried over from other parts of the machine, as in a single-acting trunk type of reciprocating compressor without a crosshead.

Oil-lubricated compressors can be grouped into any of the four main classes below :

1) Air-cooled reciprocating types with a power input up to 20 kW, usually built as single- or two-stage machines up to about 25 bar (2,5 MPa) and often for intermittent service.

2) Air-cooled reciprocating types with a power input above 20 kW, usually built as single-stage machines up to about 3 bar (0,3 MPa), two-stage up to about 25 bar (2,5 MPa) and more stages for higher pressures.

3) Water-cooled reciprocating types, usually built as single-stage machines up to about 5 bar (0,5 MPa), two-stage up to about 25 bar (2,5 MPa) and more stages for higher pressures.

4) Water- or air-cooled rotary vane types, usually built as single-stage machines up to about 4 bar (0,4 MPa) to 7 bar (0,7 MPa) and two-stage up to about 12 bar (1,2 MPa).

c) Oil-flooded rotary compressors in which relatively large quantities of oil are injected into the compression chamber not only to lubricate the working parts but also to assist in sealing and to absorb the heat of compression.

6 Potential hazards

The following sub-clauses do not attempt to identify all the possible hazards associated with running machinery but only those which are specific or particularly applicable to stationary air compressors. (See annexes A to E.)

6.1 Improper lubrication

6.1.1 The more common causes of improper lubrication are :

a) use of improper lubricant;

1) At present at the stage of draft.

b) lack of oil;

c) poor maintenance leading to bearing wear with increased clearances and too low oil pressure;

d) insufficient or excessive cooling;

e) overlubrication.

6.1.2 Malfunction of the lubrication system may lead to a temperature increase which, with continued operation, may introduce the risk of an oil fire.

6.2 Improper cooling

The risks stemming from poor cooling are obvious. However, overcooling is also to be avoided because it gives rise to internal cylinder corrosion as the condensate modifies the lubricant.

6.3 Mechanical failures

These usually emanate from one or more of the following causes :

a) excessive pressure;

b) overspeed;

c) secondary phenomena caused by improper lubrication;

d) secondary phenomena caused by improper cooling;

e) poor maintenance;

f) excessive vibrations or external forces.

6.4 Personal injury

The more common potential causes of injury are :

a) contact with moving parts;

b) contact with hot parts;

c) falling from elevated positions;

d) slipping (for example caused by oil spillage);

e) electrical hazards;

f) use of incorrect tools during maintenance;

g) bursting or explosion of an apparatus or component under pressure;

h) production of smoke or toxic oil vapour arising from accidental ignition of the oil.

6.5 Exposure to noise

Noise, even at reasonable levels, can cause irritation and disturbance which over a long period of time may cause severe injuries to the human nervous system and can take forms such as lack of sleep, irritation, etc. Noise at average sound pressure levels exceeding 90 dB(A) is considered to damage hearing. The effect depends on the level and the duration of the exposure. Reference is made to national regulations.

The noise from a compressor has three main components : intake noise, noise radiated from the surfaces of the machine and noise from pipework. The noise level in a room depends on the noise emission from all noise sources in the room and the acoustic properties of the room itself, i.e. the sound absorption of walls, floors and ceiling. The noise emission from the compressors is not always the most important factor for the total noise level. The noise from the prime movers must also be considered. See also annex A.

6.6 Fires and explosions in the pressure system

6.6.1 Oil-lubricated compressors

It is generally accepted that the occurrence of fires in oil-lubricated compressor systems is dependent on the build-up of oil degradation (oilcoke) deposits. When the pressure system is designed according to the advice given in annex B and the lubricating oil is chosen according to the advice in annex D, both the compressor and the pressure system should remain clean without any oil degradation, thereby reducing the risk of fire. However, with pressure systems that allow the build-up of oil degradation deposits, the quality of the oil is still more important, as is also a regular cleaning of the pressure system (see annex C).

Four factors that affect coke formation are listed below.

a) Rate of oil feed

Excessive oil feed promotes deposit formation.

b) Air filtration

Solids ingested with the suction air thicken the oil and delay its passage through the hot part of the delivery system, increase the time it is subject to oxidation, and hence increase the rate of deposit formation.

c) Temperature

The temperature at which significant oxidation starts is related to the grade and type of oil used. In the case of compressors with water-cooled cylinders, it is recommended that treated or demineralised water be used to prevent the formation and deposit of scale inside the pipework. A failure of cooling water can result in a sharp rise in temperature above the level appropriate to that particular machine, and is a well-recognized cause of fire initiation when the coke layer in the hot zone is thick enough. Failure of valves can similarly raise the temperature and cause dangerous conditions.

NOTE — In compressors with a very high stage pressure ratio, "dieseling" can occur when the cooling is poor and the lubrication is rich. Such a cylinder "explosion" can, under special circumstances, propagate along the delivery pipe as a detonation.

d) Catalysts present, for example iron oxides.

6.6.2 Oil-flooded rotary compressors (special precautions)

Experience shows that oil-flooded rotary air compressors of good design, correctly lubricated and maintained, are free from fire hazards. Abnormal temperature rise in the oil filter pads can, however, accelerate the oil oxidation with consequent fire risk.

Laboratory tests and experience from the field indicate that three factors are important to prevent the risk of such oil fires occurring. These are :

a) the design;

b) the choice of oil;

c) the operation and maintenance of the compressor; the following points are of particular importance :

1) keeping the oil consumption low;

2) regular oil changes;

3) ensuring that the oil cooling arrangements are working satisfactorily.

6.7 Crankcase explosions

Explosions can and have occurred in the crankcases or gear cases of compressors (see annex E).

6.8 Incorrect installation, operation or maintenance

Besides the types of potential hazard described above, hazards also exist if the installation, operation and maintenance work are not carried out in the correct way. (See also section four and annex B.)

Section two : Compressor design and construction

Implementation of and compliance with the requirements of this section will normally be the responsibility of the compressor supplier.

7 General

Compressors shall be designed and built to withstand safely all specified pressures, temperatures and other service conditions. The design shall facilitate the convenient operation and maintenance of the compressor unit, whilst minimizing the risk of physical injury.

7.1 Every compressor shall have a permanently attached and clearly visible nameplate of durable material and carrying the following minimum information :

— manufacturer;

— model designation and serial number;

— maximum allowable working pressure;

— maximum allowable continuous shaft speed.

NOTE — On compressors above 20 kW, information about capacity, shaft input and coolant flow, etc. is often included.

7.2 The function of all instruments shall be clearly indicated, and in the case of a remote capacity control the actual capacity load must be displayed in the compressor room.

7.3 Compressor parts which cannot be lifted by one man without danger shall be fitted with suitable devices for attaching them to lifting gear unless the shape of the part is such as to make this unnecessary.

7.4 Reciprocating compressor valve and valve port design shall be such that no inlet valve can be fitted instead of a discharge valve and that no discharge valve can be wrongly fitted in such a way as to prevent the proper discharge of air.

7.5 To provide safe conditions during removal of the piston rod from the piston, provision should be made in the design to ensure that dangerous quantities of compressed air cannot remain trapped in the piston.

7.6 When considered necessary for large compressors, crankcase explosion-relief devices should be fitted. (See annex E.)

8 Guards

8.1 Guards shall be provided on all rotating and reciprocating parts which may be hazardous to personnel. Guards shall also be provided for flywheels. An opening shall be provided in flywheel guards, when required, for barring over the machine and to provide access to timing marks, wheel centre and any other part which may require attention.

8.2 The guards shall be easy to remove and to re-install, and shall have sufficient rigidity to withstand deflection and prevent rubbing as a result of bodily contact.

8.3 Belt- and chain-drive guards for outdoor installations shall be weatherproof.

8.4 Pipework or other hot parts shall be adequately guarded or insulated (see 14.2).

8.5 Pipework runs in a horizontal plane or which might otherwise be accessible for personnel should either be guarded or be robust enough, when supported, to carry a vertical load of 1,5 kN* without unacceptable deflection or damage.

9 Pipework and pressure vessels

9.1 All pipework and auxiliaries integral to a unit shall be supported in such a way that the possibility of damage due to vibration, thermal expansion and own mass is eliminated.

9.2 Unguarded pipework (other than local gauge, cylinder lubrication, instrument and control air and similar pipework) shall have a wall thickness great enough to resist damage by accidental impact.

9.3 Delivery pipework, up to the aftercooler or receiver, for oil-lubricated compressors should, where possible, be run so that gravity assists the flow of oil through the hot zone. Interstage pipework and coolers like other vessels, where fitted, should be similarly arranged. (See annex B.)

9.4 Pipework and compressor accessories such as water jackets, coolers, pulsation dampers and air receivers shall be provided with drainage facilities at low points to prevent damage from freezing during idle periods.

* 1,5 kN ≈ 150 kgf

9.5 The coolant outlet from cylinder jackets and compressor casings shall be open or so arranged that excessive pressures cannot occur.

9.6 All auxiliaries which come within the scope of pressure vessel codes (for example air coolers, silencers, separators and traps) shall be designed in accordance with applicable codes.

9.7 The compressed air side of the compression space shall be hydrostatically tested at a pressure of not less than 1,3 times the maximum allowable stage working pressure. However, sample testing is sufficient for batch-produced compressors for effective working pressures below 15 bar (1,5 MPa).

NOTE — Valves and fittings shall be properly vented before the hydrostatic test in order to prevent the formation of air pockets.

10 Vibrations and pressure pulsations

10.1 Vibration and shaft axial movement alarms and shutdowns may be utilized to prevent destructive failures.

10.2 Pressure pulsations are inherent in reciprocating compressor installations owing to the pulsating flow of air into and out of the cylinders. If the frequency of the pulsations is in resonance with the natural frequency of pipework or the foundations, fatigue failure of pipework, nipples, anchor bolts and other parts may result. With air compressors it is often possible to calculate the resonance frequency and to arrange the pipework system to obtain satisfactory damping. (See annex B, clause B.7.) When this is not possible, properly designed pulsation dampers with draining devices should be installed adjacent to the compressor cylinders or incorporated into the cylinder construction to minimize the pressure pulses and their effect on other parts of the system. When pulsation dampers are used with lubricated compressors, they should be designed to prevent the build-up of oil degradation deposits (see also 9.3).

11 Electrical equipment

11.1 All electrical equipment shall comply with the applicable international or national regulations and directives.

12 Overheating

12.1 The design of single-stage, oil-flooded compressors should be such that the maximum temperature at the delivery flange of the compressor before the oil separator does not exceed 110 °C at an ambient temperature of 30 °C.

NOTE — Higher temperatures are permissible when special oils are used.

12.2 Oil-flooded compressors shall have an automatic shutdown device to prevent the temperature of the compressor oil from exceeding the safe limit. The tripping temperature shall not exceed 120 °C.

NOTE — Higher temperatures are permissible when special oils are used.

12.3 When electric immersion heaters are used for heating the lubricant, they should have a maximum energy dissipation of 25 kW/m^2 (2,5 W/cm^2). If overheating or ignition of the oil occurs, the oil shall be systematically replaced.

12.4 Oil-choking sometimes occurs in gear transmissions with high pitchline velocities. This has in some instances resulted in overheating of the oil and subsequent fires. Sufficient free volume inside the gear casing and adequate draining facilities must be provided.

13 Materials

13.1 In each compressor, all seals or gaskets shall be made from materials which are capable of withstanding any pressure and temperature likely to be encountered in service.

13.2 Materials used shall be compatible with the lubricants.

13.3 It is recommended that cast iron valves and fittings be avoided in pipework subjected to shocks or vibrations.

Section three : Compressor installation and air distribution system

Implementation of and compliance with the requirements of this section may be the responsibility of the compressor supplier, the plant contractor or the purchaser, depending on the scope of supply as defined in the relevant contracts.

14 General

For compressor package units and compressors together with their auxiliaries, as well as for components forming part of an air distribution system, clause 7 applies. If special requirements exist for noise emission or/and vibration magnitude, this shall be clearly stated in the contract.

14.1 All pipework, vessels and other items shall be designed in accordance with applicable national regulations or international codes.

14.2 Pipework or other parts with an external surface temperature in excess of 80 °C and which may be accidentally contacted by personnel in normal operation shall be guarded or insulated. Other high-temperature pipework should be clearly marked in accordance with ISO 3864 and ISO 508.

14.3 Check valve(s) to prevent rotation reversal shall be installed on the discharge side of compressors which do not have built-in non-return valves, when the design of the system would permit reverse flow of air through the compressor. Such compressors operating in parallel shall require check valves without exception.

14.4 An anti-surge device shall be utilized on turbo-compressors if system requirements indicate that the compressor may operate near the surge limit for extended periods. Such a device shall vent or recycle air from the compressor discharge in order to maintain a flow into the compressor which exceeds the surge flow. Recycled air shall be cooled to avoid excessive temperatures.

14.5 Vibration and shaft axial movement alarms and shutdowns may be utilized to prevent destructive failures.

14.6 For manual shut-down of electric motors, a stop button shall be provided at a readily accessible location to interrupt power to the motor.

14.7 Emergency stop buttons shall be red.

14.8 In some installations, the air is reheated after compression in order to increase its volume or to reduce the relative humidity. Direct fired reheaters shall not be used when the compressed air contains traces of oil.

14.9 When the prime mover is potentially capable of developing power significantly in excess of that required by the compressor, adequate protection shall be provided to avoid mechanical overload (for example an overcurrent trip device in the case of an electric motor).

14.10 When the prime mover is of a variable-speed type, the compressor shall be protected from unacceptably high speeds by either a speed governor or an overspeed trip device unless it can be shown that dangerous overspeeding is not a practical possibility.

14.11 The speed governor or overspeed trip device shall be set to operate at a level which will not allow the transient speed to exceed the maximum safe limit of the shaft under any sudden loss of load.

Reference is made to the following publications :

- ISO 2314;
- ISO 3046;
- ISO 3977;
- IEC Publication 34;
- IEC Publication 45.

14.12 Reciprocating compressors having oil-lubricated cylinders and a shaft input power greater than 200 kW should be fitted with an easily readable thermometer to indicate the delivery temperature at the last stage.

15 Compressor installation

15.1 If possible, each compressor should be placed in position where the ambient air is cool and clean. However, should it be necessary to place a compressor in hot or dusty surroundings, the inlet air should be drawn through a suction duct from an area as cool and free from dust as possible. Care shall be taken to minimize the entry of moisture with the inlet air.

15.2 The aspirated air shall be free from flammable fumes or vapours, such as those from paint solvents, which could lead to internal fires or explosions.

15.3 Air-cooled compressors shall be installed in such a way that an adequate flow of cooling air is available.

15.4 Sufficient space shall be allowed around each compressor unit for inspection, necessary attention, and dismantling when required.

15.5 To enable maintenance work and subsequent testing to be carried out safely, it shall be possible to start and stop any compressor independently of others.

15.6 Remotely controlled compressors shall have provisions for stopping at site.

15.7 Remotely controlled and automatically controlled compressors shall have a sign[1)] in the appropriate language of the user's country reading :

DANGER
THIS COMPRESSOR IS REMOTELY CONTROLLED
AND MAY START WITHOUT WARNING

As a further safeguard, persons switching on remotely controlled compressors shall take adequate precautions to ensure that no one is at, or working on, the compressors. To this end, a suitably worded notice shall be placed at the starting switch.

15.8 The compressor air intake shall be so arranged that loose clothing cannot be sucked in and cause personal injury.

15.9 No compressor shall be installed unless it is provided with an inlet air filter or screen designed and constructed in such a manner that all the air entering the compressor passes through the filter system.

15.10 A water manometer or other pressure-drop indicating device should be fitted to each inlet air filter of compressors having a shaft input power exceeding 100 kW, when the filter is of such a type that accumulation of dust or other objects could lead to a significant increase in pressure drop over the filter.

15.11 Whenever a metallic or concrete suction line, of such length that it cannot be properly cleaned, is used, screens or filters shall be installed before the compressor suction flange during initial start-up and running-in as protection against damage from foreign materials (for example welding beads, concrete dust). Such temporary screens or filters shall be removed when the intake pipework is clean.

16 Access platforms

16.1 When platforms, stairs and railings are required for the daily maintenance, they shall be positioned so that access is given to all areas where routine maintenance or operator inspection is necessary. Their positioning, however, shall not interfere with maintenance of any parts with respect to accessibility or lifting.

16.2 Elevated platforms and floors shall be of grid or plate construction. All open sides shall be guarded with safety rails, set at about 1 050 mm and 600 mm above the platform, and a toeboard about 100 mm high or in accordance with national regulations. Stairs or ladders of more than four steps shall have a safety rail on one side as a minimum.

16.3 Access to elevated platforms should, wherever possible, be by stairways with a slope not greater than 50°.

16.4 Stairs and platforms shall be protected from corrosion. Sheet metal floors shall incorporate a non-slip surface.

17 Pressure gauges

17.1 A suitable pressure gauge shall be fitted to :

a) each air receiver;

b) each final stage of piston-, screw- or vane-compressors with an effective working pressure exceeding 1 bar (100 kPa);

c) each stage of diaphragm compressors with an effective working pressure exceeding 3 bar (300 kPa);

d) each stage of compressors with a shaft input exceeding 20 kW;

e) the delivery side of each turbo-compressor casing.

NOTE — It is recommended that there should be a red field on the discharge pressure gauge scale to indicate the maximum allowable working pressure. A line should indicate the normal working pressure.

17.2 The operating pressure of the gauge shall be within the middle of the full scale reading.

17.3 The final stage air pressure gauge dial shall be graduated from zero to not less than one-and-a-half times (but not more than twice) the maximum allowable working pressure of the air receiver. The scale must be graduated in the same units as the "set-pressure" marking on the associated safety valve.

17.4 A pressure gauge shall be fitted on all compressors with an input power exceeding 75 kW to indicate the lubricant pressure in any force-feed system.

17.5 For effective working pressures above 10 bar (1 MPa) and for pressure gauges with a casing diameter exceeding 63 mm, safety type gauges having an unbreakable window and an unloading opening shall be used.

17.6 Where pressure gauges are subject to pulsations, precautions shall be taken to protect them from damage and to ensure adequate readability.

18 Pipework

18.1 Any blanking flanges or plates, as well as desiccant bags, shall be removed before connecting the pipes.

18.2 Delivery and cooler pipework should, where possible, be run so that gravity assists the flow of oil through the hot zone. The air velocity shall not normally fall below 8 m/s.

1) See ISO 3864.

18.3 Pipework and compressor accessories such as water jackets, coolers, pulsation dampers and air receivers shall be provided with drainage facilities at low points to prevent damage from freezing during idle periods.

18.4 The coolant outlet from cylinder jackets and compressor casings shall be open or so arranged that pressures exceeding design pressure cannot occur.

18.5 All pipework and auxiliaries integral to a unit shall be supported in such a way that the possibility of damage due to vibration, thermal expansion and own mass is minimized.

18.6 Pipework runs in a horizontal plane or which might otherwise be used by personnel for support should either be guarded or be robust enough, when supported, to carry a vertical load of 1,5 kN* without unacceptable deflection or damage.

18.7 The discharge pipe from the compressor to the after-cooler or air receiver should be free to expand under heat and should not be in contact with wood or any other flammable material. If such material is in close proximity to the pipework, steps shall be taken to preclude ignition.

18.8 In multiple-unit compressor systems, valves shall be provided for isolating each compressor. Check valves shall not be relied upon for isolating compressors.

18.9 Unguarded pipework (other than local gauge, instrument and control air and similar facilities) shall have a wall thickness great enough to resist damage by an accidental impact.

19 Design of pressure relief devices

19.1 Pressure relief devices for normal compressed air systems should preferably be spring-loaded valves. Bursting discs may be used in lieu of, or in conjunction with, relief valves provided that they are properly designed and installed.

19.2 Bursting discs may have application for very high capacity compressors where required relief capacity is in excess of that which can be handled by a reasonable number of relief valves. When bursting discs are used, the maximum allowable working pressure of the protected equipment shall be sufficiently above the intended operating pressure to prevent premature failure of the disc due to creep or fatigue.

19.3 When a bursting disc is used, it shall have a specified bursting pressure at a specified temperature and be stamped with identifying serial letters and numbers unless the size of the disc is insufficient for this purpose. In the latter case, the disc shall be contained in a sealed envelope prior to its installation. The envelope shall be clearly marked so as to identify the disc with its intended service.

19.4 The design of pressure relief devices shall allow for the possible effect of differential expansion and contraction and of gumming or deposits.

19.5 The materials used in the construction of pressure relief devices shall be suitable for the pressure, temperature and corrosion conditions as well as other relevant conditions, for example erosion. Non-metallic inserts of suitable material, properly secured and reinforced, may be used in the valve discs of relief valves. Fibrous or other materials which may become distorted under operating conditions shall not be used. The use of membrane valves shall be considered for corrosive conditions.

19.6 Relief valves shall be so designed that the moving parts are efficiently guided and have adequate clearance under all conditions of service. The spindle shall not be fitted with a packed gland (stuffing box).

19.7 Relief valves shall be so designed that breakage of any part or failure of any device will not obstruct free and full discharge through the valve.

19.8 Relief valves shall be so designed that they cannot inadvertently be reset beyond the set pressure marked thereon.

19.9 Relief valves for compressed air shall be provided with lifting gear, arranged so that the valves can be lifted positively off their seats when under working pressure. The lifting gear shall be such that it cannot lock or hold the valve off its seat when the external lifting force is released.

19.10 When the relief valve load is applied by a coil spring, the spring shall be so made that all coils still have a clear space of half the wire diameter or at least 2 mm at the necessary lift at full discharge.

19.11 Every relief valve shall incorporate permanent markings as follows :

a) manufacturer's identification;

b) direction of flow;

c) set pressure;

d) coefficient of discharge and related net flow area or flow capacity of valve.

20 Application of pressure relief devices

20.1 Every pressure vessel, compressor, and auxiliary used to contain air above atmospheric pressure shall be protected by a pressure-relieving device or devices as required to prevent the pressure in any element of the system from exceeding its maximum allowable working pressure by more than 10 %. Each

* 1,5 kN ≈ 150 kgf

compartment of a subdivided vessel shall be treated as a separate vessel and suitably connected to a pressure-relieving device.

20.2 Positive displacement compressors shall always be protected with pressure-relieving devices between compressor discharge and the first shut-off valve.

20.3 Pressure-relieving devices may not be required in systems using centrifugal or axial compressors where the maximum pressure that may occur in any element cannot exceed its maximum allowable working pressure by more than 10 %. To determine whether relief facilities may be omitted, the maximum pressure which may occur within the system should be evaluated for the various combinations of inlet pressure, inlet temperature, flow and speed, which could occur simultaneously.

20.4 In cases when sub-atmospheric pressures may occur and the vessel is incapable of withstanding such conditions, a vacuum break device shall be fitted.

20.5 The system shall be analysed to determine what circumstances, or combinations thereof, will result in the pressure on any compressor element exceeding its maximum allowable working pressure by more than 10 %. The flow at this pressure for the most severe conditions shall govern the capacity of relief facilities.

NOTES

1 The most frequent causes of excessive compressor pressure are :

a) blocked outlets or other restrictions to flow;

b) failure of automatic controls combined with low air consumption;

c) increase in inlet pressure;

d) excessive speed;

e) inlet air or intercooler temperatures lower than the design values of turbocompressors.

2 Excessive pressure on equipment resulting from various combinations of the causes above shall not be considered as controlling if such an occurrence is only possible in the event of two or more unrelated causes occurring simultaneously.

20.6 To eliminate leakage from the relief device, the set pressure at which it starts to open shall preferably be a minimum of 10 % or 1 bar (100 kPa), whichever is the greater, above the intended operating pressure at the valve inlet.

NOTES

1 To prevent unnecessary lifting of the relief valves, it is desirable to have a margin between the pressure at which the compressor delivers air and the lowest pressure at which any of the relief valves is set to lift.

2 Too frequent blowing of a relief valve endangers its proper function. However, when such conditions cannot be avoided, two relief valves with different settings, each of sufficient capacity, shall be used.

20.7 Vessels which are to operate completely filled with liquid shall be equipped with a relief valve capable of releasing any vapour generated, unless they are otherwise protected against over-pressure.

20.8 When a vessel is fitted with a heating coil or other element, malfunctioning of which might increase the normal pressure of the fluid in the vessel, the designed relieving capacity of the protective device shall be adequate to limit this increase to no more than 10 % of the maximum allowable working pressure, allowing for any vapour which may be generated.

20.9 Vessels connected together by a system of pipework of adequate flow area, which does not contain any valve that can isolate any vessel, may be considered as a system of vessels for the application of pressure relief devices.

21 Installation of pressure relief devices

Pressure relief devices shall be installed as close as practical to the system being protected. Under no circumstances shall it be possible to shut off a relief device with a valve unless duplicate or multiple relief devices are provided with isolation valves so interlocked that adequate relieving capacity is always ensured. Total blow-off capacity shall be sufficient to prevent the pressure from exceeding the maximum allowable working pressure by more than 10 % at maximum continuous air delivery into the system.

21.1 For most compressor installations, excessive pressure protection for the compressor and its auxiliaries requires a pressure-relieving device only on the discharge of each compressor stage. Such an arrangement will usually suffice, provided that the system pressure gradient under relieving conditions is such that the pressure on the weakest element will not exceed its maximum allowable working pressure by more than 10 %.

21.2 The inlet line to a relief device, including all valves and fittings, shall have an effective flow area at least equal to that of the inlet to the relief device.

21.3 The maximum pressure drop through inlet lines to pressure relief devices shall not exceed 3 % of the set pressure under conditions of maximum flow.

21.4 Where feasible, direct relief to the ambient atmosphere is recommended. Atmospheric discharge or discharge pipes shall terminate at a location which will not create a hazard to personnel.

21.5 Any discharge pipe used shall be of such size that the pressure that may exist or develop therein will not reduce the relieving capacity.

21.6 The size of a discharge line serving two or more pressure-relieving devices which may reasonably be expected to discharge simultaneously shall be based on the sum of their outlet areas with due allowance for pressure drop in the downstream sections.

21.7 Discharge lines, together with their supports and anchorages, shall be so designed and constructed that reactions are resisted without excessive forces being transmitted to the pressure-relieving devices.

21.8 Relief valve discharge lines shall be so designed and constructed as to preclude the collection of liquid at any point in the system.

22 Noise

It is often good practice to have a separate compressor room in order to screen off the compressor noise from the general working area. Depending on the number of compressors and their noise emission, the noise in the compressor room can be considerable. Intake noise can, however, be reduced to a satisfactory level by the use of suction silencers. (See annex A.)

Section four : Compressor operation and maintenance

Implementation of and compliance with the requirements of this section is the responsibility of the owner or user of the plant of which the compressed air system forms part.

23 Operation

23.1 A foreman or other adequately qualified person should be designated as supervisor for the compressor and be responsible for its proper operation and maintenance.

23.2 The supervisor shall ensure that the operators are adequately instructed about all safety measures necessary to prevent accidents or personal injuries.

23.3 Compressors should only be operated by appointed and properly instructed operators.

23.4 The start-up, shut-down and emergency procedures for all operations involving compressors shall be periodically reviewed with the operators.

23.5 A clear operating instruction shall be provided in the form of a plate or a book.

23.6 Only oils of a grade and type recommended or agreed to by the manufacturer shall be used. (See annex D.)

23.7 Overcooling of compressor cylinders shall be avoided as this can lead to internal corrosion. Rust acts as a catalyst for building up oil-carbon deposits on the pressure side. The use of a thermostatic water valve is recommended for water-cooled compressors.

23.8 Records shall be kept of oil consumption and all major inspections, examinations, repairs, pressure tests, etc., carried out on all compressors with a shaft input power exceeding 100 kW.

NOTE — Lack of oil is a common cause of compressor breakdowns. A compressor failure is often preceeded by an increase in oil consumption. A regular follow-up of the oil consumption will therefore help the operator to spot the trouble in time.

23.9 In the case of "oil-free" compressors, it should be checked that the oil consumption is not abnormal. This will indicate if excessive quantities of oil are leaking into the air stream and creating a potentially hazardous situation.

23.10 Inlet pipework to compressors and prime movers, condensate traps and cylinders shall be drained prior to start-up.

23.11 On starting-up the compressor initially, and after any alteration to the electrical connection(s) or switch-gear, the direction of rotation of all electric motors shall be checked to ensure that they rotate in the correct direction.

23.12 When oil-wetted or oil-bath type filters are used, the oil should be chosen so that the fire risk is not increased. It is important that only oils recommended or agreed for this purpose by the compressor and air filter manufacturer be used.

23.13 Care shall be exercised to avoid damage to pressure relief devices. Care shall also be exercised to avoid plugging by paint or dirt accumulation that could interfere with the functioning of the device.

23.14 Operators and maintenance personnel should use ear protectors when staying in compressor rooms with a sound pressure level exceeding the value set by local regulations.

23.15 The cooling system of oil-flooded compressors shall be kept clean, inside and outside, to ensure that overheating of the circulating oil or the separating filter does not occur.

NOTES

1 When the compressor operates in a dusty atmosphere, the cooler shall be cleaned externally daily or weekly, as required.

2 When the compressor works at an elevated ambient temperature, care shall be taken to ensure that the internal oil circulation in the cooler is not restricted by sludge formation.

3 The over-temperature shut-down device shall be checked regularly.

4 The oil shall be replaced at regular intervals as specified by the manufacturer. It is recommended that these intervals be reduced when the compressor operates at an elevated ambient temperature.

23.16 In large reciprocating compressors, with a power exceeding 200 kW, the user should consider measuring the temperature of the cooling water, the delivered air and the crankcase oil.

24 Maintenance

24.1 The supervisor (23.1) shall check annually, at least, that all instructions regarding compressor operation and maintenance are properly followed and that the compressor with all accessories and safety devices are in good working order.

24.2 Maintenance work shall be carried out only by adequately trained personnel.

24.3 All maintenance work other than routine attention to filters designed for cleaning in service shall be undertaken only when the compressor is stopped.

24.4 Before dismantling any pressurized component, the compressor shall be effectively isolated from all sources of pressure and completely vented to the atmosphere.

24.5 The compressor unit shall be kept as clean and free from oil and dust deposits as possible.

24.6 When maintenance is carried out on electrically driven compressors, the electrical switch shall be locked in "open" position, or other positive means of current interruption shall be employed, for example taking out the fuses.

24.7 All safety devices should be maintained to ensure that they always function properly. They shall not be put out of operation and shall be replaced only by devices giving at least the same security. Pressure and temperature gauges shall be checked regularly with regard to their accuracy. They shall be replaced whenever they are outside accepted tolerances.

24.8 A check of the safety devices on compressor equipment shall be included as part of the regularly scheduled maintenance.

24.9 All relief valves shall be tested according to advice from the manufacturer and at regular intervals to determine whether they are in good operation condition.

24.10 When compressors are being repaired, steps shall be taken to prevent inadvertent starting, and the control power shall be disconnected. In addition, a warning sign bearing a legend (in the appropriate language of the user's country) such as :

WORK IN PROGRESS —
DO NOT START

shall be attached to the starting equipment.

24.11 Prior to stripping or undertaking major overhaul on a reciprocating compressor, all movable parts with a mass exceeding 15 kg shall be prevented from roll-over or movement. After such work has been completed, the compressor shall be barred over at least one revolution to ensure that there are no mechanical interferences within the compressor or its prime mover.

24.12 Under no circumstances shall flammable liquids be used to clean valves, filters, the air passages of coolers, air chests, air pipes or any other part exposed to air flow during normal operation. If chlorinated hydrocarbon non-flammable liquids are used for cleaning, appropriate safety precautions shall be taken against any toxic vapours liberated during such usage. Carbon tetrachloride shall not be used.

24.13 In the case of oil-lubricated compressors, the delivery ports and all the pipework, vessels and fittings between the delivery port and that point in the system at which the air temperature can be confidently expected to be below 80 °C, shall be regularly inspected. Any carbonaceous deposit shall be efficiently removed. The frequency of these inspections and cleaning should be such that at no time will the layer of deposit exceed the thickness shown in table 1.

Table 1 — Maximum tolerable thickness of coke layer

Effective operating pressure bar	**Maximum tolerable thickness of coke layer** mm
⩽ 10	3
> 10 ⩽ 30	2
> 30 ⩽ 50	1

24.14 Whenever there is any reason to suspect that a bearing or other internal part may be over-heating, after stopping the machine no crankcase door or other inspection cover should be opened until sufficient cooling time has elapsed (at least 15 min) for the temperature of the overheated part to have fallen below the minimum spontaneous ignition temperature (for air/oil vapour or mist mixtures, approximately 275 °C) to avoid the risk of a crankcase explosion. (See annex E.)

24.15 An open flame must never be used for inspecting the interior of a compressor or pressure vessel.

24.16 If the operating conditions of a relief valve are changed so as to require setting for a pressure outside the pressure range recommended by the manufacturer for the particular spring, the spring shall be changed and the valve re-adjusted accordingly and re-marked.

24.17 Bursting discs should be inspected regularly for any sign of fatigue cracking, corrosion or other deterioration.

24.18 To prevent an increase in air delivery temperature, heat transfer surfaces (for example intercoolers and water jackets) should be regularly inspected and cleaned as necessary. For every plant, the time interval between cleaning operations should be made known.

Annex A

Exposure to noise

(This annex is an integral part of the standard.)

A.1 Noise, even at reasonable levels, can cause irritation and disturbance which over a long period of time may cause injuries to the human nervous system and can take forms such as lack of sleep, irritation, etc. For more than 8 h exposure per day, noise at sound pressure levels exceeding 90 dB(A) is considered to cause hearing damage. For more details relating to hearing damage, see ISO 1996, ISO 1999 and national regulations on the subject.

A.2 It is often good practice to have a separate compressor room in order to screen off the compressor noise from the general working area. Depending on the number of compressors and their noise emission, the noise in the compressor room can be considerable. Intake noise can, however, be reduced to a satisfactory level by the use of suction silencers.

The acoustic environment in the compressor room can be improved and the general noise level reduced by introducing absorbing materials on walls and ceilings and putting up baffles for noise reduction and to prevent formation of standing waves. Care shall be taken that noise transmitted through walls and windows does not create too high noise levels in the surrounding environment.

It is recommended to follow the advice of the ISO publications as regards the sound pressure level in all places where personnel may be exposed for a certain time.

A.3 Measurement of noise from stationary compressors shall be carried out in accordance with ISO 2151 or ISO 3989.

Annex B

Design principles for the pressure system of oil-lubricated compressors

(This annex is an integral part of the standard.)

B.1 It is generally accepted that oil fires in compressed air systems are nearly always due to the ignition of deposits of oil coke. In a compressed air system, high temperature and high partial pressure of the oxygen lead to oxidation of the oil. When an oil is oxidized, it generally becomes more viscous, and sludge-like products are formed which in their final stage convert into oil coke. If sufficiently thick deposits are built up, this coke may self-ignite and cause a fire in the pressure system. This fire can in rare cases initiate an explosion (see annex C).

B.2 Practice has shown that the design of the hot zone of the air discharge system of the compressor has a decisive influence on the formation of coke deposits, since it is mainly the design of the system which determines the time needed for an oil molecule to pass through the hot zone.

B.3 Some of the lubricating oil leaving the delivery flange or pressure valve of the compressor is "atomized" in droplets of such a small mass that they will rapidly be transferred by the air directly to the cold zone of the pressure system without touching the hot walls. This part of the oil passes the hot pressure zone so quickly that practically no oxidation of the oil occurs.

B.4 Owing to their greater mass and inertia, the larger oil droplets cannot be transported by the air flow and are therefore deposited on the walls of the hot system, where the oil may be exposed to oxidation for a sufficient length of time for decomposition to begin.

B.5 There are two principal ways of ensuring rapid transport to the cold zone of the oil which has settled on the walls. The first is by partial vaporization of the oil and the second is to design the interior of the pressure system in such a way that the sweeping effect of the passing air, together with gravitational forces, will assist the oil in creeping along the walls towards the cold zone. As a rule, both of these conditions must be positively exploited for a hot compressed air system to remain clean. (See further annex D, clause D.4.)

B.6 Systematic investigations have shown that the discharge system of a reciprocating, oil-lubricated compressor will stay clean and free from deposits if the air velocity in every part of the piping system and its elements is above 8 m/s provided that the proper oil viscosity and type is chosen according to annex D. At this air velocity, any oil deposited on a vertical wall will creep upwards. Of course, whenever possible the air flow should be directed downwards so that gravitational forces will assist the oil creeping.

B.7 As a consequence of the preceding clause, the best aftercooler design will have the compressed air inside the tubes and the coolant outside. Such a design with narrow tubes will also give a good pressure pulsation damping. The length of the pipework connecting the compressor and the aftercooler must be designed to obtain the maximum damping of the pressure pulsations.

To best utilize this pulsation damping, each compressor should have its own aftercooler and preferably also air receiver. Such a layout is also favourable from service and maintenance viewpoints.