

BS EN 1012-3:2013



BSI Standards Publication

Compressors and vacuum pumps — Safety requirements

Part 3: Process compressors

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National foreword

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The UK participation in its preparation was entrusted to Technical Committee MCE/8/-/1, Compressors - Safety.

A list of organizations represented on this committee can be obtained on request to its secretary.

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Foreword

This document (EN 1012-3:2013) has been prepared by Technical Committee CEN/TC 232 “Compressors, vacuum pumps and their systems”, the secretariat of which is held by SIS.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by May 2014, and conflicting national standards shall be withdrawn at the latest by May 2014.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive(s).

For relationship with EU Directive(s), see informative Annex ZA, which is an integral part of this document.

EN 1012, *Compressors and vacuum pumps*, is composed of the following parts:

- *Part 1: Air compressors*;
- *Part 2: Vacuum pumps*;
- *Part 3: Process compressors* (the present document).

The responsibility of CEN/TC 232 includes coordination of safety standards with CEN/TC 182, Refrigerating systems, safety and environmental requirements, and CEN/TC 234, Gas infrastructure.

According to the CEN-CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

Introduction

This document is a type C standard as stated in EN ISO 12100.

The machinery concerned and the extent to which hazards, hazardous situations and events are covered are indicated in the scope of this document.

When provisions of this type C standard are different from those which are stated in type A and B standards, the provisions of this type C standard take precedence over the provisions of the other standards for machines that have been designed and built according to the provisions of this type C standard.

When published in 1996, Part 1 of EN 1012 applied to all types of compressor. The standard is now divided into 3 parts with Part 1 addressing compressors for compressed air, nitrogen and inert gases and Part 3 addressing compressors for process gases. Part 2 continues to address vacuum pumps.

Separating requirements for process gas compressors from those for compressors for air, nitrogen and other inert gases was considered a practical move so that the requirements for one type of compressor could be changed without affecting the complete standard.

Where texts parts of EN 1012-3 are identical with EN 1012-1:2010, these are identified and formatted in italics.

If common requirements for functional safety would be applied to all process compressors, the variety in the application of process compressors may cause significantly different levels of residual risk. Therefore, in addition to the requirements of this standard, the application of risk assessment may be required for safety related control systems in the case of particular applications to specify performance levels and/or safety integrity levels for related aspects of functional safety.

Informative Annex C has been included to provide guidance on risk assessment for related aspects of functional safety, including the determination of safety integrity levels and/or performance levels. The manufacturer of the compressor is responsible for carrying out such a risk assessment and applying appropriate preventive measures. These tasks are outside the scope of this standard.

1 Scope

This European Standard is applicable to process gas compressors and process gas compressor units having an operating pressure greater than 0,5 bar (gauge), an input shaft power greater than 0,5 kW and designed to compress all gases other than air, nitrogen or inert gases which are covered in Part 1. This document deals with all significant hazards, hazardous situations and events relevant to the design, installation, operation, maintenance, dismantling and disposal of process gas compressors and process gas compressor units, when they are used as intended and under conditions of misuse which are reasonably foreseeable by the manufacturer (see Clause 4).

This part of EN 1012 includes under the general term compressor units those machines which comprise:

- the compressor;
- a drive system including the prime mover;
- any component or device supplied which is necessary for operation.

This part of EN 1012 is not applicable to compressors which are manufactured before the date of publication of this document by CEN.

The requirements of this European Standard do not take into account the interaction between the compressor/compressor unit and other processes carried out on site.

Excluded are:

- refrigerant compressors used in refrigerating systems or heat pumps for which the safety requirements are given in EN 60335-2-34 or EN 12693;
- the specification of performance levels and/or safety integrity levels for safety related parts of control systems.

Performance levels and/or safety integrity levels are an important aspect of compressor design and should be determined by the manufacturer and the user based on a risk assessment (see Introduction).

This European Standard does not cover those safety aspects of road transport dealt with by EC legislation for trailers.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 626-1:1994+A1:2008, *Safety of machinery — Reduction of risks to health from hazardous substances emitted by machinery — Part 1: Principles and specifications for machinery manufacturers*

EN 764-7:2002, *Pressure equipment — Part 7: Safety systems for unfired pressure equipment*

EN 837-2, *Pressure gauges — Part 2: Selection and installation recommendations for pressure gauges*

EN 953:1997+A1:2009, *Safety of machinery — Guards — General requirements for the design and construction of fixed and movable guards*

EN 1005-2, *Safety of machinery — Human physical performance — Part 2: Manual handling of machinery and component parts of machinery*

EN 1005-3, *Safety of machinery — Human physical performance — Part 3: Recommended force limits for machinery operation*

EN 1127-1, *Explosive atmospheres — Explosion prevention and protection — Part 1: Basic concepts and methodology*

EN 12021, *Respiratory protective devices — Compressed air for breathing apparatus*

EN 12195-1, *Load restraining on road vehicles — Safety — Part 1: Calculation of securing forces*

EN 13001-2, *Crane safety — General design — Part 2: Load actions*

EN 13155, *Cranes — Safety — Non-fixed load lifting attachments*

EN 13309, *Construction machinery — Electromagnetic compatibility of machines with internal power supply*

EN 13445-5:2009, *Unfired pressure vessels — Part 5: Inspection and testing*

EN 13445-6, *Unfired pressure vessels — Part 6: Requirements for the design and fabrication of pressure vessels and pressure parts constructed from spheroidal graphite cast iron*

EN 13463-1, *Non-electrical equipment for use in potentially explosive atmospheres — Part 1: Basic method and requirements*

EN 15198, *Methodology for the risk assessment of non-electrical equipment and components for intended use in potentially explosive atmospheres*

EN 60079-0, *Explosive atmospheres — Part 0: Equipment — General requirements (IEC 60079-0:2011, modified)*

EN 60079-1, *Explosive atmospheres — Part 1: Equipment protection by flameproof enclosures "d" (IEC 60079-1)*

EN 60079-14, *Explosive atmospheres — Part 14: Electrical installations design, selection and erection (IEC 60079-14)*

EN 60204-1:2006¹⁾, *Safety of machinery — Electrical equipment of machines — Part 1: General requirements (IEC 60204-1:2005, modified)*

EN 60204-11, *Safety of machinery — Electrical equipment of machines — Part 11: Requirements for HV equipment for voltages above 1 000 V a.c. or 1 500 V d.c. and not exceeding 36 kV (IEC 60204-11)*

EN 61000-6-2, *Electromagnetic compatibility (EMC) — Part 6-2: Generic standards — Immunity for industrial environments (IEC 61000-6-2)*

EN 61000-6-4, *Electromagnetic compatibility (EMC) — Part 6-4: Generic standards — Emission standard for industrial environments (IEC 61000-6-4)*

EN 61310-2:2008, *Safety of machinery — Indication, marking and actuation — Part 2: Requirements for marking (IEC 61310-2:2007)*

¹⁾ EN 60204-1:2006 is impacted by the stand-alone amendment EN 60204-1:2006/A1:2009 (IEC 60204-1:2005/A1:2008).

EN 61508-1:2010, *Functional safety of electrical/electronic/programmable electronic safety-related systems — Part 1: General requirements* (IEC 61508-1:2010)

EN 61508-2:2010, *Functional safety of electrical/electronic/programmable electronic safety-related systems — Part 2: Requirements for electrical/electronic/programmable electronic safety-related systems* (IEC 61508-2:2010)

EN 61508-3, *Functional safety of electrical/electronic/programmable electronic safety-related systems — Part 3: Software requirements* (IEC 61508-3)

EN 61508-4, *Functional safety of electrical/electronic/programmable electronic safety-related systems — Part 4: Definitions and abbreviations* (IEC 61508-4)

EN 61508-5, *Functional safety of electrical/electronic/programmable electronic safety-related systems — Part 5: Examples of methods for the determination of safety integrity levels* (IEC 61508-5)

EN 61508-6, *Functional safety of electrical/electronic/programmable electronic safety-related systems — Part 6: Guidelines on the application of IEC 61508-2 and IEC 61508-3* (IEC 61508-6)

EN 61508-7, *Functional safety of electrical/electronic/programmable electronic safety-related systems — Part 7: Overview of techniques and measures* (IEC 61508-7)

EN 61511-1, *Functional safety — Safety instrumented systems for the process industry sector — Part 1: Framework, definitions, system, hardware and software requirements* (IEC 61511-1)

EN 61511-2, *Functional safety — Safety instrumented systems for the process industry sector — Part 2: Guidelines for the application of IEC 61511-1* (IEC 61511-2)

EN 61511-3, *Functional safety — Safety instrumented systems for the process industry sector — Part 3: Guidance for the determination of the required safety integrity levels* (IEC 61511-3)

EN 62061, *Safety of machinery — Functional safety of safety-related electrical, electronic and programmable electronic control systems* (IEC 62061)

EN ISO 2151:2008, *Acoustics — Noise test code for compressors and vacuum pumps — Engineering method (Grade 2)* (ISO 2151:2004)

EN ISO 4126-1, *Safety devices for protection against excessive pressure — Part 1: Safety valves* (ISO 4126-1)

EN ISO 4413:2010, *Hydraulic fluid power — General rules and safety requirements for systems and their components* (ISO 4413:2010)

EN ISO 4414:2010, *Pneumatic fluid power — General rules and safety requirements for systems and their components* (ISO 4414:2010)

EN ISO 11688-1, *Acoustics — Recommended practice for the design of low-noise machinery and equipment — Part 1: Planning* (ISO/TR 11688-1)

EN ISO 12100:2010, *Safety of machinery — General principles for design — Risk assessment and risk reduction* (ISO 12100:2010)

EN ISO 13849-1:2008, *Safety of machinery — Safety-related parts of control systems — Part 1: General principles for design* (ISO 13849-1:2006)

EN ISO 13850:2008, *Safety of machinery — Emergency stop — Principles for design* (ISO 13850:2006)

EN ISO 13857, *Safety of machinery — Safety distances to prevent hazard zones being reached by upper and lower limbs (ISO 13857)*

EN ISO 14122-1, *Safety of machinery — Permanent means of access to machinery — Part 1: Choice of fixed means of access between two levels (ISO 14122-1)*

EN ISO 14122-2, *Safety of machinery — Permanent means of access to machinery — Part 2: Working platforms and walkways (ISO 14122-2)*

EN ISO 14122-3, *Safety of machinery — Permanent means of access to machinery — Part 3: Stairs, stepladders and guard-rails (ISO 14122-3)*

EN ISO 14122-4, *Safety of machinery — Permanent means of access to machinery — Part 4: Fixed ladders (ISO 14122-4)*

EN ISO 14163, *Acoustics — Guidelines for noise control by silencers (ISO 14163)*

EN ISO 15156-1, *Petroleum and natural gas industries — Materials for use in H₂S-containing environments in oil and gas production — Part 1: General principles for selection of cracking-resistant materials (ISO 15156-1)*

EN ISO 15667, *Acoustics — Guidelines for noise control by enclosures and cabins (ISO 15667)*

ISO 3857-1, *Compressors, pneumatic tools and machines — Vocabulary — Part 1: General*

ISO 3857-2, *Compressors, pneumatic tools and machines — Vocabulary — Part 2: Compressors*

ISO 8573-1, *Compressed air — Part 1: Contaminants and purity classes*

ISO 8573-2, *Compressed air — Part 2: Test methods for oil aerosol content*

ISO 8573-3, *Compressed air — Part 3: Test methods for measurement of humidity*

ISO 8573-4, *Compressed air — Part 4: Test methods for solid particle content*

IEC 60417 (2002-10), *Graphical symbols for use on equipment*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN ISO 12100:2010 apply.

Definitions specifically needed for compressors are listed below and in the standards ISO 3857-1 and ISO 3857-2.

3.1 General terms

3.1.1

compressor

part of a compressor unit that compresses a gas or vapour media to a pressure higher than that at the inlet

3.1.2

compressor unit

unit that comprises the compressor, a drive system and any component or device which is necessary for operation

3.1.3 depressurisation

reduction of the pressure difference between the inside of a pressure containing part and its environment to zero

EXAMPLE Stopping a compressor may lead to higher pressures on the suction side. In such cases, achieving a safe state may include depressurizing.

3.1.4 drive system

system that consists of a prime mover and coupling mechanism

Note 1 to entry: *Prime mover may be an electric motor, steam engine (turbine), etc.*

Note 2 to entry: *Coupling mechanism may be a drive belt, shaft, gears, etc.*

3.1.5 harm

physical injury or damage to health

[SOURCE: EN ISO 12100:2010, definition 3.5]

3.1.6 hazard

potential source of harm

[SOURCE: EN ISO 12100:2010, definition 3.6]

3.1.6.1 hazard zone

danger zone

space within and/or around machinery in which a person can be exposed to a hazard

[SOURCE: EN ISO 12100:2010, definition 3.11]

3.1.6.2 hazardous event

event that can cause harm

Note 1 to entry: A hazardous event can occur over a short period of time or over an extended period of time.

3.1.6.3 hazardous situation

circumstance in which a person is exposed to at least one hazard

Note 1 to entry: The exposure can result in harm immediately or over a period of time.

[SOURCE: EN ISO 12100:2010, definition 3.10]

3.1.6.4 hazardous gas or vapour

gas or vapour with chemical, radioactive or biological properties (such as flammable, explosive, unstable, pyrogenic, corrosive, caustic, toxic, carcinogenic), which generate hazards by reactions inside the compressor or through dispersal or through reactions with the environment

Note 1 to entry: A hazardous gas may be a mixture of gases with these properties.

3.1.7

inert gases

chemically inactive gas which retains this characteristic even at elevated pressures and temperatures

3.1.8

liquid shock

excessive force resulting from an attempt to compress incompressible media

3.1.9

maximum allowable pressure

maximum allowable working pressure

maximum pressure for which the compressor or compressor unit is designed, as specified by the manufacturer

3.1.10

maximum allowable temperature

maximum allowable working temperature

maximum operating temperature, as specified by the manufacturer

3.1.11

maximum continuous shaft speed

highest rotational speed at which the compressor at any of the specified operating conditions is capable of continuous operation

Note 1 to entry: The maximum continuous speed is specified by the manufacturer.

3.1.12

nominal discharge pressure

rated discharge pressure

pressure at the outlet of the compressor, as specified by the manufacturer

3.1.13

normal operating conditions

conditions considered to be when the compressor is properly maintained and operated within admissible limits in particular ambient temperature, as specified by the manufacturer compressing the specified media

3.1.14

pressure

pressure relative to atmospheric pressure, i.e. gauge pressure

Note 1 to entry: In many cases, this is referred to as effective pressure.

Note 2 to entry: The unit bar for pressure is used. 1 bar = 100 kPa.

3.1.15

rated power

maximum permitted power (mechanical or electrical)

Note 1 to entry: Nominal power is a synonym for rated power.

3.1.16

risk

combination of the probability of occurrence of harm and the severity of that harm

[SOURCE: EN ISO 12100:2010, definition 3.12]

3.1.17

residual risk

risk remaining after protective measures have been taken

Note 1 to entry: See EN ISO 12100:2010, Figure 2.

[SOURCE: EN ISO 12100:2010, definition 3.17]

3.1.18

safety function

function of the machine whose failure can result in an immediate increase of the risk(s)

[SOURCE: EN ISO 12100:2010, 3.30; EN ISO 13849-1:2008, 3.1.20]

3.1.19

safety related control

safety instrumented system

SIS

control device that carries out one or more safety function(s)

Note 1 to entry: This definition corresponds to safety instrumented system (SIS) according to EN 61511-1.

3.1.20

shutdown

stopping of all prime movers of a compressor

3.1.20.1

automatic shutdown

automatically initiated stopping of a compressor initiated by limiting device or safety device

Note 1 to entry: Automatic shutdown is commonly denoted as “tripping”.

Note 2 to entry: This definition describes the way of initiating a normal, safety related controlled or emergency shutdown.

3.1.20.2

normal shutdown

manually or automatically initiated stopping of a compressor which may include full sequential actuation of auxiliary equipment and drive system

3.1.20.3

safety related controlled shutdown

manually or automatically initiated stopping of a compressor which includes a reduced (compared to normal shutdown) sequential actuation of auxiliary equipment and drive system

Note 1 to entry: This type of shutdown is initiated by a safety related function.

Note 2 to entry: Reduced sequential actuation means a reduced number and/or duration of steps of the sequence.

Note 3 to entry: After a normal shutdown the energy to the prime movers can be cut off or not (see stop category 1 or 2 of 9.2.2 of EN 60204-1:2006).

Note 4 to entry: Manually initiated stopping of a compressor which includes a reduced (compared to normal shutdown) sequential actuation of auxiliary equipment and drive system is often denoted as emergency stop.

3.1.20.4

emergency shutdown

manually or automatically initiated stopping of a compressor with immediate cut of the energy to the prime mover

Note 1 to entry: This type of shutdown is initiated by a safety related function.

Note 2 to entry: This shutdown definition is related to the stop category 0 of 9.2.2 of EN 60204-1:2006.

3.1.21

unexpected start-up

unintended start-up

start-up which, because of its unexpected nature, generates a hazard by, for example:

- a start command which is the result of a failure in, or an external influence on, the control system;
- a start command generated by inopportune action on a start control or other parts of the machine as, e.g., a sensor or a power control element;
- restoration of the power supply after an interruption;
- external / internal influences (e.g. gravity, wind, self-ignition in internal combustion engines) on parts of the machine.

Note 1 to entry: Machine start-up during the normal sequence of an automatic cycle is not unintended, but can be considered to be unexpected from the point of view of the operator. Prevention of accidents in this case involves the use of safeguarding measures (see EN ISO 12100-2:2010, Clause 5).

[SOURCE: EN ISO 12100:2010, 3.31]

3.2 Specific terms

3.2.1

acetylene compressor

compressor intended for handling technically pure acetylene

Note 1 to entry: For mixtures of acetylene with other gases or liquids the applicability of the relevant acetylene specifications will be decided on a case by case basis.

3.2.2

air compressor

compressor intended for compression of air, nitrogen or inert gases

3.2.3

auxiliary energy supply

energy which forces auxiliary systems (e.g. oil systems, cooling system or valves) to operate

3.2.4

compressor assembly

assembly of compressor units and ancillary equipment to provide a compression facility that functions as an integrated whole

Note 1 to entry: The limits of the assembly are as defined by the manufacturer.

3.2.5

control energy supply

energy supply for the control system (e.g. control voltage)

3.2.6

high pressure compressor

compressor for maximum allowable working pressures above 50 bar

3.2.7

large compressor

compressor with an input shaft power above 1 000 kW

3.2.8

low temperature compressor

compressor for continuous handling of media other than air, inert gases or nitrogen, having an inlet temperature below 0 °C

3.2.9

main energy supply

energy which forces the prime mover(s) of the compressor to turn

3.2.10

oil-flooded compressor

compressor design in which the compressed gas or vapour and the oil are mixed

Note 1 to entry: In such compressors, a considerable amount of oil is injected into the gas or vapour in order to reduce the gas discharge temperature.

3.2.11

oil-free compressor

compressor design in which the compressed gas or vapour does not come in contact with oil

3.2.12

oil-lubricated compressor

compressor design in which the compressed gas or vapour may come in contact with oil but excluding oil-flooded compressors

3.2.13

oxygen compressor

compressor for handling pure oxygen or oxygen rich mixture, of more than 70 mole percent oxygen

Note 1 to entry: If ideal gas law is applicable mole fraction is equivalent to volume fraction.

3.2.14

portable and skid-mounted compressor

3.2.14.1

portable compressor unit

compressor unit which is wheel-mounted and can be towed on and off-site

3.2.14.2

skid-mounted compressor unit

compressor unit which is mounted on skids and which is intended to be towed short distances on-site or transported on-site

3.2.14.3

gross mass

maximum specified mass of the skid mounted or portable compressor unit (including tools, equipment and fuel)

Note 1 to entry: Tools and equipment includes for example concrete breakers, picks and hoses likely to be carried for a typical working application.

3.2.15

process (gas) compressor

compressor intended for compression of all gases other than air, nitrogen or other inert gases

3.2.16

water-injected compressor

compressor design in which the compressed gas and the water are mixed

4 List of significant hazards – Hazard analysis and risk assessment

The hazards listed in Table 1 have been identified by risk assessment as applicable and are related to all compressors/compressor units within the scope of this European Standard.

NOTE Basis of the risk assessment is EN ISO 12100.

Table 1 — Hazard listing

No.	Hazard type	Reference to safety requirement	
		By design or guarding	Information for use
1	Mechanical hazards due to:		
1.1	Rotating or moving elements resulting in — crushing — shearing — drawing-in, trapping or entanglement	5.2.2.1 5.2.2.2 5.2.2.3	
1.2	Shape (e.g. sharp edges) and/or superficial finishing of accessible parts of the machine in: — contact with rough surfaces — contact with sharp edges and corners, protruding parts resulting in: — cutting or severing — friction or abrasion	5.2.1 5.2.2.2	7.2.1.6 q), 7.2.1.7 a)
1.3	Ejection of parts resulting in: — crushing — being hit / being thrown / being gripped	5.2.2.4	
1.4	Instability of parts or components resulting in: — crushing — cutting — impact	5.2.4	7.2.1.11a) and d) 7.3.3 i)
1.5	Loss of stability / overturning of machinery as a result of: — geometry of base — weight distribution — oscillation of the centre of gravity — external forces (e.g. wind pressure, manual forces)	5.2.4, 5.2.5, 5.2.5.8	7.2.1.4 7.3.3 i) 7.2.1.11 a) and d) 7.2.1.6
1.6	High pressure injection or ejection resulting in: — displacement of moving elements — ejection of high pressure fluids — uncontrolled movements	5.2.3 5.10.6.2 5.11	7.2.1.6 r)

Table 1 (2 of 6)

No.	Hazard type	Reference to safety requirement	
		By design or guarding	Information for use
1.7	High pressure (stored energy) resulting in: a) bursting 1) ejection of pressure containing parts or particles 2) being thrown b) escape of hazardous fluids 1) poisoning 2) suffocation 3) burn	5.4.6.3, 5.8.3, 5.8.4, 5.10.1, 5.10.3, 5.10.6.1, 5.10.6.2 5.11 5.12	7.2.1.6 d), e), i), k), m), 7.2.1.11 b), c), 7.2.1.7 0 7.3.4.1 f)
1.8	Stored energy (kinetic or potential energy) of the machine, parts of the machine, tools and materials used or elastic elements resulting in: — being thrown — crushing — shearing	5.10.3	7.2.2.2
2	Electrical hazards due to:		
2.1	Contact of persons with electrical equipment parts or live parts (direct contact) or electrical equipment parts which become live under fault conditions (indirect contact) — shock — electrocution — falling, being thrown — burn — fire	5.3	7.2.1.5.1, 7.2.1.5.2 7.2.2.2
2.2	External influences on the electrical equipment e.g.: — short-circuit — overload — electromagnetic phenomena — interruptions or variations in the supply voltage — earthing faults causing fire, burn, chemical effects	5.3; 5.4.5.3	7.2.1.5.1

Table 1 (3 of 6)

No.	Hazard type	Reference to safety requirement	
		By design or guarding	Information for use
2.3	Electrostatic phenomena resulting in: — shock — electrocution — uncontrolled motion, e.g. falling because of being scared	5.8.2	7.2.2.2
2.4	Electromagnetic phenomena resulting in: — effects on medical implants — malfunction of electrical equipment of the compressor / compressor unit due to lack of EMC- immunity (surge immunity) — effects on other electrical equipment due to EMC emissions from the compressor / compressor unit	5.4.5.4	
3	Thermal hazards due to		
3.1	Contact of persons with objects or materials with extremely high or low temperature resulting in: — burns — scalds — other injuries	5.5	7.2.1.7 e) 7.3.2
4	Hazards due to noise		
4.1	Noise: — hearing loss (deafness), tinnitus — stress, tiredness — other physiological disorders (e.g. loss of balance, loss of awareness) — accidents due to impairment of speech communication or of the perception of acoustic signals	5.6	7.2.1.10,
5	Several hazards due to materials and substances processed or used:		
5.1	Breathing or contact with the materials and substances processed or used, resulting in: — breathing difficulties, suffocation — impairment of health (e.g. poisoning)	5.7.1, 5.7.2, 5.7.3, 5.7.4, 5.7.5, 5.7.6, 5.7.7, 5.7.8, 5.7.9	7.2.1.7h), 7.2.1.7f), 7.2.2.1, 7.2.2.2,

Table 1 (4 of 6)

No.	Hazard type	Reference to safety requirement	
		By design or guarding	Information for use
5.2	Fire and/or explosion hazards	5.8	7.2.1.6 o) and p) 7.2.1.7g) and o)
5.3	Biological or microbiological (e.g. viral or bacterial) hazards, resulting in: — breathing difficulties, suffocation — impairment of health (e.g. poisoning)	5.7.10	7.2.1.7 i), j) and k) 7.2.1.7 f) and 7.2.1.11 e)
6	Hazards due to neglecting ergonomic principles in machinery design:		
6.1	Poor visibility and/or readability and/or accessibility of indicators and visual displays	5.9	
6.2	Poor accessibility of access closures and other machine areas that have to be accessed for routine maintenance	5.2.2.5	7.2.2.2
7	Hazards due to the environment in which the machine is used, e.g. hazards created by operating the compressor/compressor unit in:		7.2.1.8 f)
7.1	Environmental conditions, e.g. dusty air or polluted air or moist air, temperature and ambient pressure		7.2.1.8 c)
7.2	Loads created by snow, wind and earthquake: — hazard resulting from breaking down of machinery parts and other functional disorders	5.10.2	7.2.1.6
7.3	Low temperature	5.10.4	7.2.1.6 b), c), i) and m)
7.4	Hazards created by lightning	5.3.4	7.2.1.5.5
8	Hazards due to an unexpected start/restart caused by:		
8.1	Failure/disorder of the control system	5.4.3, 5.4.4, 5.4.5, 5.4.5.1, 5.4.5.2; 5.4.5.3	7.2.1.7 c) and d) 7.2.1.9 h), 7.2.1.9 d)
8.2	Restoration of the power supply after a long term electric power interruption	5.2.8	7.2.1.5.2, 7.2.1.7c) and d) 7.2.2.1
9	Hazard due to loss of main energy/power supply or short term interruption:		
9.1	— reverse running of the compressor — higher settle out pressure	5.2.9	

Table 1 (5 of 6)

No.	Hazard type	Reference to safety requirement	
		By design or guarding	Information for use
10	Hazards due to breaking down of machinery parts and other functional disorders caused by:		
10.1	Improper material properties, e.g. deficient ductility and fatigue resistance: — displacement of moving elements — uncontrolled movements — bursting — escape of hazardous fluids — ejection of pressure containing parts or particles	5.10.3	
10.2	Incompatibility of materials used with the lubricants or other fluids used and with the gases being processed	5.10.3	7.2.1.6 g), h), i), m), n), o), p), 7.2.2.2
10.3	Liquid shock	5.10.5	7.2.1.7 l)
10.4	Overstressing of integral pipework, hoses and auxiliaries	5.2.3	7.2.1.6 r)
10.5	Overstressing of power transmission element, e.g. coupling, gear, shaft	5.10.3	
10.6	Underspeed /overspeed /critical speed	5.2.7	7.2.1.7 n)
10.7	Exceeding temperature of the process	5.5, 5.7.2, 5.7.3, 5.7.4, 5.8.1, 5.8.3, 5.8.4, 5.10.1, 5.10.7, 5.10.8	7.2.1.6 c), 7.2.2.2
10.8	Failure of shaft seals system	5.7.8	
10.9	Surge of a turbo compressor	5.10.3, 5.10.9	
10.10	Axial displacement of shaft	5.10.3	
10.11	Reverse running	5.2.9	
11	Hazards due to access to hazardous areas, e.g.:		
11.1	— mechanical hazards, e.g. crushing, shearing, drawing-in, trapping or entanglement — breathing difficulties, suffocation, impairment of health, poisoning — getting/being trapped	5.2.2.5, 5.7.7	7.2.1.6 q), 7.2.2.1, 7.2.2.2
12	Hazard due to lifting and transportation		
12.1	— e.g. crushing, loss of stability	5.2.4, 5.2.5, 5.2.5.8	7.2.1.4

Table 1 (6 of 6)

No.	Hazard type	Reference to safety requirement	
		By design or guarding	Information for use
13	Hazard due to slip, trip and fall of persons (related to machinery)	5.2.6	
14	Hazards due to insufficient information for use		7
15	Additional hazards from portable compressors		
15.1	Exhaust gases/lack of oxygen/toxic gases at the work position		7.2.1.8 f), h), 7.2.1.11 e)
15.2	Noise at the operator's position	6.5	7.2.1.10,
15.3	From handling the machine (lack of stability)	5.2.5.8, 5.9.2	7.2.1.11 d)
15.4	Hazards from the engine and the batteries	5.3.5.2	
15.5	Hazards from coupling and towing	5.2.5.8, 5.9.3	7.2.1.11 a), f)
15.6	Lack or inadequacy of visual or acoustic warning means		7.3.3
15.7	Unhealthy postures or excessive effort	5.9.3	

5 Safety requirements and/or protective measures

5.1 General

Machinery shall comply with the safety requirements and/or protective measures of this clause. In addition, the machine shall be designed according to the principles of EN ISO 12100 for relevant but not significant hazards, which are not dealt with by this document.

When choice is necessary for the application of type B standards referred to in this European Standard, such as EN 60204-1, EN ISO 4414, EN 953 and others listed in Clause 2 of this standard and the specific measures are not identified in this clause, the manufacturer shall carry out an appropriate risk assessment for making these decisions.

This risk assessment according to EN ISO 12100, which is required because of the variability of the machinery involved, should be part of the general risk assessment that a manufacturer should carry out to identify and deal with any hazards not covered by this standard (see Introduction). When this standard does not fully cover a particular hazard, identified as significant by the risk assessment carried out by the manufacturer, so far as practicable associated risks should be reduced by the principle of inherently safe design. When the remaining risk is not tolerable, risk should be reduced by the application of protective devices. If such protective devices rely on safety related control systems, EN ISO 13849-1, EN 62061, EN 61508 or EN 61511 should be applied as appropriate. For the application of these standards to process gas compressors / compressor units, see Annex C of this standard for guidance and examples. If the risk cannot be reduced to a tolerable level (see the risk graph given in Annex C, Figure C.4) by such measures, information on the procedures required to control the residual risk should be established and documented. The specification of the additional measures referred to in this paragraph are not within the scope of this standard and are the responsibility of the compressor or compressor unit manufacturer.

The measures adopted to comply with the requirements of this clause shall take account of the state-of-the-art when more effective technical means become available.

Components used in the design and construction of process compressors shall comply with the requirements of appropriate standards. Such standards having a specific normative reference in this standard shall take precedence.

5.2 Mechanical safety

5.2.1 General

Outer shapes (e.g. sharp edges) of accessible parts of the machine which could lead to cutting, stabbing, etc. shall be avoided.

5.2.2 Guards

5.2.2.1 General

When fixed guards have to be removed for periodic maintenance their fixing systems shall remain attached to the guard or machinery when the guards are removed.

5.2.2.2 Cutting and severing, friction and abrasion

All moving parts shall be enclosed within the permanent compressor casing or compressor unit cover, enclosure or canopy. When this is not possible, separate guards shall be provided to prevent contact with all rotating and reciprocating parts to minimize the risk of cutting and severing, friction and abrasion to personnel in accordance with Clause 5 of EN 953:1997+A1:2009 and EN ISO 13857 for safety distances.

The term "moving parts" may include parts which are moving infrequently only under certain operating conditions.

5.2.2.3 Bodily contact

Guards shall be sufficiently rigid so as not to deflect excessively as a result of bodily contact. Such deflections shall not result in contact with moving parts, or that the deflection should not result in permanent deformation of the guard. The provisions for rigidity of guards shall be in accordance with 5.5.3 of EN 953:1997+A1:2009.

5.2.2.4 Ejection of parts

Moving parts shall be designed and mounted in such a way that in all foreseeable modes of operation the risk of ejection of parts is minimized. Where the risk assessment identifies a remaining risk of ejection, e.g. a drive belt from a belt driven compressor, then the impact resistance for guarding shall be in accordance with 5.5.2 of EN 953:1997+A1:2009.

If cooling inside a closed coupling guard is necessary, an appropriate cooling medium such as oil or nitrogen may be injected.

5.2.2.5 Openings in guards

Openings in guards, e.g. arising from the use of mesh, shall comply with the safe reach distances given in EN ISO 13857.

5.2.2.6 Access closures in guards

Access closures for inspection and maintenance activities, e.g. in acoustic hoods also providing a guarding function, flywheel enclosures, shall be in accordance with this clause and Clause 5 of EN 953:1997+A1:2009.

Where maintenance activities requiring access within the guarded areas are necessary whilst the compressor is still operational, consideration in accordance with 6.3.2.4 of EN ISO 12100:2010 shall be given to the additional hazards created.

Access closures can be divided into four types which shall have the following provisions:

- a) Access closures large enough to enable whole body entry and that can be opened with tools or having a lock requiring a key, e.g. bolted elements or lockable doors of an acoustic hood also providing a guarding function:

The use of tools and locks to control access is acceptable if the expected frequency of entry is low. The guard provided for the opening shall be in accordance with 5.4.3 of EN 953:1997+A1:2009. Access closures of this type do not require additional design features. See 7.2.2.2 for information on procedures for controlling access to keys.

Access closures large enough to enable whole body entry and that can be opened without tools or without a lock requiring a key, e.g. door with latch of an acoustic hood also providing a guarding function. The door provided for the opening shall be in accordance with 5.4.8 of EN 953:1997+A1:2009.

Access closures of this type shall have provisions to automatically shutdown a running compressor before or when the guard is opened.

The compressor shall be protected against unintentional start/restart according to 5.4.2 of this standard as long as the opening is open.

An unintentional restart shall be avoided by e.g.:

- 1) preventing the closing of the door when a person is inside, e.g. by means of a door that is lockable in the open position using a padlock. See 7.2.2.2 for warnings and information on procedures; or
 - 2) the door shall be openable from the inside and a compressor restart shall require the operation of a separate restart control before the starting procedure can commence.
- b) Access closures large enough to enable access of body parts and that can be opened only with tools or having a lock requiring a key, e.g. bolted inspection cover in gear box casing: The guard provided for the opening shall be in accordance with 5.4.3 of EN 953:1997+A1:2009. Access closures of this type do not require additional design features.
- c) Access closures large enough to enable access of body parts and that can be opened without tools or without a lock requiring a key.
E.g. access closures in fly wheel guards required to provide access to timing marks, wheel hub and other parts which may require attention.
The guard provided for the opening shall be either a fixed or a self-closing guard. If this is not possible then the provisions of 7.2.1.6 q) of this standard shall be applied.

Generally, access frequency is understood as being "high" if it is more often than once per day.

5.2.3 Fluid injection

The risk of fluid (gas or liquid) injection into the human body shall be minimized by:

- *designing and supporting integral pipework, hoses and auxiliaries to withstand vibration, thermal expansion and their own mass, foreseeable external forces, influence of contaminants and external chemical substances;*
- *ensuring that all piping which is in a position likely to be damaged is protected, robust and sufficiently supported but shall be free to move with changing temperature;*
- *ensuring that the design of oil/coolant filler plugs does not allow the dangerous release of fluid, e.g. by means of preventing the removal of the filler plug under pressure or an effective warning system;*
- *the design and location of pressure vents and drains, shall take account of the velocity of air, gas, vapour or liquid likely to be discharged.*

5.2.4 Loss of stability

5.2.4.1 Generally applicable

Compressor units shall be in accordance with 6.2.6 of EN 12100:2010.

5.2.4.2 Portable and skid-mounted compressor units

The centre of gravity of the engine/compressor combination shall be sufficiently close to the supporting surface to ensure that the compressor remains stable, without tipping or slipping, when used within intended limits. The intended limits shall be specified in the instruction handbook supplied with the compressor (see 7.2.1.11 d)).

Tyres of a portable compressor shall be rated to carry the maximum gross mass of the portable compressor at the highest towing speed the compressor unit is intended for. All tyres shall be of the same construction.

The support leg or jockey wheel shall be capable of supporting the gross nose weight of the portable compressor unit as defined in the instruction handbook. It shall be possible to securely lock it in the support and towing positions by, for example, a clamping system or removable pin in locating holes.

The jockey wheel device shall be positively retained in the draw bar in the event of the operator leaving it unlocked.

NOTE Portable compressor units used on-road are also subject to regulations related to motor vehicles and their trailers.

5.2.5 Lifting and transportation of compressor units and parts

5.2.5.1 General

When the lifting of a compressor or compressor unit is not possible without lifting points then these shall be provided. The design of lifting points shall be based on:

- load;
- positioning and number of lifting points;
- possible direction of the forces acting on the lifting points ;
- application of suitable safety factors.

5.2.5.2 Load

5.2.5.2.1 Static load

The static load (F_s) in N shall be the multiplication of the gravitational acceleration (g) in m/s^2 and the maximum mass (m) of the load in kg. That is:

$$F_s = m * g \quad (1)$$

where

$$g = 9,81 \text{ m/s}^2$$

5.2.5.2.2 Dynamic load

For the calculation of the dynamic load in order to account for acceleration during lifting a minimum dynamic factor of $\Phi_2 = 2,5$ (worst case value according to EN 13001-2) shall be applied. The dynamic load (F_d) is the dynamic load factor times the static load (F_s). That is:

$$F_d = \phi_2 * F_s \quad (2)$$

If higher acceleration is foreseeable this shall be taken into account by adjusting Φ_2 in the calculation of the vertical dynamic load.

If the maximum dynamic load factor of the lifting equipment to be used is known to be lower than 2,5 (e.g. less than 2,5 when lifting devices are used at the limit of their lifting capacity) this can be used for the calculation of the dynamic load. In this case, the maximum allowable hoisting class and lifting velocity according to EN 13001-2 have to be stated in the manual and transportation documents (see 7.2.1.4). In addition, the same information has to be given in suitable signs mounted in the vicinity of the lifting points.

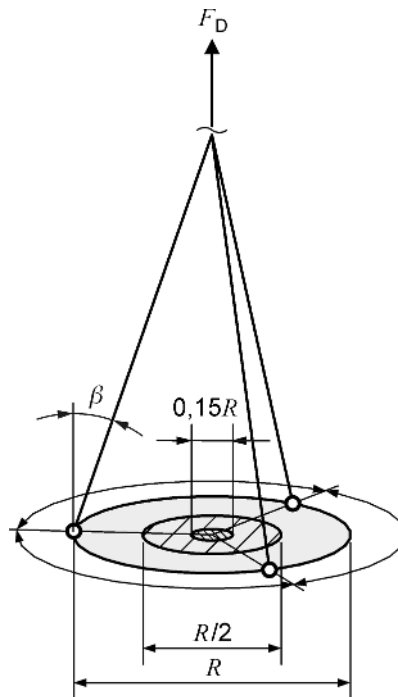
5.2.5.3 Positioning and number of lifting points

The following shall be taken into account when determining the position and number of lifting points:

- a) In the case of rigid compressors or compressor units the number of lifting points to be used simultaneously shall not exceed 4.
- b) The possible tilting of the load during lifting shall be avoided. Preferably the lifting points should be located above the centre of gravity of the load.

NOTE Locating the lifting points horizontally further away from the centre of gravity also reduces the risk of tilting.

- c) The geometric position of the lifting points should be preferably symmetrical with respect to the centre of gravity of the compressor or the compressor unit and shall be in the same plane. In some cases unsymmetrical positioning of the lifting points in the same plane cannot be avoided. This results in the application of a potentially higher load to a particular lifting point or leg of lifting equipment and this shall be accounted for in the design and information supplied. The distribution of the load on the lifting points shall be taken to be as follows:
 - 1) One lifting point: the lifting point is exposed to the full load.
 - 2) Two lifting points: the load of each lifting point has to be determined according to the balance of moments.
 - 3) Three lifting points: the load of each lifting point has to be determined according to the balance of the moments and the forces. The vertical load on lifting points shall be determined in accordance with Figure 1 — which defines minimum values:
 - i) Area where symmetrical position of centre of gravity of the load can be assumed:
Vertical load on each lifting point = $F_D/2,3$;
 - ii) Area where unsymmetrical position of centre of gravity of the load applies and where it can be assumed:
Vertical load on each lifting point = $F_D/1,5$;
 - iii) An individual analysis is required.



Key

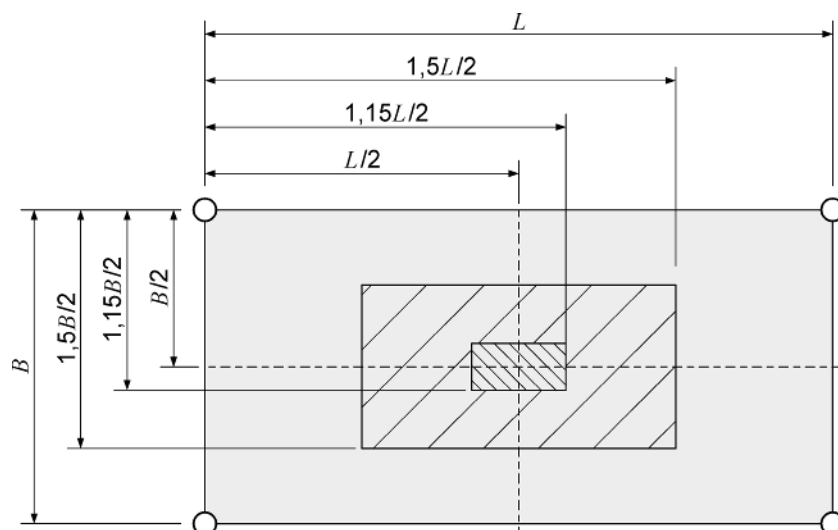
- position of the lifting points
- ▨ symmetrical position of centre of gravity: $F_D/2,3$
- ▧ unsymmetrical position of centre of gravity: $F_D/1,5$
- An individual analysis is necessary.

Figure 1 — Load distribution in the case of three lifting points

4) Four lifting points:

The load of each lifting point has to be determined according to the balance of the moments and the forces. The vertical load on lifting points shall be determined in accordance with Figure 2, which defines minimum values.

- i) Area where symmetrical position of centre of gravity of the load can be assumed:
Vertical load on each lifting point = $F_D/3$;
- ii) Area where unsymmetrical position of centre of gravity of the load applies and where it can be assumed:
Vertical load on each lifting point = $F_D/2$;
- iii) An individual analysis is required.



- position of the lifting points
-  symmetrical position of centre of gravity: $F_D/3$
-  unsymmetrical position of centre of gravity: $F_D/2$
-  An individual analysis is necessary.

Figure 2 — Load distribution in the case of four lifting points

- 5) More than four lifting points: no general statement can be made. An individual analysis is required.

5.2.5.4 Influence of direction of the forces acting on the lifting points

The foreseeable direction of the forces acting on the lifting points (angle of inclination (β) between vertical and the lifting accessories, see Figure 3) shall be taken into account.

The angle β affects the applied load with the load increasing as the angle β increases. Under the normal use of lifting accessories the angle β should not exceed 60° .

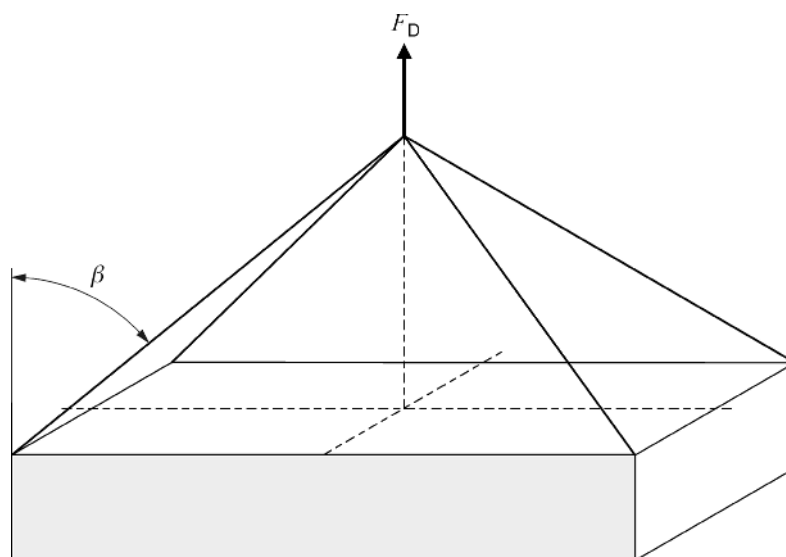


Figure 3 — Angle of inclination (β)

5.2.5.5 Safety factors

Lifting points shall be designed to withstand a load equal to the static safety factor (S_s)-times the static load. Lifting points shall be capable of bearing this load, however, permanent deformation or patent defect may occur.

The static safety-factor S_s equals:

- 4 for materials which are ductile at temperatures during lifting;
- 9 as a minimum for materials which are non-ductile at temperatures during lifting.

Lifting points shall be designed to withstand the dynamic load multiplied by S_D without permanent deformation.

The dynamic safety-factor S_D equals:

- 1,1 for materials which are ductile at temperatures during lifting;
- 9 as a minimum for materials which are non-ductile at temperatures during lifting.

5.2.5.6 Design consideration

In order to obtain a symmetrical load distribution in practice a minimum flexibility of the lifting devices is necessary. Uneven load distribution may occur by using very rigid lifting devices. This can be avoided by designing the lifting points (e.g. restricting size and shape of the lifting points) so that the use of lifting devices with excessive lifting capacities is prevented.

Some heavy components of the compressor or of the compressor unit may have lifting points in order to ease assembly. It shall be ensured that these component lifting points are not used as lifting points for lifting the assembled compressor or the compressor unit.

Possible measures are:

- design for removal or blinding of component lifting points after transport;
- limitation of the size of component lifting points so that only special lifting devices can be used;
- marking with special symbol (see Annex A, A.18) or giving written instructions (see 7.2.1.4 in this standard).

NOTE Bails, eyes and other lashing and lifting points exist as standardized components (see e.g. EN ISO 3266).

5.2.5.7 Lashing points

If lashing without specific lashing points will not be possible, the required lashing points shall be designed and incorporated in accordance with EN 12195-1.

The lashing points shall be designed to withstand S_1 -times the load according to EN 12195-1. Although lashing points shall withstand this load, permanent deformation or defects not affecting this requirement may occur. The safety-factor S_1 shall be taken as 3 for ductile materials (see EN 13155).

Lashing points shall be designed to withstand S_2 times the load according to EN 12195-1, where $S_2 = 2$ without permanent deformation (see EN 13155).

It shall be ensured that these lashing points are not used as lifting points. Possible measures are:

- design for removal or blinding of lashing points after transport;

- limitation of the size of lashing points so that only special lashing devices can be used;
- marking with special symbol (see Annex A, A.19) or giving written instructions (see 7.2.1.4 in this standard).

5.2.5.8 Portable and skid-mounted compressor units

a) *Off-road portable compressor units shall meet the following requirements:*

- 1) *for machines with a gross mass over 750 kg a parking brake system shall be fitted;*
- 2) *for machines with a gross mass less than 750 kg where a parking brake system is not fitted then 7.2.1.11 h) applies;*

NOTE *Portable compressor units used on-road are also subject to regulations related to motor vehicles and their trailers.*

b) *When the lifting of a compressor unit is required it should preferably have only one lifting point. The design of a lifting bail or bails shall be based on:*

- 1) *a minimum vertical load of 2,5 (worst case value according to EN 13001-2) times the machine gross mass in order to account for acceleration during the lifting;*
- 2) *any additional load due to unequal distribution of machine mass.*

c) *Lashing points for portable and skid mounted compressor units shall be provided to allow safe securing to a vehicle on which the compressor unit may be transported. Lashing points shall be marked according to Annex A, A.21.*

5.2.6 Slip, trip and fall

If access to elevated areas around a compressor is necessary and is an integral part of a compressor or compressor unit then these access areas shall be in accordance with EN ISO 12100:2010, 6.3.5.6.

Permanent means of access to working platforms, walkways, fixed ladders and stairways shall be in accordance with EN ISO 14122-1, EN ISO 14122-2, EN ISO 14122-3 and EN ISO 14122-4.

If access to elevated areas is required and is not an integral part of the compressor unit, an appropriate specification and installation instructions shall be given in the instruction handbook.

Supply and/or installation of working platforms and access to them by the user should be by formal agreement between the compressor manufacturer and the user.

5.2.7 Speed

5.2.7.1 Overspeed

Should the drive system be able to operate the compressor at speeds unacceptably higher than the maximum speed of the compressor, overspeed protection of the drive system shall be provided to avoid mechanical damage of the compressor or the compressor unit in order to protect persons and the environment.

The required performance level (PL) in accordance to EN ISO 13849-1 or safety integrity level (SIL) in accordance to EN 61508/EN 61511/EN 62061 of the safety related parts of the overspeed protection system shall be determined (for guidance, see Annex C).

5.2.7.2 Underspeed and critical speed ranges

NOTE Some components need certain rotational speeds for proper operation, for example:

If dry gas seals are operated at speeds lower than their allowable minimum speed wear is significantly increased.

If the normal operating speed range of the compressor/compressor unit is higher than the lateral or torsional natural frequency, lowering the rotational speed may result in running the compressor/compressor unit at critical speeds, which may lead to mechanical damage.

In some cases compressors may have critical speed ranges even within the overall operational speed range. These critical speed ranges are not suitable for continuous operation.

As operational times at such speeds shall be kept as low as possible, the instruction manual supplied with the compressor shall indicate procedures (e.g. start-up procedures) for avoiding excessive running within critical speed ranges (see 7.2.1.8 n)).

The required performance level (PL) in accordance to EN ISO 13849-1 or safety integrity level (SIL) in accordance to EN 61508/EN 61511/EN 62061 of the safety related parts of the underspeed protection system shall be determined (for guidance, see Annex C).

5.2.8 Loss of main energy supply or short term power interruption

NOTE Loss of main energy supply may lead to an uncontrolled situation, possibly resulting in a hazardous situation, e.g. reverse running of the compressor (see 5.2.8 in this standard), higher settle out pressure.

In case of loss of main energy supply the machine shall go into an automatic shutdown. In addition to automatic shutdown the pressure containing parts of the unit shall be either designed for settle out pressure or protected by safety relief devices relieving to a safe location, i.e. a place where the process gas cannot harm persons or environment (if applicable 5.8 shall apply).

Possible energy sources may be electric power, compressed air, steam, gas, hydraulic, etc.

Short term electric power interruptions may lead to a higher load on moving parts of the compressor unit such as couplings and gears. Possible measures to prevent damage are:

- monitoring the electric power grid and initiating an automatic emergency shutdown if the electric power interruption period is longer than acceptable;
- choice or design of the affected components such as couplings and gears for the expected load;
- consideration of torque limiting devices.

For further information, see 5.10.1 in this standard.

5.2.9 Reverse running of the compressor

NOTE Reverse running of the compressor can occur if the compressor is still connected to a pressurized system after each type of shutdown or after the loss of main energy supply (see 5.2.7 in this standard).

If reverse running of the compressor can lead to hazardous situations then suitable means to avoid reverse running shall be provided, e.g. non-return valve, brake.