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Gas turbine applications — Safety

Applications des turbines à gaz — Sécurité

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 192, *Gas turbines*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 399, *Gas Turbines applications*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This second edition cancels and replaces the first edition (ISO 21789:2009), which has been technically revised.

The main changes are as follows:

— modified to include required annexes for ISO version;

— general update to simplify text;

— updated all cross references.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document is a type-C standard as stated in ISO 12100:2010.

This document is of relevance, in particular, for the following stakeholder groups representing the market players with regard to machinery safety:

— machine manufacturers (small, medium and large enterprises);

— health and safety bodies (regulators, accident prevention organisations, market surveillance etc.)

Others can be affected by the level of machinery safety achieved with the means of the document by the above-mentioned stakeholder groups:

— machine users/employers (small, medium and large enterprises);

— machine users/employees (e.g. trade unions, organizations for people with special needs);

— service providers, e.g. for maintenance (small, medium and large enterprises);

— consumers (in case of machinery intended for use by consumers).

The above-mentioned stakeholder groups have been given the possibility to participate at the drafting process of this document.

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

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

Where local or national legislation accepts other established codes or standards, or an alternative international or national standard providing equivalent requirements for achieving risk reduction the use of these alternative codes or standards is permissible.

The extent of the applicability of the references may be limited by the context of the text within this document. Where a dated standard is specified this does not preclude the use of later versions provided that the requirements continue to meet the safety issues and identified hazards detailed in this document. Where a reference is made to a specific clause in a standard only the text of that clause and references therein apply.[1)]

1) References within NOTEs are provisions but not normative provisions of this document and are listed in the Bibliography.

Gas turbine applications — Safety

1 Scope

This document covers the safety requirements for aero derivative and industrial gas turbine prime mover applications using liquid or gaseous fuels and the safety related control and detection systems and essential auxiliaries for all types of open cycles (simple, combined, regenerative, reheat, etc.) used in onshore and offshore applications including floating production platforms.

This document applies to mechanical, electrical, and pressure equipment components and systems necessary for the functionality of the prime mover. For example, but not limited to, a core gas turbine auxiliary gearbox, an output transmission gear box, combustion system, air filtration, gas turbine controls, oil systems, and fuel system. This document also covers integration of safety risks within the overall installation, e.g. exhaust purging or drainage.

This document details the anticipated significant hazards associated with aero derivative and industrial gas turbine prime movers and specifies the appropriate preventative measures and processes for reduction or elimination of these hazards. This document addresses the risks of injury or death to humans and risks to the environment. Equipment damage without risk to humans or the environment is not covered.

The overall objective of this document is to ensure that equipment is designed, constructed, operated and maintained throughout its life in accordance with ISO 12100:2010.

This document approaches gas turbine safety from an international perspective based on the content of existing, recognized ISO and IEC standards to the greatest extent possible. Where no ISO or IEC standard exists, other codes or standards (such as EN, NFPA, etc.) have been included.

Minimum functional safety levels cannot be addressed in this document, as minimum functional safety levels are both application and site specific.

This document excludes the following items;

— exhaust-system structural design;

— driven equipment;

— micro turbines as covered by ISO 19372:2015;

— gas turbines used primarily for direct and indirect propulsion;

— gas turbines used for mobile applications;

— special heat source applications;

— gas turbines in research and development programs;

— compressed-air energy storage plants.

Where appropriate, this document can be used to give general guidance in such applications.

This document is not applicable to machinery or safety components manufactured before the date of its publication.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 1182:2020, *Reaction to fire tests for products — Non-combustibility test*

ISO 3977-1:1997, *Gas turbines — Procurement — Part 1: General introduction and definitions*

ISO 3977-3:2004, *Gas turbines — Procurement — Part 3: Design requirements*

ISO 3977-9:1999, *Gas turbines — Procurement — Part 9: Reliability, availability, maintainability and safety*

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

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

ISO 6184-4:1985, *Explosion protection systems — Part 4: Determination of efficacy of explosion suppression systems*

ISO 7010:2019, *Graphical symbols — Safety colours and safety signs — Registered safety signs*

ISO 9355-1:1999, *Ergonomic requirements for the design of displays and control actuators -Part 1: Human interactions with displays and control actuators*

ISO 10441:2007, *Petroleum, petrochemical and natural gas industries — Flexible couplings for mechanical power transmission — Special-purpose applications*

ISO 10494:2018, *Turbines and turbine sets — Measurement of emitted airborne noise — Engineering/survey method*

ISO 11086:1996, *Gas turbines — Vocabulary*

ISO 11925-2:2020, *Reaction to fire tests — Ignitability of products subjected to direct impingement of flame — Part 2: Single-flame source test*

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

ISO 12499:1999, *Industrial fans — Mechanical safety of fans — Guarding*

ISO 13732-1:2006, *Ergonomics of the thermal environment — Methods for the assessment of human responses to contact with surfaces — Part 1: Hot surfaces*

ISO 13732-3:2005, *Ergonomics of the thermal environment — Methods for the assessment of human responses to contact with surfaces — Part 3: Cold surfaces*

ISO 14118, *Safety of machinery — Prevention of unexpected start-up*

ISO 14120:2015, *Safety of machinery — Guards — General requirements for the design and construction of fixed and movable guards*

ISO 14122-1:2016, *Safety of machinery — Permanent means of access to machinery — Part 1: Choice of fixed means and general requirements of access*

ISO 14123-1:2015, *Safety of machinery — Reduction of risks to health resulting from hazardous substances emitted by machinery — Part 1: Principles and specifications for machinery manufacturers*

ISO 14691:2008, *Petroleum, petrochemical and natural gas industries — Flexible couplings for mechanical power transmission — General-purpose applications*

ISO 19353:2019, *Safety of machinery — Fire prevention and fire protection*

ISO/IEC 80079-20-1:2017, *Explosive atmospheres – Part 20-1: Material characteristics for gas and vapour classification – Test methods and data*

ISO 80079-36:2016, *Explosive atmospheres — Part 36: Non-electrical equipment for explosive atmospheres — Basic method and requirements*

ISO 80079-37:2016, *Explosive atmospheres — Part 37: Non-electrical equipment for explosive atmospheres — Non-electrical type of protection constructional safety "c", control of ignition sources "b", liquid immersion "k"*

IEC 60079-0:2017, *Explosive atmospheres — Part 0: Equipment — General requirements*

IEC 60079-10-1:2015, *Explosive atmospheres – Part 10-1: Classification of areas – Explosive gas atmospheres*

IEC 60079-13:2017, *Explosive atmospheres – Part 13: Equipment protection by pressurized room "p" and artificially ventilated room "v"*

IEC 60079-14:2013, *Explosive atmospheres — Part 14: Electrical installations design, selection and erection*

IEC 60079-17:2013, *Explosive atmospheres — Part 17: Electrical installations inspection and maintenance*

IEC 60079-29-1:2016+A1:2020, *Explosive atmospheres — Part 29-1: Gas detectors — Performance requirements of detectors for flammable gases*

IEC 60079-29-2:2015, *Explosive atmospheres — Part 29-2: Gas detectors — Selection, installation, use and maintenance of detectors for flammable gases and oxygen*

IEC 60079-32-2:2015, *Explosive atmospheres – Part 32-1: Electrostatics hazards - Tests*

IEC 60204-1:2016, *Safety of machinery — Electrical equipment of machines — Part 1: General requirements*

IEC 60204-11:2018, *Safety of machinery — Electrical equipment of machines — Part 11: Requirements for equipment for voltages above 1 000 V AC. or 1 500 V DC. and not exceeding 36 kV*

IEC 60529, *Degrees of protection provided by enclosures (IP Code)*

IEC 60695-1-10:2016, *Fire hazard testing – Part 1-10: Guidance for assessing the fire hazard of electrotechnical products – General guidelines*

IEC 60695-1-11:2014, *Fire hazard testing – Part 1-11: Guidance for assessing the fire hazard of electrotechnical products – Fire hazard assessment*

IEC TR 61000-5-1:1996, *Electromagnetic compatibility (EMC) — Part 5: Installation and mitigation guidelines — Section 1: General considerations — Basic EMC publication*

IEC TR 61000-5-2:1997, *Electromagnetic compatibility (EMC) — Part 5: Installation and mitigation guidelines — Section 2: Earthing and cabling*

IEC 61000-6-2:2016, *Electromagnetic compatibility (EMC) — Part 6-2: Generic standards - Immunity standard for industrial environments*

IEC 61000-6-4:2018, *Electromagnetic compatibility (EMC) — Part 6-4: Generic standards - Emission standard for industrial environments*

IEC 62305:2010 (all parts), *Protection against lightning*

IEC 62485-2:2010, *Safety requirements for secondary batteries and battery installations – Part 2: Stationary batteries*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 3977-1:1997, ISO 3977-3:2004, ISO 3977-9:1999, ISO 11086:1996, ISO 12100:2010 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
auto-ignition temperature
AIT
lowest temperature of a heated surface at which the ignition of a combustible substance in the form of gas or vapour mixture with air can occur

Note 1 to entry: AIT is also referred to as ignition temperature, minimum ignition temperature or self-ignition temperature (see 5.16.4.4).

3.2
drain valve
valve that is intended to remove liquids from a pipework system and that normally drains to atmospheric pressure

3.3
emergency shutdown
controlled and automated sequence of events to immediately cease the operation of the gas turbine and its associated equipment

EXAMPLE Isolation of the fuel supply to reduce the likelihood of an unsafe event from occurring, continuing, or escalating.

3.4
emergency stop
single human action to initiate an automated sequence of events to immediately cease the operation of the gas turbine and its associated equipment

3.5
shutdown
controlled sequence of events to cease the operation of the gas turbine and its associated equipment in an orderly fashion

Note 1 to entry: It can be initiated by human and non-human action. This is a normal stop.

3.6
extinction safety time
maximum allowable period of time between the direct or indirect detection of loss of combustion and cessation of the fuel supply

3.7
flow control valve
device used to control flow-rate

3.8
foreseeable lifetime
all phases of life of a part or a system, for example, but not limited to, construction, transportation, commissioning, use, operation, cleaning, troubleshooting, maintenance, decommissioning, dismantling, final disposal, etc.

3.9
ignition safety time
maximum allowable period of time between the opening of the fuel supply valve, which permits fuel to flow, and cessation of the fuel supply, in the absence of confirmation that combustion has commenced

3.10
interlock
interlocking device
mechanical, electrical or other type of device, the purpose of which is to prevent the operation of machine elements under specified conditions by an inhibit command that directly interrupts the energy supply or directly disconnects parts from the equipment, or is introduced into the control system so that interruption of the energy or disconnection of parts from the equipment is triggered by the control system

3.11
LFL
lower flammability limit
volume concentration of flammable gas or vapour in air, below which the mixture is not explosive

Note 1 to entry: Lower flammability limit (LFL) and lower explosive limit (LEL) are deemed to be equivalent terms.

3.12
operator
person or organization having responsibility for the operation of the equipment

3.13
OEM
original equipment manufacturer
person or company having design responsibility for the equipment or for parts of it

Note 1 to entry: This may be the manufacturer/*packager* (3.14) of the equipment.

3.14
packager
person or company having responsibility for integrating the technical aspects of the equipment and all auxiliary systems included in the scope of the supply

3.15
prime mover
gas turbine as a source of rotating force and heat designed to receive energy as supplied by a fuel source and apply the torque/heat to equipment

3.16
purchaser
person or company having authority to specify and to buy the equipment

Note 1 to entry: This, in some cases, may designate the *operator* (3.12).

3.17
relief valve
safety device (3.18) used for over-pressure protection and which does not operate under normal running conditions

3.18
safety device
all elements that are used to measure, limit or control safety relevant process variables, for processing safety relevant signals or for activation of automatic or manual safety related interventions

3.19
safety related system
systems/components whose primary failure is shown by the failure analysis as likely to cause a hazard and can require special measures in order to achieve an acceptable low probability of occurrence

3.20
spill valve
control valve that is intended to divert a portion of the liquids during normal running conditions

3.21
valve pressure proving
system that checks the effective closure of automatic shut-off valves by detecting leakage

3.22
vent
opening intended to discharge gases, fumes or mists except the exhaust gas of the gas turbine, the latter being called the exhaust system

4 List of significant hazards

Hazards and the associated hazardous situations have been identified utilizing the procedure defined in ISO 12100:2010, 5.4. The results have been documented in Annex A, Table A.1 for subsequent use in risk assessments to define the protective measures and associated references in the text of this document.

5 Safety requirements

5.1 General

The overall objective of the safety requirements is to ensure that equipment is designed, constructed, operated and maintained throughout its life to attain an appropriate level of safety for its intended application.

Each risk assessment shall consider all reasonably foreseeable operating conditions in the design of the equipment.

Machinery and its associated equipment shall comply with the safety requirements and/or protective measures of this document. In addition, the machine shall be designed according to the principles of ISO 12100:2010 for relevant but not significant hazards, which are not dealt with by this document.

The content of this document shall not prejudice technical advances in the field of gas turbine safety or be used to inhibit innovation that can lead to increased safety.

5.2 Risk assessment

Risk assessments have been undertaken for the hazards identified by Clause 4 and detailed in Annex A in accordance with the principles defined in ISO 12100:2010, Clause 5. The resulting protective measures and the associated clauses of this document have been listed in Annex A, Table A.1. The applicable verification actions for the protective measures are listed in Annex B, Table B.1.

The criteria for protective measures comprise:

— references to applicable standards;

— definition of specific requirements; and

— further risk reduction or a combination of the criteria;

as applicable to comply with the requirements of 5.2.1.

The results of assessments and the criteria used shall be documented.

Other methods can be used in addition to the principles of ISO 12100:2010 to resolve risks. Possible methods are provided in standards such as IEC 60812:2018 (FMEA), IEC 61025:2006 (Fault tree) and IEC 61882:2016 (HAZOP).

The assessment process shall eliminate the hazard or reduce the risk associated with the hazard by applying the criteria defined in the relevant clauses of the standard, in the order given below:

— design for safety with passive protection measures;

— apply active protective measures;

— communicate the information covering any residual risk.

Reliance on risk assessment for the selection of protective measures, to supplement the specific protective measures defined in Clauses 5, 6 and 7, is essential.

The design of gas turbine equipment shall take into account:

— the variations in the applied protective measures necessary to accommodate individual site conditions;

— the need to relate protective measures to hazards arising from reasonably foreseeable operations carried out on site;

— the need to have options in the selection of measures to control risk.

The criteria identified in the clauses of this document may not identify every possible risk due to the different approaches taken by manufacturers. To ensure that safety is not compromised, additional measures shall be considered, where necessary, to achieve the requirements of 5.2.1.

Requirements for functional safety are defined in 5.20 and these identify the significant risks applicable to functional safety from Table A.1. Where risk reduction measures are undertaken, it is essential to ensure that additional measures do not introduce additional hazards.

Operation and maintenance requirements shall ensure that the levels of risk are maintained to comply with 5.2.1

In the event that subsequent analysis or experience identifies additional risks with the design, affected equipment shall be identified and communicated in accordance with Clause 7.

5.2.1 Risk assessments requirements

For hazards identified, risk assessments covering the gas turbine(s) and the associated equipment shall be performed. A quantitative or a qualitative risk assessment method shall be applied.

For qualitative risk assessments care shall be taken to ensure that the factors and parameters used for risk assessment are clearly defined so that objective judgements can be made, and that the values used for each parameter are appropriately calibrated, where applicable, to ensure that they are valid for the assessment being undertaken.

For quantitative risk assessments, evaluate each hazard to ensure measures comply in achieving a maximum tolerable risk of fatality for a specific individual of 10^{-3} per year (individual risk level for employees) and 10^{-4} (public) shall be considered. The broadly acceptable level of individual risk is set at 10^{-6} per year.

NOTE 1 For additional guidance on these values and how to apply them, see Reference [72].

NOTE 2 These are meant to be valid and verified values when performing quantitative risk assessment. As such a significant level of conservatism is applied to predicted likelihood. Confidence levels, occupancy and avoidance and limits on risk reduction from protection layers will limit how low a risk likelihood can be predicted. Based on broad industry experience, the actual achieved risk level is expected to be significantly lower.