

BS ISO 19372:2015



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Microturbines applications — Safety

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National foreword

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

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Microturbines — 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 on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT), see the following URL: [Foreword — Supplementary information](#).

The committee responsible for this document is ISO/TC 192, *Gas turbines*.

Introduction

This International Standard is a type C standard as stated in ISO 12100. A type C standard is “a standard dealing with the detailed safety requirements for a particular machine or group of machines”.

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

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

The extent of the applicability of the references can be limited by the context of the text within this International Standard. 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 International Standard. Where a reference is made to a specific clause in a standard, only the text of that clause and references therein apply. References within notes are provisions but not normative provisions of this International Standard and are listed in the bibliography.

In addition to covering the relevant safety requirements, this International Standard has also been produced to assist designers, manufacturers, and others by providing methods of compliance with the relevant, essential safety requirements of the following New Approach European Directives for microturbine applications without prejudicing compliance with this International Standard outside the European Union:

- Machinery Directive (2006/42/EC);
- ATEX (Equipment) Directive (94/9/EC);
- Pressure Equipment Directive (97/23/EC).
- Low Voltage Directive (2006/95/EC);
- Electromagnetic Compatibility Directives (2004/108/EC).

Methods are also provided as far as practical and where relevant for compliance with the relevant, essential safety requirements of the following European Directives:

- Integrated Pollution Prevention and Control Directive (96/61/EC);
- Environmental Noise Directive (2002/49/EC);
- Chemical Agents Directive (98/24/EC);
- Classification, Packaging, and Labelling of Dangerous Substances Directive (1999/45/EC);
- Exposure of workers to the risks arising from physical agents (noise) (2003/10/EC).

NOTE When this International Standard was issued, the currently quoted European directives were in force but are subject to updates which may add additional essential safety requirements and users of this standard should check, where applicable, if a later version of a directive is in force or has been released. A later released version of the directives can be used as an alternative before the listed directives are superseded.

Microturbines applications — Safety

1 Scope

This International Standard covers the safety requirements for industrial, commercial, and residential automated stationary microturbine (micro gas turbine) engine generator assemblies with an individual system or subsystem output rating with nominal supply voltages not exceeding 1 000 V for alternating current (A.C.) and not exceeding 1 500 V for direct current (D.C.), 500 kW per individual unit/subsystem or less that are intended for installation and use in ordinary and hazardous location using liquid or gaseous fuels and the safety related control and detection systems and essential auxiliaries for all types of open cycles, closed-cycle, and semi-closed (simple, combined, regenerative, reheat, etc.) used in onshore and offshore applications including floating production platforms.

This International Standard applies to driven machinery only where it is an integral part of the microturbine (e.g. a gearbox integral to the microturbine), or is located within the microturbine enclosure and forms part of the enclosure hazardous area classification (e.g. a generator within the microturbine enclosure), or where the driven machinery has a direct effect on the operational safety of the microturbine.

This International Standard details the anticipated significant hazards associated with microturbines and specifies the appropriate preventative measures and processes for reduction or elimination of these hazards. This International Standard 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.

Microturbine packages are generally specified using International Standards and national standards. Achieving safety is promoted by using additional safety codes and standards, which are shared by microturbines with other technologies.

NOTE It is necessary to recognize that local legislation in the country in which the equipment is to be put to use might not be covered by this International Standard.

This International Standard approaches microturbine 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. Where local legislation accepts other established codes or standards, or an alternative international or national standard providing equivalent requirements for achieving the desired tolerable level of risk, the use of these alternative codes or standards in place of the references provided in [Clause 2](#) is permissible.

This International Standard excludes microturbines used primarily for direct and indirect propulsion, special heat source applications, and in research and development programmes. It also excludes microturbines for compressed-air energy storage plants. Where appropriate, this International Standard can be used to give general guidance in such applications.

This International Standard is not applicable to machinery or safety components that were manufactured before the date of its publication as an International Standard.

2 Normative references

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

ISO 3864-3, *Graphical symbols — Safety colours and safety signs — Part 3: Design principles for graphical symbols for use in safety signs*

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

- ISO 3977-3, *Gas turbines — Procurement — Part 3: Design requirements*
- ISO 3977-9, *Gas turbines — Procurement — Part 9: Reliability, availability, maintainability and safety*
- ISO 4413:1998, *Hydraulic fluid power — General rules relating to systems*
- ISO 4414:1998, *Pneumatic fluid power — General rules relating to systems*
- ISO 4871, *Acoustics — Declaration and verification of noise emission values of machinery and equipment*
- ISO 6183, *Fire protection equipment — Carbon dioxide extinguishing systems for use on premises — Design and installation*
- ISO 7000, *Graphical symbols for use on equipment — Registered symbols*
- ISO 9772, *Cellular plastics — Determination of horizontal burning characteristics of small specimens subjected to a small flame*
- ISO 10441, *Petroleum, petrochemical and natural gas industries — Flexible couplings for mechanical power transmission — Special-purpose applications*
- ISO 10494, *Gas turbines and gas turbine sets — Measurement of emitted airborne noise — Engineering/survey method*
- ISO 11086, *Gas turbines — Vocabulary*
- ISO 12100:2010, *Safety of machinery — General principles for design — Risk assessment and risk reduction*
- ISO 12499, *Industrial fans — Mechanical safety of fans — Guarding*
- ISO 14001, *Environmental management systems — Requirements with guidance for use*
- ISO 14118, *Safety of machinery — Prevention of unexpected start-up*
- ISO 14120, *Safety of machinery — Guards — General requirements for the design and construction of fixed and movable guards*
- ISO 14123-1, *Safety of machinery — Reduction of risks to health from hazardous substances emitted by machinery — Part 1: Principles and specifications for machinery manufacturers*
- ISO 14520-1, *Gaseous fire-extinguishing systems — Physical properties and system design — Part 1: General requirements*
- ISO 14691, *Petroleum, petrochemical and natural gas industries — Flexible couplings for mechanical power transmission — General-purpose applications*
- ISO 16010, *Elastomeric seals — Material requirements for seals used in pipes and fittings carrying gaseous fuels and hydrocarbon fluids*
- ISO 19353, *Safety of machinery — Fire prevention and protection*
- ISO/TR 13387-7, *Fire safety engineering — Part 7: Detection, activation and suppression*
- IEC 60034-22, *Rotating electrical machines — Part 22: AC generator for reciprocating internal combustion (RIC) engine driven generating sets*
- IEC 60079-0, *Explosive atmospheres — Part 0: Equipment — General requirements*
- IEC 60079-2, *Explosive atmospheres — Part 2: Equipment protection by pressurized enclosures “p”*
- IEC 60079-4, *Electrical apparatus for explosive gas atmospheres — Part 4: Method of test for ignition temperature, amended by IEC 60079-4-AM:1995*
- IEC 60079-10, *Electrical apparatus for explosive gas atmospheres — Part 10: Classification of hazardous areas*

- IEC 60079-14, *Explosive atmospheres — Part 14: Electrical installations design, selection and erection*
- IEC 60079-17:2007, *Explosive atmospheres — Part 17: Electrical installations inspection and maintenance*
- IEC/TR 60079-20, *Electrical apparatus for explosive gas atmospheres — Part 20: Data for flammable gases and vapours, relating to the use of electrical apparatus*
- IEC 60079-29-1:2007, *Explosive atmospheres — Part 29-1: Gas detectors — Performance requirements of detectors for flammable gases*
- IEC 60079-29-2:2007, *Explosive atmospheres — Part 29-2: Gas detectors — Selection, installation, use and maintenance of detectors for flammable gases and oxygen*
- IEC 60068-2-18, *Environmental testing — Part 2-18: Tests — Test R and guidance: Water*
- IEC 60204-1:2009, *Safety of machinery — Electrical equipment of machines — Part 1: General requirements*
- IEC 60364-1, *Low-voltage electrical installations — Part 1: Fundamental principles, assessment of general characteristics, definitions*
- IEC 60417 (all parts), *Graphical symbols for use on equipment*
- IEC 60529, *Degrees of protection provided by enclosures (IP Code)*
- IEC 60695-1-1, *Fire hazard testing — Part 1-1: Guidance for assessing the fire hazard of electrotechnical products — General guidelines*
- IEC 60730-1 Ed. 4, *Automatic electrical controls for household and similar use — Part 1: General requirements*
- IEC/TR 61000-5-1, *Electromagnetic compatibility (EMC) — Part 5: Installation and mitigation guidelines — Section 1: General considerations — Basic EMC publication*
- IEC/TR 61000-5-2, *Electromagnetic compatibility (EMC) — Part 5: Installation and mitigation guidelines — Section 2: Earthing and cabling*
- IEC 61000-6-2, *Electromagnetic compatibility (EMC) — Part 6: Generic standards — Section 2: Immunity for industrial environments*
- IEC 61000-6-4, *Electromagnetic compatibility (EMC) — Part 6: Generic standards — Section 4: Emission standard for industrial environments*
- EN 1127-1:2011, *Explosive atmospheres — Explosion prevention and protection — Part 1: Basic concepts and methodology*
- EN 13463-1:2009, *Non-electrical equipment for potentially explosive atmospheres — Part 1: Basic method and requirements*
- EN 953, *Safety of machinery — Guards — General requirements for the design and construction of fixed and movable guards*
- EN 12845, *Fixed firefighting systems — Automatic sprinkler systems — Design, installation and maintenance*
- EN 13478, *Safety of machinery — Fire prevention and protection*
- EN 50272-2, *Safety requirements for secondary batteries and battery installations — Stationary batteries*
- CEN/TS 14816, *Fixed firefighting systems — Water spray systems — Design, installation and maintenance*
- NFPA 12:2008, *Standard on Carbon Dioxide Extinguishing Systems*
- NFPA 13:2007, *Installation of Sprinkler Systems*
- NFPA 15, *Water Spray Fixed Systems for Fire Protection*

NFPA 68, *Standard on Explosion Protection by Deflagration Venting*

NFPA 750, *Standard on Water Mist Fire Protection Systems*

NFPA 2001, *Clean Agent Fire Extinguishing systems*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 3977-1, ISO 3977-3, ISO 3977-9, ISO 11086, ISO 21789, and ISO 12100, and the following apply.

3.1 auto-ignition temperature

AIT

lowest temperature in degrees Celsius 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 in other standards and in the literature (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 extinction safety time

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

3.4 foreseeable lifetime

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

3.5 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 (e.g. unsuccessful ignition)

3.6 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 from the interlocking device that

- a) directly interrupts the energy supply or directly disconnects parts from the equipment, or
- b) 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

3.7 lower explosive limit

LEL

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

Note 1 to entry: The terms “explosive limit” and “flammable limit” are equivalent.

3.8

operator

person or organization having responsibility for the operation of the equipment

3.9

original equipment manufacturer

OEM

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

Note 1 to entry: This may be the manufacturer/packager of the equipment.

3.10

packager

supplier(s) having responsibility for integrating the technical aspects of the equipment and all auxiliary systems included in the scope of the supply

3.11

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

relief valve

safety device used for over-pressure protection and which does not operate under normal running conditions

3.13

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

3.14

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 acceptably low probability of occurrence

3.15

spill valve

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

3.16

tolerable risk

risk that is accepted within a given context based on the current values of society

Note 1 to entry: See IEC 61511-3 and/or ISO/IEC Guide 51.

3.17

valve pressure proving

system to check the effective closure of automatic shut-off valves by detecting leakage

3.18

vent

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

3.19

diverter valve

control valve that is intended to divert a portion of the liquids during normal running conditions, also known as an unloader or regulator valve

3.20

electrically operated safety shut-off valve

automatic valve in which the transmission is effected by an electrical prime mover and in which the operation controls the flow of fluid, normally closed valve that prevents the delivery of fluid when de-energized by the action of a limiter, a cut-out, or burner control system

Note 1 to entry: A safety shut-off valve is considered a protective control and may also be used as an operating control.

Note 2 to entry: A safety shut-off valve may be either of the automatic or semi-automatic opening type

Note 3 to entry: A semi-automatic valve is opened manually and closed automatically, this is considered a manual reset condition.

4 List of significant hazards

Anticipated significant hazards are listed in broad outline in [Annex A](#), which indicates the significant corresponding preventative measures and which should be used in conjunction with [Clauses 5](#) through [7](#) to reduce or eliminate these hazards.

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.

To achieve this, the safety management process shall eliminate the hazard or reduce the risk associated with the hazard by applying measures, in the following order :

- design for safety with passive protective measures;
- apply active protective measures (e.g. automatic protection intervention if preset limit values are exceeded);
- communicate the information for use about the residual risk to the installer/operator by instructions to reduce the risk to a tolerable level.

See ISO 12100:2010, 5.4, 5.5, and Clause 6.

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

The content of this International Standard should not prejudice technical advances in the field of microturbine safety or be used to inhibit innovation that can lead to increased safety.

5.2 Risk assessment

Risk assessments shall be performed to determine whether the microturbine and associated components/equipment can cause injury to people or pose a threat to people's lives, or to the environment, or can cause significant collateral damage. Where risk reduction measures are undertaken, it is essential to ensure that additional measures do not introduce additional hazards. Risks identified during risk assessment should be eliminated but, where this is not possible, risks shall be reduced to a tolerable level for the associated consequence.

The design of microturbine equipment has to account for variations in the applied protective measures necessary to accommodate individual site conditions, the need to relate protective measures to hazards arising from other operations carried out on site, and the need to have options in the selection of

measures to control risk. Therefore, reliance on risk assessment for the selection of protective measures, to supplement the specific protective measures defined in [Clauses 5](#) through [7](#) is essential.

When risk assessment is applied according to this International Standard, the manufacturer of the microturbine equipment shall accept responsibility for ensuring that a tolerable level of risk is achieved by this process.

When this International Standard indicates that a risk assessment shall be carried out, the manufacturer of the microturbine equipment shall demonstrate both that a suitable risk assessment was carried out and the basis on which the selection of protective measures was defined. The results of the assessments shall be documented and retained by the manufacturer. Residual risks identified shall be communicated to the operator who shall take additional mitigation action as necessary. The content of the risk assessment process shall, as a minimum, address the safety issues raised within this International Standard considering reasonably foreseeable activities over the life cycle of the plant.

NOTE Safety is achieved by reducing risk to a tolerable level. Tolerable risk is determined by the search for an optimal balance between the ideal of absolute safety and the demands to be met by a product, process or service and factors such as benefit to the user, suitability for purpose, cost effectiveness, and conventions of the society concerned. It follows that it is necessary to review continually the tolerable level, in particular when developments, both in technology and in knowledge, can lead to economically feasible improvements to attain the minimum risk compatible with the use of the product, process or service.

Where this International Standard states that the risk of a potential hazard shall be reduced to a tolerable level, and that hazard is associated with a safety related control function in conjunction with the associated system components (as mentioned in [5.20.1](#)), a qualitative or quantitative risk assessment method shall be applied for the events to define the corresponding safety requirements and/or safety integrity level (SIL) of the protection system.

Where the reduction of potential hazards to a tolerable level of risk for components and/or equipment not associated with SILs is required, an appropriate quantitative or qualitative risk assessment or a mixture of both methods shall be used, where applicable, to ensure that a tolerable level of risk is achieved. Information on risk assessment, tolerable levels of risk and references for the determination of SIL levels are given at informative [Annex C](#).

The general principles used for risk assessment shall comply with ISO 12100.

The level of risk obtained shall assume that the requirements of this International Standard are being considered and that the operation and maintenance procedures ensure that the obtained levels of risk are maintained.

If new information that significantly affects a risk assessment becomes available, operators of affected equipment shall be advised.

5.3 Modifications and replacement parts

All modifications and updates/upgrades to protection systems and safety relevant components shall be implemented to achieve the required tolerable level of risk. Replacements of components beyond the requirements of normal maintenance as well as modifications and upgrades of equipment to newer technology require that a risk assessment be performed to ensure that the resulting level of risk remains tolerable.

5.4 Foreseeable misuse

Equipment and protective systems shall be designed and integrated into the end product after due analysis of possible operating faults to preclude dangerous situations due to the consequences of reasonably foreseeable misuse. Examples are as follows:

- a) tool required to gain entry to the enclosure;
- b) pass word protected controls;

c) locking devices.

5.5 Lifetime

Life predictions for safety related systems/components, including safety protection systems and components, shall be performed to establish that the microturbine can be operated with a tolerable level of risk throughout its foreseeable service life of the product.

A periodic maintenance schedule shall be provided by the OEM to reduce risk to a safe level for the product protection systems and safety relevant components. The redundancy of protection systems as designed shall be inspected and maintained during the service lifetime of the product by the purchaser.

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 the risk to a tolerable level.

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 to reduce the risk to a tolerable level.

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

5.7 Noise

Where the noise levels in work areas exceed 85 dB (A), warning signs shall be displayed at the entry to an area, building or enclosure indicating that personal ear protectors shall be used. Personal access to work areas with foreseeable, unweighted, instantaneous sound levels exceeding 140 dB (200 Pa) shall not be allowed.

Where high pressure/flow vents, bleeds or air/gas motor exhausts are utilized the design shall limit the velocity at the outlet, and silencers shall be fitted or outlets shall be located such that when the outlets discharge the limit to personal noise exposure of a worker specified above shall not be exceeded, or appropriate warning signs shall be located at a safe distance from the noise source.

NOTE 95 dB sound power levels are the limits for the European Union for non-stationary engine generator assemblies. A sound power level test report should be available for stationary engine generators upon request. Local regulations might require additional sound attenuation for the installation site.

5.8 Mechanical

5.8.1 Guarding

5.8.1.1 General

Guards shall be provided in accordance with ISO 14120 or EN 953, against the mechanical hazards described in ISO 12100:2010, 6.3.

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 and 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 and 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 and ISO 13732-3 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.

5.8.2 Accessibility for maintenance

Where applicable, measures for safe access shall comply with ISO 12100:2010, 6.3.5.6.

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

Positioning of safety components and danger, warning, and caution labels shall be considered in the design phase to reduce the chance of injury during maintenance activities.

All safety and instruction labels shall comply with ISO 12100, ISO 3864-3, ISO 7000, and IEC 60417.

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 reasonably foreseeable loads including transient and abnormal operating conditions (e.g. microturbine 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, but not for 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 the relevant and reasonably foreseeable operating conditions and a containment report shall be available upon request.

5.8.4 Microturbine compressor surge

In the event of a surge, the forces, deflections, and consequences of flame reversal shall be mitigated to a tolerable level of risk during shut-down.

5.8.5 Stability and handling

Engine supports, casings, and, if used, base frames shall be mounted in their environment in a manner such that they remain in their intended position during all reasonably foreseeable events.

Where equipment is not suitable for manual handling, lifting arrangements shall be designed to transfer the load of the microturbines or components smoothly from the normal supports to a resting place in a safe and controlled manner, taking account of 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 supplied 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 safely. Special arrangements shall be made for the handling of tools and/or machinery parts which, even if lightweight, could be hazardous.

Fixed lifting attachments shall be designed in accordance with ISO 13628-1, Annex K to withstand at least 1,5 times the mass lifted, unless otherwise specified in ISO 13628-1 and shall include consideration of any dynamic loads applied during use or testing to ensure an adequate level of safety taking into account failure from fatigue, wear, corrosion, and environmental conditions where the equipment could be used. Lift fittings/lugs on a complete microturbine unit enclosure are to be subjected to a two times load test for 1 min and then examined. The unit shall show no evidence of permanent deformation. Lifting equipment shall comply with a recognized standard applicable to the equipment and its use and shall be appropriately tested, marked and where applicable certificated.

5.8.6 Overload of rotating shafts due to torque

Where there is the potential for faults in the driven machinery (e.g. short circuits) that under reasonably foreseeable circumstances can cause an overtorque greater than the specified design limits in the equipment drive shafts or the associated microturbine rotor, a torque-limiting device or other appropriate measures shall be provided to prevent a dangerous failure.

If torque limiting devices are used for controlling this risk, the activation of such devices shall not change the bearing support condition of the shafts into a situation where overhanging rotors rotate above their critical speed.

5.8.7 Vibration

Where vibration levels in the drive shaft line/train can escalate to excessive levels resulting in the potential for dangerous situations, vibration monitoring equipment shall be installed to continuously monitor and detect any escalation and initiate appropriate action (e.g. shut-down) to bring the microturbine to a safe condition if vibration levels exceed a preset limit.

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 caused by the environment. Possible effects are reduction of the fatigue limit, stress corrosion cracking (SCC), and stress accelerated grain boundary oxidation (SAGBO). The supplier shall make sure that all necessary steps are taken to address hazards caused by these effects.

5.8.9 Design methods and materials

Microturbines shall be designed so that, when correctly operated and maintained, the risks of failures that result in the release of high-energy debris, rupture of pressure casings or the release of hot, flammable or toxic gases are reduced to tolerable levels of risk for the lifetime of the machinery.

The selection and use of materials for the safety related parts of the microturbine 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 [5.23.12](#) and [5.23.13](#).

Where the use of titanium or magnesium based alloys creates a fire risk, measures to prevent a dangerous situation or extinguish such a fire shall be taken. See also [5.23.11](#).

Components that are highly stressed (e.g. by aerodynamic or rotational loads and/or high temperature conditions) and that can fail and cause personal injury shall be identified and made traceable for quality control purposes.

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 used to confirm that a tolerable level of risk is achieved over the

range of operating speeds of the parts during their foreseeable lifetime. The analysis shall at least take into account the risks of crack growth, elastoplastic deformation, creep, corrosion, and fatigue failure.

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

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

5.8.10 Microturbine temperatures

Protective measures (e.g. direct or indirect temperature monitoring, cooling air flow, and calculation) shall be taken to prevent failures due to over temperature where the release of high-energy debris, rupture of pressure casings, or the release of hot, flammable or toxic gases is likely to give rise to a hazard. If temperatures exceed the tolerated level, then microturbine unloading to a safe condition or shut-down shall be initiated automatically.

5.8.11 Environmental loads

Machinery, support and enclosure structures, and associated auxiliary piping and ducting shall be designed to withstand a reasonably foreseeable combination of loads caused by site winds, snow fall, ice, low ambient temperatures, and seismic activity without causing structural collapse or other dangerous situations. Local codes and standards normally govern the design, but where such local codes or standards do not exist, the purchaser shall specify the wind speed, snowfall and ice accumulation rates, seismic accelerations, and temperature conditions to be used.

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

Microturbine components whose correct assembly is safety related shall be protected from incorrect assembly in the field or during repair. These components shall undergo a review to determine if assembly features shall be designed into the components and/or distinctive markings shall be used and appropriately documented to minimize the risk of incorrect assembly.

5.8.13 Couplings

Flexible couplings external to the microturbine core used to transmit the microturbine output power shall take account of the design requirements of ISO 14691 for speeds up to 4 000 r/min and ISO 10441 for speeds exceeding 4 000 r/min. Further, for critical service, ISO 10441 should be used irrespective of speed. If rigid couplings are used, the supplier shall ensure that the coupling can transmit the torque.

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 reasonably foreseeable loss of microturbine compressor blades and/or turbine blades to ensure that unsafe conditions (uncontained failure, breached pressure casing, fire) do not result. 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.

NOTE This clause is not applicable for air lubricated bearing designs.

5.8.15 Rotating part failure

5.8.15.1 General

All microturbine compressor, directly driven generator, and turbine rotating parts that are relevant for safety shall be designed for the conditions and stresses that they encounter during start-up, running, transient, shut-down, or trip conditions.

5.8.15.2 Rotor and disc failure

Due to the large amount of energy contained in the rotating components of a microturbine, rotor or disc failure shall be contained or the risk of overspeed shall be reduced to a tolerable level with passive and/or active measures.

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

- 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 microturbine compressor and turbine;
- c) manufacturers blade/disk containment test conducted and containment test report published and be made available upon request.

Active measures include overspeed protection and the automatic drain of liquid fuel out of the casing before ignition, according to [5.10.9](#).

5.8.15.3 Overhanging rotor parts

Overhanging rotor parts shall not operate above or within an intolerable margin of their critical speed related to the first bending mode.

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 unsafe vibration levels are reached.

5.8.16 Foreign object damage (FOD) screen

If there is a possibility of foreign objects entering the microturbine and causing loss of containment of rotating parts, a FOD screen/filter 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. The location of the screen/filter 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

Gear wheels are loaded with a superposition of residual stress, thermal stress, and centrifugal stress, which are dependent on size and speed. This creates a risk of brittle fracture especially in the centre of the wheel body, which increases with size. This risk shall be addressed during production with non destructive testing of pinions and wheels combined with a fracture mechanics assessment, which indicates no risk emerging from flaws at the acceptance limit. Pinions or wheels, for which the acceptance limit of flaws cannot be achieved, shall undergo an appropriate overspeed proof test. This test shall be arranged such that the wheel is rotated up to a speed level that causes a tensile stress inside the disc exceeding the maximum operating stress level with the margin required to ensure the safety of any potential undetected internal flaw with respect to sub-critical crack growth and crack stability during the whole design life of the rotor.

Where the type or design of the gearbox is such that other components are loaded in the same manner as above and assessment indicates that an acceptance limit of flaws cannot be achieved, the gear shall be subjected to the same overspeed proof test described for the gear wheels to achieve the equivalent safety criterion. The oil inlet and drain temperatures shall be recorded during the overspeed test.

Appropriate service factors shall be applied to the gearbox design commensurate with the equipment to be driven and duty range in accordance with a recognized international or national standard.

NOTE 1 See ISO 13691, API 613, or AGMA 6011 for high speed gears.

NOTE 2 For epicyclic gears, reference can be made to the general guidelines in AGMA 6023.

Oil retention in gearbox casings, from gear transmissions with high pitchline velocities can lead to overheating of the oil resulting in oil fires or explosions. The gearcase design shall be such that sufficient free oil volume exists and adequate free drainage facilities are provided to avoid these hazards. Where such hazards cannot be eliminated by design, additional precautions shall be taken.

The oil supply conditions to the gearbox shall be monitored to ensure that the viscosity conditions used as the design basis are achieved to preclude premature wear and failure.

The gearbox design shall prevent failure under the overload conditions described in [5.8.6](#).

5.8.18 Starting systems

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

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, suitable controls shall be provided to ensure that hazardous over-temperatures do not arise.

If a separate, dedicated, starting driver that does not run continually with the driven microturbine rotor is installed, it shall disengage and shut-down automatically before reaching its maximum tolerable speed. Failure to disengage shall automatically trip the microturbine.

Starting systems using pressurized flammable gas as the source of power 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 degree of isolation as a 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 a gas starter is used and vented to atmosphere, it shall be vented in accordance with [5.22.2](#).

NOTE 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 are eliminated.

In the event of a starter motor rotor failure, the starter motor casing shall be capable of containing the release of high-energy debris. If this capability does not exist, then other safeguards shall be provided to protect personnel from injury (e.g. enclosure access prevented during starter operation).

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

5.8.19 Storage and operating ambient temperature conditions

Where low or high 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 within the manufactures stated temperature ranges. The microturbine system shall be clearly marked with its operational temperature ranges and documentation shall state the storage temperature ranges for the microturbine electronics system.

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

The manufacturer shall provide technical specifications for proper ambient storage and operating conditions/limits. The manufacturer shall take appropriate measures to protect the equipment for reasonably foreseeable conditions that can exist within a proper storage environment. See the requirements of IEC 60204-1:2009, 4.4

NOTE The microturbine engine power output rating ambient conditions are established in ISO 3977-2.

5.9 Microturbine air inlet system

5.9.1 General

The microturbine air inlet system conditions and directs the air into the microturbine compressor and where applicable power electronics.

The microturbine systems equipped with purge pressurization enclosures placed in Group II Zone 2 locations shall comply with the requirements of IEC 60079-2.

5.9.2 Inlet air contamination

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

The air inlet filtration system shall be capable of experiencing pressure changes due to credible turbine compressor surge events to ensure that a tolerable level of risk is maintained.

Where applicable, cooling air inlet filtration for electronics shall be provided that minimizes the entry of atmospheric contaminants, airborne contaminants from environmental conditions and saliferous atmospheres, where necessary, that can lead to premature failure of microturbine power electronics and safety components, creating a hazardous situation.

5.9.3 Icing monitoring and prevention

Where site conditions of temperature and humidity can be reasonably foreseen to cause icing at the microturbine compressor inlet system, which can cause a dangerous situation, appropriate measures shall be taken to prevent the accumulation of hazardous quantities of ice, or controls utilized that initiate a trip before a hazardous situation is created. Where the measures for preventing inlet icing can become inoperable and while the microturbine system is operating in the range of temperature and humidity where ice in the compressor inlet can form, the microturbine should be shut-down automatically on a fault indication when a hazardous situation is reasonably foreseeable.

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.

If site monitoring instrumentation is to be installed, it 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 microturbine compressor inlet, the water supply shall be shut-off when air temperature monitoring at the microturbine compressor inlet indicates that conditions exist for ice formation, which can lead to microturbine compressor damage, resulting in 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 can include the use of a suitable anti-freeze agent (see [7.5.2](#) and [5.24.2](#)).

5.9.4 Implosion protection

Where an implosion flap door is provided in the inlet system to open at a specific pressure drop to prevent implosion of the inlet ducting with the potential for the ingestion of dangerous foreign objects if an upstream blockage occurs, suitable measures shall be taken to prevent foreign object ingress at the bypass door, which, due to the size of the object, could cause a dangerous situation. Measures shall be installed to ensure that the implosion flap door, where provided, cannot become frozen shut where its failure to operate can cause a dangerous situation.

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 credible leak from a secondary source would be diluted to such an extent by the surrounding air that a hazardous situation would not arise in the combustion air supply.

Gas detector(s) to initiate a microturbine trip 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 microturbine compressor air inlet from either

- a) adjacent plant, should there be an uncontrolled event or major incident,
- b) the atmosphere, due to excessive venting or similar uncontrolled conditions [e.g. in natural gas or liquefied petroleum gas (LPG) plants or offshore platforms], 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 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.

5.9.6 Waste disposal through combustion

In some applications the combustion inlet air can 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 microturbine start-up cycle and prior to shut-down. The allowable flow rate and concentration of the waste flammable gases, vapours or aerosols prior to mixing with the combustion air flow, and the temperature and pressure of combustion shall be monitored and controlled within limits verified as tolerable by detailed analysis and tests. If the flow rate or concentrations exceed the defined levels, the supply shall be terminated.

Where this disposal process is adopted, suitable gas detector(s) shall be installed at the microturbine compressor air inlet as an additional precaution to trip the microturbine in the event of an excess waste flow. 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 microturbine enclosure is used for anti-icing at the microturbine compressor air inlet, there is the risk that a potentially explosive mixture of fuel and air can be ingested into the microturbine if there is a fuel leak within the microturbine 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 microturbine compressor air inlet plenum and in the microturbine enclosure ventilation-air outlet.
- b) All equipment within the ventilation air and combustion inlet air flows shall comply with [5.16](#) for use in zone 2.
- c) All surface temperatures within the ventilation and combustion inlet air flows shall not exceed the AIT of any flammable substances that can be present (see [5.16.4.4](#)).
- d) The gas detector(s) and associated safety systems response times shall prevent a potentially dangerous explosive mixture from reaching the anti-icing outlet within the microturbine compressor air-inlet plenum based on a sudden fuel leak within the enclosure at the minimum ventilation flow rate.

Where microturbine compressor delivery air is piped to the microturbine 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 microturbine compressor surge.

5.9.8 Microturbine compressor air inlet ducting

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

The air inlet ducting system shall be capable of experiencing pressure changes due to credible turbine compressor surge events to ensure a tolerable level of risk is not exceeded.

5.10 Fuel systems

5.10.1 General

The microturbine fuel system shall be considered to include all components within the production enclosure from the point of entry to enclosure, including any internal automatic shut-off valves, up to and including the burners/combustion injectors. The site fuel system shall be considered to include all components outside the enclosure including the external manually operable shut-off valve up to microturbine enclosure. The most common fuels used by microturbine applications within the scope of this International Standard 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.

The microturbine enclosure shall have a fuel system label at the fuel connection point and shall clearly display the following information: the type of fuel to be used, maximum and minimum fuel inlet pressure in kPa, and optionally - the thermal energy value of the fuel to be used in MJ/m³.

NOTE 1 The fuel label can be incorporated within the name data plate as long as the fuel connection and electrical connection point are in close proximity of one another and the name data plate is located between the connections.

NOTE 2 The external fuel valve train shall comply with the national standards of the country of installation and the manufacturers installation requirements.

NOTE 3 Some countries can require maximum and minimum fuel inlet pressure in psig and optionally thermal energy value of the fuel to be used in Btu/scf.

5.10.2 Fuel supply quality and supply conditions

Manufacturers shall provide detailed fuel specifications (including dew point margins for gaseous fuels and potential for wax formation) and condition ranges required for safe, reliable operation of their machines to the operator and to the designer of the fuel supply system. When the fuel does not comply with the detailed fuel specification the operator shall provide a fuel analysis (including up to C12 for gas fuels) so that the manufacturer can specify the specific fuel treatment necessary to mitigate any associated risks to a tolerable level. Treatment can include varying degrees of pressure and flow control, filtration, condensate removal or heating of the fuel supply. The operator has the responsibility to ensure that the supplied fuel composition remains within the range of the agreed fuel specification throughout the lifetime of the plant, unless a deviation is formally agreed with the manufacturer.

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 should also be given to any trace element content likely to lead to an unacceptable reduction of metallurgical properties.

Materials that provide a tolerable level of resistance to cracking, corrosion or other contaminant-related failure modes shall be selected with alternative fuels, such as bio-gas (landfill and digester) and raw gas (oil-field/well-head) that can contain contaminants or properties with the potential for causing embrittlement/corrosion of fuel system components. Attention shall also be given to any trace element likely to lead to an unacceptable reduction of elastomeric material properties (e.g. gasket seals), see ISO 16010.

Measures shall be taken to ensure temperatures and pressures are within the ranges that are acceptable for use with the selection of a given material.

NOTE ISO 15156-1 and ISO 15156-2 provides guidance on the selection of materials resistant to stress corrosion cracking in the presence of hydrogen sulfide at different levels of contamination, pressures, and temperatures.

5.10.3 Pressure testing

The microturbine (pre-production) fuel system design shall be validated for its integrity by pressure testing for 2 min at 1,5 times the maximum system design pressure with a calibrated pressure gauge verified by a volume metric flow meter and shall show no evidence of leaking.

- a) Pressure testing shall be conducted on all final production fuel system assemblies. A pneumatic or hydrostatic pressure test on the piping/tubing shall be conducted on the assembly line of all production units at maximum system design pressure for 1 min and show no evidence of leaks.
- b) A site pressure test shall be conducted as part of a safe commissioning procedure which shall be adopted to check for leaks on the running microturbine system. The field test procedure adopted with the technical guidance of the OEM shall be shown to achieve a tolerable level of risk and shall be appropriately documented.

NOTE Where it is not practical to conduct a final assembly pneumatic or hydrostatic pressure test on the piping connected to the combustion system, a safe commissioning procedure shall be adopted to check for leaks on the running microturbine. The procedure adopted shall be shown to achieve a tolerable level of risk and shall be appropriately documented.

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. Reliable overheat protection shall be provided to ensure that excessive heat input to the fuel or its associated piping cannot occur.

Where heat exchangers use fluid media as the heat input and fuel leakage followed by entrainment into the media can cause a dangerous 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, and be of an explosion proof design with evidence of a competent body certification.

5.10.5 Gas fuel systems

5.10.5.1 General

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

- a) site installation manual isolation (see [5.10.5.2](#));
- b) leak tight 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 leak tight and automatic fast acting shut-off valves (see [5.10.5.4](#));
- f) venting for pipework depressurization (see [5.10.5.4](#) or [5.10.5.5](#));
- g) site installed valve and piping connections to allow for the addition of pressure gauges and test points to monitor during maintenance.

Additional equipment shall be provided where a system risk assessment of all reasonably foreseeable conditions and the reliability of the equipment used indicates that additional control is required.

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](#).

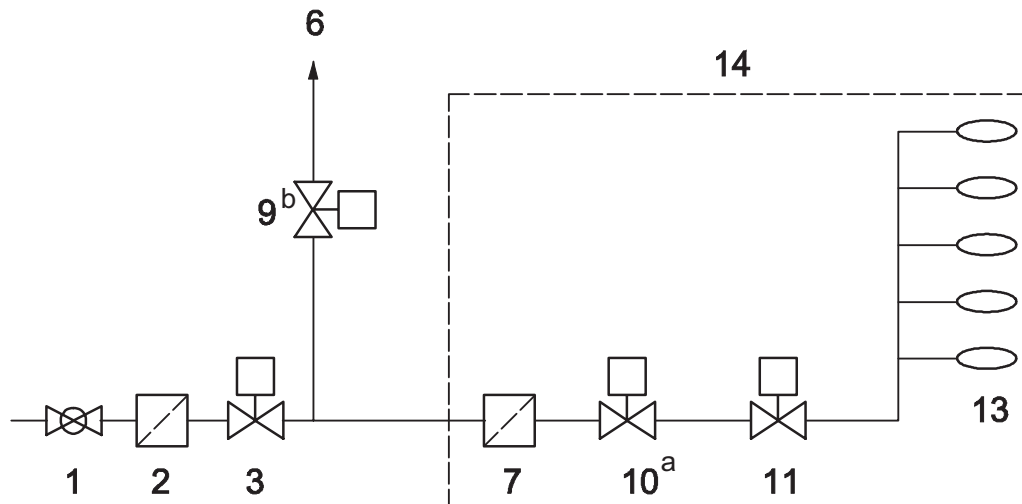
A strainer shall be fitted in accordance with [5.10.5.6](#) where necessary for safe operation.

Suitable and sufficient means for assessing the gas tightness of safety shut off systems as well as the pressure and flow throughout a gas valve train during commissioning and maintenance shall be provided.

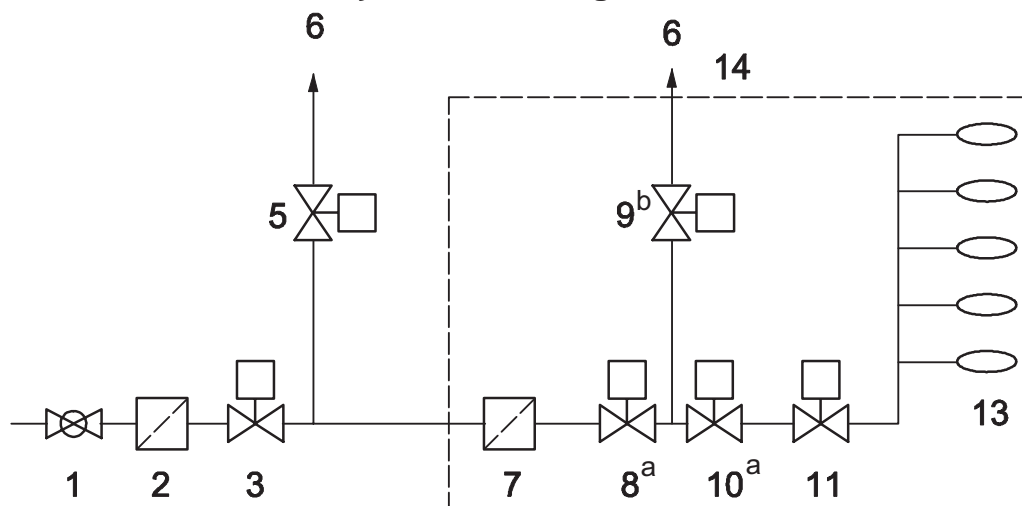
NOTE This can be provided by the functions of the control system (see [7.7.7](#)), physical means such as test points or a combination of both.

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

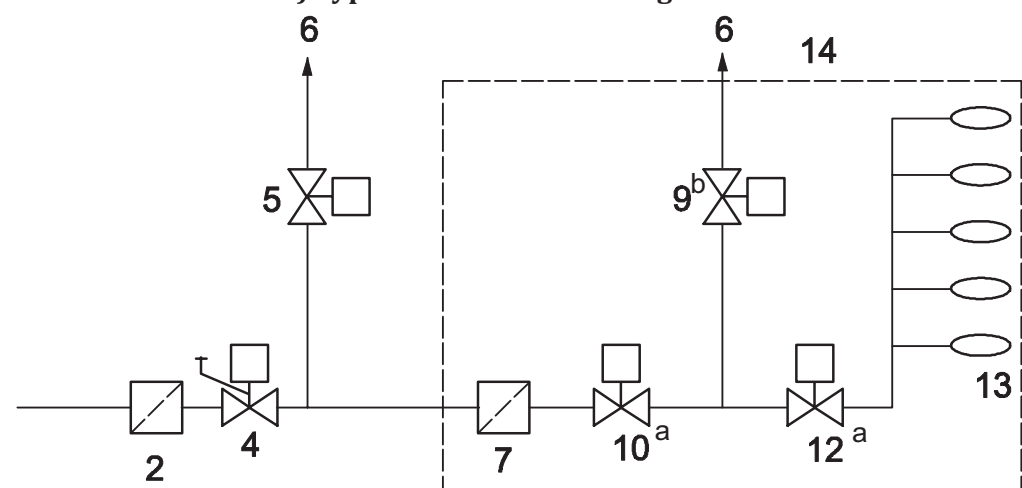
NOTE National regulations can require (100 k cycles of operation) certification of safety shut-off valves, flow control valves serving as safety shut-off valves and vent valves. Examples of equivalent valve safety standards are: ANSI Z21.21/CSA 6.5-2005, UL429, IEC 60730-2-17, EN 161.



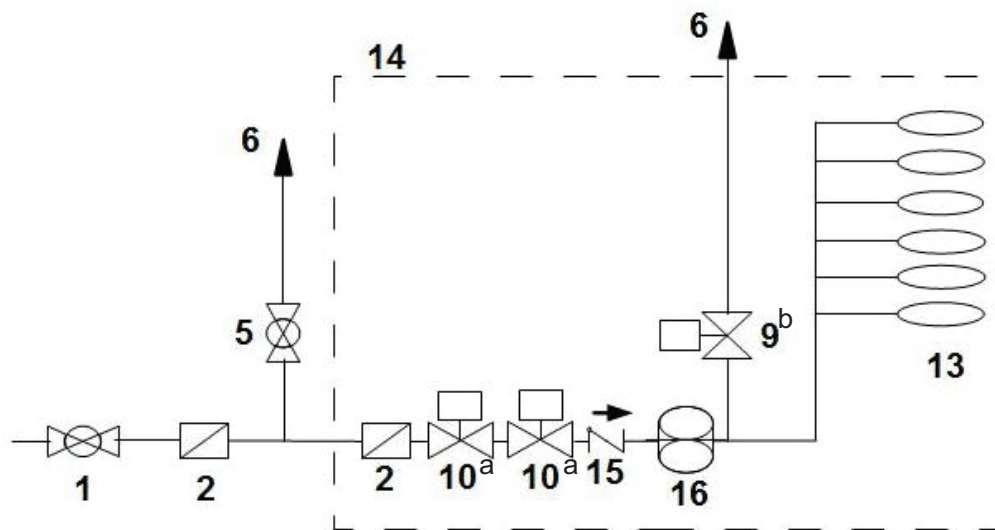
a) Minimum arrangement



b) Typical alternative arrangement



c) Typical alternative arrangement



d) Typical alternative arrangement

Key

1	manual isolation valve	9	vent valve
2	strainer, optional	10	automatic fast acting shut-off valve
3	shut-off valve	11	flow control valve
4	shut-off valve and manual isolation valve	12	flow control and shut-off valve
5	vent valve	13	combustion system
6	Vent	14	typical microturbine enclosure limits
7	strainer, optional position	15	check valve
8	shut-off valve	16	fuel gas booster pump
a	Close on every shut-down.	b	Vent on every shut-down.

Figure 1 — Gas fuel system

Leak tight and automatic fast acting shut-off valves shall fail closed by permanent available energy, e.g. spring force. The fail-safe status of vent valves shall minimize any risks. All valves shall be specified such that a tolerable level of risk and reliable operation will be achieved under all reasonably foreseeable operating conditions.

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

Optional site fuel supply 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.

Integral valve combinations can be used providing the necessary functional safety is achieved without introducing additional risk.

See [5.11.2](#) relating to fuel control during ignition.

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 microturbine unit installation upstream of the automatic