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Gas turbine applications — Safety

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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.

5.2.2 As low as reasonably practical

During risk assessment, consider applying as low as reasonably practicable (ALARP) consideration, in accordance with local criteria.

5.3 Modifications and replacement parts

All modifications and updates/upgrades to protection systems and safety relevant components shall be assessed to comply with 5.2.1. Replacements of components beyond the requirements of normal maintenance as well as modifications and upgrades of equipment to newer technology shall be assessed to comply with 5.2.1.

An assessment to ensure that no additional hazardous situations are introduced shall be undertaken.

The replacement of protection system parts and/or equipment which become obsolete shall be considered as part of a normal maintenance activity provided the parts or equipment replaced are validated to comply with the original specification, performances and safety requirements.

5.4 Foreseeable misuse

Equipment and protective systems shall be designed and manufactured after due analysis of possible operating faults to preclude hazardous situations due to the consequences of reasonably foreseeable misuse.

5.5 Lifetime

Safety related systems/components shall be designed/selected to operate within defined limits for the planned lifetime of the equipment when maintained in accordance with the manufacturer's instructions and operated with in the allowable limits defined by the manufacturer. The planned lifetime and maintenance instructions shall be documented in the maintenance and operating manual.

Where the design life of components is less than the planned lifetime, they shall be subject to replacement at planned intervals.

5.6 Hazard combinations

Where the potential exists for gases, vapours, mists and liquids to mix and cause a hazardous situation or affect the operation of a safety device, appropriate measures shall be taken to mitigate risks.

Where fuel lines are purged or cooled by auxiliary media the risks associated with reverse flow and the discharges of mixtures shall be assessed and appropriate mitigation measures taken.

Where additives are used to enhance the properties of a given medium, a check shall be undertaken to ensure a hazardous situation is not created in the gas turbine or any associated equipment.

5.7 Noise reduction at design stage

When designing the gas turbine and its systems, the available information and technical measures to control noise at the source shall be taken into account. The main sources of airborne noise include but are not limited to: the gas turbine itself; air intake and filter cleaning system; exhaust system; pressurized and relief systems; drains, auxiliary motors and pumps. Noise reduction measures may include but are not limited to the use of an enclosure, silencers, baffles, or other sound attenuation. Sound pressure emission may be assessed with reference to comparative emission data for similar machinery.

Verification of the gas turbine sound pressure level shall be in accordance with ISO 10494:2018. This can be performed at various locations as deemed appropriate or by agreement. Locations may include place of manufacture, at site during commissioning, or at another location.

NOTE 1 ISO/TR 11688-1:1995 provides general specifications for the reduction of noise emissions generated by machinery and methods for comparing the noise emission data of similar machinery.

NOTE 2 ISO 11689:1996 provides guidance for the comparison of noise-emission data for machinery.

5.8 Mechanical

5.8.1 Guarding

5.8.1.1 General

Fixed guards shall be provided in accordance with ISO 14120:2015, against the mechanical hazards described in ISO 12100:2010.

Where an enclosure, with controlled access, acts as a guard against moving mechanisms and hot surfaces the entry points shall have signs warning against the potential hazards.

5.8.1.2 Hot or cold surfaces

Equipment shall be designed so as to minimize the risk of burn injury caused by contact with or proximity to surfaces at high or low temperatures.

This can be achieved when the surface temperatures for incidental contact for a given material/finish do not exceed the burn threshold for a minimum contact period of 1 s. Where the threshold temperature is exceeded on normally accessible surfaces, appropriate guarding, barriers or other suitable measures shall be implemented to remove the potential for burns. On surfaces not normally accessed, warning sign(s) shall be posted at a clearly visible location in the vicinity.

Typical 1 s burn threshold levels are 70 °C for uncoated metal, 80 °C for coated metal and 85 °C for glass. ISO 13732-1:2006 and ISO 13732-3:2005 shall be used to determine if a potential risk of a burn is present.

For deliberate contact surfaces (e.g. manual valves and door handles), means shall be provided to ensure that the surface temperatures do not exceed the burn threshold for a contact time of 10 s.

Where personal injury can be caused by artificially cold surfaces created as a result of the operation of the equipment, protection measures shall be implemented, or signs shall be displayed in the vicinity warning of the hazard.

5.8.1.3 Sharp edges

The equipment design shall avoid sharp edges and corners, protruding parts: in so far as their purpose allows, accessible parts of the machinery shall have no sharp edges, no sharp angles, no rough surfaces, no protruding parts likely to cause injury, and no openings which can “trap” parts of the body or clothing. In particular, sheet metal edges shall be deburred, flanged or trimmed, and open ends of tubes which can cause a “trap” shall be capped or a guard used.

5.8.2 Accessibility for maintenance

Permanent means of access to machinery shall meet ISO 14122-1:2016.

Machinery should be so designed as to enable operation and all routine tasks relating to setting and/or maintenance to be carried out as far as possible by a person remaining at ground level.

Where this is not possible, machines shall have built-in platforms, stairs or other facilities to provide safe access for those tasks.

The walking areas shall be made from materials which remain as slip resistant as practicable under working conditions.

Means of access to parts of machinery located at height shall be provided with means of protection against falls (for example, guard-rails for stairways, stepladders and platforms and/or safety cages for ladders, anchorage points for personal protective equipment against falls from height).

Where access provisions are not available for non-operational maintenance, temporary access provisions shall be used.

Positioning of safety equipment and warning signs shall be considered in the design phase to reduce the chance of injury during maintenance activities.

Interlocking of safety equipment with the control system shall be considered as required by the risk assessments.

Where practicable, structural members or permanently installed equipment shall not visually or physically obstruct adjustment, servicing, removal of replaceable equipment or other required maintenance tasks.

5.8.3 Casing design

Casings shall be designed to withstand the maximum foreseeable loads including transient and abnormal operating conditions (e.g. gas turbine compressor surge) without leading to a failure of the casing itself or its flanges. Hot air leakage that can cause damage or potential injuries shall be prevented.

Casings shall be designed, or suitable guarding shall be provided to contain a blade-off event and the subsequent consequential damage. Casings are not required to be designed to contain a disc burst or overhang failure (see 5.8.15).

Non-destructive testing, non-destructive examination or pressure testing techniques shall be used to ensure the integrity of the casing under all defined design conditions.

5.8.4 Gas turbine compressor surge

In the event of a surge, the forces, deflections and consequences of flame reversal shall be mitigated.

5.8.5 Stability and handling

Bearing supports, casings and, if used, base frames shall be mounted in their environment in a manner such that they remain in their intended position.

Where equipment is not suitable for manual handling, lifting arrangements shall be designed to transfer the load of the gas turbines or components smoothly from the normal supports to a resting place in a controlled manner, taking into account dynamic and overturning loadings.

Where machinery is being moved that could, due to its own weight, lack of stability or the conditions under which the operation is being undertaken, create a crushing force causing injury, maintenance equipment shall be used that applies restraints to ensure that the potential for crushing is mitigated.

Where machinery or one of its component parts is to be moved by hand, it shall be easily movable, or be equipped for picking up and moving. Special arrangements shall be made for the handling of tools and/or machinery parts which, even if lightweight, could be hazardous.

Lifting attachments are those that are part of the machine or component being handled. Lifting attachments should be designed to a recognized code and in accordance with its specified design criteria.

Lifting accessories and machinery shall comply with a recognised standard applicable to the equipment and its use and shall be appropriately tested, marked and where applicable certificated. Fixed or non-fixed lifting attachments shall take into account the factors relating to dynamic effects.

NOTE 1 Lifting accessories are those items that exist between the attachment and the lifting hook of the machinery.

NOTE 2 Lifting machinery is the machine that moves the load.

NOTE 3 Be aware of local requirements which change extensively worldwide regarding lifting attachments, accessories and machinery. Exported lifting equipment can need to comply with several different sets of regulations.

5.8.6 Overload of couplings, rotating shafts and gears due to torque

Where there is the potential for faults in the driven machinery (e.g. short circuits) that can cause an overtorque greater than the specified design limits in the couplings, equipment drive shafts or the associated gas turbine rotor, a torque-limiting device shall be provided to prevent such overtorque.

If torque limiting devices are used for controlling this risk, the activation of such devices shall not lead to a hazardous situation. If activation of the torque limiting device will result in that rotor parts run over their critical speed, requirement as per 5.8.15.3 shall be considered.

5.8.7 Vibration

Where vibration levels in the drive shaft line/train can escalate to excessive levels resulting in the potential for hazardous situations, vibration monitoring equipment shall be installed to continuously monitor and initiate appropriate action (e.g. shutdown).

5.8.8 Mechanical failure caused by corrosion

Mechanical properties of stressed or vibrating materials (e.g. rotors and piping) can be significantly affected by corrosion which can reduce the fatigue limit, promote stress corrosion cracking and stress accelerated grain boundary oxidation. Special consideration shall be taken to address hazards caused by these factors. (See also material embrittlement in 5.23.12.)

5.8.9 Design methods and materials

Gas turbines shall be designed so that, when operated and maintained, as per manufacturer's instructions, the potential for failures that result in the release of high-energy debris, rupture of pressure casings or the release of hot, flammable or toxic gases are mitigated to comply with the requirements for the lifetime of the machinery.

The selection and use of materials for the safety related parts of the gas turbine and its related systems shall be based on validated material data and validated design techniques. The selection shall consider the effects of material property deterioration due to manufacturing processes, environmental or operational causes. See also 5.23.13.

Where the use of titanium or magnesium-based alloys creates a fire risk, measures to mitigate a hazardous situation or extinguish such a fire shall be taken.

Components that can fail and cause a hazardous situation shall be identified and made traceable for quality control purposes, such components should be avoided or submitted to a specific inspection and maintenance program to ensure that such a failure will be avoided.

The soundness of critical rotating components shall be confirmed by non-destructive testing combined with a fracture mechanics assessment, to indicate that the flaws present no risk at the acceptance limit. Analysis based on material tests shall be utilized to ensure that the parts can operate within the limitations of the materials used and the applied loads over the range of operating conditions and speeds during their foreseeable lifetime. The analysis shall at least take into account the risks of crack growth, elastoplastic deformation, creep, corrosion and fatigue failure, where applicable.

If the failure of a driven equipment rotor has a direct effect on the safety of the gas turbine, the soundness of rotor materials shall be confirmed.

Materials of construction and methods of use shall be such as not to cause effects on human health or the environment over the life cycle of the gas turbine system and its components.

5.8.10 Gas turbine temperatures

Automated protective measures shall be implemented to prevent a hazardous situation due to internal gas turbine over temperature.

5.8.11 Environmental loads

Machinery, support and enclosure structures, and associated auxiliary piping and ducting, shall be designed to withstand a combination of loads caused by site winds, snow, ice, seismic activity and ambient temperatures without causing structural collapse or other hazardous situations. The design shall consider the wind speed, snowfall and ice accumulation rates, seismic accelerations and temperature conditions to be used.

NOTE Local codes and standards can often dictate the environmental conditions.

For floating production storage and offloading vessels (FPSO) and floating production units (FPU) applications account shall be taken of the pitch and roll angles and acceleration forces generated by the vessel during operation and maintenance.

5.8.12 Assembly features

Gas turbine components whose correct assembly is safety related shall be protected from incorrect assembly, and this at any point in their lifecycle.

NOTE Typical protection from incorrect assembly can include special features (poka-yoke), distinctive markings, etc.

5.8.13 Couplings

Flexible couplings external to the gas turbine core used to transmit the gas turbine output power shall take account of the design requirements of ISO 14691:2008 or ISO 10441:2007 according to the rotating speed and the application.

5.8.14 Rotor bearings

Bearing design shall take into account the resulting effects and risks of the off balance of a spinning rotor due to the potential for the loss of gas turbine compressor blades and/or turbine blades to ensure that hazardous conditions (uncontained failure, breached pressure casing, fire) do not happen. Protective measures shall be taken to prevent the hazards of lube oil loss, fire, and explosion of lube oil vapour or mist (within and around the bearing compartment). Fire protection shall be considered if high temperature surfaces that can ignite the lube oil exist in proximity to the bearing and lubricating oil. See 5.15.

5.8.15 Rotating part failure

5.8.15.1 General

All gas turbine compressor and turbine rotating parts that may generate a hazard in case of failure shall be designed for the conditions and stresses that they encounter during start-up, running, transient, emergency shutdown, or emergency stop conditions.

5.8.15.2 Rotor and disc failure

Due to the large amount of energy contained in the rotating components of a gas turbine, rotor or disc failure cannot always be contained. Therefore, the containment risks related to overspeed shall be mitigated to achieve the requirements of 5.2.1 by active measures.

Active measures shall include an overspeed protection system, according to 5.20.7.

Passive measures may also be employed to further reduce the level of risk but shall not be the primary method used to meet 5.2.1.

NOTE Passive measures can include a limitation of the speed to values below rotor failure speed by one or a combination of the following measures such as:

a) prevention of further rotor acceleration by loss of blades due to centrifugal load, burning out or other effects;

b) limitation of the speed at highest fuel flow due to aerodynamic effects in the blading of gas turbine compressor and turbine.

5.8.15.3 Overhanging rotor parts

If overhanging rotor parts operate above their critical speed related to the first bending mode, calculations and test running on a prototype shall demonstrate that no hazardous vibration levels are reached.

5.8.16 Foreign object damage (FOD) screen

If there is a possibility of foreign objects entering the gas turbine and causing loss of containment of rotating parts, a FOD screen shall be installed at the machine inlet to reduce the size of objects that can enter to that which is unlikely to cause such a failure. Where utilized, the location of the screen shall be sufficiently upstream to avoid the potential for large objects to cause significant localized flow blockage that can induce blade failure.

5.8.17 Gearbox

The gearbox shall be designed and produced according to recognized standards taking into consideration the safety risk associated with wheel/pinion explosions and oil evacuation under all operating conditions during the product life cycle.

NOTE 1 For high speed gears, reference can be made to ISO 13691:2001, API 613:2003 or AGMA 6011:2014.

NOTE 2 For epicyclic gears, reference can be made to the general guidelines in AGMA 6123:2016.

NOTE 3 Problems with oil evacuation can lead to fire or explosions.

5.8.18 Starting systems

The starting system shall be suitable for the acceleration of the gas turbine and, where appropriate, driven equipment and for extended operation during purge and gas turbine compressor cleaning cycles. Failure to accelerate at the correct rate can lead to hazardous situations not covered by other controls, for example, flame or temperature monitoring, therefore, the speed shall be monitored and hazardous deviations shall automatically shut down the gas turbine.

Starter systems (including gas pressurized or internal combustion engine driven systems) shall be protected by design or by the use of additional controls against overspeed conditions.

Where electric starter motors are intended to operate above their continuous rating, controls shall be provided to ensure that hazardous over-temperatures do not arise.

If starting systems using pressurized flammable gas as the source of power are used, they shall be designed to prevent associated fire and explosion hazards. The gas supply shall be isolated effectively when the starter is not in use to the same level of isolation as the turbine gas fuel supply (see 5.10.5). Means shall be provided to enable gas to be purged from the starter system for maintenance purposes. Where the gas starter is not vented separately to atmosphere, precautions shall be implemented to prevent over pressure and reverse flow to the starter motor (see 5.22.2).

For safety and environmental reasons, the use of pressurized flammable gas starting systems is not recommended.

A filter/strainer shall be fitted in the supply to gas driven starter systems. It shall prevent any contaminants that can cause damage to the motor, leading to premature failure with the potential for loss of containment and/or ignition, from entering the motor or system components. The dew point of any gas supply shall be such that the formation of liquid hydrocarbons which can cause a motor malfunction or a hazardous situation at the vent discharge is eliminated.

Where due to the type of starter motor used there is the potential for the motor rotor to fail due to over speed, before the over speed is detected, with the potential for the release of high-energy debris the starter motor casing shall be capable of containing the release of such debris. If this capability does not exist, then an enclosure shall be provided covering the starter motor and access within the enclosure during starting shall be prohibited.

For starting systems having common starting capabilities for multiple units, proper electrical and mechanical interlocks shall be provided and tested prior to commissioning in order to avoid starting the wrong gas turbine.

5.8.19 Low ambient temperature conditions

Where low ambient temperatures can exist during storage, transportation, handling, start-up and/or running conditions, which have the potential for causing premature failure of equipment and/or brittle fracture of structures, appropriate materials shall be used, or protective measures shall be taken to prevent a hazardous situation.

Precautions shall be taken to prevent premature failure of the gas turbine compressor components that can be subject to malfunction caused by low inlet air temperature conditions.

5.9 Gas turbine compressor air inlet system

5.9.1 General

The air inlet system shall be designed to withstand pressure changes due to foreseeable turbine compressor surge events, without causing a hazardous situation.

5.9.2 Inlet air contamination

An air inlet filtration shall be provided which minimizes the entry of atmospheric contaminants, airborne contaminants from adjacent plant and saliferous atmospheres, where necessary, that can lead to premature failure of gas turbine components, creating a hazardous situation.

5.9.3 Icing monitoring and prevention

Where site conditions of temperature and humidity can be foreseen to cause icing at the gas turbine compressor inlet system, appropriate measures shall be taken to prevent ice accumulation that can present a hazardous situation. Additional controls can be applied to initiate a shutdown before a hazardous situation is created. Where the measures for preventing inlet icing become inoperable and the gas turbine system is operating in the range of temperature and humidity where ice in the compressor inlet can form that may lead to hazardous situation. Where compressor bleed anti-icing systems distribute hot air over the inlet openings or in the inlet duct, access shall be restricted in the vicinity of the hot air outlets during operation of the system.

Monitoring instrumentation shall be installed in such a manner that icing conditions shall not adversely affect the accuracy of the monitoring method. Instrumentation piping shall be routed so that inclusion of atmospheric condensates is prevented.

Where an evaporative cooling system or a direct water mist system is used at the gas turbine compressor inlet, the water supply shall be shut-off when air temperature monitoring at the gas turbine compressor inlet indicates that conditions exist for ice formation, which can lead to a hazardous condition.

Where either on or offline water wash is installed, appropriate precautions shall be taken to prevent the formation of ice. Such precautions may include the use of a suitable anti-freeze agent (see 5.24.2 and 7.5.2).

5.9.4 Implosion protection

Implosion protection can be achieved using different methods, e.g. instrumentation and control actions or implosion doors.

Where an implosion door is provided in the inlet system, suitable measures shall be taken:

- to prevent foreign object ingress at the implosion door, which, due to the size of the object, could cause a hazardous situation;
- to ensure that the implosion door cannot become frozen shut where its failure to operate can cause a hazardous situation;
- to shut down the gas turbine when the implosion door is opened.

5.9.5 Inlet explosion protection

The combustion air intake shall not be located in a zone 0 or zone 1 area (see 5.16.2). Location in a zone 2 area shall be considered acceptable only where the largest foreseeable leak from a secondary source would be diluted to such an extent by the combustion air that a hazardous situation would not arise.

The manufacturer shall advise on the risk of flammable substances ingestion to the gas turbine inlet related to an unlimited release during an abnormal event from another site equipment.

NOTE 1 Uncontrolled ingestion of flammable substances can result in engine damage due to overspeed and/or over temperature.

Gas detector(s) to initiate a gas turbine emergency shutdown shall be located at the gas turbine compressor air inlet where a zone 2 area exists from a credible leak, as described above, or where there is still the potential for flammable gases or vapours to enter the gas turbine compressor air inlet from either:

a) adjacent plant, should there be an uncontrolled event or major incident; or

b) the atmosphere, due to excessive venting or similar uncontrolled conditions [e.g. in natural gas or liquefied petroleum gas (LPG) plants]; or

c) ingestion of unburnt flue gas.

Where such risks exist, gas detector(s) and any other equipment located in the combustion air stream shall be suitably certified and marked for use in the zoned area.

Gas detectors and associated alarm systems shall comply with 5.19 and be selected taking into account the speed of escalation of any reasonably foreseeable leak source, the response rate of the detector(s), the system time constants and any other relevant factors.

NOTE 2 Risk assessment in the form of HAZOP/HAZID is a recognized means of ensuring adequate requirements specifications.

5.9.6 Waste disposal through combustion

In some applications the combustion inlet air may be deliberately mixed with waste flammable gases, vapours or aerosols to eliminate such substances from the environment. The supply of the waste products shall be controlled and shut-off during the gas turbine start-up cycle and prior to shutdown. The allowable flow rate and concentration of the waste flammable gases, vapours or aerosols prior to mixing with the combustion air flow, shall be monitored, controlled, tested and verified to stay within limits. If the flow rate or concentration exceed the defined levels, the supply shall be terminated or diverted to vent to atmosphere.

The temperature and pressure of the combustion process (within the chamber) shall be monitored and controlled to stay within limits. The monitoring is not limited to direct measurement, assumption from other measurement values may be applied.

Where this disposal process is adopted, suitable gas detector(s) shall be installed at the gas turbine compressor air inlet as an additional precaution to detect and initiate a shutdown or emergency shutdown of the gas turbine in the event of an unacceptable concentration of flammable hydrocarbons. Gas detector(s) shall comply with 5.19 and be selected taking into account the speed of escalation of the flammable content of the waste stream, the detector response rate, the system time constants and any other relevant factors.

5.9.7 Recirculation

If ventilation outlet air from the gas turbine enclosure is used for anti-icing at the gas turbine compressor air inlet there is the risk that a potentially explosive mixture of fuel and air can be ingested into the gas turbine if there is a fuel leak within the gas turbine enclosure.

Where this risk exists, the following safety precautions shall be taken, or the air shall be heated by other means (e.g. indirectly):

a) gas detector(s) shall be located in the gas turbine compressor air inlet downstream of the injection point or in the gas turbine enclosure ventilation-air outlet ensuring sufficient protection is provided; and

b) all equipment within the ventilation air and combustion inlet air flows shall comply with 5.16 for use in zone 2; and

c) all surface temperatures within the ventilation and combustion inlet air flows shall not exceed the AIT of any flammable substances that may be present (see 5.16.4.4); and

d) the gas detector(s) and associated safety systems response times shall prevent a potentially explosive mixture from reaching the anti-icing outlet within the gas turbine compressor air-inlet based on a sudden fuel leak within the enclosure at the minimum ventilation flow rate.

Where gas turbine compressor bleed air is piped to the gas turbine compressor inlet system to control exhaust emissions during operation under partial load, the take-off point, controls and piping design shall prevent excess flow occurring, the accumulation of unburnt hydrocarbons and the potential for burnt/unburnt products of combustion entering the inlet and causing a hazardous situation on flameout or gas turbine compressor surge.

5.9.8 Gas turbine compressor air inlet ducting

The gas turbine compressor air inlet ducting shall normally be routed to avoid hazardous areas. Where this is not possible, the ducting integrity shall prevent leakage paths.

5.10 Fuel systems

5.10.1 General

The fuel system shall be considered to include all components from the manually operable shut-off valve up to and including the burners. The most common fuels used by gas turbine applications within the scope of this document are natural gas and liquid fuels. However, a wide range of alternative fuels can be used and others are under consideration or trial. Design and construction shall take the relevant properties of the fuel into account including AIT, viscosity, lubricity, vapour pressure, toxicity, pour point and any other reasonably foreseeable properties that could create a hazardous situation.

NOTE For further information see IEC 60079-10-1:2015 and ISO/IEC 80079-20-1:2017.

5.10.2 Fuel supply quality and supply conditions

Manufacturers shall provide detailed fuel specifications for which the gas turbine is designed (including dew point margins for gaseous fuels and potential for wax formation) and condition ranges required for reliable operation of their machines. When the fuel does not comply with the detailed fuel specification a fuel analysis (including up to C_{12} for gas fuels) shall be provided so that the manufacturer can specify the specific fuel treatment necessary to mitigate any associated risks. Treatment may include varying degrees of pressure and flow control, filtration, condensate removal or heating of the fuel supply.

Particular attention shall be given to the dew points and release of liquid hydrocarbons or water for gas fuels, and to wax formation at low temperatures for liquid fuels.

Attention shall also be given to any trace element content that can compromise metallurgical properties.

5.10.3 Pressure (leakage) testing

Where it is not practical to conduct a final assembly pneumatic or hydrostatic pressure test on the piping connected to the combustion system, a procedure shall be specified to check for leaks on the running gas turbine and shall be included in the information for use. The procedure shall take into consideration the potential hazards to personnel during operational testing.

5.10.4 Fuel supply heating

Electrically powered heaters or any alternative means shall be assessed for safety for use with the proposed fuel specification. Overheat protection shall be provided to ensure that excessive heat input to the fuel cannot occur.

Where heat exchangers use fluid media as the heat input, and fuel leakage followed by entrainment into the media can cause a hazardous situation, protective measures shall be taken. The potential for such leakage shall be minimized by detailed design.

Flame fired direct heating shall not be used. Where trace heating or comparable means are used, the design shall self-limit the temperature, or control thermostats shall be used.

NOTE Electrical heater designs are covered by IEC 60079-30-1:2015 and IEC 60079-30-2:2015.

5.10.5 Gas fuel systems

5.10.5.1 General

As a minimum, each gas fuel supply shall include the following functions:

a) manual isolation (see 5.10.5.2);

b) safety shut-off (see 5.10.5.4);

c) automatic fast acting shut-off (see 5.10.5.4);

d) flow control (see 5.10.5.3);

e) venting for depressurization between safety shut-off valve and automatic fast acting shut-off valves (see 5.10.5.4); and

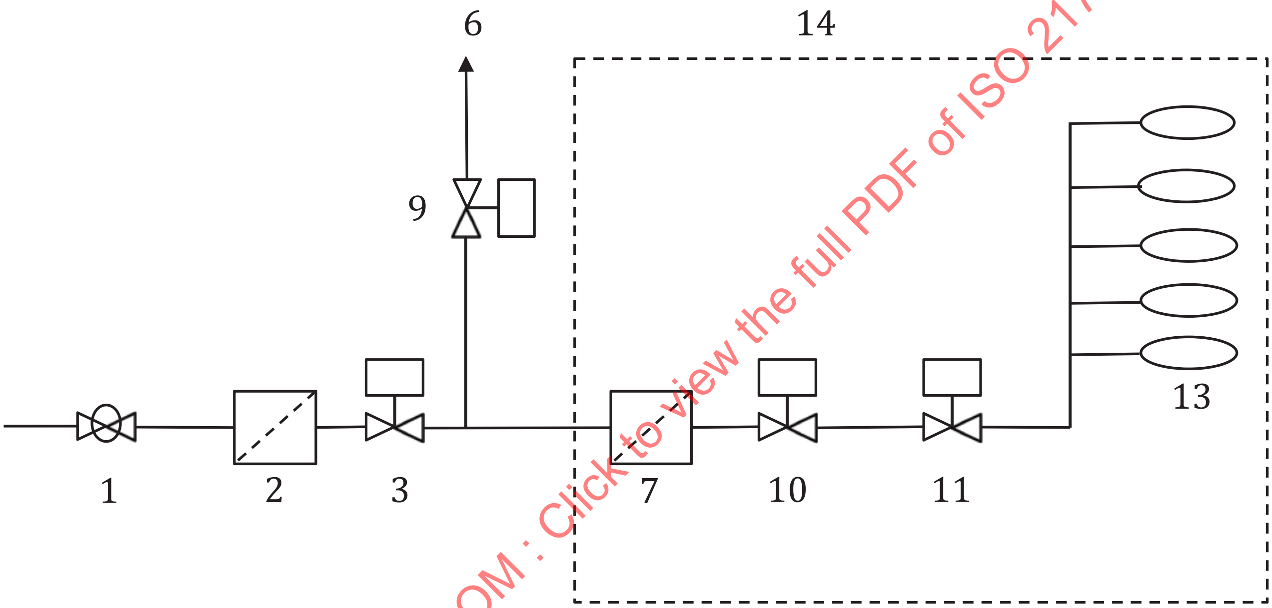
f) venting for pipework depressurization (see 5.10.5.4 or 5.10.5.5).

Where the gas fuel supply system comprises more than one supply or a single supply is divided for multiple use, equipment in each supply shall be duplicated such that the individual supplies comply with 5.10.5.

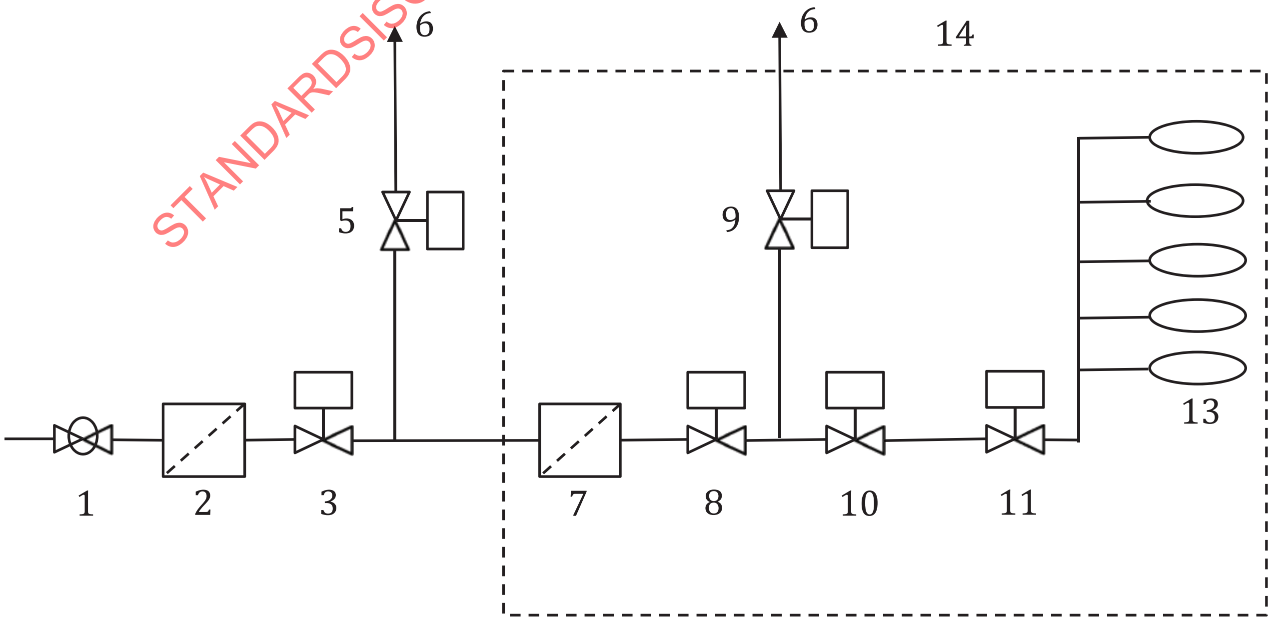
A strainer shall be fitted in accordance with 5.10.5.6 where necessary for operation.

Figure 1 a) shows the minimum arrangement and indicates the operation of the valves. Figure 1 b) and c) show typical alternative arrangements.

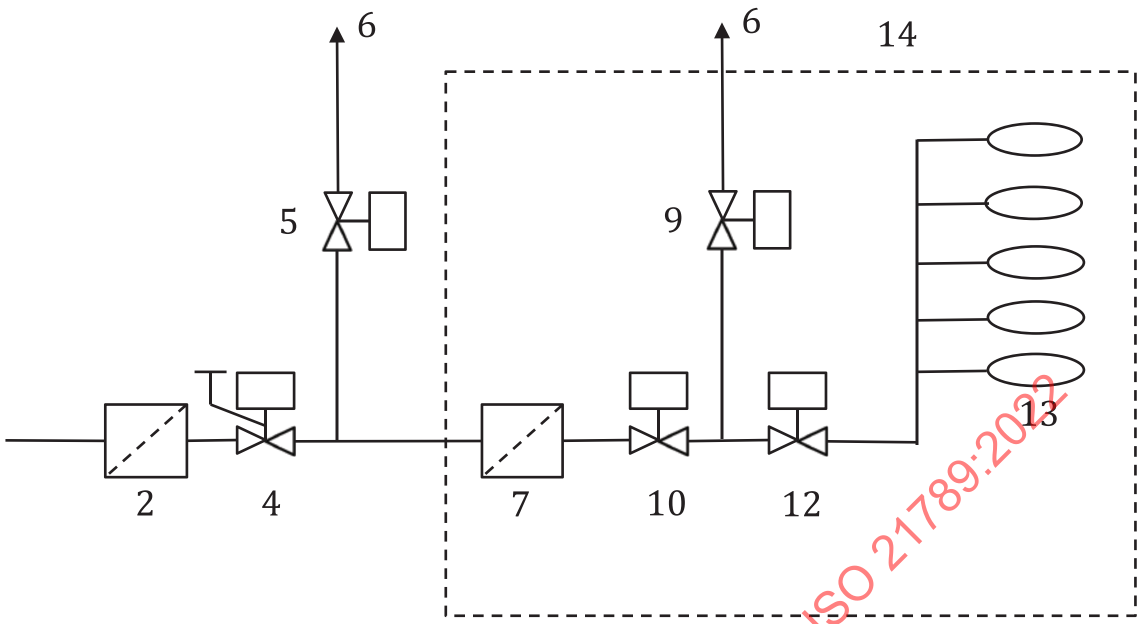
NOTE 1 National regulations can require certification of safety shut-off valves and vent valves.



a) Minimum arrangement



b) Typical alternative arrangement



c) Typical alternative arrangement

Key

1 manual isolation valve
2 strainer, optional position
3 shut-off valve
4 shut-off valve and manual isolation valve
5 vent valve
6 vent
7 strainer, optional position
8 shut-off valve [a]
9 vent valve [b]
10 automatic fast acting safety shut-off valve [a]
11 flow control valve
12 flow control and shut-off valve [a]
13 combustion system
14 typical gas turbine enclosure or building limits

[a] Close on every shutdown.
[b] Vent on every shutdown.

Figure 1 — Gas fuel system

Safety shut-off valves shall fail closed by permanent available energy, e.g. spring force. The fail-safe status of vent valves shall minimize any hazards. All valves shall be specified such that reliable operation is maintained.

Automatic shut-off valves shall not be energized to open until the associated downstream vent valve has been proved closed.

Vent valves and associated pipework shall be sized to ensure that the depressurized pipe remains at atmospheric pressure taking into account the potential for leakage in upstream valves.

Different arrangements and combinations of devices may be utilized to fulfil the above functions provided the concepts described in 5.10.5 are achieved and the fuel can be shut-off at a rate that prevents failure of the gas turbine, and the possibility of fuel entering the gas turbine in its shutdown condition is eliminated.

See 5.11.2 relating to fuel control during ignition.

NOTE 2 Fast acting means the valve closes quickly enough to stop the fuel supply, to avoid a hazardous overspeed situation.

5.10.5.2 Isolation

For operation during maintenance activity or by fire service personnel, a valve, which can be manually operated, shall be fitted to the inlet of each gas turbine installation upstream of the automatic valves. This valve shall be clearly marked, located in an accessible position and shall be capable of being operated by an acceptable level of physical force. The valve shall have provision to be locked in the closed position only.

NOTE Guidance on the physical strength for the hand-operation of equipment is given in EN 614-1:2006.

5.10.5.3 Flow control valve

The fuel flow control valve shall be specified and positioned to control the fuel flow to the gas turbine.

Where fuel flow control equipment fault condition is detected that would create a hazardous situation, an emergency shutdown shall be initiated.

5.10.5.4 Shut-off valves and associated vent valve

Shut-off of the gas fuel supply shall be performed by two independently operated automatic shut-off valves; the piping between the valves shall be vented. At least one of the shut-off valves shall be an automatic fast acting safety shut-off valve. Fast acting valves shall be specified and positioned so that the fuel supply to the gas turbine will be shut-off in the event of a hazardous situation at a rate that will prevent failure of the gas turbine.

The safety shut-off valves, including the automatic fast-acting safety shut-off, may serve as flow control valves provided that the following functionalities are fulfilled:

a) the valve shall fail closed and de-energize to trip (e.g. using spring force, boosting accumulator);

b) the failure modes of the control valve feature shall not affect the operation of the shutdown feature of the valve;

c) the safety shut-off function shall be independently activated and override the fuel flow control function when initiated.

Upon shutdown, both shut-off valves shall be closed, and the automatic vent valve opened to create atmospheric pressure in the supply line to eliminate the possibility of fuel entering the gas turbine in its shutdown condition.

On some shutdowns the shut-off valve outside the gas turbine package shall be closed and the vent opened (see 5.10.5.5).

Where the design of the fuel system is such that the flow of fuel to the gas turbine requires further reduction, due to the stored energy in the piping system downstream of the automatic fast acting shut-off valve, an appropriately sized and positioned fast acting vent valve or alternative equipment shall be used to dissipate the stored energy.

Vent lines shall be run to atmosphere and gas recirculation prevented. For vent lines that may contain toxic or hazardous substances, see 5.10.5.8, 5.22.2 and 5.22.3 for additional requirements.

5.10.5.5 Shut-off valve — Outside the gas turbine package

A shut-off valve shall be located outside the gas turbine enclosure or building limits, or in a separately enclosed gas fuel package at the interface of the enclosure or building, to automatically isolate the fuel supply to the gas turbine in the event of a hazardous situation. The associated vent valve can be located either inside or outside the gas turbine or gas fuel package to vent the section of the pipe between the shut-off valve and the automatic fast acting shut-off valve.

Where the potential exists for loss of containment from high speed rotating equipment which can cause damage to the valves or rupture of the fuel supply pipe to the gas turbine, the shut-off valve(s) outside the gas turbine package and the supply pipe to the valves shall be located outside the zone where hazardous projectiles can occur from a potential failure of rotating equipment to ensure fuel shut-off can be achieved. Where the gas turbine package is located in a building, the valves shall be located outside the building if further mitigation is required to provide additional isolation.

The fuel safety shut-off and the vent valve(s) shall be operated automatically on a gas turbine emergency shutdown, if:

a) a fire has been detected within the gas turbine fire protection area; or

b) the cause of the shutdown can cause damage to or failure of the pipe between the valves and the gas turbine package, or damage to the equipment on the gas turbine package, either leading to the uncontrolled leakage of fuel; or

c) ventilation is lost and/or hazardous leakage of fuel is identified (see 5.17.10 and 5.19 for more details); or

d) the gas turbine emergency shutdown system is activated (see 5.20.8).

5.10.5.6 Strainer

A strainer shall be installed upstream of any automatic fast acting shut-off valve at a suitable location to prevent valve malfunction due to debris entering the valve.

5.10.5.7 Valve proving and position monitoring

At start-up the position of valves necessary for shutdown shall be confirmed.

At shutdown the correct functioning of the automatic fast acting shut-off valve, the automatic safety shut-off valve and the automatic vent valve shall be automatically monitored to ensure that correct operation of the valves has been achieved.

Monitoring the correct function of the valves shall be achieved, by either supervision of the valve position or valve proving of process pressure taking into account the location of the vent outlet and the hazardous area created should the vent valve fail to operate correctly. Where valve pressure proving is used, additional equipment as appropriate may be installed to facilitate pressurization and pressure monitoring. Any additional valves shall be pressure proved as part of the proving sequence.

5.10.5.8 Venting — Not to atmosphere

Where due to the toxicity of the gas, or where dispersion cannot be assured, or where environmental considerations prohibit venting to atmosphere, the gas vents may be piped to a low pressure [< 50 kPa (0,5 bar)] flare stack, and additional precautions to prevent gas from entering the gas turbine shall be implemented. As a minimum this shall consist of a double block and vent in the supply line prior to the gas turbine, the valves of which shall be proved and monitored for leak tightness. The vent valve shall be closed after venting to form a double block between the vent line and the gas turbine and the pressure in the vented section of the line monitored for any pressure increase. If an increase in pressure is detected this shall be annunciated at the control system to enable rectification action to be taken.

5.10.6 Liquid fuel systems

5.10.6.1 Fuel control

As a minimum, each liquid fuel supply shall include the following functions:

a) manual isolation (see 5.10.6.2);

b) flow control (see 5.10.6.3);

c) automatic fast acting shut-off (see 5.10.6.4);

d) safety shut-off (see 5.10.6.5);

e) spill and/or drain (see 5.10.6.4 and 5.10.6.6); and

f) fuel pump (see 5.23.8.7).

NOTE Fast acting means the valve closes quickly enough to stop the fuel supply, to avoid a hazardous overspeed situation.

Different arrangements and combinations of devices may be utilized to fulfil the above functions provided the concepts described in 5.10.6 are achieved and the fuel can be shut-off at a rate that prevents failure of the gas turbine, and the possibility of fuel entering the gas turbine in its shutdown condition is eliminated.

Some or all of the system components can be located outside the gas turbine package provided that associated hazardous situations are assessed and appropriate mitigation measures are taken.

Operational requirements may require the liquid fuel system to remain pressurized when liquid fuel is not being furnished to the gas turbine in order to minimize either starting time or fuel transfer. In these applications any necessary design steps and additional equipment including but not limited to:

— pressure monitoring;

— valve position monitoring;

— valve proving;

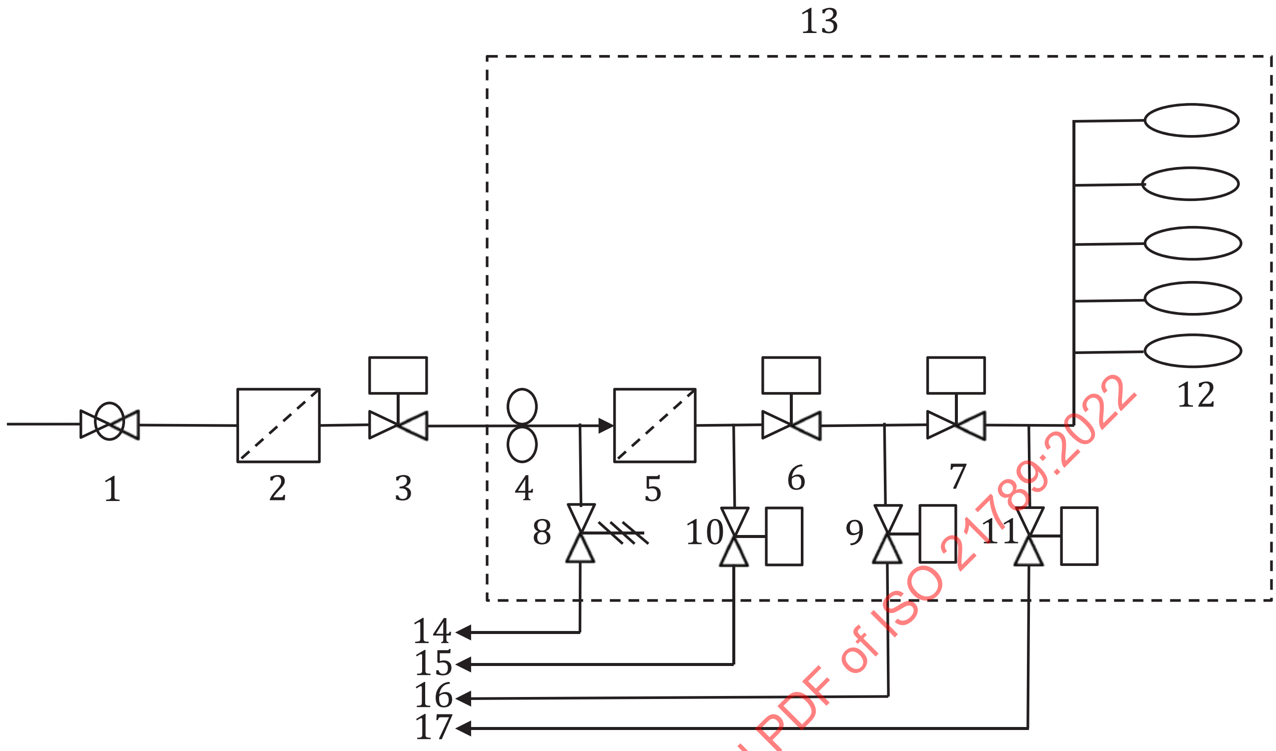
— sequencing valves;

— drain valves;

shall be introduced to mitigate risks.

Figure 2 shows a typical arrangement. Other arrangements or configurations are permitted.

Shut-off valves shall fail closed by permanent available energy, e.g. spring force. The fail-safe status of drain valves shall minimize any risks. All valves shall be specified such that reliable operation is maintained.



Key

1	manual isolation valve	10	spill valve — alternative location
2	filter or strainer, optional position	11	drain valve [b]
3	safety shut-off valve	12	combustion system
4	fuel pump, may be located outside gas turbine enclosure	13	typical gas turbine enclosure or building limits
5	filter or strainer, optional position	14	relief
6	flow control device	15	return to supply — alternative location with 10
7	automatic fast acting shut-off valve [a]	16	return to supply
8	relief valve (See 5.23.8.7)	17	drain
9	spill valve		

[a] Close on every shutdown.

[b] Controlled operation on shutdown.

Figure 2 — Typical liquid fuel system arrangement

5.10.6.2 Isolation

For operation during maintenance activity or by fire service personnel, a valve, that is capable of manual operation, shall be fitted to the inlet of each gas turbine installation upstream of the automatic valves. This valve shall be clearly marked, located in an accessible position and shall be capable of being operated by an acceptable level of physical force.

The valve shall have provision to be locked in the closed position only.

NOTE Guidance on the physical strength for the hand-operation of equipment is given in EN 614-1:2006.

5.10.6.3 Flow control device

The fuel flow control device shall be specified, located and governed to control the fuel flow to the gas turbine.

Where failure of fuel flow control equipment can lead to excess fuel flow or other hazardous conditions the gas turbine condition shall be monitored and compared to:

a) the fuel flow demand and associated speed; or

b) the demanded position of the control valve.

If a fault condition is detected that would create a hazardous situation, an emergency shutdown shall be initiated.

5.10.6.4 Automatic fast acting shut-off valve and spill valve

Shut-off of the liquid fuel supply shall be performed by two independently operated automatic shut-off devices. At least one valve shall be an automatic fast acting shut-off valve.

After operation of the shut-off devices and after any fuel purging, a valve shall drain a section of the supply line to eliminate the possibility of fuel entering the gas turbine in its shutdown condition. This valve shall be sized to ensure the drained pipe volume remains near atmospheric pressure taking into account the potential for leakage in upstream valves. Where a spill valve does not spill to atmospheric pressure a drain valve shall be supplied in accordance with 5.10.6.6.

Where spill flow is returned to the pump suction sufficient cooling and/or make-up flow shall exist to prevent overheating and the potential for vapour lock, or the fuel supply temperature before the pump suction should be monitored and a shutdown initiated if overheating occurs.

5.10.6.5 Safety shut-off valve — Outside the gas turbine package

An automatic safety shut-off valve shall be located outside the gas turbine package to automatically isolate the fuel supply to the gas turbine (see Figure 2, key item 3).

Where the potential exists for the loss of containment from high speed rotating equipment that can cause damage to the valves or rupture of the fuel supply pipe to the gas turbine, the shut-off valve(s) outside the gas turbine package and the supply pipe to the valves shall be located outside the zone where hazardous projectiles can occur from a potential failure of rotating equipment, to ensure that fuel shut-off can be achieved. Where the gas turbine package is located in a building the valve shall be located outside the building if further mitigation is required.

The fuel safety shut-off and the vent/drain valve(s) shall be operated automatically on a gas turbine emergency shutdown if:

a) a fire has been detected within the gas turbine fire protection area; or

b) the cause of the shutdown can cause damage to or failure of the pipe between the valves and the gas turbine package, or damage to the equipment on the gas turbine package, either leading to the uncontrolled leakage of fuel; or

c) ventilation is lost, and/or hazardous leakage of fuel is identified (see 5.17.10 and 5.19 for more details); or

d) the gas turbine emergency shutdown system is activated (see 5.20.8).

5.10.6.6 Drain valve

Where the spill valve does not spill to atmospheric pressure, an automatic drain valve shall be installed to drain fuel downstream of the automatic fast acting shut-off valve. The automatic drain valve shall operate on every shutdown to drain liquid. The valve may be closed during periods of shutdown where other hazards are mitigated.

Alternatively, where the safety shut-off valve - Figure 2, key item 7 - is also leak tight and downstream liquid volume cannot be trapped the drain valve - Figure 2, key item 11 - is not required.

Where a drain valve is used to drain a part of the system which on shutdown is subject to the reverse flow of high pressure and/or high temperature gas turbine compressor delivery air capable of causing the ignition of any hydrocarbons in the drain or purge lines, the drain sequence shall be controlled to prevent this condition.

Alternatively, cooling and/or a flame arrester shall be used to prevent any ignition escalating outside the gas turbine package or a separator mechanism shall be used to vent any hot gases to atmosphere whilst draining fluids to a waste liquids tank.

If there is the potential for reverse flow from the tank, appropriate devices and/or instrumentation shall be installed to provide protection against reverse flow into the gas turbine.

5.10.6.7 Filter/strainer

A filter/strainer shall be fitted upstream of the fuel flow control device and automatic fast acting shut-off valve at a suitable location to prevent device or valve malfunction due to debris entering the device or valve.

5.10.6.8 Valve proving and position monitoring

At start-up the position of the valves necessary for shutdown shall be confirmed.

At shutdown the correct function of the automatic fast acting shut-off valve, the automatic safety shut-off valve and the automatic drain valve shall be monitored to ensure that correct operation of the valves has been achieved.

Monitoring the correct functioning of the valves shall be achieved either by supervision of the valve position or valve proving of process conditions.

5.10.6.9 Thermal relief

Where the potential exists for a liquid to be trapped between closed leak tight valves a suitably located thermal relief shall be provided in accordance with 5.23.9.3.

5.10.7 Multi-fuel systems

It shall not be possible under any condition for the reverse flow of fuel into any other system to occur, where this can cause a hazardous situation. Appropriate precautions shall be taken to ensure that liquid fuels cannot enter purge systems where the resulting mixture may create a hazardous situation.

Where only a single fuel can be fired at any one time, interlocks shall be provided to ensure that the standby fuel system cannot operate or is isolated.

Where more than one fuel can be fired at any one time, it shall be assured that excess energy input due to over-fuelling cannot occur in the gas turbine.

5.10.8 Fuel purging

Where fuel lines are purged or cooled by auxiliary media the hazards risks associated with reverse flow and the discharges of mixtures shall be assessed taking into account all reasonably foreseeable risks including but not limited to the following:

a) failure of purge/drain sequences;

b) uncontrolled shutdown during purge/drain sequences;

c) potential for ignition of vapours in the purge drain lines/vent tank(s);

d) potential for vapour lock;

e) uncontrolled supply, venting or draining of hazardous media.

Risk mitigation measures such as the use of appropriate instrumentation, double block and vent valves, valve position monitoring, prevention of reverse flow, separation of media, flame arresters, etc., shall be considered.

5.10.9 Fuel drainage

Suitable drain points shall be incorporated to drain off unburnt fuel from the pressure section of the casing and/or exhaust system (e.g. in the event of a flame failure on start-up). The drain points shall have valves, preferably automatically operated, that open on shutdown and close as part of the start sequence. If manual valves are used clear instructions shall be given on their operation. The start cycle shall provide a sufficient period to allow draining of any unburnt fuel prior to initiating a restart.

Fuel drainage shall take into account:

a) uncontrollable overspeed caused by burning undrained fuel during start-up;

b) hot gas entering the drain system during operation;

c) unburnt gaseous fuel and air mixtures entering the drain system.

Drain sequence shall be such that predicted volumes of fluid are removed.

5.11 Combustion supervision

5.11.1 General

Protective devices shall be provided for the purpose of detecting that flame is established at start-up and maintained during operation. Direct and/or indirect flame sensing systems may be utilized for this function. The flame monitoring system shall employ diagnostic test functions to abort any start attempt if flame is detected prior to the burner ignition sequence.

NOTE Indirect flame monitoring is defined as a flame signal derived from gas turbine operational parameters such as temperature, pressure, speed or reverse load.

If fitted, the indirect system shall be verified by testing to correctly detect presence of flame at start-up as well as detecting loss of flame in all operating conditions.

If air and gas fuel is mixed upstream of the combustor, the risk of unintended ignition in the system causing a failure shall be assessed and reduced.

Where the potential exists for thermo-acoustic pulsations or flashback (the temporary movement of the combustion flame front from its normal position). in the combustion system that may lead to loss of containment or other hazardous situations a protection system shall be implemented to detect hazards and shutdown or change the running parameters such that a hazardous situation is avoided.

5.11.2 Requirements for ignition

Gas turbine combustors, except reheat combustors based on auto-ignition, shall have a permanently installed device that provides proven ignition energy to light the combustion system. The igniter may consist of a simple electrical (spark) igniter or of an igniter and ignition system (ignition flame), or of an ignition system with cross-fire tubes. The main burner may contain a pilot burner (pilot flame) as part of the main burner (main flame).

The energy released during the ignition safety time shall be limited and the maximum pressure rise from a delayed ignition shall not cause any damage. The ignition safety time shall be determined to prevent such an occurrence. Failed starts with liquid fuels shall be followed by a drain cycle. Failed starts with gaseous fuels require an exhaust purge before a restart. See also 5.12.4.

The requirements for enclosure purging in 5.13.6 and gas turbine and exhaust purging in 5.12.4 shall be satisfied prior to ignition (characterized by the occurrence of the first ignition spark). Igniters shall be energized prior to fuel being admitted to the combustion system.

Overfueling during ignition shall be prevented (e.g. by control valve position, pressure or exhaust temperature monitoring or fuel flow monitoring).

5.11.3 Extinction safety time

On loss of flame, the flame detection and fuel shutdown system shall have a combined maximum response time less than the extinction safety time to limit the release of unburned fuel to an amount that prevents a hazardous situation.

5.12 Exhaust system

5.12.1 Damper controls

If exhaust dampers are fitted, controls shall be provided to detect uncontrolled damper closure and to shut down the gas turbine before an overpressure condition can arise. Where rapid closing of dampers can create excessive exhaust pressures leading to a hazardous situation, the closing speed of the dampers shall be limited.

5.12.2 Flexible joint location

Where possible, flexible exhaust joints shall not be situated close to walkways or to any electrical or instrument cable or hydrocarbon pipework where leakage or radiation or the potential temperature increase can lead to a hazardous situation. Where the above is not possible, the flexible joints shall be shielded.

5.12.3 Exhaust outlet

The exhaust outlet design shall take into account the risk for large amounts of oxygen depleted air, carbon monoxide or other hazardous air pollutants being emitted that can cause asphyxiation. The emissions shall not cause a hazard to nearby persons or property.

NOTE National or local regulations can govern stack heights.

In areas where personnel can be in proximity to the exhaust ducting, thermal protection shall be provided as an integral part of the design. If supplied, for emission monitoring, access ports shall be suitably extended and insulated so that access is not impeded and if required suitable personnel access platforms shall be supplied.

Access shall be provided so that regular checks for leaks can be undertaken on exhaust ducting and exhaust flexibles where these are routed through a building where leakage, due to the above, can lead to asphyxiation or poisoning of personnel in or passing through the building. (See 7.5.2.)

5.12.4 Explosion protection

Where the potential exists for the exhaust system to contain an explosive atmosphere, or gases or vapours that can create an explosive atmosphere, the exhaust system shall be purged before gas turbine start-up. The purge flow rate shall be sufficient to prevent hazardous accumulations of unburnt fuel. At least three complete volume changes of the gas turbine and downstream exhaust system equipment shall be undertaken. The volume is measured up to the base of any main chimney or to that point where, under all load conditions, the exhaust gas temperature of any flammable gases or vapours that can be present is below 80 % of the AIT, measured in degrees Celsius (see 5.16.4.4). Attention shall be given to the potential for entrainment/re-entry/collection of heavier-than-air gases.

Exhaust purging shall be achieved by rotating the gas turbine compressor, by the use of separate, suitably controlled fans or by a combination of both to achieve the required volume changes in the total system that may be subject to exhaust gas temperature above the AIT (see 5.16.4.4) of any flammable gases or vapours that can be present. The gas turbine exhaust gases can be used for purging provided that they are proven and controlled to be less than 80 % of the AIT measured in degrees Celsius of any flammable gases or vapours that can be present. Additional requirements can be necessary for purging the downstream plant and any associated firing equipment.

The required air purge volume shall be proven by the use of instrumentation interlocked to the start-up sequence. Where the gas turbine air compressor itself is used to provide the purge flow, proof of gas turbine compressor rotation speed and proof of correct variable guide vane and/or compressor bleed valve positions shall be used to verify the flow rate.

In the case of a normal controlled shutdown where it is demonstrated that there is no hazardous atmosphere within the gas turbine or the associated exhaust system and a fuel shut-off valve(s) operating check has been undertaken, a start-up without a full purge may be undertaken.

NOTE NFPA 85:2019, 8.8.4.6 for gaseous fuels and 8.8.4.7 for liquid fuels, provides additional guidance on purge credit.

Vent outlets shall be to atmospheric pressure and routed to a safe area, and the requirements shall ensure that an explosive atmosphere does not exist within the gas turbine or the exhaust system following the shutdown and prior to starting the gas turbine.

The fuel used for start-up shall be such that auto-ignition on hot internal surfaces does not lead to overpressure conditions or uncontained component failure. This typically applies to fuels such as naphtha where significant potential exists for the formation of large potentially explosive vapour clouds.

Where more than one gas turbine supplies a heat recovery system, precautions shall be taken to ensure that reverse exhaust gas flows cannot pass back into another gas turbine under any purge, start-up or other flow condition.

5.13 Enclosures

5.13.1 General

Enclosures shall protect the equipment installed within against environmental conditions or influences to ensure that safety equipment is not impaired. See 5.25 for installation of enclosures in hazardous areas.

Where the enclosure is protected by a gaseous fire extinguishant the seals at retained panels, doors and other closure points shall withstand any increase in pressure caused during the release of the extinguishant and maintain the concentration of the extinguishant in accordance with the fire extinguishing code or standard that has been adopted (see 5.15.6).

Non-metallic materials used for flexible connections and seals shall be selected to withstand the loading and environmental conditions to which they are subjected, without impairing the effectiveness of gaseous extinguishant and cooling or dilution ventilation.

Where there is the potential for leakage from driven machinery, of gases of subgroup IIC of ISO/IEC 80079-20-1:2017 (e.g. hydrogen cooled generators or driven gas compressor compressing gasses of subgroup IIC as per IEC 60079-10-1:2015, Annex H) or vapours or mists where the AIT (see 5.16.4.4) is less than the gas turbine surface temperature, the machinery shall not be installed in the same enclosure as the gas turbine unless a gas tight dividing wall or an air gap between two dividing walls is provided, or other equally effective means shall be provided to prevent such gas or vapours from entering the gas turbine enclosure.

5.13.2 Enclosure structure

The structure of enclosures, attached panels, doors and their latches shall be designed to withstand the following:

a) environmental loading associated with the location;

b) pressure loads caused by the operation of the ventilation system, gaseous extinguishant systems and machinery vents/bleed valves and blockage of ventilation outlets;

c) overpressures caused by any reasonably foreseeable rupture or leaks from pressure casings and pressurized ducting;

d) overpressure prior to pressure relief where the requirements of 5.16.5.2 are being implemented or overpressure up to 1 000 Pa (10 mbar), unless extrapolated to 1 500 Pa (15 mbar), where the overpressure is being limited in accordance with 5.16.5.3;

e) loads applied by permanently supported equipment such as the ventilation system;

f) loads generated from tools or lifting equipment supported in the enclosure.

The enclosure structure shall include attachments and integrated tools necessary to allow maintenance activities to be carried out.

NOTE Statutory building codes or regulations normally govern the design, manufacturing and testing criteria of load bearing structural steel.

5.13.3 Enclosure fire precautions

5.13.3.1 General

The risk of fire shall be assessed in all enclosures and, where necessary, fire precautions shall be implemented in accordance with 5.15.

5.13.3.2 Gas turbine enclosure

A fire protection system, including fire detection and suppression equipment, together with the necessary controls and instrumentation shall be provided in the gas turbine enclosure in accordance with 5.15.

5.13.4 Explosion prevention and protection — Area classification — Ventilation

Hazardous areas within the enclosure shall be classified, and explosion prevention and protection measures shall be implemented in accordance with 5.16. Where flammable gases, vapours or mists that have an AIT below the temperature of any exposed hot surface can be present, the additional measures described in 5.16.5.2 (explosion relief) and/or 5.16.5.3 (pressure resistant design) and/or 5.16.5.4 (suppression) shall be implemented.

NOTE The gas turbine enclosure can be considered as an artificial ventilated room according to IEC 60079-13:2017 and IEC 60079-10-1:2015 by dilution thereby the required Equipment Protection Level (EPL) and hazardous area is reduced.

5.13.5 Gas detection

Where an enclosure contains hazardous area due to potential leakage of flammable gas or vapour, gas detection shall be implemented in accordance with 5.19.

5.13.6 Enclosure purging

Where an enclosure contains equipment that during a secondary release (according to IEC 60079-10-1:2015) of gases or liquids capable of producing flammable vapours or mists, the enclosure and associated upstream and downstream ducting volume shall be purged according to IEC 60079-13:2017 prior to start-up unless the ventilation has run continually since previous operation of the gas turbine.

To shorten the duration of fire or explosion risk in comparison to a natural cooling cycle, the ventilation system shall normally continue to operate at shutdown to reduce the surface temperature of any surface to less than 80 % of the AIT, measured in degrees Celsius (see 5.16.4.4), of any combustible fluids and gases. A margin shall be made, where applicable, for the effects of heat soak from hot masses internal to the surfaces.

In the case of loss of ventilation during the cool down cycle the actions related to the loss of ventilation shall occur. See 5.16.2 and 5.21.9.

NOTE The ventilation validation CFD described in 5.16.5.3.3 is a path for reduction of purge time.

5.13.7 Flammable mist

Systems containing pressurized flammable fluids shall be designed with suitable couplings limiting the risk of leakage creating flammable mist and with as few couplings as reasonably practicable to reduce the risk of leakage.

If additional risk mitigations are needed the design shall be improved with suitable measures such as positive locking of fitting, spray retainers, flange guards or a liquid mist detection system.

NOTE Flammable mist can be formed from pressurized fluid leakage at a temperature below the flash point of the fluid (see 5.16.2).

5.13.8 Access and doors

Suitable safeguards shall be provided to allow prompt evacuation, to restrict entry to personnel to hazard zones and allow means for rescue of any trapped personnel.

To prevent operator entrapment, the access doors used during operation of the gas turbine shall:

a) open outwards in the direction of exit;

b) have a means that overrides any locking mechanism (for example panic bolts) to allow opening from the inside without the use of a key or tool;

c) have the possibility to be opened against negative pressure ventilation forces;

d) have a minimum access-door requirement of 2 100 x 700 mm free height and width.

All doors shall be fitted with devices to prevent unexpected movement due to wind, ventilation pressure or other actions that can lead to impact or crushing hazards.

Access ways and escape routes used during operation of the gas turbine shall be designed as per ISO 14122-1:2016 if applicable.

NOTE 1 See 7.6 for information to be supplied in relation to access.

NOTE 2 Door requirements can apply to hinged hatches.

When the servicing equipment is not reachable from the access ways inside the enclosure the risk of entrapment shall be considered.

NOTE 3 Additional guidance is given in ISO 15534-1:2000.

5.13.9 Entrapment

The arrangement of equipment within enclosures shall be such that access for reasonably foreseeable purposes is available without the risk of entrapment.

Account shall be taken of the need for emergency escape routes inside the enclosure to avoid trapping personnel in the event of a hazard.

Risks related to work in confined spaces and the need for rescue of injured personnel shall be considered.

5.14 Lighting

Lighting shall be provided in areas where visibility is required for execution of inspection and operational activities. Emergency lighting shall be provided where illumination is required for egress.

An appropriate level of local lighting shall be available for maintenance areas; the use of temporary lighting for the maintenance tasks is acceptable. Lighting for use in a hazardous area shall meet the elevated temperatures expected in the gas turbine enclosure.

NOTE 1 Guidance on emergency lighting can be found in EN 1838:2013, ISO 30061:2007 and NFPA 101:2018.

NOTE 2 For additional information of lighting design refer to EN 1837:1999 or ISO 8995-1:2002.

5.15 Fire precautions

5.15.1 General

A risk-based approach to the requirement for fire risk reduction, protection, detection and suppression measures shall be taken based on the requirements of ISO 19353:2019, or an equivalent national standard providing equivalent requirements, taking into account the existence of a fire hazard, the probability of its occurrence and the degree of possible harm. The fire protection system shall be based on an integrated set of standards and the guidance described in 5.15.2 to 5.15.13 inclusive.

NOTE NFPA 551:2019 is an acceptable equivalent to ISO 19353:2019. Guidance on fire protection for gas turbines (and associate accessories) can be found in NFPA 850:2020.

5.15.2 Structural fire risk reduction

The materials of construction of enclosed spaces where a fire risk exists, their associated structural members and any acoustic shall be of fire resisting materials per ISO 11925-2:2020 and thermal insulation shall be of non-combustible materials per ISO 1182:2020 to reduce fire loads and inhibit the spread of a fire. The use of small parts that are not connected, such as gaskets made out of combustible materials, is acceptable.

Fire hazards of electrotechnical products shall be assessed in accordance with IEC 60695-1-10:2016 and IEC 60695-1-11:2014.

Where a fire extinguishant system is provided, the enclosed space shall be designed with the objectives of containing the fire for the maximum period before detection can be assured, overcoming extinguishant delays and achieving a concentration of extinguishant to extinguish the fire.

5.15.3 Flammable fluids mitigation and containment

5.15.3.1 General

Tanks containing hydrocarbons shall be equipped with level monitoring equipment for leak detection and, where applicable, detection of over filling.

When defining the fire protection measures for gas fuel areas and other areas containing pressurized hydrocarbons, the actuation of any extinguishing measures shall initiate the automatic shut-off of the fuel supply (see also 5.13.3.2).

Pressurized equipment containing gas fuel, liquid fuel or other flammable hydrocarbons with the potential for forming flammable mists due to high pressure leaks, shall, in addition to the requirements of 5.23, be designed with the minimum number of connections required for correct assembly and maintenance. Where a leak can impinge on electrical equipment which can be a source of ignition, or a hot surface with a temperature above the AIT (see 5.16.4.4) of the potential leak source, additional precautions shall be taken to mitigate the potential for leakage and guard against impingement.

So far as possible, joints shall be positioned so that leaks do not drip or spray onto electrical equipment or hot surfaces.

Where appropriate insulation materials shall be protected against the penetration of hydrocarbons.

The flammability properties of any fluids shall be assessed. For liquid fuels of low AIT, such as naphtha, segregation of hazardous areas and the use of explosion relief or other effective measures such as coalescers, wire locking of fittings, spray retainers, flange guards at leak points shall be considered where additional mitigation is required due to the presence of hot surfaces.

5.15.3.2 Lubrication and hydraulic systems

Where the measures taken in 5.13.7 with respect to flammable oil mists in the presence of hot surfaces does not provide the required risk reduction, further mitigation shall be undertaken, e.g. by the use of fire resistant or non-flammable fluids. Oil system vents where oil mist can appear shall be fitted with a mist eliminator and routed away from hot surfaces. If vent line outlets are located near a potential ignition source, they shall be provided with flame arresters.

5.15.3.3 Post-shutdown lubrication

Where it is necessary to protect the gas turbine from damage after a fire shutdown by maintaining lubrication to bearings and associated instrumentation that may otherwise be damaged, a limited duty, emergency lubricating oil systems may remain in operation to those areas requiring protection provided the risk assessment ensures equipment, process, and protection is adequate, and the consequence of the failure of these protections is identified. Some examples of risk reduction techniques may include reducing the lube oil flow and pressure, using high integrity piping and fittings, and the ability to manually shut down the power supply to the emergency lubricating oil pump(s).

5.15.4 Fire protection

Where indicated by 5.13.3 or 5.2, an automatic integrated fire protection system shall be provided, together with the necessary controls and instrumentation.

The design shall ensure the integrity and functionality of the fire protection system in the context of fast and reliable detection of fire, discharge after detection, extinguishing and suppression of fire with regard to personnel safety.

5.15.5 Fire detection

To ensure that fires are detected at an early stage, areas of enclosure and halls requiring a fire extinguishant system, in accordance with 5.12.2 shall be monitored with automatic fire detectors. Detectors shall be selected from the following types:

a) smoke detectors;

b) flame detectors;

c) heat detectors.

Heat detectors shall always be present in the event that flame detectors are blinded by smoke or mist. Other detectors shall be used in conjunction with heat detectors where necessary to mitigate hazardous situations or prevent damage.

Manual push-button fire alarms shall be installed near the main escape routes from any enclosed spaces and at exits from buildings within which a fire protection system is installed. The alarm function may be integrated with the extinguishant release manual push-button at the enclosure.

The minimum number of detectors required for an area being protected shall be assessed based upon the location of potential fire hazards, the field size covered by the selected detector and shall be installed to provide a fire alarm signal and minimize false alarms to an acceptable level.

Where the location of a fire detector is such that the accuracy of detection could be affected by contamination of the sensing components, due to pollutants or substances in the local air stream or atmosphere, the detector type selected shall produce a fault signal if contamination is detected.

5.15.6 Fire extinguishing systems

Preference should be given to the use of a fire extinguishing system using a non-hazardous extinguishant.

The extinguishing media shall be selected so as not to cause any damage to the safety related equipment within the enclosed space.

Risks of the extinguishant such as asphyxiation and electrocution shall be assessed.

A suitable alarm shall be incorporated into the fire protection control system to provide sufficient warning to people within an enclosed space to make their escape before the discharge of a hazardous extinguishant. The pre-discharge alarms shall provide a time delay of sufficient duration to allow for evacuation under “worst case” conditions.

Extinguishing systems capable of asphyxiation shall not be installed in or used to protect normally occupied spaces.

Means for mechanical isolation of extinguishing systems shall be provided. The isolation device shall be fitted with position monitoring interfaced to the turbine control system. Isolation shall be repeatedly annunciated at the control system. The unit shall not start if the system is isolated.

Electrical isolation of the extinguishant release may be permitted for short-term entry in large spaces with ease of egress. Isolation shall be repeatedly annunciated at the turbine control system or identified through site safe work procedure such as lockout tagout process.

Any air exhausts or air inlet openings into the enclosure should be fitted with an automatic closing damper. If openings are kept open during extinguishant release, this shall be taken into account in the extinguishant quantity calculation. When calculating the quantities of extinguishant for discharge, due consideration shall be given to unavoidable leakage from the enclosed space. Where dampers are utilized the closing force shall be such to ensure closure of the damper.

The extinguishant concentration shall persist effectively to prevent re-ignition by hot surfaces until other safety measures are available (e.g. local fire service). Where re-ignition or lack of site replenishment of extinguishant is a high risk, consideration shall be given to a multi-shot system or providing reserve extinguishant capability.

There shall be two independent discharge release methods:

a) one automatic, after a signal from the detection system; and

b) one manual, by push button(s) at predefined points near to the enclosed space. Manual release may use electrical assistance to initiate the discharge.

NOTE 1 Some national standards require additional methods for manual release.

Each different design of enclosure shall be subjected to a one-time full extinguishant discharge release type test, or a door fan retention test in conjunction with a functional test on the extinguishment system to ensure the applicable integrity/sealing is achieved.

Proper functioning of all related systems and the sealing of the enclosed space shall be checked on each installation. See also 5.23.13 in relation to the suitability of pipework.

NOTE 2 For an example of door fan retention test procedures, see ISO 9972:2015.

NOTE 3 There are globally accepted standards for extinguishant systems:

a) ISO 6183:2009 or NFPA 12:2018 for CO_2 systems;

b) ISO 14520-1:2015 or NFPA 2001:2018 for other gaseous systems;

c) NFPA 750:2019 or EN 14972-1:2020 for water mist systems;

d) NFPA 13:2019 or EN 12845:2015 for sprinkler systems, and NFPA 15:2017 or CEN/TS 14816:2008 for water spray systems;

e) ISO 7203-1:2019 or NFPA 11:2016, for low-, medium-, and high-expansion foam;

f) ISO 7076-5:2014 or NFPA 16:2019, for foam-water sprinkler and foam-water spray systems;

g) ISO 15779:2011 or NFPA 2010:2020, for aerosol fire-extinguishing systems.

5.15.7 Water mist extinguishant

Where a water mist extinguishant system is used and where a continual discharge system can cause damage to the gas turbine leading to premature failure, a pulsed release system that has been proven not to cause such damage may be used. The interval of pulsing shall be such as to extinguish the maximum credible fire and maintain continual protection against re-ignition.

The numbers and positions of the water mist nozzles shall be selected to provide the required effect of the extinguishing spray taking into account the actual geometry and access of the parts.

Suitable measures shall be taken to prevent icing of the system.

The water mist system shall be suitably type tested and validated.

Water mist nozzles shall be fitted with a suitable filter/strainer such that any reasonably foreseeable blockage of the discharge orifices by particulates is prevented. System materials shall be chosen to reduce the potential for blockage of orifices by corrosion deposits. Water quality shall comply with the manufacturer's specification.

5.15.8 Extinguishing system controls

Each fire protection and extinguishing system shall be equipped with a fire protection control system. This may be a local panel, may be integrated with the gas turbine control system or may be installed in the main control panel area.

The system shall be capable of the functions specified in Table 1.

Table 1 — System functions

Function	Implementation
Manual push-button release	Installed at predefined points outside an enclosed space. Use of this release shall not override the required pre-discharge alarm sequences.
Automatic release	Automatic release on fire detection.

Table 1 *(continued)*

Function	Implementation
Selector switch	The extinguishing system shall be able to be inhibited. The use of electrical selector switches to isolate suppressant release can give rise to a false sense of security when the manual release is still available and should not be used as an alternative to mechanical isolation for systems using a suppressant that poses a risk of harm to persons, (e.g. CO_2). The use of a selector switch is not required when the extinguishant media cannot cause asphyxiation.
Acoustic alarm	At enclosed spaces by horn or alarm sirens.
Visual alarm	At enclosed spaces with a high noise level [e.g. gas turbine acoustic enclosure (irrespective of scope of supply)] by flashing lights.
Interface to turbine controls	Suitable contacts and associated logic.

In the event of a loss of the primary electrical power supply to the fire protection system, it shall be protected by an independent back-up/emergency system capable of maintaining the electrical supply for a period sufficient to allow shutdown of the gas turbine, personnel evacuation and allow cooling of hot surfaces to take place and the venting / draining / and supply of lubricating / hydraulic media.

The fire protection system shall, where specified, transmit a specific alarm signal to any associated central control panel to provide comprehensive information for operational personnel.

Activation of a single fire detector shall initiate an alarm signal.

Activation of a second detector or second detector type shall initiate an emergency shutdown and additional actions that may include but are not limited to the following:

a) transfer a signal to the gas turbine control system indicating detection of a fire;

b) actuate related warning devices;

c) shut down the ventilation system of the enclosure;

d) close ventilation inlet and exhaust dampers where utilized;

NOTE 1 In some cases, this can be achieved by the extinguishant action.

e) actuate the automatic fire extinguishing system, after the time delay necessary for personnel protection, where applicable.

Activation of a single fire detector, where applicable, may be used to initiate the appropriate actions above.

The sound pressure level of an acoustic alarm shall be audible above the noise level of the building/area in normal operation.

Red (or another nationally required colour) flashing lights shall be provided in areas with excessive local sound levels in addition to the acoustic alarm.

Where a serious fault alarm signal is received from the fire protection system, an alarm, which can only be manually reset, shall be initiated. Equipment start-up shall be interlocked, or the operation manual shall indicate that start-up is not permitted before the failure is identified and solved. Equipment shall be monitored for open and short circuit conditions. It shall be possible to test the function of warning devices at any time (this test may be allowed to lead to unit stop).

NOTE 2 A serious fault alarm is an alarmed fault that, if not rectified, affects the ability of the system to operate correctly.

5.15.9 Escape

Suitable safeguards in accordance with 5.13.8 and 5.13.9 shall be provided to allow prompt egress.

5.15.10 Uncontrolled release of media and loss of propellant pressure

A method of monitoring and/or weighing the fire extinguishant vessels' contents that does not require disconnection of the vessel shall be provided so that, if the vessel contents escape or leak, appropriate action can be taken. If manual checks are recommended, to ensure that unacceptable leakage is detected, manufacturer should communicate this through the instructions for use in Clause 7.

Where a nitrogen gas supply is used to actuate the extinguishant release mechanism or as a propellant to eject water in a water mist system, the pressure in the nitrogen vessel(s) shall be monitored so that, if the vessel(s) contents escape or leak, an appropriate alarm shall be provided.

Where low temperature conditions can cause a drop in the pressure of propellant gas vessels suitable heating shall be provided to maintain the vessel(s) at a temperature such that an acceptable pressure is achieved.

Where the potential exists for external influences to activate fire detection equipment appropriate precautions shall be taken, e.g. covers at enclosure windows to prevent activation of detectors by local radiation, such as welding arcs.

5.15.11 Vessel thermal relief (burst disc)

Protection shall be provided against overheating when fire extinguishant or nitrogen propellant vessel(s) are located in areas subject to strong sunlight or other heating effects that can cause an uncontrolled pressure increase and operation of the vessel valve burst disc. Propellant or extinguishant vessels shall not be installed inside a gas turbine enclosure.

Methods of protection may include but are not limited to:

a) vessels mounted in a suitably ventilated cabinet,

b) vessels located in natural shade,

c) provision of canopies or similar protection against surface heating.

The vessel valve burst disc shall be orientated or otherwise guarded so that if the burst disc operates personnel in the immediate area cannot be harmed.

5.15.12 Propellant vessels

If provided, fire extinguishant and nitrogen propellant vessels shall be supplied in accordance with applicable local requirements. Potential misuse or damage of the associated equipment shall be considered.

5.15.13 Release of extinguishant into gas turbine halls, control rooms, etc.

If vessels and the associated pipework for fire extinguishant systems are located in gas turbine halls, control rooms or similar areas where personnel access is required and there is the potential for asphyxiation due to the extinguishant used and the potential concentrations that could be achieved on release, the precautions in 5.15 and 5.13.9 shall be applied where relevant.

5.16 Hazardous area classification and explosion prevention and protection

5.16.1 General

Where the potential exists for flammable gases, vapours or mists to arise, the areas shall be classified in accordance with IEC 60079-10-1:2015 and appropriate precautions shall be taken against explosions in accordance with IEC 60079-0:2017, IEC 60079-13:2017, IEC 60079-14:2013, ISO 80079-36:2016 and ISO 80079-37:2016.

NOTE 1 IEC TS 60079-46:2017 provides additional guidance on equipment assemblies.

NOTE 2 Where local legislation recognizes other established standards, such as UL 121201:2017, NFPA 70:2020, ANSI/ISA-TR12.13.03:2009, EN 1127-1:2019 and NFPA 497:2017, that achieve an equivalent level of safety and certification of equipment, these can be used.

5.16.2 Area classification

Hazardous area classification shall be carried out for all plant items where flammable gas, vapour or mist risks can arise.

Areas shall be classified into zones and the extent of the zone defined, and the hazardous area classification drawings shall be in accordance with IEC 60079-10-1:2015.

The extent of the zone adjacent to any ventilation inlet shall take into account the increased airflow in the area and the potential for flammable gases, vapours or mists to be drawn into the inlets.

Special consideration shall always be given to the danger of ignition of flammable mists in the presence of hot surfaces.

Flammable mist can be formed from pressurized fluid leakage at a temperature below the flash point of the fluid. Mists can form or be present at the same time as flammable vapours which can affect the way the flammable material disperses and the extent of any hazardous areas. The strict application of area classification for gases and vapours may not be appropriate because the flammability characteristics of mists are not always predictable. Whilst it can be difficult to decide upon the type and extent of zones, the criteria applicable to gases and vapours will, in most cases, give a safe result. See 5.13.7. IEC 60079-10-1:2015, Annex G provides instructions and guidance where mists may occur.

Where equipment is located in an enclosure and ventilation is used to control the hazardous areas, the area classification shall take into account the conditions when the ventilation is not present. Actions such as but not limited to de-energizing the electrical supplies or isolation and venting/de-pressurization of fuel and high-pressure hydrocarbon systems or a higher level of equipment classification shall be initiated where necessary to remove the potential for a hazardous situation.

Hazardous area classification drawings shall be prepared in accordance with IEC 60079-10-1:2015.

NOTE 1 The category defining the extent of protective measures to be taken can be as defined in EN 1127-1:2019, 6.4.1.

NOTE 2 The specific requirements from the classification of zones to the equipment of the different categories to avoid ignition sources are described in EN 1127-1:2019, 6.4.

5.16.3 Explosion prevention

The basic mitigation methods described in ISO 12100:2010, 6.2.4 shall be used in conjunction with ISO 80079-36:2016 for non-electrical equipment for the identification and assessment of the hazardous situations. The concepts and methodology for explosion prevention therein shall be applied.

In the planning of explosion prevention and protection measures, consideration shall be given to normal operation, which includes start-up and shutdown. The possibility of technical malfunctions as well as foreseeable misuse per ISO 12100:2010, 5.3 shall be taken into account.

Where there is the potential for any significant quantity of hot gas or air to leak from the equipment casings and cause damage to ancillaries, controls, certified equipment or safety devices, means shall be provided to prevent such an occurrence leading to a hazard.

NOTE The explosion prevention methods described in EN 1127-1:2019, Clauses 4 and 6 or NFPA 68:2018 and NFPA 69:2019 meet the intent of ISO 12100:2010, 6.2.4.

5.16.4 Avoidance or reduction of effective ignition sources

5.16.4.1 General

All equipment shall be designed and constructed so far as possible to prevent ignition sources that can occur during normal operation and reasonably foreseeable machinery fault conditions.

All electrical and non-electrical equipment and components, intended for use in potentially explosive atmospheres, shall be designed and constructed in conformity with the required categories for group II equipment to ensure avoidance of any ignition sources.

To classify the category of the electrical parts of the equipment, it shall be subjected to an ignition hazard assessment.

To classify the category of the non-electrical parts of the equipment, it shall be subjected to an ignition hazard assessment.

5.16.4.2 Electrical ignition sources

Electrical apparatus for explosive gas atmospheres, for the identified zone and category, shall comply with IEC 60079-0:2017.

Any electrical equipment installed and located in hazardous areas shall be suitable for the hazardous area classification as defined in IEC 60079-0:2017.

The electrical equipment shall be clearly identified by a durable marking to show the level of protection and/or the type of protection.

NOTE IEC TS 60079-46:2017 provides additional guidance on equipment assemblies.

5.16.4.3 Non-electrical ignition sources

5.16.4.3.1 General

Non-electrical equipment used in hazardous areas shall comply with the requirements of ISO 80079-36:2016 or shall be located in an area that meets the dilution ventilation requirements in 5.16.5.3.

NOTE A combination of techniques can be used.

5.16.4.3.2 Hot surface temperatures

Where the surface temperature exceeds the AIT (see 5.16.4.4) of any flammable gas, vapour or mist leak that can impinge on the surface, additional guarding measures shall be taken to contain, deflect, or dilute (see 5.17.5) such leaks, to reduce the risk of contact with the surface.

5.16.4.4 Auto-ignition temperature data

Values of AIT from ISO/IEC 80079-20-1:2017, or otherwise from a verified source, shall be used. For mixtures, unless test data are available, the AIT of the component having the lowest AIT and present at a concentration of over 3 % (by volume) shall be used. If no relevant data are available, the AIT of relevant substances shall be measured in accordance with ISO/IEC 80079-20-1:2017.

An appropriate safety margin shall be applied to the value of the AIT where uncertainty exists due to the constituents of the gas, hot surface size and conditions, contact time, the potential for stagnant conditions and any other foreseeable circumstances.

NOTE The capability of a heated surface to cause ignition of a potentially explosive atmosphere depends on the type and concentration of the particular substance in the mixture with air. This capability becomes greater with increasing temperature and increasing surface area. The temperature that triggers ignition depends on the size and shape of the heated body, on the concentration gradient in the vicinity of the surface, the contact time of the explosive atmosphere with the heated body and, to a certain extent, also on the surface material and the potential for catalytic reactions. Thus, for example, an explosive atmosphere can be ignited by surface temperatures lower than the AIT. On the other hand, in the case of heated bodies with convex rather than concave surfaces, a higher surface temperature is necessary for ignition; the minimum ignition temperature increases, for example, with spheres or pipes as the diameter decreases. Likewise, when an explosive atmosphere flows past heated surfaces, a higher surface temperature is normally necessary for ignition owing to the brief contact time.

5.16.5 Reduction of explosion effects in an enclosed space

5.16.5.1 General

If the measures described in 5.16.1 and 5.16.2 (area classification), 5.16.3 (explosion prevention), 5.16.4 (ignition source control) and 5.13.4 (ventilation) do not provide a sufficient level of safety for enclosed spaces, the additional measures described in 5.16.5.2 (explosion venting) and/or 5.16.5.3 (pressure resistant design) and/or 5.16.5.4 (suppression) shall be implemented.

5.16.5.2 Explosion venting

Where necessary in accordance with 5.16.5.1 explosion venting construction (relief panels) to protect the enclosure space shall be implemented.

NOTE EN 14797:2006 and NFPA 68:2018 provide guidance on relief panels sizing.

The set point for the operation of relief panels shall be less than the internal overpressure that can cause any personnel access doors or maintenance panels to be forced open. Relief panels (if fitted) shall be retained by hinges or other mechanical means to prevent them from becoming loose missiles and so as to prevent injury to personnel during opening.

In the event of relief panel operation appropriate action shall be initiated. A gas turbine emergency shutdown shall be initiated.

5.16.5.3 Explosion pressure resistant design

5.16.5.3.1 General

Where necessary in accordance with 5.16.5.1, an explosion pressure resistant design shall be implemented for enclosed spaces based on the use of dilution ventilation and its validation in accordance with 5.16.5.3.2 and 5.16.5.3.3 to limit the overpressure from an explosion event such that the pressure is reduced to a level that is unlikely to cause personnel injury and is contained within the enclosed space.

The pressure resistant design shall withstand the predicted explosion overpressure, see 5.16.5.3.3, without becoming permanently deformed.

5.16.5.3.2 Dilution ventilation

Dilution ventilation shall be applied to ensure that areas of stagnant or insufficient ventilation are minimized so that, in the event of a leak, the potentially explosive cloud is diluted by jet mixing with the surrounding air and the mixture is immediately and effectively removed by the ventilation.

Explosive concentrations are, therefore, restricted to the mixing zone and its immediate vicinity, and shall be sufficiently small, as given in 5.16.5.3.3, relative to the size of the enclosure space.

In the event of ignition, the maximum overpressure from an explosion event is limited such that the pressure rise consequences are insignificant and contained.

Thus, the effective distribution of ventilation is more important than its quantity, since high ventilation rates can preclude the detection of small leaks by detectors (see also 5.19) in the outlet ducts and can result in larger explosive clouds with significant consequences in the event of ignition.

Dilution ventilation shall always be associated with the use of gas detectors since it is designed to dilute reasonably foreseeable leaks to be within a defined range.

Where necessary to achieve effective dilution ventilation, a combination of additional inlet positions, distribution ducts and distribution baffles may be used to direct the ventilation air flow to points of stagnation and re-circulation.

Account shall be taken of the flow patterns at cold start-up and running when different thermal conditions exist.

5.16.5.3.3 Ventilation validation

Computational fluid dynamics (CFD) modelling or other quantifiable techniques shall be used to validate dilution ventilation in accordance with 5.16.5.3.2 to ensure adequate dilution of a leak is achieved. The modelling shall show that the leak cloud volume at the 100 % LFL contour arising from the leak that can cause a gas turbine emergency shutdown based on gas detection device settings in the ventilation outlet ducts.

The volume of this leak cloud shall be limited to an extension such that in event of ignition the enclosure can withstand the overpressure generated. To evaluate the overpressure created, the cloud volume shall be converted to an equivalent volume at stoichiometric concentration and compared with a defined volume threshold.

This criterion has been validated to show that the ignition of a stochiometric cloud equal to 0,1 % of the net volume of the enclosure will create an overpressure not exceeding 1 000 Pa (10 mbar). If the enclosure strength can be assessed to withstand a higher overpressure (e.g. 1 500 Pa) the criterion may be extrapolated to a larger envelope (e.g. not exceeding 0,15 %) of net volume. In all cases, the gas leak rate for the purposes of CFD shall be based on a hole size no smaller than 0,25 mm^2 and no larger than 25 mm^2 and the equivalent volume at stoichiometric concentration shall not exceed 1 m^3.

Prior to the completion of commissioning of each initial design, ventilation validation in-situ measurements shall be undertaken to ensure that areas of stagnant or insufficient ventilation are minimized.

Where analysis shows that gas clouds or concentrations that cannot be removed by other means can occur, additional appropriately located gas detectors shall be installed.

Measurements shall verify that the CFD model provides an acceptable representation of the air velocities and heat balance. Where necessary the CFD geometry and parameters shall be adjusted to obtain an acceptable match between the measurements taken and the CFD model output.

NOTE Additional guidance is given in References [68], [69] and [70].

5.16.5.4 Explosion suppression

Explosion suppression systems prevent an explosion from attaining its maximum explosion pressure by rapidly injecting extinguishing agents into the equipment in the event of an explosion. Where necessary in accordance with 5.16.5.1, explosion suppression in accordance with ISO 6184-4:1985 shall be implemented. In the event of a signal indicating activation, an emergency shutdown shall be initiated.

NOTE See EN 14373:2005 or NFPA 69:2019 for additional guidance.

5.17 Ventilation

5.17.1 General

Ventilation of enclosed spaces shall be provided to:

a) provide temperature control to ensure the intended operation of equipment is achieved;

b) control hazardous areas and promote the dilution of flammable gas, vapour and mist leaks.

5.17.2 Cooling

Where the functionality of safety relevant equipment is dependent upon its use within its designed temperature range and alternative systems that are capable of keeping the equipment temperatures within the range are not installed, ventilation shall be used to provide an appropriate level of cooling or heating. See 5.17.3.

The effectiveness of the chosen solution to provide temperature control of equipment within its designed temperature range, under any reasonably foreseeable operating or fault condition, shall be validated.

5.17.3 Heating

Where ventilation air is heated to prevent icing conditions or heated where the functionality of safety relevant equipment is designed only for a specific temperature range and alternative systems that are capable of keeping the equipment temperatures above its minimum operating limit are not installed, the heating shall be by:

a) an electrical heater, appropriately certified as necessary, e.g. for use in a hazardous area; or

b) an indirect heat source, the design of which ensures that flammable gases and vapour or any other substance that can create a hazardous situation do not enter the air stream.

Gas turbine compressor delivery air may be used directly to provide heating when stable running conditions are achieved. The take-off point, controls and piping design shall prevent the occurrence of excess flow and the accumulation of unburnt hydrocarbons and shall reduce the potential for burnt/unburnt products of combustion to enter the inlet and cause a hazardous situation on flameout or gas turbine compressor surge.

5.17.4 Hazardous area control

Where a hazardous area exists in an enclosed space, a partially enclosed space or an enclosure, ventilation shall be used to dilute potential leaks of flammable gases and vapours by dispersion into the air until their concentration is below the lower explosive limit. The ventilation shall be assessed in accordance with IEC 60079-10-1:2015 for the purpose of area classification. See also 5.16.2.

Areas of stagnant or poor ventilation, where recirculation and re-entrainment can arise, shall be avoided by ensuring that the ventilation is effectively distributed.

Where heavier-than-air flammable gases or vapours can be present in enclosures, artificial ventilation shall be used to ensure that any gas or vapour concentrations are effectively dispersed from low levels. Where there is the potential for vapours to migrate and accumulate in adjacent low-level areas and trenches, precautions shall be taken (e.g. filling or sealing of trenches, additional gas detectors). The permit to work system shall include testing of the atmosphere prior to accessing any trench or low-level area.

5.17.5 Hot surfaces

Where hot surfaces exist or can exist under normal operating conditions in the hazardous area that are above the AIT (see 5.16.4.4) of a flammable gas, vapour or mist that can be present due to a leak, or where conditions exist that indicates a residual risk of ignition, additional measures in accordance with 5.16.5 shall be implemented. The potential for hazardous leaks in enclosures containing hot surfaces shall be limited to secondary grades of release as defined in IEC 60079-10-1:2015.

Where practical, the ventilation airflow direction shall be arranged so that any flammable leaks are directed away from hot surfaces.

5.17.6 Ventilation inlet location

The ventilation air should be drawn from a non-hazardous area taking into account the suction effects on the surrounding area. Location in a zone 2 area shall be considered acceptable only where the largest credible leak is capable of being diluted by the ventilation air stream, during running conditions or natural ventilation during shutdown conditions where reverse flow can occur.

Where a zone 2 area exists, as described above, or the potential still exists for a potentially explosive atmosphere to enter the ventilation air inlet as described in 5.9.5 for the gas turbine compressor air inlet, the actions described therein shall be taken for the ventilation inlet.

5.17.7 Ventilation inlet filtration

Where the potential exists for dusts or other forms of contaminant to enter the ventilation air inlet that can build up to form combustible deposits, especially on hot surfaces, or prevent the correct operation of safety equipment, suitable filtration shall be installed to prevent this build-up.

Where, due to the type of filtration used or environmental conditions, the potential exists for icing, suitable precautions shall be taken.

Where atmospheric pollution or environmental conditions exist (e.g. build-up of salt spray) that can affect the operation of safety devices within enclosures, appropriate filtration shall be supplied.

If filtration is installed, its fouling/blockage shall be monitored, and the appropriate alarms and shutdown set to avoid any operation of the gas turbine in hazardous conditions.

5.17.8 Ventilation inlet ducting

The ventilation inlet ducting shall normally be routed to avoid hazardous areas. Where this is not possible, the ducting integrity shall prevent leaks and gas detection shall be employed at the ventilation inlet to the enclosed space.

5.17.9 Ventilation outlet location

The ventilation air outlet shall not be located in a zone 0 or 1 area. Location in a zone 2 area shall be considered acceptable only where the largest credible outdoor leak is capable of being diluted to such an extent by natural ventilation that the risk from reverse flow when the ventilation system is not operating is mitigated.

Account shall be taken of any hazardous area created by the ventilation outlet.

5.17.10 Ventilation monitoring

Ventilation shall be monitored and interlocked to the start sequences of equipment so that the start-up is inhibited without sufficient ventilation and enclosure purging.

Means shall be provided to prevent a start-up with defective ventilation monitoring equipment.

During operation, if insufficient ventilation is detected, a shutdown shall be initiated within a defined period of time unless the supply is automatically restored from alternative fans or any alternative power supply. The shutdown delay period shall be as short as practicable based on plant conditions and the presence of any alarm condition associated with the ventilation system.

Where the concept of 5.16.5.3 has been applied, ventilation flow monitoring shall detect insufficient or excessive ventilation flow rates if excessive ventilation flow rates are possible due to design or installed equipment.

If a gas leak that can lead to a hazardous concentration is detected before the required level of ventilation is re-established, the gas turbine shall be shut down and the gas system within the enclosure vented.

Where a method is implemented to inhibit the ventilation flow monitoring to allow the opening of enclosure doors (e.g. for inspection) a suitable warning shall be repeated at the gas turbine control panel until the monitoring has been restored.

5.18 Fans

5.18.1 Fan guards and structural failure

Guarding for fans shall be provided to eliminate the risk of entrapment or contact with moving parts. Guards shall comply with ISO 12499:1999 and retain the fan blades in the event of failure. The design of the fan housing shall contain any failure of fan components.

NOTE Guidance on failure caused by mechanical hazards is given in ISO 80079-36:2016 and ISO 80079-37:2016.

5.18.2 Air blast oil coolers

The design of the cooler shall include protection against foreign objects impacting either the fan blades or the cooler matrix and the impact hazard of the fan blades being released and causing damage to the cooler matrix. Such conditions may cause damage to the cooler matrix leading to process fluid release and the possibility for fire. Where appropriate suitable bunding shall be provided for the cooler.

The design of the fan plenum shall contain any failure of fan components.

The location of the air blast cooler assembly shall be such that if leakage of the matrix occurs, the potential for ignition is minimized.

5.18.3 Sparking of fan blades

Material pairing selection shall avoid materials that generate the potential for sparking between the stationary and rotating elements of fans that operate within a hazardous area.

NOTE Additional guidance on material selection is available in EN14986:2017.

5.19 Flammable gas detection

5.19.1 Type / selection principles

Gas detector measuring principles and selection shall be based on the relevant requirements of IEC 60079-29-2:2015, taking into account the potential for malfunction of the detector(s) due to pollutants/substances in the air stream, vibrations and thermal conditions.

5.19.2 Location principles

The sampling location of fixed gas detectors shall be based on the criteria in IEC 60079-29-2:2015, Clause 8. Enclosed ventilated spaces containing gas fuel or liquid fuel handled above its flash point shall be equipped with at least one gas detector sampling gas from the ventilation outlet. The location of the detector(s) in the outlet shall take into account the mixture concentration contours within the air stream to ensure detection is achieved.

NOTE Reference [67] provides further guidance on vapours produced by liquid fuels at flash point temperatures.

When heavier-than-air gases are used as the main or alternative fuel, extra gas detectors shall be fitted at a low level in the enclosed space to detect any gas or fuel vapours that have accumulated.

5.19.3 Settings

The lowest practical level shall be used for the gas detector settings taking into account the need to avoid nuisance signals. In all cases the alarm to the control interface shall be set at not more than 10 % LFL and emergency shutdown at not more than 25 % LFL. Adjustments shall be carried out in accordance with the manufacturer's manual.

Where used at ventilation outlets, settings shall be chosen in conjunction with the ability of the ventilation system to dilute potentially flammable gas and vapour leaks.

Where gas is detected at the device emergency shutdown setting, the control system (HMI) shall initiate a gas turbine emergency shutdown and give an audible and visual warning to the operator and potential sources of leaks shall be isolated and vented.

5.19.4 Enclosures containing hot surfaces — Screening tool

Where hot surfaces exist in an enclosure, as described in 5.17.5, a one-dimensional jet model may be used as a preliminary screening tool. It can be used to determine if the % LFL setting of a gas detector at an enclosure vent outlet, in conjunction with dilution ventilation, is likely to control the size of the explosive cloud considering a detectable leak, and the size of the leak cloud being compared with the enclosure size. It can also be used to determine if the consequences of the pressure rise are insignificant and contained in the event of ignition.

The screening calculation may be undertaken by comparing the volume of the cloud at the envelope defined by the 100 % LFL contour, and converted to an equivalent volume at stoichiometric concentration, with 0,1 % of the enclosure volume. Where the defined cloud volume is less than this proportion of the enclosure volume, well distributed dilution ventilation is likely to ensure that the gas-detector setting and design-ventilation rate may allow the cloud volume to be controlled. However, such a method cannot take account of turbulence, ventilation direction, recirculation or the effect of obstacles, and should be used with caution. Jet leak impingement on a flat surface adjacent to the leak source might not be adequately diluted by normal ventilation velocities, whilst ventilation direction can reduce the cloud size by a large factor.

The effects of the dilution ventilation air flow on the size of the jet leak cloud shall always be validated in accordance with 5.16.5.3.3.

5.19.5 Maintenance and calibration

Maintenance and calibration procedures shall comply with 7.7.6. The test gas used for calibration shall comply with the general requirements of IEC 60079-29-1:2016+A1:2020, 5.3.

The LFL levels shown in ISO/IEC 80079-20-1:2017 shall be used as datum values except where the major constituent is less than 90 % by volume, in which case specialist advice shall be obtained from the detector manufacturer with respect to an appropriate LFL value.

5.20 Control and automatic protection systems

5.20.1 General

Safety related control functions and the associated sensors, control logic and actuated devices (e.g. those for fuel isolation, fire detection, fire suppression, combustion supervision, gas detection, ventilation detection, overspeed detection and emergency stop) shall be identified and designed, tested, installed, commissioned and validated.

NOTE Standards such as IEC 61508-1:2010, IEC 61511-1:2016, IEC 62061:2005 or ISO 13849-1:2015 along with the appropriate normative references therein, can be applied.

5.20.2 Environmental suitability

Protective systems shall be designed, selected and constructed such that they are capable of performing their intended function under specified environmental/operating conditions (e.g. voltages, humidity, vibration, contamination, UV exposure, pollution, climatic and other external effects), taking into account the operating-condition limits specified by component/equipment manufacturers.

Equipment parts used shall be appropriate to the intended mechanical and thermal stresses and capable of withstanding attacks by existing or reasonably foreseeable aggressive substances.

Special consideration shall be given to the temperature capabilities of control devices, taking into account the effects of thermal radiation. This shall involve the completion of temperature surveys where any uncertainty exists.

Where a heating or air conditioning system is required to control the environment for the gas turbine control module to ensure that the required level of functional safety is achieved, if power is lost to this system, automatic actions shall be taken to safeguard the gas turbine control module.

Sources of ionizing radiation shall be identified and it is important to be aware of atomic regulations to ensure safe installation, use, maintenance, and disposal [e.g. thermal barrier coating (NORM), ignition exciters].

5.20.3 Ergonomics

The human-machine interface shall be intuitive, easy to read and interpret by the operator and designed to display abnormal behaviour of the equipment in a timely fashion. Ergonomic principles shall comply with ISO 12100:2010, 6.2.8 and ISO 9355-1:1999.

5.20.4 Failure

The probability of failure of safety functions shall be minimized in accordance with the requirements of ISO 12100:2010, 6.2.12. When the control signal is removed from a valve or control device that is essential for shutdown or continued operation, the valve or device shall automatically move to its fail-safe position.

Where required, component redundancy or the fail-safe principle for electrical circuits shall be used to perform a safety function and provide the necessary risk reduction. See 5.2.

Measures shall be taken to ensure that errors in the control system logic do not lead to failure and create a hazardous situation. Control parameters shall not change in an uncontrolled way, where such changes may lead to hazardous situations.

Reasonably foreseeable human error shall be identified during risk assessment (see 5.2). Reasonably foreseeable human error during operation shall not lead to failure and create a hazardous situation.

5.20.5 Calibration

Control systems shall be designed to allow calibration of safety related functions where applicable. If calibration is required to be performed while the gas turbine is running it shall not lead to an interruption of operation or compromise the safety of the machine. See 7.7.7.

5.20.6 Testing

As far as practicable control systems shall be designed to allow testing of safety functions with the gas turbine stopped and fuel isolated.

Where necessary to achieve the required level of integrity, the control system shall allow the in-service testing of functions during gas turbine operation without allowing unprotected operations.

The safety functions shall be listed in the operation manual and the procedures for such testing shall be suitably described unless fully automated by the control system. See 7.7.7.

Safety related control systems shall be self-monitoring and self-diagnostic, where necessary, to achieve an acceptable level of reliability. Errors discovered shall be annunciated to the operator. Where operator action is required, it shall be clearly indicated on the control panel, and the action required shall be similarly indicated or described in the operation manual.

Functional tests shall be made during commissioning, after any intrusive maintenance or automatically before starting. The manufacturer shall recommend the frequency and extent of the testing. See 7.7.7.

5.20.7 Speed control

To provide protection against failure of the speed measurement or of the speed controller, an independent or fail-safe overspeed protection system shall be provided to limit the overspeed of each shaft by immediately stopping the fuel supply to the gas turbine. The measurement range of the speed sensors shall be selected such that the measurement at the overspeed limit is still reliable and accurate.

The speed sensors, in multiples with voting, and their associated control equipment shall be arranged so that the checking of the system is undertaken whilst the gas turbine is in operation and an emergency shutdown is initiated if the control parameters are exceeded. Overspeed settings shall consider the gas turbine and driven-unit equipment. The setting shall exceed the speed resulting from sudden loss of maximum potential power with a margin that avoids nuisance shutdowns but does not result in overstressing of the rotating parts.

The overspeed protection system shall have in-built testing functionality, or provisions shall be made for the testing of all overspeed protection devices at intervals specified by the gas turbine manufacturer.

Gas turbines with separate power turbines or with heat exchangers can require additional protection against overspeed because of the stored heat, and/or large stored volumes of high-pressure air. Protection measures such as but not limited to aerodynamic braking or air release valve(s) shall, where necessary by analysis, be utilized to prevent a hazardous situation.

For multiple rotor shaft gas turbines, if it can be shown that it is not possible for a rotor to overspeed due to aerodynamic forces, an overspeed protection system is not required on that rotor.

5.20.8 Gas turbine emergency shutdown system

An emergency shutdown system shall be provided. The integrity of the shutdown and emergency trip functions shall be ensured even if protection and control logic are executed on common hardware. The system shall be capable of manual operation and shall be a back-up and not a substitute for other safeguarding measures. It shall also be operated automatically by safety related gas turbine protection devices and any safety related process plant protection devices that affect the operation of the gas turbine.

The control system shall be designed so that the emergency shutdown system including the emergency stop buttons, stops the gas turbine by acting on the fuel shut-off valves to immediately cut off the fuel supply and all associated equipment upstream and/or downstream if its continued operation can produce a hazard. Shutdown shall not be preventable after the command has been initiated.

Emergency stop push buttons shall be provided at each local operator control location, appropriately located, clearly marked and directly accessible, which shall be active during normal and maintenance operations. These buttons shall:

a) have clearly identifiable, clearly visible and quickly accessible controls and require manual reset after operation;

b) stop the gas turbine and any associated equipment at risk as quickly as possible, without creating additional hazards;

c) not be part of a human-machine interface (HMI) (e.g. touch screen) display.

The action of the emergency stop shall set the driven equipment to a safety state commensurate with shutdown of the gas turbine and shall override any other functions of the driven equipment and be available and operational at all times, regardless of the operating mode.

If other standards require local stop buttons for each drive or subsystem, this can create additional risks for the complete gas turbine system, which shall be taken into account.

An audible warning shall be set off at the operator station by any emergency stop. If an HMI is used, a message shall be displayed to indicate that the emergency stop has occurred.

The functions to be maintained in each case of emergency stop shall be assessed to minimize the consequences (e.g. in case of gas leakage detection, the ventilation system is maintained in action to purge the enclosure, but in the event of fire the ventilation shall be shut down and the retention dampers, where utilized shall close to enable the fire to be extinguished).

An automatic re-start shall not be possible after an emergency shutdown without a manual intervention. Prior to a re-start a check by operating personnel shall be undertaken to ensure that the fault that initiated the shutdown has been resolved.

5.20.9 Interlocks

The control system shall provide interlocks that prevent gas turbine start or ignition if this can result in hazardous conditions based on the current status of the systems. Interlocks shall be reset only after correction of the cause. The control system shall indicate which system has initiated the operation of an interlock.

5.20.10 Cyber security

Cyber security aspect shall be considered when identified as a potential source of hazard in the risk assessment.

NOTE ISO/IEC 27032:2012, ISO/TR 22100-4:2018 and the IEC 62443 series provide guidance on cyber security.

5.21 Electrical

5.21.1 Design/Installation

Electrical equipment of drives, control systems, measuring and control devices, lighting and heating shall, where relevant, comply with IEC 60204-1:2016, IEC 60204-11:2018 and IEC 60079-14:2013.

5.21.2 Isolation and stored energy

5.21.2.1 General

For maintenance and inspection purposes and in an emergency, means for energy isolation for electrical supplies with voltages not exceeding 1 000 v AC or not exceeding 1 500 v DC and frequencies not exceeding 200 Hz shall comply with IEC 60204-1:2016, 5.3. Isolating devices shall provide all-pole load disconnection and contact clearances shall be appropriate to ensure isolation.

Devices for the prevention of unexpected start-up shall comply with ISO 14118. Where required, local stop buttons shall be provided in accordance with IEC 60204-1:2016, 5.4.

Where electrical isolation by a plug/socket combination under the immediate supervision of the person present in the hazard zone is not possible, the isolation devices shall be capable of being locked or otherwise secured in the "isolated" position.

Isolation devices shall be clearly identifiable.

5.21.2.2 Isolation of electrical equipment in potentially hazardous areas

Isolation of other than intrinsically safe circuits shall comply with IEC 60079-14:2013, 8.3. Isolation of intrinsically safe circuits shall comply with IEC 60079-17:2013, 4.8.

Live maintenance on intrinsically safe installations is permitted with compliance of IEC 60079-17:2013, 4.8.2.

5.21.2.3 Stored energy

Dissipation of stored energy for maintenance and inspection for supplies greater than 1 kV shall comply with IEC 60204-1:2016, 6.2.4. Supplies greater than 1 kV shall have suitable earthing, bleed resistors or short circuit arrangements. Large capacitors for variable speed drives or other similar equipment shall have warning labels detailing instructions/times for discharge.

5.21.3 Electrostatic energy and bonding

5.21.3.1 Non-conducting parts

Non-conductive mechanical equipment parts exposed to the explosive atmosphere and susceptible to electrostatic charging (for example, components that contain the flow of fluids and gases with particulates at high velocities) shall comply with ISO 80079-36:2016. Non-conductive electrical equipment parts exposed to the explosive atmosphere and susceptible to electrostatic charging shall comply with relevant standards, for material test requirements they shall comply with IEC 60079-32-2:2015.

NOTE IEC TS 60079-32-1:2013 provides additional guidance on electrostatic charging.

5.21.3.2 Conducting parts

Equipment shall be arranged so that hazardous electrical potential differences cannot exist. Bonding and potential equalization shall comply with the requirements in IEC 60204-1:2016.

If there is a possibility of isolated metal parts becoming charged and acting as an ignition source or a risk to persons, then bonded terminals shall be provided and used to continuously dissipate the charge.

Where conductive parts are used for the conveyance of non-conductive fluids and gases and the continuity of conductivity is broken by the use of non-conducting flexible connection or by other means, terminals shall be provided at each side of the break and the parts bonded together, unless there is a valid need for the insulating section, such as to prevent circulating currents in generator bearings.

Shielded cables shall be used where necessary to prevent interference and signal degradation. Continuity of shields shall be ensured. At least one end of each shield shall be earthed.

NOTE For hazards associated with lube oil conductivity, see 5.24.1.

5.21.4 Water ingress

Electrical enclosures shall be rated in accordance with IEC 60529:1989 and be suitable for the environmental conditions in which they are operated. Ingress protection IP 54 shall be used as a minimum for outdoor conditions. In cases where water jets or compressed air are used for cleaning, a suitable higher category shall be used. The means of introduction of a cable with its glands, bushings, etc., into an enclosure shall ensure that the degree of protection of the enclosure is not reduced. Cable connectors/glands, flexible conduits and fittings shall offer at least the same level of protection as defined for associated enclosures in accordance with IEC 60204-1:2016 and IEC 60204-11:2018.

5.21.5 Lightning

Risk assessment shall be carried out using IEC 62305-2:2010, any protection requirements are to be highlighted by the packager. The site installation shall comply with IEC 62305-1:2010, IEC 62305-3:2010 and IEC 62305-4:2010.

5.21.6 Electromagnetic compatibility (EMC)

The equipment shall not generate electromagnetic disturbances above levels that are appropriate for its intended place of use. In addition, the equipment shall have an adequate level of immunity to electromagnetic disturbances so that it can operate correctly in its intended environment.

Electromagnetic emissions and immunity shall comply with IEC 61000-6-4:2018 and IEC 61000-6-2:2016 respectively.

Cables shall be installed with sufficient separation to avoid electromagnetic interference. This is normally provided by routing signal cables separately from power cables, and terminating them in separate junction boxes, where applicable.

Installations and earthing and cabling shall take into account the requirements of IEC TR 61000-5-1:1996 and IEC TR 61000-5-2:1997 respectively.

General disturbances can be limited by applying the measures in IEC 60204-1:2016, 4.4.2.

5.21.7 Battery installations

Battery installations shall comply with IEC 62485-2:2010 including provisions against explosion hazards.

5.21.8 Electrical overload

Overloading of electrical equipment shall be prevented at the design stage by means of integrated measurement, regulation and control devices, such as over-current cut-off switches, temperature limiters, time-lag relays, overspeed monitors and/or similar monitoring devices.

Where there is the potential for circuit overloads in the equipment greater than the design limits, appropriate protection devices shall be installed in accordance with IEC 60204-1:2016, Clause 7.

5.21.9 Electrical power failure

5.21.9.1 System failures

The consequences of power failure to the control system and safety devices shall be assessed to identify the need for the provision of alternative power supplies such as independent feeds, standby generators or batteries.

If no alternative supply is provided, or if the alternative fails to become available within the defined time limit, a shutdown shall be initiated.

If a limited alternative supply is provided, the systems that it is to feed shall be identified so as to minimize the risks and avoid hazardous situations.

In the case of battery back-up systems, a shutdown shall be initiated before the remaining battery power becomes insufficient for a shutdown of the equipment.

5.21.9.2 Electrical power restoration

Following power failure, those systems that are automatically restored to operation shall be identified and shall be designed so as to avoid hazardous situations.

5.22 Drains, vents and bleeds

5.22.1 General

The hazards associated with drains and vents shall be determined and shall be specified for each interface point, together with the details of the type(s) of media, the mode of operation and the flow rate and temperature. The details of any hazards shall include, but are not limited to, heavy metals, recycling, corrosion, fire and explosion risks, contact and/or inhalation of harmful fluids, gases, mists, fumes and dust.

The base plate or foundation shall be designed to ease the collection of liquid and to retain the quantity of leaked liquids collected before the detection of the leak. The location of the drain point of the baseplate shall minimize the quantity of liquid retained after the drain operation.

All manual drain valves shall be easily accessible.

Gas turbine package drains and vents shall terminate in safe locations.

The noise generated from vents shall be considered (see 5.7).

5.22.2 Vents for flammable gases

Breathers from regulators or relief valves and vents from vent valves shall be terminated to atmosphere in an area without an ignition source. Protection against lightning shall be in accordance with 5.21.5. Special attention shall be given to ensuring that during running or shutdown gas cannot re-circulate into the gas turbine compressor air inlet, the gas turbine enclosure ventilation air inlet or outlet and at exhaust locations.

The hazardous area at the outlet point shall be suitably zoned in accordance with IEC 60079-10-1:2015, or another equivalent standard.

The design of the outlet shall be such that debris and any other potential foreign matter are prevented from entering the vent and arranged to achieve good dispersion taking into account the properties of the gas and anticipating any possible problems when venting from high pressures. The location of vent outlets shall not lead to hazardous areas impinging on other properties, i.e. those belonging to the public or a third party.

Vents shall be independently installed unless it can be shown that there is no potential for hazardous interaction between connected vents.

Where practical, the requirement for venting shall be minimized.

Manual valves shall not be used operationally on vent lines. During operation valves used only for maintenance shall be secured (open/closed as required) in a tamper-proof manner. Welded pipes are recommended to avoid additional hazardous area classification around mechanical joints on vent lines.

5.22.3 Toxic and hazardous emissions

Means shall be provided to prevent the emission of hazardous substances from the machine in accordance with ISO 14123-1:2015. Where the measures described in ISO 14123-1:2015 cannot reduce the risk of toxic and hazardous emissions from vents or drains, additional precautions shall be taken to ensure that such emissions cannot reach a toxic or hazardous level.

NOTE Also see NFPA 55:2020 as an acceptable equivalent to ISO 14123-1:2015.

Such measures may include, but are not limited to:

a) increasing the height of vent outlets to provide required dispersion for personnel who may be in the area;

b) locating vent outlets in suitable areas where personnel access is normally prohibited;

c) continually monitoring for toxic emissions at outlets in conjunction with the associated shutdowns and evacuation acoustic alarm and associated procedures;

d) the use of coalescers for the removal of mist from vents.

5.22.4 Gas turbine compressor bleeds

If local discharge of the bleeds can create a potentially hazardous situation they shall be piped/ducted to discharge to a safe location.

5.23 Pressure equipment

5.23.1 General

Be aware of possible regional, national, local regulations and mandatory codes or standards regarding pressure equipment (e.g. piping, vessels, associated assemblies). This section contains requirements for pressure equipment that are unique to gas turbine applications.

NOTE Several national or international design codes exist, for example ASME, API and ISO, however, the detailed requirements of each code, whilst very similar, are different and are not interchangeable. Commonly the applicable design code is called up from within national legislation.

5.23.2 Design

The pressure equipment shall be designed taking into account all relevant factors to ensure that the equipment is safe throughout its intended life and shall apply appropriate safety factors.

Special considerations shall be taken when assessing loadings on pressure equipment that are influenced by the gas turbine and associated equipment such as internal and/or external pressure, ambient and operating temperatures, mass of piping/vessel and contents, climate loads, dynamic effects of the fluid, potential movements of structures, vibrations, earthquakes, transportation, handling, fatigue, reaction forces, etc. and applicable combinations of these loadings occurring simultaneously. The material, wall thickness, tensile strength, ductility, forming, joining and test methods shall be suitable for the specific media and withstand the loadings that can occur. Where necessary, adequate allowance or protection against wear, erosion, corrosion, chemical attack and decomposition of unstable fluids shall be provided, taking due account of the intended use.

Provisions shall be provided for inspection and testing, where appropriate.

5.23.3 Hazards

The design, inspection and validation activities undertaken to minimize hazards, shall be as defined in the specified pressure design code and its supporting international or national standards.

Residual risks shall be communicated in the information for use and shall indicate appropriate special measures that need to be taken at the time of installation and/or use.

5.23.4 Misuse

Consideration shall be given to the potential misuse of the pressure equipment (e.g. use as a means of access, climbing on it, standing on it or for storage).

5.23.5 Handling and operation

Risks associated with handling and operation shall be analysed and provisions for appropriate precautions shall be made (e.g. fitting padlocks at manual valves that, if incorrectly operated, can cause a hazard, fitting blanking plugs or flanges at manual valves opened to vent or drain and monitoring the pressure and/or the temperature in the equipment prior to disassembly).

Devices containing loaded springs that can cause injury if accidentally released shall be designed such that the spring load can be reduced to below 110 N before the spring is disassembled. Otherwise they shall be suitably guarded.

5.23.6 Isolation, draining and venting

Where applicable provide provisions for draining and venting of the pressure equipment for cleaning, inspection and maintenance.

To avoid potential harmful effects (e.g. water hammer and vacuum collapse) all stages of operation and testing shall be considered.

Where required for maintenance and inspection purposes, devices shall be provided for isolation and the dissipation of fluid pressure.

5.23.7 Fluid injection

The hazard of fluid injection into the human body shall be minimized by:

a) ensuring that all high-pressure piping in a position where it is likely to be damaged is protected, robust and sufficiently supported;

b) providing shielding (e.g. screens) to flexible piping installed adjacent to an operator's assigned working position to reduce the risk resulting from a failure in the flexible piping system where failure could cause harm to persons.

5.23.8 Assemblies

5.23.8.1 General

Assemblies shall be designed so that the components to be assembled together are suitable and reliable for their duty and are properly integrated and assembled in an appropriate manner.

Assemblies shall be designed to prevent velocity and pressure fluctuations causing harmful oscillations in the system (e.g. by pressure regulation, correct pipe sizing, firm supporting and/or flexible couplings).

Piping, valves, pumps, etc. shall be arranged to minimize the number of vent connections required to prevent the formation of air or gas pockets in liquids that can cause hazardous operating conditions.

All piping, pipe fittings, passages, surge or storage tanks and cored or drilled holes shall be free from burrs or foreign matter that can cause damage to a system or lead to a hazardous situation.

Control valves and other control components requiring inspection or maintenance shall be mounted in positions that provide accessibility and avoid damage.

Where proprietary tube fittings are used, component parts from different manufacturers shall not be intermixed within a single fitting.

Tube fittings of a similar design from different manufacturers shall not be mixed on an assembly to minimize the potential for leaks and failure where mixing of fitting procedures or individual parts is possible.

Counter rotating (left hand and right hand) threads shall not be used on the same assembly where there is the potential for uncontrolled pressure release.

5.23.8.2 Pressure control and overpressure protection

Where there is the potential for exceeding the allowable pressure limits the equipment shall be protected by control or relief valves.

Adjustment of over-pressure protection devices shall be possible only with the use of an appropriate tool.

Safety devices shall be monitored as necessary and shutdown shall occur where abnormal deviations are detected.

5.23.8.3 Particulate contamination

The ingress of particles that can be detrimental to the safety of the equipment shall be prevented (e.g. by the incorporation of a suitable filter or strainer).

Filters and strainers shall be positioned in such a way that allows for periodic servicing.

Transparent bowls for filters or strainers (e.g. glass, plastic) shall be protected to prevent injury from flying particles if failure occurs.

5.23.8.4 Filling and drainage

A safe means of filling or draining systems or parts of systems during commissioning, maintenance and de-commissioning shall be provided.

5.23.8.5 Accumulators

The release of stored energy shall not lead to hazardous situations. The process side of accumulators should be automatically and completely discharged when the respective system is shut down or provisions for depressurizing shall be provided unless the accumulator has built in features that render depressurization unnecessary.

5.23.8.6 Quick release connections

Where quick release connectors are used, they shall be of the self-sealing type to prevent leakage and ingress of foreign particles and shall be of the type that prevents opening whilst under pressure. Consideration shall be given to the risk of incorrect reconnection if flexible lines are used, quick connects shall not be the same on different services.

5.23.8.7 Pumps

The system downstream of a positive displacement pump shall be equipped with a relief device if the system can be blocked or closed. The relief fluid shall be piped to a suitable location where the backpressure does not allow the system design pressure to be exceeded.

Where centrifugal pumps are used as a pressure source, relief devices need not be supplied provided the design of the associated piping and flanges is based on the maximum supply pressure and providing that excessive overheating cannot occur.

Where relief or spill valve flow is returned to the pump suction the design shall be such that the credible flow shall not be capable of causing overheating with the potential for cavitation and vapour lock.

The relief device shall be adjusted in accordance with the manufacturer’s instructions to prevent bursting of the pump casing or downstream piping if a malfunction occurs that prevents pump flow.

5.23.9 Safety accessories

5.23.9.1 General

Safety accessories are devices designed to protect pressure equipment against exceeding the allowable limits. Be aware of applicable regulations and mandatory codes and standards regarding safety accessories These shall take into account the following considerations:

a) be designed and constructed to be reliable and suitable for their intended duty and take into account the maintenance and testing requirements of the devices, where applicable;

b) be independent of other functions, unless their safety function cannot be affected by such other functions;

c) comply with appropriate design principles to obtain suitable and reliable protection and shall be designed so that fail safe principles are applied.

5.23.9.2 Pressure limiting devices

Pressurized systems, if the risk of over-pressure exists, shall be fitted with pressure limiting devices.

5.23.9.3 Thermal safety

Where hazardous excess pressure can occur in the pipework system due to thermal expansion of the liquid, means of pressure relief shall be provided.

Where thermal pressure relief valves are used on pressure equipment, the outlet from the thermal relief valve shall be piped to a suitable drain where the backpressure does not allow the system design pressure to be exceeded.

5.23.10 Flexible piping (and metal hoses)

Flexible piping shall:

a) be as short as practicable consistent with proper bend radii and routing and without being distorted to a deformed shape or stretched in a manner that causes inappropriate permanent tension;

b) be mounted in such a way as to avoid distortion, uncontrolled movement and damage during pressurization;

c) withstand the maximum vibration levels that can be imposed by the equipment;

d) have integral end fittings that allow replacement or maintenance and that enable the connections to be held in position and tightened without the risk of torsional stress being applied to the flexible section;

e) be routed and retained so that it is unlikely that they can be used as handholds or footsteps.

Where there is a possibility of hazards arising from leakage onto hot surfaces from flexible pipes additional precautions shall be taken (e.g. by appropriate higher specification, guarding or routing the pipe away from the hot surface).

Flexible pipes for gas systems shall be of corrugated stainless steel or be of a non-metallic construction having a fire-resistant surface.

Corrugated stainless steel hoses shall not be used where there is the potential for the entrapment of hazardous liquids and contaminants, e.g. within the corrugations or within any inner liner.

ISO 10380 gives design, manufacturing and testing requirements of metallic flexible hose assemblies.

5.23.11 External fire

Where the potential exists for pressure equipment to be subjected to external fire, appropriate protective measures shall be taken to minimize risks in the event of leakage.

5.23.12 Material embrittlement and corrosion

Where equipment can contain gas or other media under pressure that can be contaminated, with the potential for causing embrittlement of the pressure containing parts, materials shall be selected that provide resistance to embrittlement, corrosion and the formation of cracks that can lead to failure.

Attention shall be given to the potential for accelerated embrittlement where contaminants can interact to accelerate the corrosion process (e.g. the presence of hydrogen sulphide with trace contaminants of mercury).

NOTE ISO 15156-1:2020 provides guidance on the selection of materials resistant to stress corrosion cracking in the presence of hydrogen sulphide at different levels of contamination, pressures and temperatures.

Measures shall be taken to monitor temperatures and pressures to ensure that they are within the ranges that were used for the selection of a given material.

Consideration shall be given to drying and heating gases to reduce the potential for the presence of liquids with the potential to cause corrosion and thereby mitigate the potential for material failure.

5.23.13 Ultra-violet (UV) resistant pipework

Special considerations need to be given to the selection and use of non-metallic hoses and pipework in pressurized applications and shall be aware of relevant regulations and standards. Degradation of non-metallic pressure components due to application and environmental conditions (e.g. UV light) need to be considered.

5.24 Auxiliary systems

5.24.1 Lubrication systems

The lubrication oil system shall fulfil the requirements for oil flow, pressure and temperature required by the gas turbine. Devices shall be fitted to monitor pre-set control parameters (e.g. loss of pressure and/or temperature) and shutdown the gas turbine.

If an external seal air supply is necessary, on gas turbine shutdown, to prevent the internal leakage of oil from the gas turbine bearings to areas of high temperature within the gas turbine core which could create a fire risk, the specification of the seal air supply shall be such that the supply is maintained for a period that allows the internal gas turbine surfaces likely to be in contact with the oil to cool below a temperature at which ignition can take place.

Where a fan-assisted coalescer is used for mist removal, and a hazardous situation can arise from an increase in back pressure, a bypass or other measures shall be taken to reduce the back pressure to the design limit.

Electrostatic charging and the formation of sparks in the lube oil system, which can lead to a hazardous situation, shall be prevented. As turbine lube oils generally have a low electrical conductivity the prevention has to be carried out by installation of equipotential bonding or by appropriate systems parts, in particular, in relation to isolated conductors and non-conductive parts, such as filter elements.

NOTE For combined lube oil systems supplying the gas turbine and other driven equipment, the pre-set control parameters can be driven by components other than the gas turbine in turbine train.

5.24.2 Water systems

Where water systems (e.g. wash, injection, evaporative cooling, air inlet direct water mist spray and fire protection) are located where there is the risk of freezing, measures shall be taken to avoid equipment failure. Such measures may include:

a) the use of an appropriate anti-freeze additive;

b) trace heating of exposed equipment and pipe work with associated thermal insulation;

c) the use of suitable methods to prevent freezing of fluids in drain tanks where the lack of drainage can induce a hazard.

Solvents used to enhance the properties of the wash fluid during on-line gas turbine compressor cleaning and anti-freeze additives shall be selected so that a mixture capable of ignition or of producing a rapid increase in gas turbine combustion temperatures is not used. Off-line gas turbine compressor washing utilizing solvents and anti-freeze shall be followed by a flushing, drying and purging cycle to ensure that no harmful or combustible deposits remain.

The quality of water used for gas turbine compressor air inlet evaporation cooling or direct water mist injection, gas turbine compressor water wash, primary or secondary water injection and the source for steam injection shall be controlled such that the total contaminants entering the gas turbine shall not impair the life of components, leading to premature failure and a potentially hazardous situation.

5.24.3 Hydraulic and pneumatic systems

Hydraulic and pneumatic systems shall comply with the safety requirements of ISO 4413:2010, Clause 5, and ISO 4414:2010, Clause 4, or other applicable industry codes and standards.

NOTE ASME B31.3:2018 is commonly used for design of pressure systems (see 5.23.1).

5.24.4 Utility air supplies

Utility air supplies shall be filtered and have any undesirable condensate removed to avoid causing malfunction of the supplied equipment.

On the loss of a utility air supply, safety equipment shall either permit continued safe operation or shall fail to a safe condition.

Undesirable changes in the pressure of a utility air supply shall cause an alarm condition. If the pressure change can cause a potential hazard, the safety devices shall cause shutdown of the equipment. Where it is necessary to maintain pressure to achieve shutdown accumulators shall be included in the system.

5.25 Installation in a hazardous area

Hazardous areas shall be classified in zones in accordance with 5.16.2.

Gas turbine installations in zones 0 and 1 areas shall be prohibited. Where the gas turbine is arranged in a ventilated enclosure within a zone 2 area, the installation shall comply with the following.

a) Hazardous area equipment within the zone shall comply with 5.16.4. The equipment shall comply with the requirements of the more hazardous substance inside or outside the enclosure.

b) The requirements of IEC 60079-10-1:2015, with respect to extent of the hazardous area shall be taken into account.

c) If within the zone 2 area, the gas turbine compressor air inlet shall comply with 5.9.5 and the ventilation air inlet shall comply with 5.17.6.

d) Access within the gas turbine enclosure shall be in accordance with the requirements of 7.6.6.

e) The measures for the prevention of the ignition of flammable gas, vapour or mist on hot surfaces external to the gas turbine enclosure within the zone 2 area, as well as in the enclosure, shall comply with 5.16.4.3.2.

f) Where the gas turbine exhaust temperature exceeds 80 % of the AIT, in degrees Celsius, of any flammable gas, vapour or mist that can be present, it shall discharge to a safe area taking wind effects into account.

g) The enclosure ventilation system shall maintain a positive pressure in the enclosure.

h) On the loss of ventilation an emergency shutdown shall be initiated (see 5.17.10).

NOTE Based on a site risk assessment, gas detectors can be required at the perimeter of external zoned areas to initiate a gas turbine shutdown if there is the potential for a hazardous gas concentration level to occur. It is possible that this is not be part of the packagers supply.

5.26 Unenclosed gas turbines in a hall

Hazardous area classification shall be in accordance with 5.16. Zone 0 areas and continuous grades of release in accordance with IEC 60079-10-1:2015 shall not be permitted in the gas turbine hall.

Any surface temperatures exceeding 80 % of the AIT, in degrees Celsius, of the hazardous gas, vapour or mist that can be present in a hazardous area shall be assessed and appropriate mitigation shall be taken into account, as applicable, including but not limited to:

a) the size of the hall;

b) the areas of occupancy with respect to the potential for the ignition of a flammable mixture from a leak source;

c) the possible harm to personnel in the vicinity of the deflagration;

d) the ventilation used for the area, where appropriate the techniques described in 5.16.5.3.2 and 5.16.5.3.3 shall be employed;

e) access restrictions employed;

f) the installed non-asphyxiant fire detection and extinguishant equipment or interlock with isolation of the fire system;

g) the gas, vapor and mist detection provisions;

h) provision of deflagration relief equipment; certification of equipment in the hazardous area;

i) ability to shutoff and vent/depressurize all sources of ignition of flammable substances.

Any zone 1 areas in the hall shall be limited to the extent arising from reasonably foreseeable release rates that will be diluted by the ventilation to a defined zone that shall not encroach on any equipment not suitably certified or on any surface temperatures that exceed 80 % of the AIT, in degrees Celsius, of any flammable gas, vapour or mist that can be present in the hazardous area.

The gas turbine hall shall be fitted with:

i) a fire detection and extinguishant system in accordance with 5.15;

ii) a non-asphyxiant based extinguishant system, or entry to the hall shall be interlocked with isolation of the extinguishant, where personnel access to the hall is required during operation;

iii) a ventilation system assessed in accordance with IEC 60079-10-1:2015.

Where the potential for an explosive atmosphere exists due to a leak of a flammable gas or vapour, the hall shall be fitted with a gas detection system in accordance with 5.19, but taking into account the need to locate detectors in the vicinity of potential leak sources, credible leak sizes and the effect of ventilation, and the different conditions when starting cold and running hot. Open path detectors shall be considered for this application.

NOTE See Reference [71] for further information.

5.27 Decommissioning and disposal

Decommissioning information and instructions shall be provided that enable the user to isolate the gas turbine and make it unable to start by at least two methods, such as, for example, removal of starter motive power, removal of control circuit fuses, blinding fuel supply, removal of fuel control valve or disabling the control program.

Preservation methods shall be provided where necessary. Special considerations and information shall be given to decommissioning of hazardous noxious, toxic, and radioactive fluids, substances, and materials.

6 Compliance verification

6.1 Quality assurance

Quality assurance and quality controls, meant to ensure the achievement and maintaining of a safe product, shall be achieved by the manufacturer using a recognised quality standard (e.g. ISO 9001:2015).

Documentation records shall be kept by the OEM for the equipment life, where there is a legal duty to do so, or otherwise shall be available for a minimum of 10 years from the date of supply.

It is recommended that safety related documentation such as risk assessments, hazard and operability studies (HAZOPS) and records covering the life of components shall be kept by the OEM for the lesser of the lifetime of the equipment or 30 years.

Special consideration should be taken to ensure documentation retention periods are managed (ex. Organizational changes, acquisitions, divestitures, etc.).

6.2 Verification of safety requirements

Compliance with safety requirements shall be verified in accordance with Annex B. Mark products in accordance with applicable regulatory markings.

7 Information for use

7.1 General

The completed machinery manufacturer (e.g. final supplier/packager) is responsible to compile and provide the information for use necessary to reduce health and safety, and environmental risks. Information for use includes product manuals, operating manuals, safety data sheets, drawings, diagrams, etc. that is necessary for the assembly, installation, transportation, storage, operation, maintenance, and decommissioning. Information for use can be provided in whole or in part in electronic format.

Sales literature describing the machinery shall not contradict the instructions with regards to health and safety. Sales literature describing the performance characteristics of machinery shall contain the same information on emissions as is contained in the instructions. The information on noise emissions provided in the technical sales literature shall not contradict the instructions.

7.2 Language

Safety related documentation (e.g. instructions) shall be drawn up in the base language selected by the OEM from which any translations are produced.

Safety related documentation shall be issued in the language agreed with the purchaser. Additionally, be aware of languages demanded by local legislation. By way of derogation from this requirement, maintenance and commissioning documentation for use by specialized personnel need only be available in a single language understood by those personnel.

7.3 Packaging

The final machinery manufacturer is responsible to mitigate residual risks associated with integration where applicable and communicate the final residual risks in the information for use.

7.4 Commissioning

Commissioning documentation, related to safety devices and their associated functions, shall be available. The documentation shall include details of checks that shall be undertaken on the equipment, safety devices and associated control system functions prior to first gas turbine start-up, including checks that the control-system parameters applicable to safety functions are correctly adjusted/set. Changes made during commissioning shall be within criteria that have been validated to allow non-hazardous operation. Loop checks, including resistance to earth and continuity, shall be carried out for each applicable safety device including, where applicable, calibration of the device. Where a device is still within its calibration period this may be carried out by simulation of the device output. Where use is made of distributed networked controls and the loops have been validated at the manufacturer's works for both the devices and the controls and the equipment is within calibration, the loop check may be replaced by a communications check. Power supplies for safety devices, including those supplied and installed by the operator, shall be checked to ensure that the voltage and current supplied and protection and isolation of the circuit are in accordance with the documentation.

The documentation shall include details of bonding, earthing and shielding checks that shall be undertaken with respect to safety devices and associated wiring where the devices are susceptible to static electricity or electrical interference. The documentation shall include details of bonding and earthing checks that shall be undertaken on mechanical equipment with flowing media or that is otherwise subject to the build-up of static electricity that can affect the operation of safety devices, lead to ignition in a hazardous area or cause static shocks to personnel.

The documentation shall designate the piping connections to all safety related supply, vent lines, drain lines and tanks. It shall state that during the commissioning process, all components shall be checked for proper function. Where necessary, that the associated flow rates, pressures and temperatures are within limits and that associated safety devices, pressure equipment assemblies and locking devices are correctly installed and calibrated.

The documentation shall state that hazardous areas shall be reviewed with the operator to ensure that, where applicable, equipment is correctly certified for the zone and that zones are not compromised by such hazards as gas vents, other sources of potentially explosive leakage or hot surfaces.

The documentation shall include the necessary checks to verify that site installed fire protection equipment has been assembled and located correctly. This shall include checks that pressurized extinguishant and propellant bottles are located such that overheating will not occur and burst disc debris and discharges are directed to a safe location. Where an extinguishant discharge test is required after installation, the documentation shall include the procedure to be adopted and the safety precautions to be taken, including those where the test is undertaken from running conditions and any post-test inspections that may be required.

Pre-start checks (cold commissioning) shall include exercising of valves and other devices that are part of a safety function and checking that the equipment is correctly mounted and aligned. Where applicable, running tests shall be undertaken to verify that safety devices are operating correctly.

Where x-rays or gamma rays are used for inspection, diagnostics, or calibration, the documentation shall include precautions to be taken to protect personnel and sensitive equipment from harm.

The documentation shall state that for starting systems having common starting capabilities for multiple units, proper electrical and mechanical interlocks shall be tested prior to commissioning in order to avoid starting the wrong gas turbine.

7.5 Operation

7.5.1 General

Instructions for use shall be provided.

The information for use shall contain a description of each section of the equipment, its function and operating criteria, the associated safety devices and interlocks and safety check procedures and any limitations on use. The description shall include, where applicable, the operating sequences of equipment during start-up, changes in operation and shutdown, the locations of emergency stop devices and methods for tracing and eliminating minor faults.

The information for use shall contain instructions for the checking of safety related devices and inspections and setting checks that shall be undertaken whilst the equipment is in use.

The information for use shall identify all site specific reasonably foreseeable environmental conditions that can affect the operation of the equipment and the associated corrective actions.

The control system section of the information for use shall describe the function of the control system, the equipment operating concept and modes, and how the annunciation of start, operation and shutdown sequences, the machine status and fault conditions are arranged and displayed. The information for use shall include a description of any start-up warning devices, hold-to-run devices and how the machine will react after the actuation of safety devices. Any message: Alarms, shutdown, emergency shutdown, permissive to start, etc., shall be explained in the information for use. Where a message requires operator intervention the actions required shall be clearly indicated or described in the information for user. The information for use shall describe any actions that shall be taken before accepting an alarm condition and before resetting after an emergency shutdown or emergency stop, as applicable.

Where manual intervention is required for testing of the safety functions and devices during normal operation the periodicity and the actions required shall be described in the information for use.

7.5.2 Safety instructions and emergency procedures

The information for use shall contain safety instructions required to ensure that the machinery is operated under specified operating conditions and the actions to be taken in the event of all reasonably foreseeable emergencies and warnings against any potential misuse of the equipment.

The information for use shall contain warnings and refer to material safety data sheets (SDS) for all hazardous substances/additives approved for normal use during operation of the machine and shall clearly specify any particular working practices and personal protective equipment (PPE) that are necessary to ensure their safe use, including details of acceptable cleaning solutions and working practices during their handling and use. Additionally, the information for use shall contain information detailing the correct use of the machine to prevent exposure of the operator to harmful substances and any biological hazards. The information for use shall provide limitations on the use of flammable anti-freeze agents during gas turbine compressor washing.

The information for use shall instruct that regular checks for leaks are undertaken on exhaust ducting and exhaust flexibles where these are routed through a building where leakage can lead to asphyxiation of personnel in or passing through the building (see 5.12.3). A description of the characteristics of any vents, exhausts or drains for hazardous and noxious substances shall be included. Where the potential exists for contact with or inhalation of toxic gases, the manual shall contain information on the use of portable gas detectors in conjunction with site procedures to cope with any leakage.

The information for use shall include instructions on the actions taken by the operators in the event of a gas or mist detector alarm where fitted. Where automatic or manual processes exist to change the ventilation rate on the detection of a leak, the process shall be described in the manual together with details of the effects of its use on the gas or mist detection equipment. If more than one detector is provided, the information for use shall include instructions on the interpretation of each detector reading. The information for use shall also include the actions and precautions to be taken to locate and eliminate the source of a leak, including details of the equipment to be used, and limitations on access when a leak is known to be present. Where the incorrect operation of manual drain or vent valves can cause a hazardous situation, the information for use shall contain clear instructions on their operation.

The information for use shall instruct that hot surfaces in hazardous areas shall be maintained free of contaminants that can ignite or contaminants that can affect the ignition characteristics of the surface.

The information for use shall include instructions on the action taken by the operators in the event of fire detection, for both fires detected automatically, and fire detected by the operators, and details of any additional actions associated with manual release of the fire extinguishant at the extinguishant containers. Where manual actuation of the emergency release is required at the extinguishant containers, the operating manual shall advise that the emergency stop button shall be activated to cut off the fuel supply. The information for use shall also take into account the risks in the opening of enclosure doors after extinguishant discharge, including those associated with the inrush of air and the potential for re-ignition or explosion.

The information for use shall include details of all actions required for system replenishment after extinguishant release, including any inspection and maintenance procedures that shall be followed to ensure that subsequent operation is achieved successfully.

The information for use shall contain warnings and precautions that shall be taken where there is the potential for discharge of extinguishant from inadvertent operation of UV or other similar detectors from external interference.

The information for use shall include instructions on how to confirm the integrity of the equipment for subsequent operation after any emergency shutdown.

The information for use shall include instructions covering any necessary inspection, stabilization and re-setting actions that shall be taken prior to a gas turbine restart in the event that a turbine compressor surge event has occurred.

7.6 Enclosure access

7.6.1 General

The information for use shall provide instructions covering access to the gas turbine and all other enclosures during operation, maintenance and commissioning based on the requirements shown in 7.6.2, 7.6.3, 7.6.4 and 7.6.5, including that prior to entry to any enclosure protected by a fire suppressant system capable of asphyxiation or other hazards, the release of the suppressant shall be mechanically isolated and locked off. Electrical isolation may be permitted for short term entry in large spaces with ease of egress where this cannot be overridden by manual release. In confined spaces, mechanical isolation shall be applied.

The information for use shall contain instructions for the opening of machinery enclosure doors ventilated by positive pressure to prevent impact hazards and the closure of negatively ventilated machinery enclosure doors to prevent crushing hazards, and shall state that enclosure doors shall be correctly closed after maintenance, or any other opening of the doors, to obtain the correct integrity of any enclosure protected by an extinguishant gas.

The information for use shall contain instructions on the conditions required for access, taking into account the internal conditions such as noise levels, presence of any hazardous gas, internal temperature levels and temperature distribution.

The information for use shall include guidance, where appropriate, on the use of an additional person who shall be present external to the enclosure to monitor activities and take any emergency action if a hazardous situation arises. Where the enclosure door is closed the additional person shall monitor activities from a position local to the door with line of sight to the activity being undertaken. The additional person shall have mechanisms and means to monitor personnel within the enclosure. Where line of sight cannot be achieved other methods shall be used to enable an alarm to be raised if an incident occurs.

7.6.2 Risk assessment for accessing enclosures

Opening of the enclosure doors and any subsequent entry shall be under the control of a written permit to work (PTW) system which shall also detail PPE suitable for the given task. The PTW shall be raised taking into account at least: changes in the ventilation airflow, the presence of flammable leaks, the risk of ignition, entrapment, slips, trips and falls, thermal and noise hazards, egress restriction in the surrounding area, potential for doors to freeze closed during access, and lighting. An additional person shall be present during access.

Where access in the enclosure is being undertaken no egress restrictions shall be in place in the surrounding areas. Where emergency lighting is not provided entry shall not be undertaken unless natural ambient lighting provides visibility for exit or uninterruptible temporary lighting is installed.

7.6.3 Limitations under operational conditions

Access to the gas turbine enclosure followed by door closure shall be prohibited under running conditions, unless access routes are provided for routine maintenance activities and adequate methods of escape exist, with provision for opening enclosure doors against ventilation loads.

Access shall be permitted only when steady state running conditions have been established and no alarm condition exists that can escalate into a hazardous situation or where other reasonably foreseeable or planned changes in operation can occur. The small variations that occur during normal running are not considered to increase risk.

7.6.4 Limitations under non-operational conditions

A section of the information for use shall address conditions for access to the gas turbine enclosure under non-operational conditions. The gas turbine and other machinery appropriate to the task to be undertaken shall be interlocked from starting. Pressurized systems applicable to work to be undertaken shall be depressurized/vented and appropriately isolated.

Where access under non-operational conditions is necessary, followed by closure of the enclosure doors the availability of lighting within the enclosure shall be assured through the availability of permanent or temporary emergency lighting. Where such access is undertaken with the ventilation system operational and with ventilation loads on enclosure doors, additional precautions shall be taken (e.g. ventilation control from within the enclosure, radio communication) to prevent entrapment of personnel.

7.6.5 Access during commissioning and re-commissioning

Where special access is necessary during initial commissioning or re-commissioning after overhaul or modification, such access shall be undertaken only by appropriately qualified and experienced personnel and shall be detailed in the associated commissioning documentation supported by a written PTW in accordance with 7.10.

7.6.6 Installations in a hazardous area

See 5.25. In addition to the requirements of 7.6.1 to 7.6.5 access to gas turbine enclosures within hazardous areas shall be prevented during turbine operation and after shutdown unless at least one of the following conditions is fulfilled:

a) hot surfaces have cooled to below 80 % of the AIT, in degrees Celsius, of any potentially explosive atmosphere;

b) gas detectors are in use for checking presence of hazardous atmospheres at the point of entry and procedures are in place, should a hazardous atmosphere occur during access.

7.6.7 Stray electric currents

Activities (e.g. local arc welding) within the proximity of the equipment that can induce stray electrical currents leading to the potential for electrical discharge shall be restricted during operation. Where it is necessary to carry out essential arc welding work close to any hazardous areas, appropriate safeguards shall be taken (e.g. local earthing to ground).

7.7 Maintenance

7.7.1 General

The information for use shall include all of the instructions necessary for maintaining the reliable operation of safety equipment for its intended life. It shall include the replacement of parts whose life is limited by operating hours/cycles. Due consideration shall be taken with regards to the fragility, reliability and the importance of the device. See also 5.3 regarding modifications and replacement parts.

Where applicable to ensure reliable and safe operation the information for use shall contain instructions detailing the sampling of fluids and information on the need for replacement. Lubricating and hydraulic oil analysis shall be undertaken at defined periods to ensure that deterioration in their properties, which could lead to a hazardous situation, has not taken place.

The information for use shall identify the appropriate safeguards that shall be taken to enable maintenance activities to be carried out including the use of special tooling and fixtures. Safeguards shall cover, where applicable, the hazards arising from gas turbine rotating components (e.g. rotor windmilling), variable geometry and similar mechanisms during maintenance, adjustment and inspection. The use of any devices or lifting equipment to prevent unexpected movement and instability shall be included with recommendations on PTW, isolation and tagging procedures and the posting of warning signs. Where applicable guidance on the use of method statements shall be given where the potential for crushing, entrapment or other hazards exist whilst moving equipment.

Machinery shall be supplied with all the special equipment and accessories essential to enable it to be adjusted, maintained and used. The information for use shall specify such special tools.

7.7.2 General maintenance hazards

The information for use shall include the precautions required where there is the potential for spark generation in a hazardous area while maintenance work is being carried out, including the shut-off and venting of supplies and checks for the presence of gases prior to and during any work. The provisions to prevent spark generation in the information for use shall comply with ISO 80079-36:2016.

Where necessary to avoid specific hazards, the information for use shall include instructions for the removal and replacement of any guards without damage to components and the necessary isolation procedures to prevent unexpected movement of the guarded equipment, including instructions that guards shall be replaced and, where applicable, correctly sealed before the machine is re-started.

The information for use shall detail the acceptable methods for cleaning equipment and shall clearly state if water jets and/or compressed air can be used for cleaning and detail any applicable safeguards.

Additionally, clear instructions shall be provided in the maintenance information for use to ensure adequate understanding of the criticality of the parts, and the correct installation methods.

7.7.3 Accessibility, isolation and energy dissipation

The information for use shall include guidance on access including the requirement for temporary access platforms required to ensure that the maintenance activity can be executed. Where the activity is at an elevated level the guidance shall include the precautions to be taken against falling objects.

The information for use shall describe the means provided for the isolation of non-electrical supplies, for the release or depressurization of any stored energy and warning of the risks associated with work on non-purged equipment and the additional safeguards that shall be employed (also see 7.8). Diagrams shall be provided showing all valves and other equipment provided specifically for the purpose of the isolation of fluids.

The information for use shall describe the means provided for electrical supply isolation, earthing and short-circuit protection, the method of testing, and their proper use for maintenance and repair. Diagrams shall be provided showing all the devices provided specifically for the isolation of electrical supplies. Where maintenance is necessary on energized devices the manual shall include guidance on the methods to be used and supervision and shall state that before action on the ignition system, variable speed drive controls, or other controls that store hazardous levels of electrical energy, there shall be a wait period to allow the discharge resistances to reduce the energy stored to a non-hazardous level.

The information for use shall describe the devices to prevent unexpected start-up or movement, those for the isolation and dissipation of stored energy and their use during gas turbine maintenance and repair as shown in 5.21.2.

The information for use shall describe the inspection of the lightning protection system to be undertaken after a known lightning strike.

7.7.4 Pressure equipment

The information for use shall contain instructions for the inspection and maintenance of pressure equipment to maintain integrity including checking/testing the operation of pressure control and relief devices and the periodicity at which the activities shall be undertaken. The instructions shall include checks for wear, erosion, abrasion, corrosion or material degradation where required for continued use. The information for use shall include inspection procedures and change-out periods for flexible pipes, diaphragms and other parts subject to deterioration from continued movement where failure can create a hazardous situation.

The information for use shall contain instructions to allow the non-hazardous dismantling of pressure equipment and pipework, including but not limited to the venting/drainage of any residual pressure, any purging required to create an inert atmosphere and associated isolation and blanking. It shall also contain instructions on how to verify the leak tightness of equipment including pressure testing after re-assembly and the precautions taken during testing, including the use of PPE and the risks of asphyxiation from leakage of oxygen-depleting gases used for test purposes. Instructions, where necessary, shall be included for filling after assembly and verification of leak tightness.

Where pressure testing is not practical (e.g. between the last fuel shut-off valve and the combustion burners) the information for use shall contain alternative procedures to verify that all connects are leak tight. Where procedures cannot eliminate a hazardous leak pressure testing with dummy fittings prior to making the final connections shall be undertaken.

7.7.5 Fire protection systems

The information for use shall include inspection programmes and maintenance instructions for the total system and its components. The programme shall include the inspection intervals for the different parts of the system such that faults are detected at an early stage to allow rectification before the system may have to operate. Where the system includes retention fire dampers and their associated controls these shall be included in the inspection programme. The programme shall include periodic functional checks that the equipment operates correctly. Non-standard tools required for the maintenance of the fire protection system shall be identified and should be offered as an option.

The information for use shall state that the sound level of an acoustic alarm shall be audible above the noise level of the building/area in normal operation.

7.7.6 Gas detectors

The information for use shall include guidance on the maintenance and calibration details for gas detectors in accordance with IEC 60079-29-2:2015, Clause 11, including normal calibration intervals based on the type of detector and its location/usage. The instructions shall include guidance on the test and neutral gases to be used and, where applicable, the required flow rate, the LFL settings used and their relevance to the associated hazard.

The information for use shall specify actions taken where calibration checks show changes in reading accuracy that can allow gas concentration to arise above hazardous limits without being detected. Such action may include shortening of the calibration interval or replacement of the sensor or sensing element. The maintenance procedures shall include verification that the signal from the gas detector gives the correct measurement at the control equipment and that the correct actions are initiated at the set alarm and emergency shutdown levels.

The use of aerosols, and especially the use of silicone oil mists, shall not be permitted within, and in the vicinity of, the enclosures as they lead to an undetected poisoning of the catalysts such that the safety function of the detection system is ruined without the operators being aware. Maintenance instructions shall include this prohibition.

7.7.7 Control systems: maintenance, calibration and testing

The information for use shall include details of the safety related controls and associated equipment that require functional checks, maintenance, calibration or testing at specified intervals so that the safety integrity level of the safety functions are assured, including those functions that may be calibrated or tested when the gas turbine is running, together with details of any precautions necessary to avoid any hazard arising from the operation of the controls during maintenance. Where applicable the checks shall include a functional test of the safety systems, including safety devices and sensors, that verifies that the control system reacts correctly to the input signals. Calibration shall be completed during commissioning, after any relevant intrusive maintenance and at intervals specified by the manufacturer based on the usage of the relevant equipment, that ensures the said equipment shall remain within its specified working tolerance.

The information for use shall describe the automatic testing of the speed sensors for detecting overspeed and the associated controls as defined in 5.20.7. The information for use shall instruct any additional testing of associated equipment during shutdown conditions and the period, at which such tests are required, if such tests are necessary.

Where trend monitoring techniques are utilized to alleviate the need for maintenance activities these shall be subject to a detailed review to ensure that hazards are not introduced throughout the foreseeable lifetime of the equipment. The criteria for the use of the trend data shall be included in the information for use.

7.7.8 Hazardous materials and substances

The information for use shall contain warnings and details by referring to material safety data sheets (SDS) for all hazardous substances approved for use during maintenance of the machine and identify any hazardous materials, biological hazards or hazards generated by materials and substances (and their constituents) used or exhausted by the machinery that can be encountered during maintenance and shall clearly specify any particular working practices and PPE that are necessary during all maintenance operations.

Where toxic fuels are used which can leave harmful residues after purging or drainage the information for use shall contain instructions for the non-hazardous handling and maintenance of equipment that can become contaminated. The information for use shall identify any devices or instruments that need to be provided by the operator, which are considered necessary to detect any hazardous substances or environmental conditions.

7.8 Warning signs and notices

Machines shall be provided with markings in accordance with ISO 12100:2010, 6.4.4 and ISO 7010:2019. Signs, nameplates, markings and identification plates shall be of sufficient durability to withstand the physical environment involved.

Where access is required to a space when there is the potential for entrapment or where other hazards can exist a warning sign supplemented, if necessary, with text and/or an information sign shall be placed at the point of entry or, if not enclosed, shall be appropriately marked with colour or with fences. Where the space is protected by a fire extinguishant gas that can cause asphyxiation if released the warning sign, supplemented with advisory text, shall be placed in a prominent position covering each point of entry. The text shall advise of the risk of automatic extinguishant release, the need for isolation prior to entry and any safety instructions following a fire shutdown where an inrush of air can create the conditions for re-ignition of an extinguished fire. A warning sign shall be placed at each point of manual release indicating that extinguishant release will occur on activation.

Where additional risk mitigation is required with respect to the opening doors in enclosures with positive or negative pressure artificial ventilation, warning signs shall be positioned at the point of entry.

A warning sign shall be placed at the entry to all areas containing potentially explosive atmospheres. This may be in the form of a hazard warning sign with the letters “Ex” in the triangle or a standard hazard warning sign supplemented by the appropriate text. When choosing a solution it is important to consider local legislation in the country where the product is put to use.

Where parts or assemblies have to be handled with the aid of lifting equipment during operation and maintenance, the mass shall be marked on the part or assembly to be lifted or referenced on documents included in/with the information for use.

Where appropriate, warning signs used as protection against hot surfaces shall include a warning against high temperature and the emission of radiated heat by combining the pictograms for temperature and for the emission of heat by radiation.

Where the considerations in 5.7 or any other requirements show a need for personal ear protection a mandatory warning sign shall be posted at the entries to the area.

Where detailed documentation is not included in the information for use to allow the identification of piping or a piping section and the associated system to which it belongs, the piping as installed shall be marked by painting, lettering, tagging, etc. From the markings, it shall be possible to identify the system to which the piping belongs.

Warning signs shall be placed at points where toxic emissions can occur.

The location of warning/safety signs and notices shall be documented.

7.9 Noise

Information for use shall contain information on sound power level from the gas turbine and accessories, and the emission sound pressure level at specified positions, as follows.

— For gas turbines for which the ambient noise levels depend on the conditions of installation, it is not possible to specify these ambient noise levels in the operating and maintenance instructions. In this case, the operating and maintenance instructions shall include a warning about the dangers of airborne noise and on the need for performing, after the installation, acoustic measurements to determine the sound pressure level in the conditions specified in 5.7 and for implementing appropriate protective measures if necessary. Gas turbine noise emissions and test report shall be provided in accordance with ISO 10494:2018.

— For sound pressure levels at operator position(s):

1. Where the workstation(s) are undefined or cannot be defined, the A-weighted sound pressure levels are those measured at a distance of 1 m from the surface of the machinery and at a height of 1,6 m from the floor or access platform. The position and value of the maximum sound pressure shall be indicated.

2. Where the workstation(s) are defined:

    a. A-weighted sound power level emitted by the machine together with uncertainty of stated values, where the equivalent continuous A-weighted emission sound pressure level at the operator's station(s) exceeds 80 dB;

    b. A-weighted emission sound pressure level at the operator's station where this exceeds 70 dB, together with uncertainty of stated values; where this level does not exceed 70 dB, this fact shall be indicated.

NOTE 1 The value of the associated uncertainty can be given in accordance with ISO 4871:1996.

Noise emission shall be measured at the installation site during commissioning and declared afterwards. Noise-emission values gathered over time will allow the generation of a company data base of noise emission values that they can use to provide noise emission information in the instructions to future clients.

NOTE 2 The noise exposure levels on site are influenced by a number of factors in addition to the gas turbine, geometry and nature of surfaces of the building; climatic conditions; external noise sources. The user then carries out additional measurements for use in workplace noise assessments after the gas turbine is in full operation.

7.10 Permit to work (PTW)

The operation and/or maintenance manual shall contain guidance on the use of a written PTW system and that such a system is used for activities carried out in hazardous areas, confined spaces, on pressurized equipment, and where supply isolation is required to allow safe working. The manual shall state that it is the responsibility of the operator to issue a written PTW system and that such work be undertaken by competent and trained persons who fully understand the risks involved and, where necessary, the requirement for a second person to be present who shall maintain close communication during the operation concerned.

7.11 Training

Details of the training necessary for personnel involved in the operation, maintenance and commissioning of safety equipment covered by this document shall be available. This shall include the use of PPE, the functioning of safety devices, their interaction with the controls, the actions that follow an alarm and emergency shutdown level being activated and any subsequent actions that shall be taken.

NOTE IEC 60079-17:2013 and IEC 60079-19:2019 can be used for guidance on the inspection, maintenance and repair requirements for equipment in hazardous areas.

7.12 Decommissioning and disposal

Where required by the end operator documentation shall include guidance to render the equipment inoperative and guidance on safe decommissioning and disposal of hazardous substances based on the instructions contained in ISO 14123-1:2015.

NOTE Also see NFPA 400:2019 and/or other recognized standards or local legislation.

Annex A
(informative)

List of significant hazards

Table A.1 lists significant, anticipated hazards together with the significant corresponding preventative measures to reduce or eliminate these hazards. See also Clauses 5, 6, and 7.

Table A.1 — List of significant hazards

Hazard	Hazardous situation	Preventative measures	Reference
Lack of safety studies	Devices may not function correctly under all reasonably foreseeable situations	Risk assessment	5.2
Crushing Shearing Cutting or severing Entanglement	Moving parts Uncontrolled movement Fingers trapped during maintenance activity Operator trapped in valves/actuators Clothing trapped in rotating parts	Safe access Guards Isolation/emergency stop Permit to work Safe distances Warning signs Maintenance	5.8.2, 7.6, 7.8 5.8.1, 7.7.1, 7.7.2 5.21.2, 5.20.8 7.10 5.8.1.1 7.8 7.7
Trapping	Person trapped within an enclosed space and unable to escape Operator trapped in enclosure dampers, potential for severing	Access control Release mechanism Lighting Warning signs Isolation/emergency stop Permit to work Person in attendance	5.13.9, 7.6, 7.8 5.13.8 5.14 7.8 5.21.2, 5.20.8 7.6.2, 7.10 7.6.1
Impact	Foreign matter in the gas turbine Mechanical disassembly Blade failure	Vibration detection Design for containment Remote safety shut-off valve Traceable materials, testing FOD screen	5.8.7 5.8.15 5.10.5.5, 5.10.6.5 5.8.9 5.8.16
	Foreign matter in the ventilation system followed by violent disassembly of enclosure ventilation fan blades	Guard Design for containment	5.18
	Violent disassembly of air-blast oil-cooler fan, damage to cooler matrix creating potential for fire	Fan location Guard Design for containment	5.18
	High positive/negative enclosure pressure causing uncontrolled door movement/straining forces Entry hazards	Door stays, access control Warning signs	5.13.8, 7.6 7.8

Table A.1 *(continued)*

Hazard	Hazardous situation	Preventative measures	Reference
	Icing at gas turbine compressor air inlet causing gas turbine compressor surge	Monitoring, prevention, implosion protection	5.9.3, 5.9.4
	Starter-motor rotor failure	Containment, overspeed protection Access control	5.8.18
Cutting, severing	Sharp edges/corners	Removal/protection of sharp edges, guards	5.8.1.3, 7.6.2
Falling or ejection of objects	Maintenance tools causing sparks in a hazardous area Operator injured by falling objects during periods of maintenance	Maintenance, atmospheric checks Training Use of PPE	7.7.3, 5.24.1, 7.7.1 7.11 7.11
Break-up: Loss of containment	Fault in driven unit causing violent disassembly	Design Testing	5.8.6 5.8.17
	Failure of high-speed rotating components	Design, containment Testing Vibration monitoring	5.8.15, 5.8.17, 5.8.8 5.8.13, 5.18.4 5.8.7
High pressure-fluid injection or ejection	Over-pressure in high pressure hydraulic water wash systems, low-pressure gas turbine lubricating oil systems, fuel systems, instrument air supply, and steam-injection supply Over-pressure in fluid lines where fluid is trapped	High-integrity pipework and connectors Monitoring Regulation and relief Inspection Maintenance	5.23, 5.24, 5.10.6.9 5.23 5.23 7.7.4 7.7.4
Fuel vapour lock	Rupture of pressure equipment containing hazardous media	Design Pressure relief Monitoring	5.10.6.4 5.10.8, 5.23.8.7
Over-pressure ejection	Failure of gas turbine pressure casing containment	Design Thermodynamic design	5.8.3 5.8.15
	Over-pressure in enclosures due to extinguishant discharge Over-pressure in the gas turbine enclosure due to breach of gas turbine pressure casing	Integrity of structure Tests Maintenance Design, test	5.13.2 5.15.6 7.7.4 5.8.3, 5.8.15
	Surge causing over-pressure in the combustion inlet, inlet filter/ducting/flexible fracture and structural failure	Surge margin, control	5.8.4 5.9.2
	Exhaust over-pressure due to uncontrolled exhaust damper closure Pulse in exhaust on shutdown due to gas turbine surge	Monitoring, closing speed control Shielding of flexibles	5.12.1 5.12.2
	Hazardous discharge at gas turbine compressor bleed valve	Routing to a safe location	5.22.4