



RECIPROCATING COMPRESSORS FOR OXYGEN SERVICE

Doc 10/17

Revision of Doc 10/09

EUROPEAN INDUSTRIAL GASES ASSOCIATION AISBL



AVENUE DES ARTS 3-5 • B – 1210 BRUSSELS

Tel: +32 2 217 70 98 • Fax: +32 2 219 85 14

E-mail: info@eiga.eu • Internet: www.eiga.eu





RECIPROCATING COMPRESSORS FOR OXYGEN SERVICE

As part of a programme of harmonization of industry standards, the European Industrial Gases Association (EIGA) has issued the publication "*Reciprocating Compressors for Oxygen Service*". This has been jointly produced by members of the International Harmonization Council.

This publication is intended as an international harmonized publication for the worldwide use and application by all members of Asia Industrial Gases Association (AIGA), Compressed Gas Association (CGA), EIGA, and Japan Industrial and Medical Gases Association (JIMGA). Regional editions have the same technical content as the EIGA edition, however, there are editorial changes primarily in formatting, units used and spelling. Also, any references to regional regulatory requirements are those that apply to European requirements.

Disclaimer

All technical publications of EIGA or under EIGA's name, including Codes of practice, Safety procedures and any other technical information contained in such publications were obtained from sources believed to be reliable and are based on technical information and experience currently available from members of EIGA and others at the date of their issuance.

While EIGA recommends reference to or use of its publications by its members, such reference to or use of EIGA's publications by its members or third parties are purely voluntary and not binding.

Therefore, EIGA or its members make no guarantee of the results and assume no liability or responsibility in connection with the reference to or use of information or suggestions contained in EIGA's publications.

EIGA has no control whatsoever as regards, performance or non performance, misinterpretation, proper or improper use of any information or suggestions contained in EIGA's publications by any person or entity (including EIGA members) and EIGA expressly disclaims any liability in connection thereto.

EIGA's publications are subject to periodic review and users are cautioned to obtain the latest edition.

Table of Contents

1	Introduction	1
2	Scope	1
2.1	Design of the compressor system	1
2.2	Cleaning, preservation, and inspection	1
2.3	Erection, testing, and commissioning	1
2.4	Operation	2
2.5	Maintenance	2
2.6	Other specifications	2
2.7	Application of the publication	2
3	Definitions	3
3.1	Publication terminology	3
3.2	Technical definitions	3
4	Compressor design	4
4.1	Design criteria	4
4.2	General materials	4
4.3	Compressor parts	5
4.4	Compressor dynamic analysis, verification tests, and data to be provided.....	7
4.5	Grounding	7
5	Piping including filters	7
5.1	Pulsation and damping	7
5.2	Process pipework	8
5.3	Extent.....	8
5.4	Vents to atmosphere.....	8
5.5	Special piping	8
5.6	Bellows	9
5.7	Acoustic and thermal insulation	9
5.8	Silencers	9
5.9	Main suction filter	9
6	Valves	10
6.1	Isolation system	10
6.2	Safety relief valves.....	10
7	Coolers.....	11
7.1	Scope of supply	11
7.2	Types of cooler	11
7.3	Material selections that are common to both types of cooler—oxygen side only.....	11
7.4	Establishment and maintenance of oxygen cleanliness—gas in shell type or gas internally finned tubes	11
7.5	Establishment and maintenance of oxygen cleanliness—gas in bare tube type	12
7.6	Vents and drains.....	12
7.7	Closed circuit cooling system	12
8	Lubrication oil system	12
8.1	General	12
8.2	Pumps.....	12
8.3	Oil heater	12
8.4	Crankcase vents	12
9	Controls and instrumentation	13

9.1	General	13
9.2	Recycle system.....	14
9.3	High oxygen temperature protection	14
9.4	Vibration.....	14
9.5	Compressor isolation and venting	14
9.6	Manual isolation and vent valves.....	14
9.7	Non return valve	14
9.8	Automatic isolation valves	14
9.9	Automatic vent valves.....	14
10	Oxygen cleaning.....	15
10.1	Introduction	15
10.2	Extent of oxygen cleaning.....	15
10.3	Responsibility	15
10.4	Inspection and cleanliness standards.....	16
10.5	Preservation of oxygen cleanliness during shipping and storage.....	16
11	Compressor installation.....	17
11.1	Hazard area	17
11.2	Enclosure of the hazard area by a safety barrier.....	17
11.3	Access to the hazard area	17
11.4	Equipment location	18
11.5	Safety barrier.....	19
11.6	Safety barrier miscellaneous design features	22
11.7	Location.....	23
11.8	Fire protection and precautions	23
11.9	Protection of personnel.....	23
12	Erection, testing, and commissioning.....	24
12.1	Erection	24
12.2	Testing	24
12.3	Commissioning on oxygen.....	25
13	Operation.....	26
13.1	General	26
13.2	Combustible matter	26
13.3	Machine rubs.....	26
13.4	Machine vibrations	26
13.5	Leaking cooler tubes	26
13.6	Gas leakage hazard.....	26
13.7	Oil leakage hazard	26
13.8	Qualifications and training for operating personnel	27
13.9	Hazard area	27
13.10	Record of machine operation.....	27
13.11	Monitoring critical operating parameters.....	27
13.12	Trip override	27
13.13	Interlock systems	28
13.14	Start-up procedures	28
13.15	Advisory requirements	28
13.16	Additional requirements	28
14	Maintenance.....	28
14.1	General	28
14.2	Purging during maintenance	29
14.3	Functional test.....	29
14.4	Cleanliness during maintenance.....	29

14.5	Compressor checks after shutdowns.....	29
14.6	Compressor planned maintenance shutdowns.....	29
14.7	Spare parts.....	30
14.8	Instruction manual.....	30
15	References.....	31

Figures

Figure 1	Example of reciprocating oxygen compressor system flow diagram.....	10
----------	---	----

Tables

Table 1	Minimum instrumentation of oxygen compressors	13
Table 2	Failure modes and operating speeds of system valves.....	15

Amendments from 10/09

Section	Change
	Editorial to align style with IHC associations
	Re-alignment to a more consistent format.

Note: Technical changes from the previous edition are underlined

1 Introduction

Oxygen compression represents a special risk in that the compressor can burn violently. This publication defines design and operating parameters for reciprocating oxygen compressors. Compliance with this publication will reduce the likelihood of, and the hazards arising from, a fire in a compressor to be equal or lower than those commonly accepted in the air separation industry. There is less demanding technology in a reciprocating compressor than in a centrifugal one. Potential rubbing velocities, gas velocities and inventories are all lower. For these reasons more flexibility in design is allowed in a reciprocating compressor than in a centrifugal compressor as defined in the EIGA Doc 27, *Centrifugal Compressors for Oxygen Service* [1].¹

This publication has made a significant contribution to the safe compression of oxygen primarily because the suppliers and users have fully and frankly shared their philosophies and experiences. It is recognised by the Working Group members that the feedback of operating experiences makes a powerful contribution to safe operation and design. This publication requires that all those who build and operate reciprocating oxygen compressors that have been specified to comply with this publication should contribute towards it by fully reporting the circumstances surrounding oxygen fires.

For the purpose of safe operation of the compressor and its auxiliaries, the user and the supplier shall establish full agreement on the possible and expected modes of compressor operation (for example, specified operating points, normal operating range, start-up and shut-down).

2 Scope

This publication applies to conventional ringed and labyrinth compressors in any geometric configuration having a crosshead and distance piece. Most operating experience exists in compressors greater than 500 Nm³/hr at pressures up to 8.5 MPa with oxygen purity of 90% or greater and with a maximum 10 ppm water (volume basis)². Additionally, experience suggests that at a discharge pressure below less than 0.2 MPa the likelihood of ignition is low and the consequence of ignition slight since the trapped inventory is small and fire is difficult to sustain at low pressures. This working group believes the publication can be applied to 10 MPa without further precaution.

The safe and reliable compression of oxygen using reciprocating compressors can only be achieved by the successful combination of many factors. This publication identifies and addresses the following factors:

2.1 Design of the compressor system

- robust and well proven compressor design;
- safe materials in critical areas;
- comprehensive instrumentation; and
- safety shutdown system.

2.2 Cleaning, preservation, and inspection

- correct and properly enforced procedures and well trained personnel.

2.3 Erection, testing, and commissioning

- trained erection personnel; and

¹ References are shown by bracketed numbers and are listed in order of appearance in the reference section.

² kPa and MPa shall indicate gauge pressure unless otherwise noted as (kPa, abs and MPa, abs) for absolute pressure or (kPa, differential or MPa, differential) for differential pressure.

- comprehensive testing programme to verify the design.

2.4 Operation

- trained personnel; and
- correct procedures.

2.5 Maintenance

- condition monitoring;
- planned preventive maintenance;
- trained personnel;
- personnel protection;
- identification of the hazard;
- safety barriers;
- location of the compressor; and
- emergency procedures

2.6 Other specifications

The compressor supplied shall be in conformity with all applicable rules, codes and regulations of the country of use.

2.7 Application of the publication

2.7.1 Oxygen purity

This publication applies to reciprocating oxygen compressors operating on dry gases containing greater than or equal to 90% oxygen, and less than 10 ppm water (volume basis).

2.7.2 Oxygen-enriched gases

Experience in compressing oxygen-enriched gases containing less than 90% oxygen is very limited at this time. In the absence of such experience or established data, the working group members recommend that this publication shall be considered for reciprocating compressors operating on oxygen-enriched gases and the degree of implementation shall be agreed between supplier and user.

2.7.3 Moisture

Experience in compressing oxygen-containing moisture is limited. Specific precautions need to be taken particularly with reference to the materials of construction. Additional requirements shall be agreed between supplier and user.

2.7.4 Discharge pressure

The requirements in this publication are based on the experience gained in the compression of oxygen up to 10 MPa.

2.7.5 Suction pressure

Traditional experience is with compressor suction pressure of less than 0.2 MPa. This is the application that has been considered when putting forward the best design of ancillary systems. However, if the compressor has an elevated suction pressure it is possible that some ancillary systems may need modification and appropriate risk assessment shall be made.

2.7.6 Driver

The majority of experience has been with the use of constant speed electric motor drivers. This publication has been written giving the best solution for this type of driver. However, where another type of driver (for example, variable speed electric motor requires a different solution) this has been identified in the publication (resonance, vibrations, and lubrication issues).

3 Definitions

For the purpose of this publication, the following definitions apply.

3.1 Publication terminology

3.1.1 Shall

Indicates that the procedure is mandatory. It is used wherever the criterion for conformance to specific recommendations allows no deviation.

3.1.2 Should

Indicates that a procedure is recommended.

3.1.3 May

Indicates that the procedure is optional.

3.1.4 Will

Is used only to indicate the future, not a degree of requirement.

3.1.5 Can

Indicates a possibility or ability.

3.2 Technical definitions

3.2.1 Hazard area

Area where an incident is most likely to occur and as a consequence is capable of causing danger and/or injury to personnel.

3.2.2 Maximum continuous speed of the compressor

Maximum permitted continuous rotating speed of the compressor.

3.2.3 Maximum operating temperature

Highest temperature, which can be measured anywhere in the main gas stream, under the most severe operating conditions. See 9.4.

4 Compressor design

4.1 Design criteria

4.1.1 Possible causes of an oxygen compressor fire

It is normally very difficult to precisely ascertain the cause of a fire in an oxygen compressor because the material at and around the ignition site is completely burnt up. Therefore, during the design and manufacture of a reciprocating oxygen compressor both active and passive safety measures shall be taken to guard against any of the following situations leading to ignition:

- mechanical rub, friction—improper design, clearances, vibrations, operating pressure, assembly errors, bearing failure, alignment, improper inter-cooling, start-up/shut down instability (may include shock, adiabatic compression);
- debris impact—screen/filter failure or improper mesh size, weld debris or slag, (friction/shock) maintenance debris, shot, sand;
- contamination—oil, faulty design of bearings/seals and/or faulty design of associated vents and drains;
- resonance;
- debris in dead areas; and
- cooling system—design the system to avoid concentrating ethylene glycol in the process arising from leakage.

4.2 General materials

4.2.1 Construction materials

When selecting materials of construction for an oxygen compressor, components that come into contact with oxygen shall have good oxygen compatibility. Materials that fulfil this criterion usually have the following properties:

- high ignition temperature;
- high thermal conductivity;
- high specific heat; and
- low heat of combustion.

4.2.2 Use of aluminium

Because of its high heat of combustion the use of aluminium shall be limited for oxygen wetted or potential oxygen wetted parts. However, aluminium will not sustain combustion at certain pressures and purities. One such condition for piston construction is up to 1.4 MPa with oxygen purity 97%. Anodized aluminium is also acceptable within the constraints above.

Materials (including copper alloys) containing more than 2,5% aluminium shall be considered as aluminium.

4.2.3 Non-metallic materials

Non-metallic materials shall be tested for their suitability for oxygen service. Information can be found in Code of practice M 034, *List of non-metallic material compatible with oxygen by BAM* [3] and ASTM G63 *Standard Guide for Evaluating Non Metallic Materials for Oxygen Service* [4]. This does not

preclude other methods of determining compatibility such as by other independent bodies, customers, and suppliers.

4.3 Compressor parts

4.3.1 Cylinders and cylinder liners

4.3.1.1 Cylinder and cylinder liner material

The following materials have proved satisfactory with regard to the criteria listed under 4.2

- grey cast iron;
- nodular cast iron;
- high alloy steel - cast or fabricated; and
- welding of cast-steel and fabricated steel casings is permitted if the execution and heat treatment are properly conducted.

4.3.1.2 Repairs

Any repair shall be agreed between supplier and user, with the appropriate procedure.

4.3.1.3 Sealing material

If non-metallic materials are employed for sealing the cylinders, they shall be oxygen compatible and agreed by the supplier and user. Liquid sealant shall be applied to prevent it from creeping and projecting into the inside of the compressor. If required, threads shall also be sealed by materials that are compatible with oxygen.

4.3.1.4 Anti-galling compound

If an anti-galling compound is applied to centring fits, bolts, studs, etc., only compounds compatible with oxygen shall be used. Compounds shall be mutually agreed by the supplier and user.

4.3.2 Distance piece

The distance piece and frame oil head shall be designed to positively prevent the contact of crankcase oil with the process oxygen stream. The distance piece should be longer than the stroke length to allow the fitting of a slinger ring. For horizontal compressors, a second compartment distance piece of the same design should be used.

The interior of each distance piece should be painted white to detect presence of oil or pollution. A piston rod slinger ring shall be provided to form a positive barrier against oil migration along the rod. Oil migration shall be checked for on a regular basis.

An open distance piece is recommended to prevent oxygen enrichment. A positive purging system using air or nitrogen may be provided to ensure oxygen enrichment is not possible. Oxygen concentration in the distance piece should be checked periodically only remotely from outside the barrier or hazard area. If distance piece covers are provided, for example in case of hostile or polluted environment, a positive purging system shall be provided (dry air or nitrogen) to ensure that oxygen enrichment is not possible; in this case the concentration of oxygen at the vent of the distance piece shall be checked periodically.

Care shall be taken to avoid oxygen-enriched gas from the distance piece entering the crankcase either by over pressurizing the distance piece or by creating a vacuum in the crankcase.

4.3.3 Cylinder valves

Compressor valves contain thin materials and represent a particular hazard. Although there are no established design and construction rules for these valves, the design and material selections listed below have proven successful in operation.

The maximum continuous rotating speed of the compressor is determined primarily by the valve life cycle. The maximum continuous rotating speed of the compressor shall not exceed 750 rpm.

4.3.3.1 Design of cylinder valves

Ported plate valves with damping plates should be used for oxygen applications. Valve size should be sufficient to keep pressure losses across the valve below 5% of nominal suction and discharge pressures. Valve lift should be designed to keep opening impacts below 3.5 m/s and closing impact below 1.3 m/s to ensure maximum lifetime and safety. Valve motion natural frequencies should not correspond to system pulsation frequencies since this can lead to rapid valve failure.

4.3.3.2 Materials for compressor valves

The following materials have proven satisfactory for compressor valves:

- valve seat and guard: X20Cr13, X5CrNi1810, AISI 305, AISI 410, JIS SUS 420;
- valve plate: X20Cr13, X5CrNiCuNb177, AISI 410, JIS SUS 630;
- valve springs: X5CrNiCuNb177, Nimonic, JIS SUS 304;
- centre bolt: martensitic stainless steel, JIS SNB7; and
- nut: austenitic stainless steel.

4.3.4 Pistons

Maximum mean piston velocity shall not exceed 4 m/sec for ringed piston, and 5 m/sec for labyrinth piston.

4.3.4.1 Piston rod

Suitable materials for pressure greater than 4.5 MPa include among others, K-Monel. Martensitic stainless steel can be used less than 4.5 MPa.

If a piston rod coating is used, it shall be of a proven technology such as chrome plating, nitrided steel, or tungsten carbide coating.

4.3.4.1 Piston rings

Ringed, as distinct from labyrinth, compressors normally have piston rings to seal the gas and rider rings to carry the piston weight. The choice of ring material is important because the rubbing ring is itself a source of ignition and secondly wear of the rider ring can allow the metal piston to rub on the cylinder creating heat and a possible fire. Piston rings have successfully been made of polytetrafluoroethylene, PTFE, with one or some combination of the following fillers:

- glass fibre;
- lead powder;
- copper powder;
- bronze powder;