International Standard ISO 5388

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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

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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

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Contents

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 shut-downs 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 shut-down 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 shut-downs 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.