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Gas turbine applications — Safety

Applications des turbines à gaz — Sécurité



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Foreword

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

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

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

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

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

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

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

The main changes are as follows:

- modified to include required annexes for ISO version;
- general update to simplify text;
- updated all cross references.

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

Introduction

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

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

- machine manufacturers (small, medium and large enterprises);
- health and safety bodies (regulators, accident prevention organisations, market surveillance etc.)

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

- machine users/employers (small, medium and large enterprises);
- machine users/employees (e.g. trade unions, organizations for people with special needs);
- service providers, e.g. for maintenance (small, medium and large enterprises);
- consumers (in case of machinery intended for use by consumers).

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

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

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

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

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

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

Gas turbine applications — Safety

1 Scope

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

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

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

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

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

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

This document excludes the following items;

- exhaust-system structural design;
- driven equipment;
- micro turbines as covered by ISO 19372:2015;
- gas turbines used primarily for direct and indirect propulsion;
- gas turbines used for mobile applications;
- special heat source applications;
- gas turbines in research and development programs;
- compressed-air energy storage plants.

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

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

2 Normative references

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

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

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

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

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

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

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

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

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

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

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

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

ISO 11086:1996, *Gas turbines — Vocabulary*

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

3 Terms and definitions

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

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

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

3.1 auto-ignition temperature

AIT

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

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

3.2 drain valve

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

3.3 emergency shutdown

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

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

3.4 emergency stop

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

3.5 shutdown

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

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

3.6 extinction safety time

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

3.7 flow control valve

device used to control flow-rate

3.8 foreseeable lifetime

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

3.9**ignition safety time**

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

3.10**interlock****interlocking device**

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

3.11**LFL****lower flammability limit**

volume concentration of flammable gas or vapour in air, below which the mixture is not explosive

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

3.12**operator**

person or organization having responsibility for the operation of the equipment

3.13**OEM****original equipment manufacturer**

person or company having design responsibility for the equipment or for parts of it

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

3.14**packager**

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

3.15**prime mover**

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

3.16**purchaser**

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

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

3.17**relief valve**

safety device ([3.18](#)) used for over-pressure protection and which does not operate under normal running conditions

3.18**safety device**

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

3.19

safety related system

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

3.20

spill valve

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

3.21

valve pressure proving

system that checks the effective closure of automatic shut-off valves by detecting leakage

3.22

vent

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

4 List of significant hazards

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

5 Safety requirements

5.1 General

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

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

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

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

5.2 Risk assessment

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

The criteria for protective measures comprise:

- references to applicable standards;
- definition of specific requirements; and
- further risk reduction or a combination of the criteria;

as applicable to comply with the requirements of [5.2.1](#).

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

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

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

- design for safety with passive protection measures;
- apply active protective measures;
- communicate the information covering any residual risk.

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

The design of gas turbine equipment shall take into account:

- the variations in the applied protective measures necessary to accommodate individual site conditions;
- the need to relate protective measures to hazards arising from reasonably foreseeable operations carried out on site;
- the need to have options in the selection of measures to control risk.

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

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

Operation and maintenance requirements shall ensure that the levels of risk are maintained to comply with [5.2.1](#).

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

5.2.1 Risk assessments requirements

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

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

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

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

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

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 within 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](#));

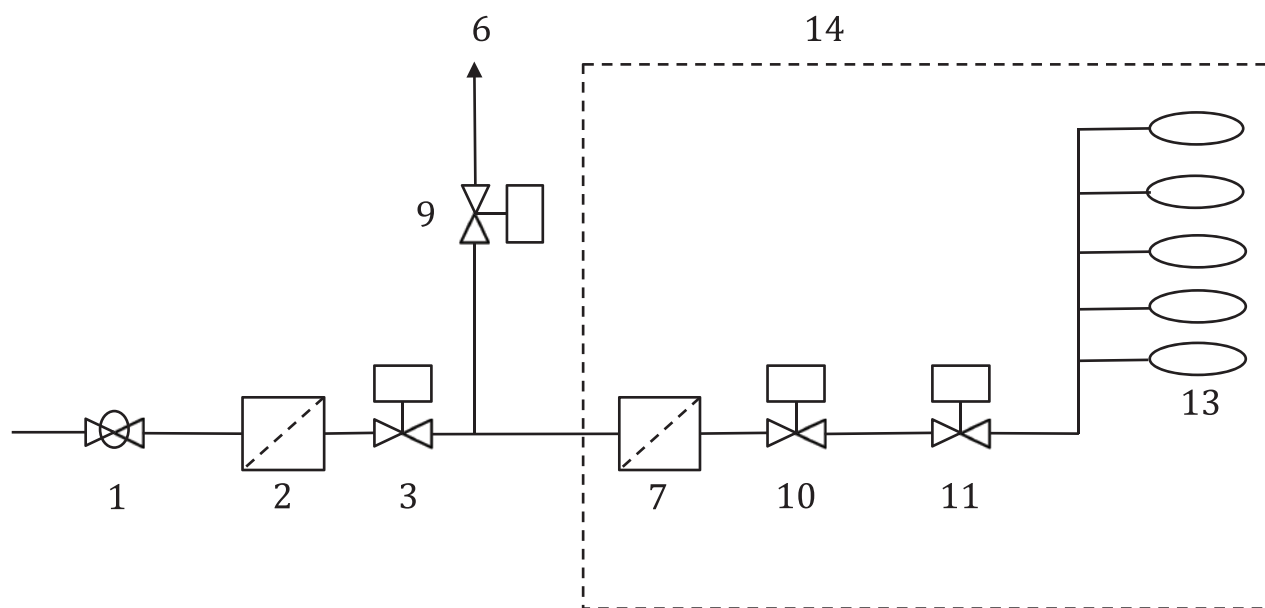
- d) flow control (see [5.10.5.3](#));
- e) venting for depressurization between safety shut-off valve and automatic fast acting shut-off valves (see [5.10.5.4](#)); and
- f) venting for pipework depressurization (see [5.10.5.4](#) or [5.10.5.5](#)).

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](#).

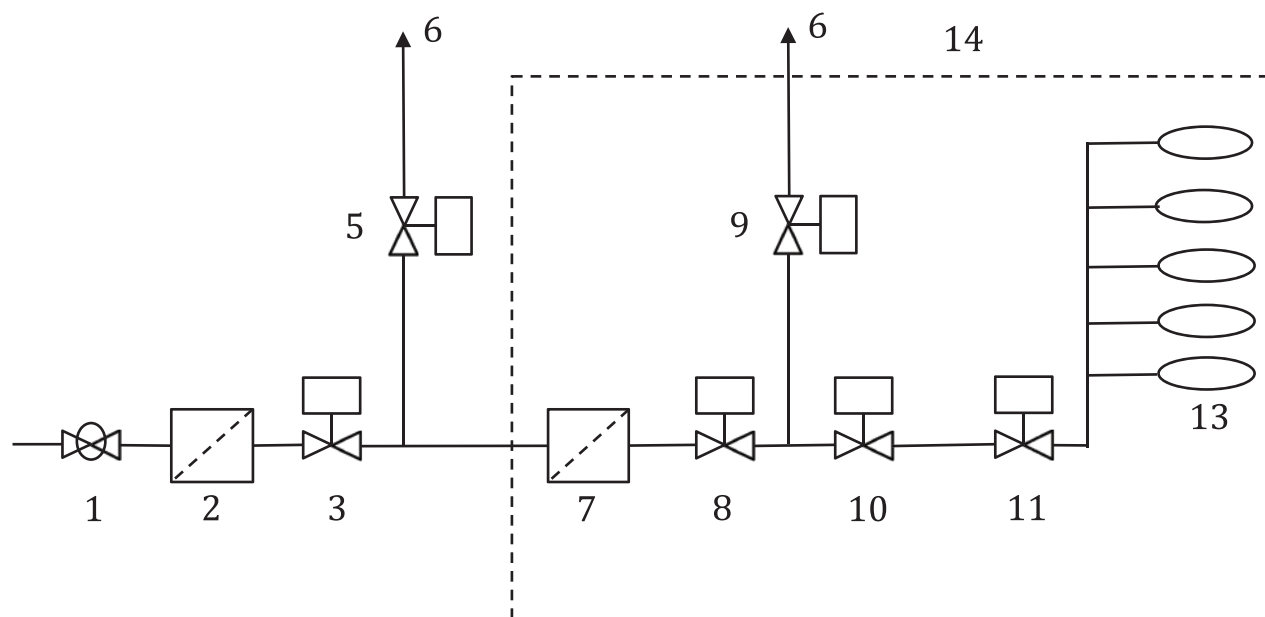
A strainer shall be fitted in accordance with [5.10.5.6](#) where necessary for operation.

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

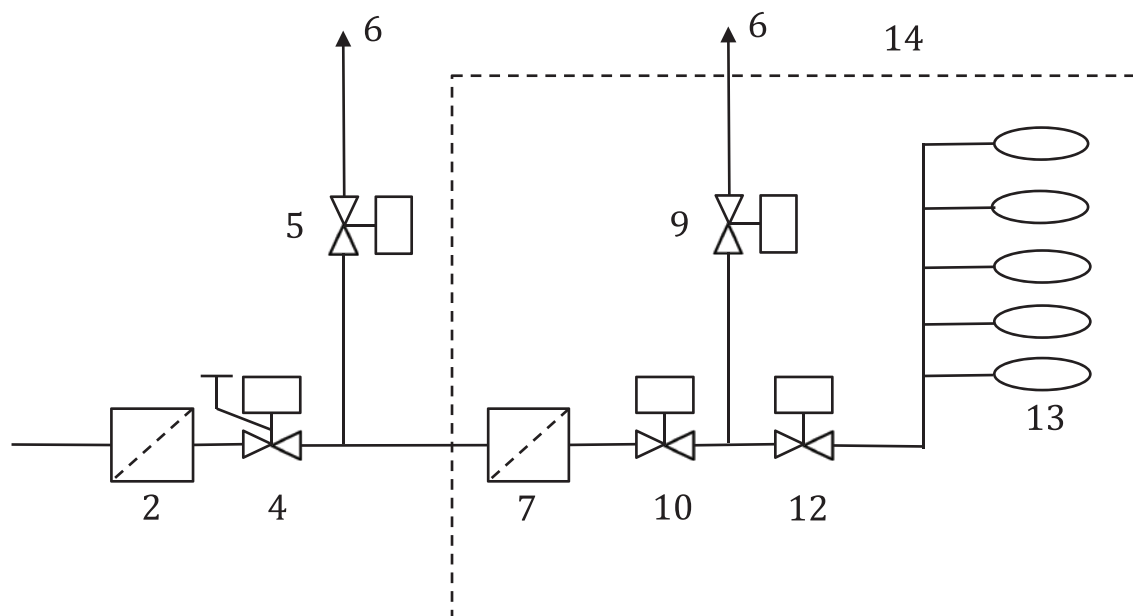
NOTE 1 National regulations can require certification of safety shut-off valves and vent valves.



a) Minimum arrangement



b) Typical alternative arrangement



c) Typical alternative arrangement

Key

- | | |
|---|---|
| 1 manual isolation valve | 8 shut-off valve ^a |
| 2 strainer, optional position | 9 vent valve ^b |
| 3 shut-off valve | 10 automatic fast acting safety shut-off valve ^a |
| 4 shut-off valve and manual isolation valve | 11 flow control valve |
| 5 vent valve | 12 flow control and shut-off valve ^a |
| 6 vent | 13 combustion system |
| 7 strainer, optional position | 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.