Indian Standard (Reaffirmed 2001)

CODE OF PRACTICE FOR COMPRESSORS SAFETY

Compressors Sectional Committee, EDC 62; Panel to Technical Supply Conditions for Various Air Compressors, EDC 62/P-2 [Ref : Doc : EDC 62 (4035)]

1. Scope — Lay down requirements for safe design and construction of stationary and skid-mounted air comperssors for general use.

1.1 This standard does not cover the prime movers.

2. Definitions

2.1 *Maximum Allowable Working Pressure* — The maximum operating air pressure which the manufacturer prescribes for any service condition specified for the compressor or any part which the term is referred, such as an individual stage of casing.

2.2 *Relief Valve or Safety Valve Set Pressure* — The pressure on the inlet side of a relief valve or safety valve when opening compresses.

2.3 *Maximum Allowable Working Temperature* — The maximum compressed air temperature which the manufacturer prescribes at any service condition specified for the compressor or any part to which the term is referred.

2.4 *Maximum Expected Outlet Temperature* — The highest predicted outlet air temperature resulting from any specified service condition including part load operation.

2.5 *Maximum Allowable Compressor Speed* — The highest rotational frequency at which the manufacturer's design will permit operation, assuming that overspeed and governor mechanisms are installed and operating.

2.6 *Trip Speed* — The rotational frequency at which the primemover is automatically tripped out.

2.7 *Surge Limit* — The limiting flow below which stable operation of a turbocompressor is not possible.

3. Compressor Categories — Air compressors are grouped into the following three categories from 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 singleacting trunk type of reciprocating compressor without a crosshead.

Oil-lubricated compressors are grouped into any of the four classes below:

i) 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) often for intermittent services.

ii) Air-cooled reciprocating types with a power input about 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.

iii) 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.

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iv) 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 compessors* 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 the compression.

4. Potential Hazards

4.1 *Improper Lubrication*

4.1.1 The more common causes of improper lubrication are:

a) use of improper lubricant,

b) lack of oil,

c) poor maintenance leading to bearing wear with increased clearance and too low oil pressure,

d) insufficient or excessive cooling, and

e) overlubrication.

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

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

4.3 *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, and

f) Excessive vibrations or external forces.

4.4 *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; and

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

4.5 *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 may take such forms as lack of sleep, and irritation. 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, that is 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* Appendix A).

4.6 *Fires and Explosions in the Pressure System*

4.6.1 *Oil-lubricated compressors* — It is generally accepted that the occurrences of fires in oil-lubricated compressor system is dependent on the build-up of oil degradation (oilcoke) deposits. When the pressure system is designed according to the advice given in Appendix B and the lubricating oil is chosen according to the advice in Appendix D, both the compressor and the pressure system shall 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* Appendix C).

Four factors that effect coke formation are listed below:

a) *Rate of oil feed* — Excessive oil feed promotes deposit formation.

b) *Air filteration* — 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 may 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 may similarly raise the temperature and cause dangerous conditions.

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

d) *Catalysts present*, for example, iron oxides.

4.6.2 *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 may, however, accelerate the oil oxidation with consequent fire risk.

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

a) Design;

b) Choice of oil; and

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

i) keeping the oil consumption low,

ii) regular oil changes, and

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

4.7 *Crankcase Explosions* — Explosions shall and have occured in the crankcases or gear cases of compressors (*see* Appendix D).

4.8 *Incorrect Installation, Operation or Maintenance* — Besides the types of potential hazard described above, hazards also exist if the installation, operation and maintenance work shall not be carried out in the correct way (*see* Appendix B).

5. General Requirements — Compressors shall be des'gned 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.

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

a) Name of manufacturer,

b) Model designation and serial number,

c) maximum allowable working pressure, and

d) maximum allowable continuous shaft speed.

Note — On compressors above 20 kW, information about capacity, shaft input and coolant flow, etc, shall be included.

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

5.3 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.

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

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

5.6 When considered necessary for large compressors, crankcase explosion-relief devices shall be fitted (*see* Appendix D).

6. Guards

6.1 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 centres and any other part which may require attention.

6.2 The guards shall be easy to remove and to reinstall, and shall have sufficient rigidity to withstand deflection and prevent rubbing as a result of bodily contact.

6.3 Belt and chain-drive guards for outdoor installations shall be weather proof.

6.4 Pipework or other hot parts shall be adequately guarded or insulated.

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

7. Pipework and Pressure Vessels

7.1 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.

7.2 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.

7.3 Delivery pipework, up to the after cooler or receiver, for oil-lubricated compressor shall, 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, shall be similarly arranged (*see* Appendix B).

7.4 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.

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

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*1·5 kN = 150 kg.

7.6 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 the relevant applicable codes.

7.7 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.

8. Vibrations and Pressure Pulsations

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

8.2 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* **B-7** of Appendix B). When this is not possible, properly designed pulsation dampers with draining devices shall 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 shall be designed to prevent the build-up of oil degradation deposits (*see also* **7.4**).

9. Electrical Equipment

9.1 All electrical equipment shall comply with the relevant statutory regulations and directives.

10. Overheating

10.1 The design of signle-stage, oil-flooded compressors shall be such that the maximum tepərature 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 shall be permissible when special oil are used.

10.2 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 shall be permissible when special oils are used.

10.3 When electric immersion heaters are used for heating the lubricant, they shall have a maximum energy dissipation of 25 kW/m² (2·5 W/cm²). If overheating or ignition of the oil occurs, the oil shall be systematically replaced.

10.4 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 shall be provided.

11. Materials

11.1 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.

11.2 Materials used shall be competible with the lubricants.

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

APPENDIX A

(*Clause* 4.5)

EXPOSURE TO NOISE

A-1. Noise, even at reasonable levels, can cause irritatian and disturbances which over a long period of time may cause injuries to the human nervous system which may take such forms as lack of sleep, and irritation. For more than 8 hour exposure per day, noise at sound pressure levels exceeding 90 dB (A) is considered to cause hearing damage.

A-2. It is often a 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 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 IS : 8152 - 1976 'Method of measurement of speed fluctuation in sound recording and reproducing equipment' 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 IS : 11446 - 1985 'Measurement of air borne noise emitted by compressor units intended for outdoor use'.

APPENDIX B

(*Clauses* 4.6.1, 4.8, 7.3 *and* 8.2)

DESIGN PRINCIPLES FOR THE PRESSURE SYSTEM OF OIL-LUBRICATED COMPRESSORS

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* Appendix 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 be rapidly 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.

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. 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 consequence of the preceeding 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 after-cooler 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.

APPENDIX C

(*Clauses* 4.6.1 *and* B-1)

THE MECHANISM OF OIL COKE IGNITION AND THE ORIGIN OF OIL EXPLOSIONS

C-1. Oil exposed to air is subject to oxidation. The rate of oxidation increases with temperature, the partial pressure of oxygen and the presence of small particles of iron or iron oxides that act as catalysts. Oxidation increases the viscosity of the oil and may produce solid deposits (oil coke) in the hot discharge system of a compressor if the residence time of the oil in the high temperature zone is sufficient. These solid deposits continue to oxidize, and as the oxidation reaction is exothermic, evolution of heat occurs. Consequently, the necessary conditions for spontaneous ignition exist.

C-2. In practice, the heat generated by oxidation is removed both by the cooling effect of the air stream over the layer and by the heat being conducted through the layer to the metal on which the layer is resting. When this heat balance is changed so that less heat is removed, the coke temperature rises and can, under special conditions, reach a temperature at which the coke ignite spontaneously, generating enough heat to weaken or melt the metal in the walls of the pressure system. Although no real explosion takes place, the sudden breakage of the wall may be mistaken for an explosion.

C-3. Studies have shown that in order for an oil fire to occur there must be a certain thickness of the coke layer [about 25 mm at 7 bar (700 kPa) effective pressure), a temperature around + 150°C and a degrade of porosity often called dryness] to limit heat transfer through the layer. Under these conditions, a fire can start when a reduction in the flow of compressed air over the coke layer unduly reduces the rate of heat dissipation. Such conditions can occur at meal breaks, shift changes or when the compressor is unloading. Alternatively, a fire can start without any change in the air flow conditions if the deposit layer builds up to such a thickness that heat transfer can no longer maintain the interior of the layer below the spontaneous ignition temperature.

C-4. The critical thickness of the coke layer, in terms of fire risk, can vary with each individual compressor depending on air pressure and temperature, foreign particles in the deposit, and actual location of the deposit and running conditions of the compressor. Consequently, the 'safe' thickness of the coke layer will vary for different installations.

C-5. Occasionally, but in practice very seldom, an oil fire in a pressure system can initiate an oil vapour or oil mist explosion. For this to occur a mixture of air and vaporized oil, or oil mist, must be within the explosive limits, and this mixture must further come into contact with a source of ignition.

C-6. Fortunately, the range of air-to-oil ratio necessary for an explosion to occur is limited. Either too much oxygen or too much flammable material inhibits the explosion. This might be the main reason why explosions are rare. Nevertheless, the risk must always be recognized.

C-7. Only limited information is available about the precise cause of an initial compressor oil explosion but the following explanation appears to be the most likely: A fire is initiated when the compressor is unloaded and no flow of air passes the burning zone of the coke bed. After a while, the oxygen in the air is consumed to an extent where incomplete combustion occurs and carbon monoxide together with decomposed and vaporized oil and oil mist from the coke bed form a potentially flammable mixture. The flammable gases and mists are transferred downstream to a cooler part of the system, where they mix with unburnt air to produce an explosive mixture. Under these conditions, an explosion can occur when the compressor starts to deliver air again and the sudden increase in air flow loosens a particle of burning coke from the layer and transfers it to the explosive zone.

Note — It must be taken into consideration that even if no explosion occurs, the compressed air will be contaminated by noxius gases from the incomplete combustion.

C-8. This initial explosion can be followed by violent detonations according to the following:

The inside of delivery lines in systems connected to lubricated compressors quickly becomes coated with a thin film of oil. A sufficiently strong shock wave from the initial explosion passing down the delivery line can then strip the oil film from the pipe and form an initimate mixture of oil-mist and air. If a flammable mixture is produced and the temperature at the shock wave front reaches the spontaneous ignition limit, a second explosion occurs, which accelerates the shock wave to the speed of detonation (supersonic) when brittle fracture of the pipe wall takes place. The process may repeat itself at intervals along the compressed air line, frequently giving breakages at restrictions. Explosions of this type are disastrous for the pressure system and highly dangerous for people in the vicinity.

C-9. If the formation of coke is minimized by strictly following the rules set forth in this standard, the risk of oil fires or explosion can be minimized.

APPENDIX D

(*Clauses* 4.6.1, 4.7 *and* 5.6)

PRECAUTIONS AGAINST CRANKCASE EXPLOSIONS

D-1. Cranckcase explosions result from ignition of a combustible mixture of lubricating oil and air. Combustion pressure which develops following ignition within the confined space frequently exceeds the strength of the crankcase and destructive failure occurs. The ignition source is generally an over-heated part.

D-2. Prevention of crankcase explosions requires either elimination of the ignition source or prevention of flammable atmospheres.

D-3. Elimination of the ignition source is not feasible as some form of mechanical seizure is always possible. Technical difficulties inherent in measuring temperatures of all moving parts preclude and attempt to prevent potential ignition sources through early detection of overheated parts.

D-4. However, proper maintenance and operation are recommended as a means of minimizing mechanical failure. If a machine is shut down owing to mechanical trouble which might involve an overheated part, inspection doors should *not* be opened immediately. This is to allow for a period of cooling of the heated part before air is permitted to enter the crankcase, and thereby minimize the possibility of an explosion.

D-5. Approaches sometimes recommended to prevent flammable mixture include forced ventilation of the crankcase or operating the crankcase below atmospheric pressure. When such methods are employed, it should be recognized that under certain conditions crankcase ventilation may dilute a rich mixture into the flammable or explosive range.

D-6. As an alternative to ventilation, the crankcase may be continuously purged with inert gas. The volume of gas required to effectively purge a large machine will usually make this approach impractical.

D-7. Because it is difficult to eliminate the cause of explosions, relief devices are sometimes installed to prevent pressures exceeding the strength of the crankcase. Relief devices may range from spring-loaded coverplates to specially designed valves fitted with flame traps.

D-8. Bursting discs are forbidden since the inrush of air to fill the partial vacuum created by an explosion may lead to a second explosion, sometimes more violent than the first.

D-9. As to sizing relief devices, investigations, including fullscale tests, have shown that it would not be practical to provide sufficient relief area to maintain a safe pressure level when conditions are favourable to an explosion developing maximum intensity. However, experience has shown that many typical crankcase explosion can be safely relieved with conventional crankcase explosion relief devices, if the total throat area of the devices satisfies the requirements:

$$A \geqslant 0.07\ V$$

where

A is the total throat area, m^2; and

V is the crankcase volume, in m^3.

EXPLANATORY NOTE

This standard specifies requirements to help minimize compressor accidents and defines general safety practice for the field. The standard is based on the requirements that the compressor components be designed in accordance with recognized good practice and applicable standards. Following types of compressors 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) Compressor specifically supplying air for breathing, diving or surgery;
e) Compressors used for air brake systems; and
f) Ejectors.

The selection, installation, operation and maintenance are already covered in IS : 6206 - 1971 'Guide for selection, installation and maintenance of air compressor plants with operating pressure up to 10 bars'.

This standard is prepared on the basis of ISO 5388-1981 Stationary air compressors—Safety rules and code of practice.

Printed at Swatantra Bharat Press, Delhi, India