INTERNATIONAL STANDARD

ISO 13577-2

Second edition
2023-12

Industrial furnaces and associated processing equipment — Safety —

Part 2: Combustion and fuel handling systems

Fours industriels et équipements associés — Sécurité —

Partie 2: Équipement de combustion et de manutention des combustibles

Reference number
ISO 13577-2:2023(E)

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Published in Switzerland

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Foreword

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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 document 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).

ISO draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). ISO takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, ISO had not received notice of (a) patent(s) which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at www.iso.org/patents. ISO shall not be held responsible for identifying any or all such patent rights.

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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 244, *Industrial furnaces and associated processing equipment*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 186, *Industrial thermoprocessing - Safety*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This second edition cancels and replaces the first edition (ISO 13577-2:2014), which has been technically revised.

The main changes are as follows:

— revised document structure with requirements consolidated for the different fuels;

— improvement and specification of the requirements for testing the fuel pipework after construction;

— addition of requirements for gas pressure boosting systems;

— integration of selected requirements from the regional annexes into the global standard text;

— requirements for solid fuels removed;

— additional informative annex listing relevant product standards for components in the different regions.

A list of all parts in the ISO 13577 series can be found on the ISO website.

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 defined 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/equipment concerned and the extent to which hazards, hazardous situations or hazardous events are covered, is 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 -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.

This document assumes that the equipment is installed in a ventilated area and does not create any potentially explosive atmosphere. The installation of a TPE in accordance with the requirements of this document will not by itself require a change to the classification of the TPE location according to IEC 60079-10-1:2020.

Conformance with product standards, e.g. ISO 22967:2010 or ISO 22968:2010 is not sufficient to ensure the minimum safety requirements for industrial furnaces and associated processing equipment (TPE). This document always has priority for TPE.

Industrial furnaces and associated processing equipment (TPE) generally consist of the following components:

— processing chamber (e.g. steel construction with lining and/or refractory);

— heating systems;

— protective system;

— control and instrumentation system / operator-control level.

ISO 13577-1:2016 provides the general safety requirements common to TPE. This document details in addition specific safety requirements for combustion and fuel handling systems that are part of TPE as listed in the Scope.

The requirements for protective systems are specified in ISO 13577-4:2022.

The requirements for reducing hazards from noise are given in ISO 13577-1:2016.

It is assumed that TPE are operated and maintained by trained personnel.

Industrial furnaces and associated processing equipment — Safety —

Part 2: Combustion and fuel handling systems

1 Scope

This document specifies the safety requirements for combustion and fuel handling systems that are part of industrial furnaces and associated processing equipment (TPE), including single and multiple burner systems in thermoprocessing equipment and machines.

NOTE The general safety requirements common to TPE are provided in ISO 13577-1:2016. ISO 13577-1:2016, Annex B also includes a list of processes for which industrial furnaces and heating systems covered by the ISO 13577 series are used.

This document deals with significant hazards, hazardous situations and events relevant to combustion and fuel handling systems as listed in Annex A, when used as intended and under the conditions for use as described in the instruction handbook.

This document covers:

— fuel pipework downstream of and including the manual isolating valve;

— combustion air supply (including oxygen and oxygen enriched combustion air) and flue gas system;

— burner(s), burner system and ignition device;

— functional requirements for safety related control system.

This document applies to any oxidation of gaseous and liquid fuels with air or other gases containing free oxygen to release thermal energy in TPE. Annex B includes examples of gaseous and liquid fuels.

For thermal or catalytic post combustion and waste incineration, this document applies only to auxiliary burners designed to start-up and/or support the process.

The pressure hazard of the piping and components covered by this document is within the maximum pressure/size relationship of category I as specified in Annex C.

This document also gives the necessary requirements regarding information for use.

This document does not cover hazards from heating generated by electricity.

This document does not deal with the hazards created by the release of flammable substances from the products processed in the TPE.

This document is not applicable to combustion and fuel handling systems:

— of gas welding and allied processes;

— up-stream of the TPE manual isolating valve.

This document is not applicable to industrial furnaces and associated processing equipment (TPE), including single and multiple burner systems in thermoprocessing equipment and machines manufactured before the date of its publication.

This document is not applicable to blast furnaces, converters (in steel plants), boilers, fired heaters (including reformer furnaces) in the petrochemical and chemical industries.

This document is not applicable to electrical cabling and power cabling upstream of the TPE control panel/protective system.

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 7-1:1994, *Pipe threads where pressure-tight joints are made on the threads — Part 1: Dimensions, tolerances and designation*

ISO 49:1994, *Malleable cast iron fittings threaded to ISO 7-1*

ISO 228-1:2000, *Pipe threads where pressure-tight joints are not made on the threads — Part 1: Dimensions, tolerances and designation*

ISO 5817:2014, *Welding — Fusion-welded joints in steel, nickel, titanium and their alloys (beam welding excluded) — Quality levels for imperfections*

ISO 7005-1:2011, *Pipe flanges — Part 1: Steel flanges for industrial and general service piping systems*

ISO 7005-2:1988, *Metallic flanges — Part 2: Cast iron flanges*

ISO 8434-1:2018, *Metallic tube connections for fluid power and general use — Part 1: 24° cone connectors*

ISO 8434-2:2007, *Metallic tube connections for fluid power and general use — Part 2: 37 degree flared connectors*

ISO 8434-3:2005, *Metallic tube connections for fluid power and general use — Part 3: O-ring face seal connectors*

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

ISO 13574:2015, *Industrial furnaces and associated processing equipment — Vocabulary*

ISO 13577-1:2016, *Industrial furnaces and associated processing equipment — Safety — Part 1: General requirements*

ISO 13577-4:2022, *Industrial furnace and associated processing equipment — Safety — Part 4: Protective systems*

ISO 16852:2016, *Flame arresters — Performance requirements, test methods and limits for use*

ISO 19879:2010, *Metallic tube connections for fluid power and general use — Test methods for hydraulic fluid power connections*

ISO 23550:2018, *Safety and control devices for gas and/or oil burners and appliances — General requirements*

ISO 23551-1:2012, *Safety and control devices for gas burners and gas-burning appliances — Particular requirements — Part 1: Automatic and semi-automatic valves*

ISO 23551-2:2018, *Safety and control devices for gas burners and gas-burning appliances — Particular requirements — Part 2: Pressure regulators*

ISO 23551-5:2014, *Safety and control devices for gas burners and gas-burning appliances — Particular requirements — Part 5: Manual gas valves*

ISO 23551-6:2014, *Safety and control devices for gas burners and gas-burning appliances — Particular requirements – Part 6: Thermoelectric flame supervision controls*

ISO 23552-1:2007+AMD 1:2010, *Safety and control devices for gas and/or oil burners and gas and/or oil appliances — Particular requirements — Part 1: Fuel/air ratio controls, electronic type*

ISO 23553-1:2014, *Safety and control devices for oil burners and oil-burning appliances — Particular requirements - Part 1: Automatic and semi-automatic valves*

ISO 23555-2:2022, *Gas pressure safety and control devices for use in gas transmission, distribution and installations for inlet pressures up to and including 10 MPa*

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

IEC 60730-2-5:2013+A1:2017, CSV, *Automatic electrical controls – Part 2-5: Particular requirements for automatic electrical burner control systems*

IEC 60730-2-6:2015+A1:2019, CSV, *Automatic electrical controls – Part 2-6: Particular requirements for automatic electrical pressure sensing controls including mechanical requirements*

ASME B1.20.1-2013, *Pipe Threads, General Purpose, Inch*

CAN/CSA-C22.2 No.199-M89:2004, , *Combustion Safety Controls and Solid-State Igniters for Gas- and Oil-Burning Equipment*

CAN/CSA-C22.2 No.60730-2-4-14: 2019, *Automatic electrical controls for household and similar use - Part 2-5: Particular requirements for automatic electrical burner control systems*

CSA/ANSI Z21.18-2019/CSA 6.3-2019, *Gas appliance pressure regulators*

CSA/ANSI Z21.21-19/CSA 6.5-2019, *Automatic valves for gas appliances*

EN 88-1:2016, *Pressure regulators and associated safety devices for gas appliances — Part 1: Pressure regulators for inlet pressures up to and including 50 kPa*

EN 88-2:2015, *Safety and control devices for gas burners and gas burning appliances — Part 2: Pressure regulators for inlet pressure above 50 kPa up to and including 500 kPa and associated safety devices*

EN 88-2:2020, *Pressure regulators and associated safety devices for gas appliances — Part 2: Pressure regulators for inlet pressures above 500 mbar up to and including 5 bar*

EN 88-3:2017, *Safety and control devices for gas burners and gas burning appliances — Part 3: Pressure and/or flow rate regulators for inlet pressures up to and including 500 kPa, electronic types*

EN 125:2010+A1:2015, *Flame supervision devices for gas burning appliances — Thermoelectric flame supervision devices*

EN 161:2013, *Automatic shut-off valves for gas burners and gas appliances*

EN 298:2012, *Automatic burner control systems for burners and appliances burning gaseous or liquid fuels*

EN 331:2015, *Manual operated ball valves and closed bottom taper plug valves for gas installations for buildings*

EN 334:2019, *Gas pressure regulators for inlet pressure up to 100 bar*

EN 1854:2010, *Pressure sensing devices for gas burners and gas burning appliances*

EN 12067-2:2004, *Safety and control devices for burners and appliances burning gaseous or liquid fuels — Control functions in electronic systems — Part 2: Fuel/air ratio control/supervision of the electronic type*

EN 14382:2019, *Gas safety shut-off devices for inlet pressure up to 10 MPa (100 bar)*

EN 13774:2013, *Valves for gas distribution systems with maximum operating pressure less than or equal to 16 bar - Performance requirements*

EN 16678:2016, *Safety and control devices for gas burners and gas burning appliances — Automatic shut-off valves for operating pressure of above 500 kPa up to and including 6,300 kPa*

EN 60730-2-5:2015+A1:2019, *Automatic electrical controls for household and similar use — Part 2-5: Particular requirements for automatic electrical burner control systems*

EN 60730-2-6:2016+A1:2020, *Standard for automatic electrical controls — Part 2-6: Particular requirements for automatic electrical pressure sensing controls including mechanical requirements*

JIS C 9730-2-5:2010, *Automatic electrical controls for household and similar use — Part 2-5: Particular requirements for automatic electrical burner control systems*

UL 372:2012, *Automatic electrical controls for household and similar use — Part 2: Particular requirements for Burner Ignition Systems and Components, 6th Edition*

UL 429:2013, *Standard for Electrically Operated Valves, 7th Edition*

UL 60730-2-5:2014, *Automatic electrical controls for household and similar use — Part 2-5: Particular requirements for automatic electrical burner control systems*

UL 60730-2-6:2016, *Standard for automatic electrical controls – Part 2-6: Particular requirements for automatic electrical pressure sensing controls including mechanical requirements*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 12100:2010, ISO 13574:2015 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
maximum allowable pressure
maximum pressure for which the equipment or piping system is designed

Note 1 to entry: This definition takes precedence over the definition specified in ISO 13574: 2015, 2.132.

3.2
line-burner
burner where the housing has a linear or grid style geometry typically equipped with multiple nozzles or other elements for introduction of fuel, air or fuel/air-mixtures and creating a linear or grid shape flame pattern by flame propagation from one nozzle/element to another

4 Safety requirements, measures and verification means

4.1 General

4.1.1 Safety objectives and basic requirements

Combustion and fuel handling systems that are part of industrial furnaces and associated processing equipment (TPE), including single and multiple burner systems in thermoprocessing equipment and machines, shall comply with the safety requirements of this document. In addition, the machine shall be designed according to the principles of ISO 12100:2010 for hazards that are relevant, but not significant, and which are not dealt with by this document.

The safety objectives of this document include:

- — choice of materials such that the construction and operation of the system are not detrimentally affected;
- — reliable ignition of the air/fuel-mixture at the burner(s);
- — prevention of unintentional release of unburned fuels;
- — shut off fuel-supply in case of relevant fault;
- — protection of pipeline to preclude the propagation of flame in reverse direction;
- — prevent firing when the evacuation of flue gas/combustion products is not ensured;
- — prevent firing when the process conditions are not in the safe state.

The safety devices-, fittings-, pipework and equipment design shall take into account the composition and properties (e.g. pressure, temperature, corrosiveness, specific gravity) of the used substance, transient conditions shall be considered also. In particular, all the components of the fuel pipework shall be located to avoid overheat above design temperature and damage, and be capable of withstanding the mechanical, chemical and thermal loads to which they can be subjected during normal operation and foreseeable abnormal operation (e.g. identified during a safety assessment).

Where other fuel gas than natural gas, manufactured gas or liquefied petroleum gas (LPG) is used (e.g. hydrogen or natural gas blend containing hydrogen) risk assessment shall prove the suitability of components and procedures. Relevant information shall be included in the instruction handbook, e.g. as part of the equipment description.

NOTE 1 Use of fuel with very high content of hydrogen for industrial heating applications can require some additional precautions due to its high flame speed, wider flammability range and hydrogen embrittlement, etc. ISO/TR 15916:2015, 6.2.2, B.3 and Annex C provides useful information for the TPE industry.

NOTE 2 Product standards, e.g. ISO 23551-1 for automatic-shut-off valves, are limited for component's use with natural gas, manufactured gas or liquefied petroleum gas (LPG), i.e. high-purity hydrogen is out of the scope of the product standard.

Electrical equipment and circuits shall be designed in accordance with IEC 60204-1:2016.

NOTE 3 According IEC 60204-1, protective equipotential bonding of pipework and its accessories can be required to reduce the risk of electric shock. The impedance of the protective equipotential bonding is maintained at a low level so that in the event of a fault the possible touch voltage between two simultaneously touchable conductive parts is lower than AC 50V and DC 120V.

To minimize ignition hazards due to electrostatic charges, pipework and its accessories shall have a resistance to earth of not more than 1 MΩ. That will ensure safe dissipation of static electricity.

Safety functions shall be designed in accordance with ISO 13577-4:2022, where the use of standards for functional safety IEC 62061:2021, ISO 13849-1:2015, IEC 61511-1:2016, IEC 61511-2:2016 IEC 61511-3:2016 and IEC 61508-1:2010, IEC 61508-2:2010, IEC 61508-3:2010, IEC 61508-4:2010, IEC 61508-5:2010, IEC 61508-6:2010, IEC 61508-7:2010 is included. Annex D provides information for the determination of the SIL or PL of safety-related functions covered in this document.

4.1.2 Over-temperature protection

Over-temperature protection shall be fitted, unless the risk assessment has identified no over temperature hazard. This protection shall cause safety shutdown when it detects combustion chamber temperature exceeding prescribed safety limit. The risk assessment shall determine whether this function shall meet the requirements of the protective system according to ISO 13577-4:2022. SIL/PL capable devices shall be used for over-temperature protection in case the function shall meet the requirements of a protective system according to ISO 13577-4:2022.

4.1.3 Accumulation of hazardous fluids

The occurrence of hazardous situations by accumulation of hazardous fluids (e.g. from unburned fuel gas) in potentially less ventilated spaces (e.g. pits, cellars, etc.) shall be prevented. The risk assessment shall determine whether gas detectors need to be installed.

4.1.4 Seismic protection

In seismic prone areas where seismic intensity can exceed 325 gal, safety measures should be implemented which cause safety shutdown when excessive seismic impact is detected. The risk assessment shall determine details.

4.1.5 Regional requirements

See Annex I, Annex J and Annex K which include background information about regional regulations and specific regional requirements.

4.2 Fuel pipework

4.2.1 General

The pipework shall be tight and the design shall take into account the composition and properties of the fuel and the need for venting, purging, cleaning, trace heating and insulation. The design of pipework shall be such as to avoid tensile loading of the joints.

NOTE Due to its tightness, external releases are not expected, nor are any explosive atmosphere foreseen in its surroundings, during the lifetime of the equipment.

Due to durability, steel is the preferred material for pipes and components but where appropriate and the same safety levels can be achieved then other materials may be utilized. Such materials and conditions of service shall be specified in the instruction handbook.

The pipework shall be designed to avoid the possibility of fuel velocities and pressure fluctuations causing oscillations which could cause damage to pipework, components or safety systems (e.g. by designing the correct sizing of pipe, using pressure regulator).

Oscillations which may cause damage to pipework, components or safety systems shall be prevented (by firm anchoring and/or use of flexible couplings).

The design of the liquid fuel pipework shall have a structure which prevents accumulation of air in the pipework and measure for removal of air shall be fitted at positions where accumulation of air may occur.

4.2.2 Connections

Pipework connections shall be metallic and shall be of threaded, compression, flanged, welded or brazed types. The number of connections shall be kept to a minimum. Threaded connections should be avoided where possible and shall only be used as specified in 4.2.2.1 and 4.2.2.2

Where the equipment has a threaded connection, this thread shall comply with ISO 228-1:2000 or ISO 7-1:1994 or ASME B1.20.1-2013, as appropriate.

The use of threads complying with ISO 228-1:2000 (parallel threads) is limited to a diameter up to DN 50. In case of threads according to ISO 228-1:2000, the tightness shall be ensured by a ring gasket, not sealants in the threads.

In case of threads according to ISO 7-1:1994 (conical threads) suitable sealants shall be used to ensure tightness. Hemp shall not be used in threaded connections unless reinforced with a suitable sealant.

Compression fittings shall comply with ISO 8434-1:2018, ISO 8434-2:2007 and ISO 8434-3:2005 or ISO 19879:2010. For gaseous fuels, compression fittings shall only be used for diameters up to 42 mm and pressures as given in the fitting standards. For liquid fuels, compression fittings shall only be used for pressures up to 4 MPa and diameters up to DN 32.

Flanges shall comply with ISO 7005-1:2011 and ISO 7005-2:1988, as appropriate. Suitable gaskets shall be used to ensure (enhanced) tightness.

NOTE Examples of suitable gaskets are:

— aramid fibres bonded with rubber (NBR) with or without PTFE envelope;

— spiral wound gasket;

— expanded graphite with grater-type core;

— moulded PTFE flat gaskets with stainless steel insert;

— plain and filled PTFE.

Arc welding shall comply with ISO 5817:2014, quality level C.

Any pipe passing through an unventilated space shall not have a connection except welded joints.

Other connections may only be used providing they ensure tight connections and are suitably identified.

Special requirements for liquefied petroleum gas in the liquid phase shall be considered.

4.2.2.1 Threaded connections for gaseous fuels

Gaseous fuel threaded connections according to ISO 7-1:1994 shall be used only for the following pressure/diameter combinations:

— pressures up to 15 kPa, and diameters up to DN 65;

— pressures up to 200 kPa, and diameters up to DN 50;

— pressures up to 500 kPa, and diameters up to DN 25;

— pressures up to 1 MPa, and diameters up to DN 15.

For threaded connections according to ISO 228-1:2000 no pressure limit is applicable; tightness shall be ensured by suitable ring gasket.

Threaded connections according to ASME B1.20.1 (NPT threads) may be used up to DN 50 without pressure limitation.

For cast iron fittings according to ISO 49:1994, the following limitations shall be observed:

— fittings shall be class “A”;

— maximum allowed pressure is 50 kPa.

4.2.2.2 Threaded connections for liquid fuels

For liquid fuels threaded connections shall be used only for the following combinations:

— pressures up to 1 MPa;

— temperatures up to 130 °C;

— diameters up to DN 25.

Threaded connections may be used for higher pressures and temperatures where the connection is specifically designed to operate under those conditions without creating a risk. In this case the connection ratings for pressure and temperature shall be specified in the instruction handbook.

4.2.3 Unconnected pipework

Any unconnected pipework shall be plugged, capped or blank flanged by means of metallic parts.

4.2.4 Galvanic cells

Corrosion in pipelines can be caused by the unintentional formation of a galvanic cell. Galvanic cells are formed when materials with different electrochemical potentials are conductively connected (e.g. copper screw in an aluminium sheet, stainless steel sheet screwed to steel sheet). This shall be taken into account when selecting the material for piping.

4.2.5 Flexible tubing and couplings

Flexible tubing shall comply with the general requirements of 4.2.1, together with the following:

— shall be as short as practicable;

— shall be capable for the maximum and minimum allowable (fuel and ambient) temperatures;

— shall be capable for a pressure 1,5 times the maximum allowable pressure (with a minimum of 15 kPa for gaseous fuels or 100 kPa for liquid fuels), at the maximum and minimum allowable temperatures;

— shall have a directly accessible, upstream manual shut-off valve;

— shall be mounted in such a way as to avoid distortion, whiplash and damage;

— shall have end fittings as integral parts of the tubing;

— shall be constructed from suitable material both metallic and/or non-metallic selected for the application duty and not be easily damaged.

Couplings for removable equipment shall ensure a tight connection with the equipment connected and disconnected.

4.2.6 Marking

The pipework shall be identified with respect to the fuel being carried.

NOTE Identification of fuel pipework is dealt with by national regulations or standards.

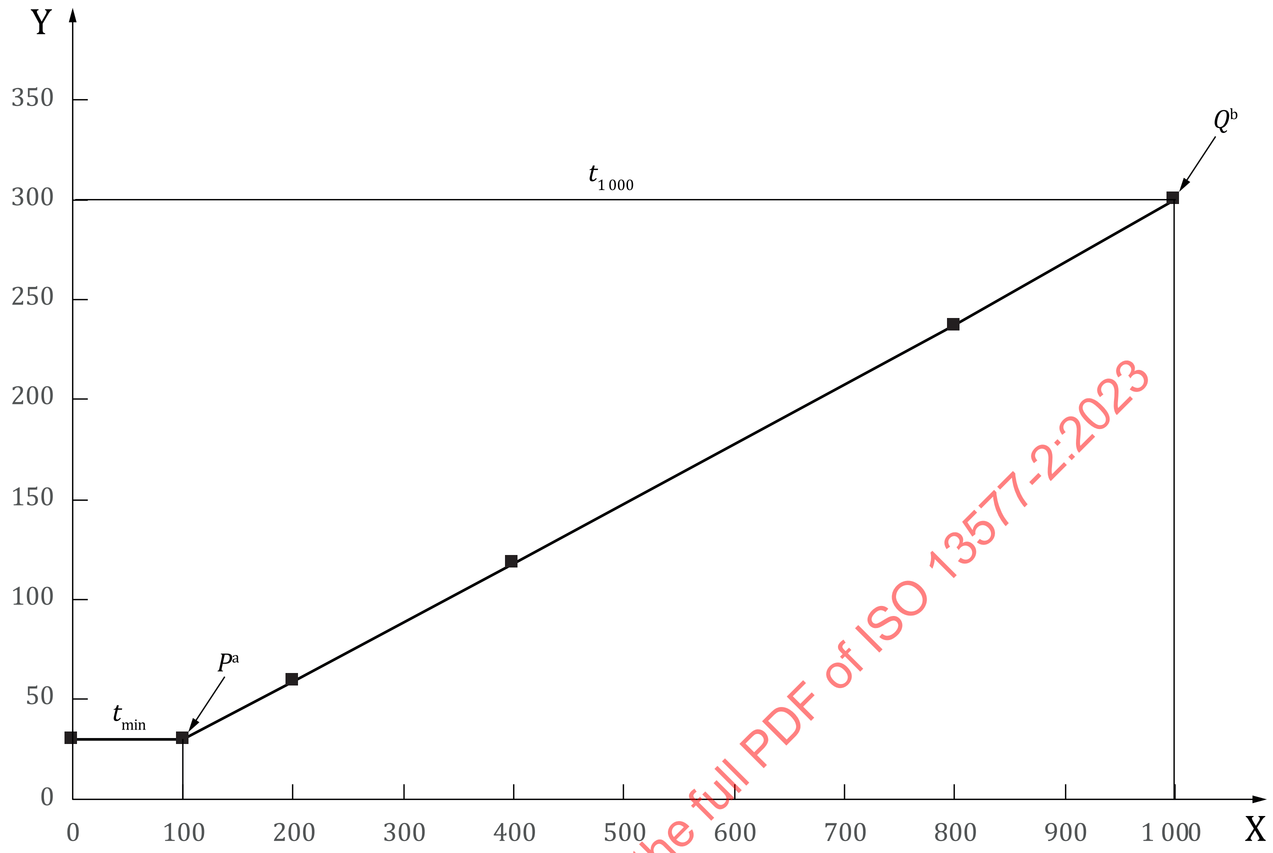
4.2.7 Soundness/tightness

After assembly and prior to commissioning, the pipework shall be subjected to a pressure decay test to verify the tightness and confirm the piping is leak free. The leakage test shall cover all the piping, from the manual isolating valve down to the final fitting before the burner(s). The test shall be conducted by a pressure decay test with the following three conditions:

— the initial test pressure shall be at least 1,1 times the maximum allowable pressure of the equipment,

— the minimum duration of the test by volume shall be according to Figure 1,

— the pressure drop shall be less than 500 Pa.



Key

X pipe volume expressed in dm^3

Y leak test time expressed in minutes

t_{min} minimum leak test time

[a] t_{min} has to be at least 30 min. for the pipe volume at and less than 100 dm^3.

P^a point of the volume at and below which t_{min} is applied

Q^b point of the volume (1 000 dm^3) at $t_{1\,000}$

$t_{1\,000}$ leak test time at the pipe volume of 1 000 dm^3

[b] $t_{1\,000}$ is estimated to be at least 300 min.

Figure 1 — Test time for pressure decay test depending on test volume

For test volumes larger than 1 000 dm^3 the graph shall be extrapolated. For gas pipework tested by using qualified and automated test rigs, shorter test times calculated to detect a leak rate of less than 1 Ndm^3/h are acceptable.

The tightness test as described serves to prove that the leakage is below 1 Ndm^3/h. For large equipment this may hardly be achievable. Alternative test procedure may be used if risk assessment proves suitability, e.g. by proving sufficient dilution of leakages to a safe level.

Where the pressure cannot be maintained, a bubble test shall be conducted at a pressure between 5 kPa and 25 kPa to identify the location of the leaks. Leaks shall be repaired and then retesting is required.

Where the maximum allowable pressure is 20 kPa or less, a bubble test may be used as an alternative to the pressure decay test.

In addition to the pressure test on the pipework, all the pressure relief valves shall be tested to ensure their operation at the correct pressure.

Testing after assembly proves tightness. Repeat testing is required during operation/usage of the equipment to verify the ongoing integrity. The instruction handbook shall include advises, e.g. recommended intervals of test procedures and documented maintenance (see 6.3.1 and 6.3.3).

4.2.8 Condensate drains on gas pipework

In cases where condensates can create a hazard, means shall be provided at the lowest points of the equipment for draining any condensate. When moist gases are being used, condensate drains of a suitable type shall be installed. Any condensate drains, siphons, etc. shall be in a position such that they can be easily checked. Flammable condensates shall be collected by an appropriate means (e.g. piped into a container).

Valves in condensate drains shall be suitably plugged, capped or blank flanged by metallic parts.

4.2.9 Fuel pipe heating

Where the fuel pipe needs to be heated and insulated to maintain the required temperature, safeguards shall be provided to prevent the temperature and/or pressure of the fuel exceeding the maximum design values.

NOTE In case of low ambient temperature or in case of ambient temperature below dew point, fuel pipe heating can be necessary for gaseous fuels.

The trace heating system shall include all equipment, such as regulating and shut-off mechanisms. In the case of vapour or liquid heating, the heating system shall be provided with suitable condensate outlets and shut-off valves.

4.2.10 Purge points

Means shall be provided to facilitate purging of the fuel pipework during commissioning and maintenance. The discharge shall take the following into account, in particular:

— risk of combustion or explosion;

— avoidance of recirculation into the combustion chamber;

— avoidance of introduction into drains and pits;

— specific gravity of the substances.

4.2.11 Pressure relief devices

Pressure relief devices shall be provided as necessary. They shall ensure that the operating pressure remains below the maximum allowable pressure of the pipework and components installed see 4.3.3 for gaseous fuels and 4.5.3 for liquid fuels.

Pressure relief devices shall be positioned such that the discharge flow and the pressure relief device does not constitute a risk to the equipment, personnel or third parties.

4.2.12 Blow-off and breather pipes or conduits

Where blow-off or breather pipes or conduits are fitted on regulators or relief valves or vent valves, adequate means shall be provided to facilitate the venting of gas from the system to a safe discharge area.

In case breather pipes or blow-off pipes are gathered, the cross section of the collector pipe shall be suitable to evacuate simultaneously total flow rates of the exhaust sources.

In case breather pipes are gathered with blow-off pipes, non-interaction of the collected pipes, valves and instruments shall be verified.

4.2.13 Equipment supplied with different fuels

Where a burner is intended for alternating use with more than one gaseous and/or liquid fuels, means shall be provided to ensure that the supply pipework of the fuel not being fired is positively isolated.

4.2.14 Bypass

Bypasses shall not be fitted mechanically and/or electronically in parallel with any item of safety equipment except in the cases where:

— interlock to prevent start-up of the equipment while bypass operation is in action, or

— the bypass is a stand-by system or for start-up equipped with automatic shut-off valve(s) like in the bypassed section, or

— the compensating measures defined by the risk assessment ensure continued safe operation.

This requirement shall not apply to valve proving systems (see ISO 23551-4:2018) on automatic shut-off valves and to testing of low-pressure safety function prior to start-up.

4.2.15 Isolation of required safety devices

Required safety devices (e.g. pressure switches, relief valves) shall not be isolated from the equipment they protect during start-up or operation of the burner. In case isolating valves cannot be avoided and are mounted between these required devices and the main lines, these isolating valves shall be lockable in the open position during operation of the equipment by adequate means (e.g. manual lock, removable handle).

4.3 Required safety devices for gaseous fuels

4.3.1 Manual isolating valve

A manually operated isolation valve shall be fitted upstream of the first control device in the gas circuit. Manual isolation valves shall be so designed or positioned as to prevent inadvertent operation but shall be easily accessible and capable of rapid operation when required.

They shall be so designed that the “OPEN” and “CLOSED” positions are readily distinguishable (e.g. a 90° turn valve if applicable and available).

Manual isolating valve(s) shall comply with ISO 23551-5:2014 or regional product standard(s) according to E.1.6 if applicable.

4.3.2 Filter/strainer

Special care shall be taken to prevent the ingress of particles, either from the pipework or from the gas, which would be detrimental to the operation of the equipment by the incorporation of a suitable filtering device immediately downstream of the first manual isolating valve of the TPE. Additional filters/strainers may be required (e.g. immediately upstream of the automatic shut-off valve). The filter and/or the strainer shall be positioned in such a way that periodic servicing remains easy. The mesh size and filtering capacity of the filter/strainer shall be chosen according to the requirements of downstream equipment.

NOTE Normally safety and control devices for gas burners and gas-burning appliances require upstream filters with mesh size ≤ 50 µm. Strainers with larger mesh size are only suitable for primary cleaning.

In case of the installation of a bypass to the filter/strainer, an identical filtering device shall be installed on the bypass line.

The intervals for checking the filter and/or the strainer shall be specified in the instruction handbook.

In case of by-product gas utilization (i.e. COG, BFG, mix gases, etc.) in lieu of a filter installation, the following different/additional precautions shall be taken:

— installation of automatic shut-off valves for which tightness is less susceptible to possible dirt accumulation (e.g. triple eccentric butterfly valves, rotary plug valve);

— gas piping designed to collect possible condensate and dirt to designated points;

— provision of inspection holes for pipes/equipment cleaning and dedicated detailed procedure in the instruction handbook (see 6.3);

— increased frequency of valve tightness test and cleaning;

— description of need for cleaning of the gas in dedicated plants upstream the TPE in the instruction handbook (see 6.3).

4.3.3 Gas pressure regulator

A gas pressure regulator shall be incorporated where this is necessary for control of the pressure and the flow rate.

Gas pressure regulators when fitted shall comply with ISO 23551-2:2018, ISO 23555-2:2022 or regional product standard(s) according to E.1.2, as appropriate.

If the outlet of the gas pressure regulator and/or the following pipe section with equipment up to the burner is/are not designed for the maximum allowable pressure (inlet pressure upstream to the gas pressure regulator under fault conditions), an overpressure cut-off device shall be installed upstream of the gas pressure regulator shutting off the gas supply before the downstream pressure exceeds the maximum allowable pressure of any downstream equipment which is only protected by this device.

The overpressure cut-off device shall be a mechanical valve which measures the gas pressure downstream of the gas pressure regulator by means of an impulse line and closes by spring force in case the pressure exceeds the set response pressure. Overpressure cut-off devices shall comply with regional product standard(s) according to E.1.3, if applicable.

Other means of conducting overpressure cut-off and relief functions shall meet the requirements of a protective system according to ISO 13577-4:2022.

A small capacity relief valve (token relief valve) shall be applied downstream of the gas pressure regulator, if an over pressure cut-off device is installed, to vent small leakages of the high-pressure cut-off and to release pressure peaks resulting from closing shut-off valve(s).

NOTE A small capacity relief valve also helps to release overpressure peaks caused by simultaneous closing of multiple automatic shut-off valves.

Pressure adjustment on the gas pressure regulator, overpressure cut-off device and relief valve shall only be possible with a tool provided for the task.

Where the gas for the pilot burner is taken from upstream of the gas pressure regulator to the main burner(s), the pilot burner shall be equipped with a separate gas pressure regulator.

4.3.4 Low gas pressure protection

Low gas pressure protection shall be fitted unless the risk assessment has identified no low-pressure hazard. The low gas pressure protection device shall provide satisfactory and reliable proof of the pressure for all operation conditions.

In the event of pressure falling below a pre-determined value, the low gas pressure protection shall:

— prevent start-up, or

— cause safety shutdown and lock-out.

This function shall meet the requirement of the protective system according to ISO 13577-4:2022.

Gas pressure sensing devices shall comply with IEC 60730-2-6:2015+A1:2019 or regional product standard(s) according to E.2.3.

4.3.5 High gas pressure protection

High gas pressure protection shall be fitted unless:

— the equipment supply pressure does not exceed 10 kPa; and

— regulator failure does not result in an unsafe start-gas rate being obtained or an unsafe gas/air-ratio of each supplied burner;

or in case the risk assessment has identified no high-pressure hazard.

NOTE This function includes protection of the gas equipment from overpressure beyond their maximum value or to protect the furnace from excess power brought on by this gas overpressure.

In the event of pressure exceeding a pre-determined value the high gas pressure protection shall:

— prevent start-up, or

— cause safety shutdown and lock-out.

This function shall meet the requirement of the protective system according to ISO 13577-4:2022.

Gas pressure sensing devices shall comply with IEC 60730-2-6:2015+A1:2019 or regional product standard(s) according to E.2.3.

4.3.6 Automatic shut-off valves

The gas supply to each burner, pilot burner or group of burners shall be under the control of two automatic shut-off valves in series in the gas pipework in accordance with ISO 23551-1:2012 or regional product standard(s) according to E.1.1.

Automatic shut-off valves shall be capable of withstanding all upstream pressures, backpressure and differential pressure under all process circumstances.

The sealing force for automatic shut-off valves, as defined in ISO 23551-1:2012, shall be equal to or greater than 15 kPa.

For natural draught burner with a controlled capacity below 70 kW, the sealing force for automatic shut-off valves, as defined in ISO 23551-1:2012, shall be at least 5 kPa.

A thermo-electric flame supervision device shall comply with ISO 23551-6:2014 or alternative regional standards according to E.1.7 to be considered acceptable for natural draught burners operating in open air with controlled capacities below 70 kW, and for natural draft burners operating in combustion chamber with controlled capacities below 2,5 kW.

The automatic shut-off valve shall endure the intended number of cycles in the TPE.

Valve construction and materials shall be suitable for the operating conditions (e.g. temperature and pressure) and the fuel gas characteristics (e.g. composition), see 4.1.1.

High cycling applications over 100 000 cycles/year (e.g. pulse firing, regenerative burners) shall use only valves and contactors/relays that are declared capable of the intended use. They shall be capable of minimum 2 million cycles, proven by requirements and test procedures as defined in ISO 23551-1:2012.

NOTE The B_{10D} value according to ISO 13849-1:2015 or IEC 62061:2021 can be used to demonstrate capability for high cycling applications.

The instruction handbook shall give guidance for replacing valves and contactors/relays after defined number of cycles.

The instruction handbook shall specify the need to check automatic shut-off valves for correct operation, the procedure to be adopted, and the intervals at which this should be carried out, and the requirements for replacement, (see ISO 13577-4:2022, 4.1). Means to permit the operator to determine when automatic shut-off valves require replacement shall be supplied.

All systems shall have the ability for manual leak testing of the automatic shut-off valves. Test connections shall be available, either at the automatic shut-off valves itself or at the piping upstream and downstream the valves. Figure F.1 shows an example with separate test connections on the piping. The instruction handbook for the TPE shall include suitable information for manual leak tightness check of the valves (see 6.3.3). Annex F includes an example test procedure; other leak test procedures and test devices may be used as appropriate.

Automatic shut-off valves may be used as control valves, provided they are designed as both automatic shut-off and modulation valves and tested for concurrent use.

The automatic shut-off valves shall not open or shall shut off the fuel to the burner when the limit of any safety condition is reached. In this case, the relevant automatic shut-off valves shall be de-energized by a protective system according to ISO 13577-4:2022 except in the following cases where closing a single individual burner automatic shut-off valve is sufficient:

— in case of high-temperature equipment when the equipment is proven to be above 750 °C;

— in case of low-temperature equipment where the individual burner automatic shut-off valve is fitted with proof of closure (POC) according to ISO 23551-1:2012, and the protective system closes an upstream automatic shut-off valve (header valve), if one of the individual burner valves is not proven closed by the proof of closure switch.

It shall only be possible to manually reset the lock out of a closed automatic shut-off valve by a protective system according to ISO 13577-4:2022.

For typical examples of piping and components, see Annex G (Figures G.1-G.12).

4.3.7 Valve proving

Automatic shut-off valves controlling capacities higher than 1 200 kW shall be proved closed at each start-up of the TPE. In case where the valve is not proved closed, the current start-up shall be stopped and the system shall go to lock-out.

The valve proving procedure and the action after failure shall be determined by the risk assessment and shall be specified in the instruction handbook (e.g. replacement of valve).

For a TPE equipped with valve proving and intended to be started up more than two times a year, the automatic shut-off valve(s) shall be proved closed by an automatic system.

Automatic valve proving shall fulfil the requirements of a protective system according to ISO 13577-4:2022.

NOTE ISO 23551-4:2018 and regional product standards according to E.1.5 provide information for automatic valve proving.

In multiple burner systems with two automatic shut-off valves for each burner with capacity lower than 1 200 kW, automatic testing does not have to prove each burner valve individually (see Figure G.3). The testing of the individual burner valves shall be specified in the instruction handbook.

4.3.8 Individual manual shut-off valves for burners

For burners which are independently ignited, each individual burner shall be fitted with a manual shut-off valve suitable for the type of gas. They shall be so designed that the "OPEN" and "CLOSED" positions are readily distinguishable (e.g. a 90° turn valve if applicable and available).

Manual shut-off valve(s) shall comply with ISO 23551-5:2014 or with regional product standard(s) according to E.1.6 if applicable.

In case the installation of such a manual shut-off valve affects the mixing characteristics of mixing devices (e.g. venturi mixers) the manual shut-off valve shall be installed upstream of the automatic shut-off valves to minimize its influence on the mixing device.

For multiple burners in which cross-ignition from burner to burner occurs by design, the complete group of burners shall be fitted with at least one manual shut-off valve.

4.3.9 Flame arrestor

Gas pipework in TPE, which may contain a flammable or explosive mixture (e.g. for landfill gas) shall be protected with a flame arrestor according ISO 16852:2016 installed directly upstream the burner. This requirement is not valid for pre-mix burner systems which are covered in 4.7.

NOTE For oxygen or oxygen enriched combustion air, see also 4.13.10.

4.4 Gas pressure boosters

When a gas pressure booster is used to ensure stable operation and control of the heating system, the following shall apply. The selection of seals and devices for the booster system shall consider:

— temperature increase by isochore compression of the gas and

— engine waste heat spreading from the booster into the pipework especially in case the gas flow stops (non-consumption of the TPE).

Gas boosters shall be tight and shall have a construction which does not draw in air from its rotator shaft and which prevents that the discharged gas is contaminated with lubricants, etc.

The system design shall meet the following minimum requirements:

— a device shall be included which automatically prevents transgression of the maximum allowable pressure (e.g. circulation pressure regulator);

— a device shall be included for shutting the system down in case the pressure in the system drops below the minimum pressure stipulated by the gas utility company (e.g. pressure sensing device, see also 4.3.4);

— a device shall be included for shutting the system down in case the gas temperature in the system exceeds the maximum allowable temperature of the components (e.g. temperature sensing device);

— when it is foreseeable (e.g. in case of a booster malfunction) that the pressurized gas can flow back to the upstream of the booster and it can interfere the upstream pressure, measures to prevent the backflow shall be provided;

— the booster shall not generate excess vibration to the pipework.

NOTE High gas pressure protection of downstream equipment is handled in 4.3.5.

Figure G.12 shows an example of a gas pressure booster system.

4.5 Required safety devices for liquid fuels

4.5.1 Manual isolating valve

A manually operated isolation valve shall be fitted upstream of the first control device in the liquid fuel circuit. Manual isolation valves shall be so designed or positioned as to prevent inadvertent operation but shall be easily accessible and capable of rapid operation when required.

They shall be so designed that the "OPEN" and "CLOSED" positions are readily distinguishable (e.g. a 90° turn valve if applicable and available).

4.5.2 Filter/strainer

Special care shall be taken to prevent the ingress of particles, either from the pipework or from the liquid fuel, which would be detrimental to the operation of the equipment by the incorporation of a suitable filter or strainer immediately downstream of the first manual isolating valve of the TPE. Additional filters/strainers shall be required (e.g. immediately upstream of the automatic shut-off valve). The filter and/or the strainer shall be positioned in such a way that periodic servicing can be carried out easily.

In the event of the installation of a bypass to the filter and/or the strainer, an identical filtering device shall be installed on the bypass line.

The intervals for checking the filter and/or the strainer shall be specified in the instruction handbook.

4.5.3 Pressure relief valve

Where required, the fuel circuit shall be fitted with calibrated pressure relief valves.

NOTE When two valves close simultaneously the pressure in between can rise above design pressure.

4.5.4 Liquid fuel pressure regulator

A liquid fuel pressure regulator shall be incorporated where this is necessary for control of the flow rate.

4.5.5 Pressure regulation of auxiliary fluids

For auxiliary fluids (e.g. compressed air, steam) automatically operating pressure regulators shall be installed where this is necessary for control of the burner system.

4.5.6 Liquid fuel and auxiliary fluid pressure protection

High- and low-pressure sensing devices shall be fitted where operation within preset pressure limits is essential in ensuring the correct flow and atomising conditions. Deviation outside of these limits shall prevent start-up or cause safety shutdown.

This function shall meet the requirements of a protective system according to ISO 13577-4:2022.

Pressure sensing devices shall comply with IEC 60730-2-6:2015+A1:2019 or regional product standard(s) according E.2.3.

4.5.7 Liquid fuel temperature protection

High and low fuel temperature sensing devices shall be fitted where operation within pre-set temperature limits is essential in ensuring the correct flow and atomising conditions. Deviation outside of these limits shall prevent start-up or cause safety shutdown.

This function shall meet the requirements of a protective system according to ISO 13577-4:2022.

4.5.8 Automatic shut-off valves

The liquid fuel supply to each burner or group of burners shall be under the control of two automatic shut-off valves. Automatic shut-off valves shall comply with ISO 23553-1:2014 or regional product standard(s) according to E.1.1.

Automatic shut-off valve shall be capable of withstanding all backpressure and differential pressure under all process circumstances.

High cycling applications over 100 000 cycles/year (e.g. pulse firing, regenerative burners) shall use only valves and contactors/relays that are declared capable of the intended use and number of cycles.

NOTE The B_{10D} value according to ISO 13849-1:2015 or IEC 62061:2021 can be used to demonstrate capability for high cycling applications.

The instruction handbook shall give guidance for replacing valves and contactors/relays after defined number of cycles.

The instruction handbook shall specify the need to check automatic shut-off valves for correct operation, the procedure to be adopted and the intervals at which this should be carried out and the requirements for replacement, refer to ISO 13577-4:2022, 4.1. Means to permit the operator to determine when automatic shut-off valves require replacement shall be supplied.

All systems shall have the ability for manual leak testing of the automatic shut-off valve. Test connections shall be available, either at the automatic shut-off valves itself or at the piping upstream and downstream the valves. The instruction handbook for the TPE shall include suitable information for manual leak tightness check of the valves.

The automatic shut-off valves shall not open or shall shut off the fuel to the burner when the limit of any safety condition is reached. In this case, the relevant automatic shut-off valves shall be de-energized by a protective system according to ISO 13577-4:2022.

It shall only be possible to manually reset the lock out of a closed automatic shut-off valve by a protective system according to ISO 13577-4:2022.

Single automatic shut-off valve shall be fitted with a device proving that the valve is in closed position in case of a shutdown and creates an alarm and prevents a restart.

4.5.9 Automatic shut-off valves for multiple burners

Where individual burners are equipped with automatic shut-off valves, such valves shall comply with ISO 23553-1:2014, if technically applicable, and their operation shall not adversely affect the safe operation of the remaining burners.

Where 4.5.8 requires two automatic shut-off valves, it is permissible for an individual burner to be shut down by a single automatic shut-off valve in the event of flame failure or for process reasons (e.g. thermal input) providing it is a high-temperature equipment as defined in ISO 13574:2015, 2.83.

4.5.10 Individual manual shut-off valves for multiple burners

For multiple burners which are independently ignited, each individual burner shall be fitted with a manual shut-off valve.

If fitted, the operation of the manual shut-off valve(s) shall not adversely affect the safety of the system.

4.6 Combustion air and fuel/air ratio

4.6.1 Combustion air system

The pipework design shall take into account the properties of combustion air (e.g. pressure, temperature).

All manual control devices (registers, valves, etc.) for the air shall be set in their pre-determined positions and protected against inadvertent movement.

The location of the combustion air intake shall be such as to prevent entry of impurities (e.g. dust) and flue products, unless provided for by the design (e.g. for reduction of emission of nitrogen oxides NO_x).

The ventilation of TPE shall be such as to allow an adequate supply of process air and combustion air to reach the burner(s) under all conditions.

Attention should be paid to sufficient air supply to the TPE. For many applications with forced air supply, it is recommended to install an air inlet filter with filter monitoring to achieve reliable operation of the installation.

The combustion air system shall be designed in a manner that prevents the back-flow of furnace atmosphere through combustion equipment.

The air circuit shall be designed so as to avoid oscillations that can lead to material defects.

4.6.2 Air flow and pressure sensing devices

TPE shall be fitted with devices for proving adequate air flow during pre-purge, ignition and operation of the burner.

Air flow failure during pre-purge, ignition or operation of the burner shall cause safety shutdown and lock-out. This function shall meet the requirements of a protective system according to ISO 13577-4:2022.

The air-proving device shall be checked in the "no flow" state prior to start-up, e.g. by stopping the combustion air supply or by interrupting the air signal to the device(s) in such a way as to simulate stopping the combustion air supply. Failure to prove the device in the "no flow" condition shall prevent start-up.

Air flow shall be monitored:

— by pressure sensing devices, or

— by flow sensing devices, or

— by air/fuel ratio check, or

— by other adequate means.

This requirement shall not apply to portable gas burners, workstation burners and equipment-integrated burners with open flame, supervised continuously by trained operators, and having a maximum burner input rating below 70 kW.

Air pressure sensing devices shall comply with IEC 60730-2-6:2015+A1:2019 or regional product standard(s) according to E.2.3. They shall be suitable for the number of operations foreseeable for the application.

4.6.3 Air/fuel ratio

The air mass flow shall always be in a ratio with the fuel mass flow in order to ensure safe ignition and that throughout the operating range, a stable and safe combustion is maintained at each individual burner. The ratio does not need to be the same value at all operational conditions.

If the variation of pressure and/or temperature of air and fuel affect the safety and combustion stability, then correction for pressure and/or temperature is required.

The design of the air/fuel ratio control has to consider process conditions as well as fuel and combustion air properties. Defect or malfunction should affect that the system will tend towards higher excess air or proceed to lock-out if the air/fuel ratio results in an unsafe condition.

Pneumatic fuel/air ratio controls for gaseous fuel shall comply with ISO 23551-2:2018 or regional product standard(s) according to E.1.4.

Electronic fuel/air ratio controls shall comply with ISO 23552-1:2007+A1:2010 or regional product standard(s) according to E.2.2.

To ensure their reliability, air/fuel ratio controllers according to product standards shall be used in conditions (temperature, pressure, flow rate) for which they have been designed. These conditions and instructions for maintenance shall be specified in the instruction handbook.

In case other methods/technologies are used for the ratio control and depending on the combustion air and fuel properties, additional protective measures shall be applied according to the results of the risk assessment (e.g. air/fuel ratio monitoring by protective system according to ISO 13577-4:2022). The method/technology and the procedure for the functional test shall be described in the instruction handbook.

4.7 Supply of pre-mixed fuel gas/air

4.7.1 Mixture pipework

The mixture pipework volume shall be minimized to reduce risk in the event of flashback, but shall not compromise pressure and flow distribution needed for stable burner operation. The system shall be designed so as to provide a sufficiently high mixture flow velocity such that flame propagation upstream cannot occur, or shall be fitted with flame trap(s)/arrestor(s), pressure relief devices or blowout devices to prevent damage in the mixture pipework and mixing equipment.

If used flame trap(s)/arrestor(s) shall be located as close to the burner(s) as practicable.

Alternatively, the system shall be fitted with a sensing device which causes lock-out in the event of the flow velocity falling below a pre-determined limit or a temperature sensing device which causes lock-out in the event of flashback. This function shall meet the requirements of a protective system according to ISO 13577-4:2022. These devices are not required for burners where it can be demonstrated that flashback cannot occur in any circumstances (e.g. pilot burners with their own mixing devices).

4.7.2 Air and gas supply to the mixture circuit

The presence of fuel gas/air mixture in the pipework supplying either fuel gas or air to the mixing device (e.g. due to reverse flow of the mixture) shall be prevented.

If a non-return valve is used for this purpose and if it is not resistant to flashback, then an additional high gas pressure switch located downstream of this non-return valve shall be incorporated to shut off the flow of fuel gas to the equipment by means of the relevant automatic shut-off valves specified in 4.3.6 in the event of a flame flashback.

A flashback shall trigger an alarm, or alternatively switch to a mechanical lock-out. The required measures after a flashback shall be described in the instruction handbook.

When a mixing blower is used for the mixing device, gas supply shall be shut off when the blower stops.

4.8 Liquid fuel atomisation

Burners for liquid fuels shall be equipped where applicable with fuel atomizing systems to permit their correct combustion.

Measures shall be taken to prevent the liquid fuel from entering the atomizing fluid pipe and vice versa. If the atomizing fluid is a combustible gas, then the requirements of the relevant subclauses of 4.2 shall apply.

4.9 Burners

4.9.1 Main burners

All burners shall be suitable for the operating conditions and shall provide safety for:

— the fuels used (type, pressure, etc.);

— the operating conditions (pressure, temperature, atmosphere, etc.);

— the nominal input rate and range of regulation (maximum and minimum capacity);

— ease of visual monitoring (sight glasses, sight holes, etc.).

4.9.2 Radiant tube burner systems

Radiant tube burner systems shall be suitable and allow safe operation. They shall:

— be constructed of suitable materials for the thermal input rate, temperature and TPE atmosphere;

— minimize the probability of combustion products having contact with the TPE atmosphere.

4.9.3 Ignition device/pilot burner

The ignition device shall be reliable and of sufficient capacity, so that immediate and smooth ignition is obtained. Detail verification procedure for use in commissioning, operation and maintenance shall be included in the instruction handbook.

Any direct ignition device or combination of the ignition device and the pilot burner in automatic installations shall form an integral part of the main burner system.

The construction and location of a pilot burner shall be such that, under all operating conditions, the pilot flame remains stable and of such a shape that the main flame is ignited.

For safety requirements, pilot burner(s) shall be treated as main burners and safety devices according to 4.3 or 4.5 shall apply, as applicable.

Where burners are supplied with gas or combustible vapours with uncertain combustion characteristics, e.g. significantly varying calorific value effecting burner performance/safety, permanent pilots shall be independently supplied with a clean fuel gas of constant quality (e.g. natural gas, liquefied petroleum gas) and be fitted with automatic burner control systems according to 4.10.

Where use is made of a portable pilot burner or ignition device:

— the pilot burner or ignition device shall be capable of being fitted in one way only and in such a way that it occupies a fixed position with respect to the burner to be ignited — if necessary the correct position shall be monitored;

— the connections for fuel, air and ignition energy shall be so designed that a reliable link-up is obtained, and errors of fitting of connections are avoided.

4.9.4 Permanent pilots

Where used, a permanent pilot(s) shall be supplied with a clean fuel (e.g. natural gas, LPG, diesel) of constant quality and be fitted with automatic burner control systems.

In the case of permanent pilot, it is recommended that shutdown of the main burner precedes shutdown of the pilot burner.

4.9.5 Burner capacity control

In any combustion system, the turndown ratio shall be such that the burner(s) is/are fully stable at all firing conditions. Means shall be provided to allow the determination of the burner capacity.

4.9.6 Flue gas venting

Flue gases shall be vented in a safe way.

TPE with a closed combustion chamber or combustion chamber with at least three surrounding walls shall be equipped with a flue system. The cross-sectional area of the flue system shall be calculated according to volume, pressure and temperature of the flue gases (products of combustion, excess air and process emissions).

For TPE equipped with natural draught burners the flue system should be fitted with an appropriate draught break above the height of the operator, or control damper (for typical example of a draft break see Figure G.11) to exclude excessive air flow.

If the flue gases are extracted by a fan or the draught is controlled by a damper and the risk is not adequately reduced by the inherently safe design or mechanical design, the system shall be fitted with a safety device to cause a safety shutdown of the burner(s) or a switching over to a backup duct system in the event of a failure in the flue venting. This function shall meet the requirements of a protective system according to ISO 13577-4:2022.

For all TPE burners supplied without a flue system, the combustion products shall be directed away from the workplace. The instruction handbook shall refer to the need for sufficient venting to ensure the correct air quality for the operator.

NOTE National laws for safety of workers give information on maintaining the air quality in workshops.

4.9.7 Purge of residual fuel

For burners requiring a purge after shutdown, any residual fuel purged into the unit shall be safely ignited. The risk assessment shall determine the need and procedure for purge including relevant safety functions.

NOTE In case of gaseous fuels with a volume fraction of more than 80 % hydrogen (H_2) or acetylene (C_2H_2) there can be a risk of flashback in case residual fuel remains in the pipeline.

4.10 Automatic burner control systems

4.10.1 General

The main flame and the pilot burner flame shall be supervised by means of an automatic burner control system complying with IEC 60730-2-5:2013+A1:2017 or regional product standards according to E.2.1. Exceptions are only permitted as specified in 4.10.3 or 4.10.4. Flame supervision and burner control function shall meet the requirements of a protective system according to ISO 13577-4:2022.

For systems where the pilot burner remains in use during main burner operation, a separate flame detector device to supervise the pilot and main flames shall be fitted. The main flame detector device shall be so positioned that it cannot in any circumstances detect the pilot flame.

Where the pilot burner and the main burner are each provided with their own flame detector device, the pilot flame shall not influence the response of the main flame detector device.

A single flame detector device shall be sufficient:

— for systems where the pilot flame is extinguished during main burner operation;

— for any metallic fuel fired radiant tubes, explosion resistant and equipped with a burner fitted with permanent pilot burner.

Where fitted, flame detector devices shall be unresponsive to unintended radiation. The detection of a flame when there should not be a flame (dark check) or a defect of the flame detector of the automatic burner control system or the protective system shall result into lock-out.

Where a burner is required to fire continuously for periods in excess of 24 h, the automatic burner control system shall be designed for permanent operation as specified in IEC 60730-2-5:2013+A1:2017 or regional product standards according E.2.1.

4.10.2 Low-temperature equipment

Low-temperature equipment fitted with a single burner shall be equipped with an automatic burner control system in accordance with 4.10.1.

For low-temperature multiple burner equipment, each burner shall be equipped with an automatic burner control system in accordance with 4.10.1.

4.10.3 High-temperature equipment

During high-temperature operation, the temperature shall be monitored. In the event the temperature falls below the limit, the protective system shall automatically shut off the fuel supply or shall switch over to flame supervision by means of an automatic burner control system according to 4.10.1. This function shall meet the requirements of a protective system according to ISO 13577-4:2022.

The temperature limit for high-temperature operation shall not be less than 750 °C and the temperature shall be detected at a location to ensure safe combustion of the fuel at any time during high-temperature mode.

NOTE 1 At radiant tube burner systems the ignition point is inside the radiant tube. The temperature inside the tube and prior to ignition can well be much lower than in the chamber in which the radiant tube is placed. It is important that this temperature difference is taken into consideration when designing.

During start-up period, flame supervision by means of an automatic burner control system shall be provided when the temperature is below the temperature limit for high-temperature operation.

Flame supervision by an operator during start-up is allowed for processes where an automatic burner control system is not possible for technical reason. Suitable protective measures shall be determined in a risk assessment, e.g. a SIL/PL capable shutdown timer. Details shall be described in the instruction handbook.

NOTE 2 Shutdown timer is a device or software function counting down time and causing action in case it is not restarted in time.

For TPE intended to be started more than 4 times a year, flame supervision below 750 °C shall only be conducted by an automatic burner control system.

Additional burners that operate during a high-temperature operation without flame supervision shall be isolated from the fuel gas supply by two automatic shut-off valves until the temperature is above the limit for high-temperature operation. This function shall meet the requirements of a protective system according to ISO 13577-4:2022.

The high-temperature operation, the method/procedure for flame supervision during start-up period and the switch over to high-temperature shall be described in the instruction handbook.

4.10.4 Automatic burner control systems for burners operating in the open air

Each burner firing in the open air (i.e. no combustion chamber) with a rated heat input greater than 70 kW shall be fitted with an automatic burner control system according to 4.10.1.

Where the burner heat input rating is 70 kW or less, the flame may be supervised by the operator, provided that the flame is always visible to the operator at his/her workstation.

Where an installation is equipped with several burners other than ON/OFF burners, no automatic burner control system is required if the burners are arranged in a configuration in which the flame of an operating burner will reliably crosslight another burner in the event of flame extinction. However, in this case at least one burner shall be equipped with spark restoration or a supervised permanent pilot designed so that a failure of the permanent pilot or the spark restoration system leads to safety shutdown of all the burners.

If required for, and allowed by production operations, the flame supervision function may be integrated into a control other than a standard automatic burner control system, if such a control is capable of triggering an automatic shutdown. Any such device shall be designed to generate an alarm in the event of a safety shutdown. This function shall meet the requirements of a protective system according to ISO 13577-4:2022.

The required measures after a flash-back shall be described in the instruction handbook.

If necessary for process reasons (e.g. load damaged due to lock-out), and where the single burner capacity is below 100 kW, the lock-out function integrated into a multiple burner installation may be replaced by an acoustic and a visual alarm providing the operator can react in a time to be specified in the instruction handbook.

4.10.5 Flame supervision for line-burners

For line-burners, the position of the flame sensor shall be such that complete flame propagation is proven. Positioning of the flame sensor shall be according to the results of the risk assessment, e.g. one flame sensor opposite to the ignition source or multiple flame sensors at various positions of the line-burner. The method/technology and the procedure for functional test shall be described in the instruction handbook.

4.11 Start-up of the heating system and burner ignition

4.11.1 Pre-purging of the combustion chamber

Start-up of the TPE after down time or restart of the TPE after a lock-out, for example, caused by a general safety limit, or restart of a burner after lock-out, for example, after flame failure, shall not be initiated until adequate steps have been taken to ensure that no combustible mixture is present in the combustion/processing chamber, connected spaces and flue system (heat exchangers, dust extractors). This condition shall be achieved by means of a period of pre-purging immediately prior to ignition or within a time to be specified in the instruction handbook.

The pre-purge time and pre-purge air flow rate shall be such as to ensure that the concentration of any combustible products in any part of the combustion chamber/connected spaces and flue system is below 25 % of the lower flammability limit (LFL) of the fuel gas or the liquid fuel, as applicable, this being calculated with the combustion chamber/connected spaces and the flue duct assumed as being initially filled up with flammable gases.

NOTE 1 In general, five complete air changes of the combustion chamber/connected spaces and flue system will suffice. Purge air flow rate of 50 % and higher will create turbulence to avoid unpurged areas in typical installations.

NOTE 2 Fuel oil can collect and remain in liquid state until vaporized thereby extending the time required for pre-purge.

In the case of natural/induced draught, the condition to achieve the above requirements shall be defined in the instruction handbook.

The pre-purge time and purge procedure and/or methodology shall be specified in the instruction handbook.

The system for ensuring correct pre-purge time and the airflow shall meet the requirements of a protective system according to ISO 13577-4:2022.

When the combustion chamber is proved to be at a temperature above 750 °C (as defined for high-temperature equipment) pre-purge may be omitted.

Inert or non-flammable gases shall be used instead of air if required by the equipment or process. Other methods of ensuring that the combustion chamber and connected spaces do not contain flammable gases may be utilized providing that the equivalent level of safety is achieved.

In multiple burner TPE an individual burner may be restarted without pre-purge in the following cases:

— when restarting a burner after shutdown for control purpose where the burner is fitted with an independently supervised permanent or alternating pilot; or

— when one or more burners remain alight in the same combustion chamber of the burner to be re-ignited and the burner(s) remaining in operation shall provide ignition of any unintended release of fuel through other burners that are not in operation without causing a hazard; or

— where the burner is fitted with two automatic shut-off valves that close simultaneously and a valve proving according to 4.3.7 is conducted before each burner start; or

— with pulse fired burners equipped with two automatic shut-off valves that close simultaneously and provided the automatic shut-off valves are declared to be capable for the intended number of cycles and on/off cycling rate — it shall be ensured, that at least once per hour at least one burner per zone is burning for at least 10 s to provide ignition of any unintended release of fuel without causing a hazard (e.g. deflagration); or

— with regenerative burners equipped with two automatic shut-off valves that close simultaneously and provided the automatic shut-off valves are declared to be capable for the intended number of cycles and on/off cycling rate; or

NOTE 3 4.3.6 and 4.5.8 provide guidance on valves for high cycling applications pulse firing and regenerative burners.

— when restarting a radiant tube burner after shutdown for control purpose provided the radiant tube is resistant to explosion and the burner is equipped with two automatic shut-off valves that close simultaneously and the radiant tube burner is equipped with an ignition device according to 4.9.3.

— In all other cases, a burner may be restarted without pre-purge provided all of the following requirements are satisfied:

  — the burner is fitted with two automatic shut-off valves that close simultaneously and the valves are declared to be capable for the intended number of cycles and on/off cycling rate; and

  — the burner has an automatic burner control system according to 4.10 and an ignition device according 4.9.3; and

  — the risk assessment proves no hazard resulting from unintended release of fuel (e.g. resulting from dilution or due to short burner off-time) or it can be demonstrated (based on acceptable leakage rate) that the combustible mixture present in the combustion chamber cannot exceed 25 % of the LFL.

In the case of a flame failure of one burner out of a group of radiant tube burners, a maximum of one restart without pre-purge is permitted before lock-out after a flame failure, if:

— each burner has an automatic burner control system according to 4.10; and

— the fuel supply to each radiant tube burner is equipped with two automatic shut-off valves according to 4.3.6 or 4.5.8; and

— the exhaust system dilutes the ignitable fuel-air-mixture inside the exhaust system below 25 % of the LFL, or the radiant tube, the burner and the connection to the exhaust are designed for the maximum pressure increase that is possible during ignition.

4.11.2 Start-up of the fuel supply

Start-up of the fuel supply shall be possible only when:

— the installed fuel proving devices (e.g. fuel pressure, atomizing fluid pressure when required) have been checked to ensure that they are in the safe condition for start-up; and

— combustion air flow has been proven (see 4.6.2); and

— all relevant interlocks [e.g. burner(s) position, valve(s) position, flue damper(s)] were proven to be in the correct position.

4.11.3 Start fuel flow rate

The energy released during the start-up of the burner(s) shall be limited so that the maximum pressure rise from ignition shall not cause any damage to the TPE (see Table 1, Table 2 and Table 3).

The start fuel flow rate shall be managed by a control and/or a protective system according to ISO 13577-4:2022 based on the outcome of the risk assessment.

Where the burner is ignited manually (e.g. by means of a lighting torch) and has a burner input rate in excess of 70 kW, it shall be equipped with a means of limiting the start-up gas flow.

4.11.4 Ignition

The ignition process shall be initiated immediately after the conclusion of the pre-purging stage or within a limited time to be specified in the instruction handbook.

NOTE 1 At the time of ignition, it is important the air/fuel ratio ensures ignition of the fuel (see 4.6.3).

Where the main burner is ignited by means of a pilot burner, the fuel supply to the main burner shall be shut-off during the pre-purge and ignition of the pilot burner. The automatic shut-off valve(s) of the main burner shall open only when the pilot burner flame was proven.

NOTE 2 Where air enriched with oxygen or oxygen alone is the oxidising agent for the combustion of a gas, (commonly called oxy/fuel firing), the ignition procedures and times for such systems can require specific additional design attention to ensure the equivalent levels of safety.

4.11.5 Maximum safety times for gas-fired natural draught burners

The safety time and total closing time for natural draught burners shall not exceed the values given in Table 1 and Table 2.

Table 1 — Maximum safety times for natural draught burners operating in open air

Burner input rate kW	**Safety time** s	**Total closing time** s
1) Thermoelectric flame supervision device		
up to and including 70	60	45
2) Flame supervision device other than thermoelectric		
up to and including 70	10	10
above 70 up to and including 360	10	3
above 360 [a]	5	3

[a] Ignition at a rate of 33 % of the burner input rating with a maximum of 360 kW.

Table 2 — Maximum safety times for natural draught burners operating in combustion chamber

Burner input rate kW	**Safety time** s	**Total closing time** s
1) Thermoelectric flame supervision device		
up to and including 2,5	60	45
2) Flame supervision device other than thermoelectric		
up to and including 70	10	10
above 70 up to and including 360	10	3
above 360 [a]	5	3

[a] Ignition at a rate of 33 % of the burner input rating with a maximum of 360 kW.

4.11.6 Maximum safety times for forced and induced draught gas-fired burners

The maximum start gas rate and the corresponding safety time for forced and induced draught burners shall not exceed the values given in Table 3.

Burner start-up shall be achieved in accordance with one of the following methods:

— direct ignition of the main burner at full rate (see Table 3, column 2), or

— direct ignition of the main burner at reduced rate, e.g. by using a slow opening valve (see Table 3, column 3) (in this case the combustion chamber shall maintain the maximum pressure rise in case the slow opening function is lost), or

— direct ignition of the main burner at reduced rate with bypass start gas supply to the burner or two step automatic shut-off valve (see Table 3, column 4), or

— ignition of the main burner by means of an independent pilot burner (see Table 3, column 5).

For methods of burner start-up, see Annex H (Figures H.1-H.15).

Table 3 — Maximum safety times for forced and induced draught burners

1	2	3	4		5	
	Direct main burner ignition at full rate	**Direct main burner ignition at reduced rate with slow opening valves**	**Direct main burner ignition at reduced rate with bypass start gas supply**		**Main burner ignition with independent pilot burner**	
					Pilot burner ignition ($Q_{ST} \leq 0{,}1 \times Q_{F\,max}$)	**Main burner ignition**
Rate $Q_{F\,max}$	**Safety time t_s**	**Safety time t_s**	**Rate Q_{ST}**	**Safety time t_s**	**First safety time t_{s1}**	**Second safety time t_{s2}**
kW	s	s	kW	s	s	s
≤ 70	5	5	≤ 70	5	5	5
> 70 ≤ 120	3	3	≤ 70	5	5	3
			> 70 ≤ 120	3		
> 120 ≤ 360	not allowed except as described below	3	≤ 70	5	5	3 with slow opening valves or $t_s \times Q_s < 150$ (maximum t_s = 3 s)
			> 70 ≤ 360	$t_s \times Q_s < 100$ (maximum t_s = 3 s)		
> 360	not allowed except as described below	not allowed except as described below	≤ 70	5	5 ($Q_{ST} \leq 70$ KW)	$t_s \times Q_s < 150$ (maximum t_s = 3 s)
			> 70	$t_s \times Q_s < 100$ (maximum t_s = 3 s)	3 ($Q_{ST} > 70$ KW)	

Key

$Q_{F\,max}$ maximum main burner input rate in kilowatts

Q_{ST} start input rate in kilowatts

Q_s maximum start input rate expressed as a percentage of $Q_{F\,max}$ ($Q_s = 100 \times Q_{ST}/Q_{F\,max}$)

t_s safety time in seconds

Higher start gas rates than those specified in Table 3 may be achieved at the end of the safety time provided that it is proved that the total amount of energy released in the combustion chamber during the safety time is not greater than the energy release calculated by multiplying the values of maximum start gas heat input and safety time given by Table 3.

Only if required for process reasons or special cases of equipment construction (e.g. long fuel gas pipes requiring more filling time) and if the safety times given in Table 3 cannot be used, the values of the safety time may differ from those given in Table 3 provided the safety of the TPE is not endangered. In any case the safety time shall not exceed 10 s.

NOTE Australian standard AS 1375 Industrial fuel-fired appliances gives guidance for calculation of longer safety times.

Where for process reasons, burners with a nominal input exceeding 360 kW are ignited directly at full rate, the combustion chamber/process chamber, flue ways and pipework shall be designed to take account of the maximum pressure rise.

For line-burners, an extension of the safety time by 1,5 s/metre of burner length, with a maximum of 10 s, is acceptable providing the flame is monitored at the end of the burner remote from the source of ignition, and safe ignition always takes place.

4.11.7 Maximum safety times for liquid fuel fired burners

The safety time shall not exceed the values given in Table 4.

Table 4 — Maximum safety times

1	2	3	4
Heat input $Q_{F\ max}$ **in kW**	**Direct main burner ignition at full rate** t_{smax} **in s**	**Direct main burner ignition at reduced rate QST** t_{smax} **in s** Q_{smax} **in %**	**Reduced rate** Q_s **by pilot burner** t_{smax} **in s** Q_{smax} **in %**
< 300	$t_{smax} = 10$	$t_{smax} = 10$	$t_{smax} = 10$
> 300 < 1 000	$t_{smax} = 5$	$t_{smax} = 5$	$t_{smax} = 5$
> 1 000 < 5 000	not allowed	$Q_{ST} \leq 1\,000$ kW $Q_{smax} \leq 70$ % $t_{smax} = 5$	$Q_s \leq 1\,000$ kW $t_{smax} = 5$
> 5 000	not allowed	$Q_{smax} \leq 35$ % $t_{smax} = 5$	$Q_{smax} \leq 50$ % $t_{smax} = 5$

Key

Q_{ST} start input rate in kilowatts

Q_{smax} maximum start heat input expressed as a percentage of $Q_{F\ max}$

$Q_{F\ max}$ maximum heat input in kilowatts

t_{smax} maximum safety time in seconds

Only if required for process reasons or special cases of equipment construction (e.g. long fuel pipes requiring more filling time) and if the safety times given in Table 4 cannot be used, the values of the safety time may differ from those given in Table 4 provided the safety of the TPE is not endangered. In any case the safety time shall not exceed 10 s unless additional risk assessment proves safety of the TPE with prolonged safety time (e.g. potential release of additional unburnt fuel etc.) and meets the requirements of ISO 13577-4:2022, 4.2.4 (Method D).

NOTE In case of long fuel pipe between the last valve and the burner, the time required for filling the fuel pipe can be calculated.

4.11.8 Flame failure on start-up

In the event that flame failure occurs during the safety time, the burner shall go to lock-out. However, recycling is acceptable provided the risk analysis has identified no hazard. The number of recycles shall not exceed two. The recycle(s) function shall meet the requirements of a protective system according to ISO 13577-4:2022. If there is no flame signal at the end of these recycles, the failing burner shall go to lock-out.

The conditions and the time period between recycle and the number of recycles shall be specified in the instruction handbook.

4.11.9 Flame failure during operation

In the event of flame failure during operation the burner shall go to lock-out and two automatic shut-off valves shall be closed. However, safety shutdown and recycling are acceptable provided the risk analysis has identified no hazard. The recycle function shall meet the requirements of a protective system according to ISO 13577-4:2022. If there is no a flame signal at the end of this recycle, the failing burner shall go to lock-out.

Not more than one recycle shall be permitted and the conditions shall be specified in the instruction handbook.

The total closing time shall not exceed 3 s. However, in cases where there is no recycle without purge and if the atmosphere in the combustion chamber does not exceed 25 % of LFL, the total closing time shall not exceed 5 s.

The TPE shall be designed such that a recycle of an individual burner system requires a complete recycle including pre-purge.

4.12 Multiple fuels

4.12.1 General

Equipment heated with multiple fuels may be fitted with burners supplied with two or more types of fuel, i.e. gaseous / vapour, liquid, operating either simultaneously or separately.

4.12.2 Fuel circuit

Each type of fuel shall be distributed to the burner(s) by means of an independent system constructed in accordance with the requirements of 4.2, 4.3, 4.4 and 4.5, as appropriate.

In particular, each burner shall be fitted with automatic shut-off valves for each type of fuel. In addition, the flame supervision system shall be chosen such that it complies with the specifications appropriate to the types of fuel used.

Means shall be provided to ensure that the supply pipework of each individual fuel can be positively isolated from the other fuels whether or not non-return valves are fitted.

4.12.3 Combustion air supplies

It is acceptable to use a common combustion air system for all fuels.

4.12.4 Operation of the safety devices

Where malfunctions that affect only one type of fuel occur, the individual safety shut-off device relating to that fuel shall close.

Where a fuel supports the combustion of other fuels, the safety device of the assisted fuel shall also operate as intended.

Simultaneous closure of the safety shut-off devices installed for each type of fuel shall be ensured under all other circumstances given in 4.3.6 or 4.5.8.

4.12.5 Air/fuel ratio

For each individual fuel or combination of fuels the requirements specified in 4.6.3 shall apply.

The air/fuel ratio control function shall meet the requirements of a protective system according to ISO 13577-4:2022, if applicable.

4.13 Oxygen or oxygen-enriched combustion air (OOECA)

4.13.1 General

For the purpose of 4.13, oxygen or oxygen-enriched combustion air containing more than 25 % oxygen is named as oxygen. The application of oxygen or oxygen-enriched combustion air needs particular consideration. Oxygen or oxygen-enriched air shall be released only when essential and in a safe discharge area. The hazards related to the use and handling of oxygen shall be specified in the instruction handbook.

4.13.2 Suitability for oxygen service

Due to the high ignition hazard of flammable material in contact with oxygen, all components coming into contact with oxygen shall be prepared, cleaned and sufficiently free of flammable substances (e.g. dust, grease, particulates) prior to start-up. They shall be suitable for oxygen service.

NOTE Reference [23] provides guidance on suitability assessments.

4.13.3 Pipework

The design and material of pipework and their equipment and connections shall be suitable for oxygen and the intended pressures, velocities and temperatures.

Suitable materials for pipework are those indicated in Table 6.

In case carbon steel or low-alloyed steel is used, right angle impingement of gaseous oxygen onto the pipe walls shall be avoided and the minimum bending radius shall be at least 5 times its piping diameters.

Depending on the operating pressure, the flow velocity shall be limited due to possible presence of particulates. See 4.13.4.

NOTE Reference [23] provides guidance on suitability assessments.

A manually operated isolation valve shall be fitted at the inlet of the TPE's oxygen pipe system.

Filter(s) shall be fitted at the inlet of the oxygen pipe systems to prevent ingress of particulates (e.g. rust).

4.13.4 Flow velocities

Flow velocities of oxygen inside piping and devices for temperatures between −10 °C and +200 °C shall not exceed the values specified in Table 5.

NOTE Flow velocity inside devices, for example, filters, can be considerably higher than in pipes.

Table 5 — Pipe velocities for oxygen

Pressure	Velocity
A) for carbon and stainless steels piping and impinging flow	
0,3 MPa (abs) < P ≤ 1,5 MPa (abs) 1,5 MPa (abs) < P ≤ 10 MPa (abs) 10 MPa (abs) < P ≤ 20 MPa (abs)	30 m/s $P \times v$ = 45 MPa × m/s 4,5 m/s
B) for carbon and stainless steels piping and non-impinging flow	
0,3 MPa (abs) < P ≤ 1,5 MPa (abs) 1,5 MPa (abs) < P ≤ 10 MPa (abs) 10 MPa (abs) < P ≤ 20 MPa (abs)	60 m/s $P \times v$ = 80 MPa × m/s 8 m/s
C) for copper, nickel, and copper/nickel alloys piping	
up to 6,5 MPa	no velocity limit

For piping after pressure reducing or control valves, the velocity for impinging flow shall be applied. If the velocity for impinging flow is exceeded, the pipe shall be straight for a minimum length of 8 pipe diameters and fabricated from stainless steel [wall thickness shall be ≥ 3,18 mm (≥1/8 inch)], copper, nickel or Cu/Ni alloys.

For operating temperatures exceeding 200 °C or below −10 °C, these materials and conditions shall not apply. In this case, the limits of use are to be specified in the instruction handbook.

4.13.5 Connection for oxygen pipework

Connection shall be of threaded, flanged or welded. Threaded connection shall comply with ISO 7-1:1994.

4.13.6 Sealing materials for oxygen pipework

Sealing materials shall be suitable for application at the particular pressure levels, installation methods and operating temperatures and shall meet the safety requirements.

Suitable metallic sealing materials for oxygen pipework are those indicated in Table 6, column 2.

4.13.7 Fittings

The design and material of fittings for gaseous oxygen such as automatic shut-off valves, control devices and non-return valves shall be suitable for oxygen at the intended pressures and temperatures.

Suitable materials for housings and built-in parts of fittings and their sealing materials are those indicated in Table 6.

Fittings for gaseous oxygen at an operating temperature exceeding 200 °C or below −10 °C shall be made of materials which are suitable for these conditions.

4.13.8 Blow off and venting lines

Oxygen line shall be vented to an area where the release of oxygen will not create a hazard.

4.13.9 Flexible tubing and couplings

Hoses, flexible pipes and connections shall be gas-tight.

Hoses and flexible pipes associated with manually operated torches shall be lockable in position by means of fittings within the solidly laid piping. They shall be easily accessible.

Manual torches shall be equipped with a flash back arrestor and a lockable manual shut-off valve upstream of the hose.

4.13.10 Safety devices against backflow

For oxygen pipework connected to other fluids, it shall be ensured that back-flow cannot occur.

Oxygen pipework shall be equipped with a non-return valve suitable for the maximum allowable pressure.

Fuel gas pipework shall have non-return valve (check valve) close to the burners. A risk assessment shall be done to determine whether flame arrestor is required in addition.

NOTE Guidance on how flashback risk can be covered is given in 4.7.

If oxygen is mixed with other substances (e.g. fuel gas, air) it shall be ensured that back-flow cannot occur.

4.13.11 Material requirements

Materials in contact with oxygen shall be suitable for the intended operating pressures and temperatures. The installation method shall be selected to ensure that it will be safe in oxygen service.

The materials indicated in Table 6 (depending on the mounting location and the pressure) are suitable for use with oxygen or oxygen enriched combustion air.

Table 6 — Materials requirements

Pressure range [MPa]	Materials for housings, built-in components and seals
exceeding 4	copper, copper alloys with a mass proportion of at least 55 %, nickel, nickel-wrought alloys with copper high-alloy Cr-Ni-steels with a mass proportion of Cr and Ni of a total of at least 22 % high-alloy Cr-Si-steels with a mass proportion of Cr of at least 22 %
0 up to 4	copper, copper alloys with a mass proportion of copper of at least 55 % high-alloy Cr-Ni-steels with a mass proportion of Cr and Ni of a total of at least 22 % high-alloy Cr-Si-steels with a mass proportion of Cr of at least 22 %
0 up to 1,6	grey cast iron, at least quality class GG 25, cast iron with nodular graphite, at least quality class GGG 40
0 up to 1	metallic materials (except titanium, zirconium and their alloys)

Besides the metals indicated in Table 6, lead and tin may be used as metallic sealing materials for all pressure ranges.

For gaseous oxygen at an operating temperature exceeding 200 °C or below −10 °C materials which are suitable for these conditions shall be used.

5 Verification of the safety requirements and/or measures

Table 7 shall be used as a check list for manufacturers to prepare their own specific table of methods used to verify that the safety requirements and measures described in Clause 4 are complied with and contains references to the respective clauses of this document.

Table 7 — Verification of the safety requirements and/or measures

Clause	Safety requirements and/or measures	Visual inspection[a]	Functional test[b]	Measuring[c]	Examination of drawings/ calculations[d]
4.1	General				
4.1	Electrical equipment	X3	X3	X3	X3
4.1	Over-temperature protection	X	X2		X
4.1	Gas detectors	X	X2		X
4.1	Seismic protection	X			X
4.2	Fuel pipework				
4.2.1.	General	X			X
4.2.2	Connections	X			X
4.2.3	Unconnected pipework	X			X

Key

X test as described in this document

X1 functional test according to device manufacturer's specification

X2 functional test as described in the instruction handbook, see 6.3.3

X3 test as specified in IEC 60204-1:2016, Clause 18

[a] Visual inspection is carried out for testing the required characteristics and properties by visual study of the delivered equipment and components.

[b] The functional test will show whether the parts in question function in such a way as to satisfy the requirements.

[c] Verification by means of measuring instruments is used to check whether the requirements are fulfilled within the specific limits.

[d] Drawings and calculations are used to check whether the design characteristics of the components used the specific requirements.

Table 7 *(continued)*

Clause	Safety requirements and/or measures	Visual inspection[a]	Functional test[b]	Measuring[c]	Examination of drawings/calculations[d]
4.2.4	Galvanic cells	X			X
4.2.5	Flexible tubing and couplings	X			X
4.2.6	Marking	X			
4.2.7	Soundness/tightness		X2		X
4.2.8	Condensate drains on gas pipework	X			X
4.2.9	Fuel pipe heating	X			X
4.2.10	Purge points	X			
4.2.11	Pressure relief devices	X	X1		X
4.2.12	Blow-off and breather pipes or conduits	X			X
4.2.13	Equipment supplied with different fuels	X			X
4.2.14	Bypass	X			X
4.2.15	Isolation of required safety devices	X			X
4.3	Required safety devices for gaseous fuels				
4.3.1	Manual isolating valve	X	X1		X
4.3.2	Filter/strainer	X	X1		X
4.3.3	Gas pressure regulator	X	X1		X
4.3.4	Low gas pressure protection	X	X1		X
4.3.5	High gas pressure protection	X	X1		X
4.3.6	Automatic shut-off valves	X	X1		X
4.3.7	Valve proving	X	X1		X
4.3.8	Individual manual shut-off valves for burners	X	X1		X
4.3.9	Flame arrestor	X			X
4.4	Gas pressure boosters	X		X	X
4.5	Required safety devices for liquid fuels				
4.5.1	Manual isolating valve	X			X
4.5.2	Filter/strainer	X			X
4.5.3	Pressure relief valve	X	X2	X	X
4.5.4	Liquid fuel pressure regulator	X	X1/X2		X
4.5.5	Pressure regulation of auxiliary fluids	X	X2		X
4.5.6	Liquid fuel pressure protection		X1		X

Key

X test as described in this document

X1 functional test according to device manufacturer's specification

X2 functional test as described in the instruction handbook, see 6.3.3

X3 test as specified in IEC 60204-1:2016, Clause 18

[a] Visual inspection is carried out for testing the required characteristics and properties by visual study of the delivered equipment and components.

[b] The functional test will show whether the parts in question function in such a way as to satisfy the requirements.

[c] Verification by means of measuring instruments is used to check whether the requirements are fulfilled within the specific limits.

[d] Drawings and calculations are used to check whether the design characteristics of the components used the specific requirements.

Table 7 *(continued)*

Clause	Safety requirements and/or measures	Visual inspection[a]	Functional test[b]	Measuring[c]	Examination of drawings/calculations[d]
4.5.7	Liquid fuel temperature protection		X2		X
4.5.8	Automatic shut-off valves	X	X1		X
4.5.9	Automatic shut-off valves for multiple burners	X	X1		X
4.5.10	Individual manual shut-off valves for multiple burners	X			X
4.6	Combustion air and air / fuel ratio				
4.6.1	Combustion air system	X			X
4.6.2	Air flow and pressure sensing devices	X	X1		X
4.6.3	Air / fuel ratio	X	X1/X2		X
4.7	Supply of pre-mixed fuel gas/air				
4.7.1	Mixture pipework	X			X
4.7.2	Air and gas supply to the mixture circuit	X	X1/X2		X
4.8	Liquid fuel atomisation	X			X
4.9	Burners				
4.9.1	Main burners	X			X
4.9.2	Radiant tube burner systems	X			X
4.9.3	Ignition device/pilot burner	X	X2		X
4.9.4	Permanent pilots	X	X2		X
4.9.5	Burner capacity control	X	X2		X
4.9.6	Flue gas venting	X			X
4.9.7	Removal of residual fuel	X	X		X
4.10	Automatic burner control systems				
4.10.1	General	X			X
4.10.2	Low-temperature equipment	X			X
4.10.3	High-temperature equipment	X	X2		X
4.10.4	Automatic burner control systems for burners operating in the open air	X			X
4.10.5	Flame supervision for line-burners	X			X
4.11	Start-up of the heating system and burner ignition				
4.11.1	Pre-purging of the combustion chamber		X2		X

Key

X test as described in this document

X1 functional test according to device manufacturer's specification

X2 functional test as described in the instruction handbook, see 6.3.3

X3 test as specified in IEC 60204-1:2016, Clause 18

[a] Visual inspection is carried out for testing the required characteristics and properties by visual study of the delivered equipment and components.

[b] The functional test will show whether the parts in question function in such a way as to satisfy the requirements.

[c] Verification by means of measuring instruments is used to check whether the requirements are fulfilled within the specific limits.

[d] Drawings and calculations are used to check whether the design characteristics of the components used the specific requirements.

Table 7 *(continued)*

Clause	Safety requirements and/or measures	Visual inspection[a]	Functional test[b]	Measuring[c]	Examination of drawings/ calculations[d]
4.11.2	Start-up of the fuel supply	X	X2		X
4.11.3	Start fuel flow rate	X	X2		X
4.11.4	Ignition	X	X2		X
4.11.5	Maximum safety times for gas-fired natural draught burners	X			X
4.11.6	Maximum safety times for forced and induced draught gas-fired burners	X			X
4.11.7	Maximum safety times for liquid fuel fired burners	X			X
4.11.8	Flame failure on start-up		X2		X
4.11.9	Flame failure during operation		X2		X
4.12	Multiple fuels				
4.12.1	General	X			X
4.12.2	Fuel circuit	X			X
4.12.3	Combustion air supplies	X			X
4.12.4	Operation of the safety devices	X	X2		X
4.12.5	Air/fuel ratio		X1/X2		X
4.13	Oxygen or oxygen-enriched combustion air (OOECA)				
4.13.1	General	X			X
4.13.2	Suitability for oxygen service	X			X
4.13.3	Pipework	X			X
4.13.4	Flow velocities	X			X
4.13.5	Connection for oxygen pipework	X			X
4.13.6	Sealing materials for oxygen pipework				X
4.13.7	Fittings	X			X
4.13.8	Blow off and venting lines	X			
4.13.9	Flexible tubing and couplings	X			X
4.13.10	Safety devices against gas backflow	X			X
4.13.11	Material requirements				X

Key

X test as described in this document

X1 functional test according to device manufacturer's specification

X2 functional test as described in the instruction handbook, see 6.3.3

X3 test as specified in IEC 60204-1:2016, Clause 18

[a] Visual inspection is carried out for testing the required characteristics and properties by visual study of the delivered equipment and components.

[b] The functional test will show whether the parts in question function in such a way as to satisfy the requirements.

[c] Verification by means of measuring instruments is used to check whether the requirements are fulfilled within the specific limits.

[d] Drawings and calculations are used to check whether the design characteristics of the components used the specific requirements.

6 Information for use

6.1 General

The manufacturer of the TPE shall provide an instruction handbook which contains the necessary information for the combustion and fuel handling system. The format and content shall comply with ISO 12100:2010, 6.4.

The information for use shall be written in the user's language and shall contain one copy in the original language chosen by the manufacturer.

The information for use shall contain details for commissioning, start-up and use together with information for test procedure and general maintenance and the intended use defined by the manufacturer.

6.2 Marking

The minimum information marked on the TPE is given in ISO 13577-1:2016, Clause 6.

The pipework shall be identified by colour and/or sign.

6.3 Instruction handbook

6.3.1 General

For the combustion and fuel handling system the instruction handbook of the TPE shall at least contain the following details:

— exact description of the combustion and fuel handling system of the TPE and of the safety equipment;

— instructions for use and requirements for the training of personnel;

— complete range of application of the combustion and fuel handling system of the TPE (tolerable range of application, if necessary);

— schematic description of the safety functions;

— detailed maintenance procedures to be carried out by the user to ensure tightness of both the pipework and equipment.

Moreover, the following aspects shall be treated by the instruction handbook:

— operation of combustion and fuel handling system of the TPE only by competent personnel according to the conditions of use defined by the manufacturer;

— information on correct work place of operator.

6.3.2 Description of equipment

The instruction handbook shall contain the following information:

— a description of the combustion and fuel handling system, including as-built schematic diagrams of pipework and electrical wiring;

— a list of all safety and control equipment parts with their settings and an indication of the relevant standards;

— instructions for documentation of equipment settings/adjustments as made during final commissioning;

— a description of any deviations from the requirements of relevant standards in the construction and/or function of parts of the combustion and fuel handling system;

— requirements for handling the waste products of combustion from the TPE.

All the information given on the marking plate(s) shall be repeated together with information relevant to combustion and fuel handling.

6.3.3 Inspection procedures

The instruction handbook shall contain details of inspection intervals and periodic checking procedures for:

— leak tightness test of the complete system (as per 4.2.7);

— leak tightness of all pipework; periodic checking of leak tightness should be carried out at intervals to be determined by considering the operating conditions, fuel type and material of construction;

— leak tightness of the TPE and the flue ducts in cases where pressurized combustion is used;

— leak tightness check of the valves;

— leak tightness check of the filter and/or the strainer;

— all safety equipment, especially automatic burner control systems, warning devices and automatic shut-off valves;

— combustion quality (e.g. temperatures and/or combustion products analysis), if applicable;

— safety functions in order to ensure that these manual functions are not impaired by concealed faults or errors.

A documentation form shall be included in which the date, the results and the person who carried out the checks are recorded together with the date of the next inspection.

6.3.4 Commissioning, start-up and operating procedures

The instruction handbook shall provide details of the procedure for commissioning, start up, including preliminary checks (e.g. cleaning of pipework), a description of conditions and a list of manually and automatically operated system checks, for example, opening equipment doors, if applicable.

Attention shall be drawn to the necessity of ensuring that the pipework is free of debris, welding slag, etc. after initial commissioning, before the equipment is put into service, after maintenance or long periods of shutdown.

The instruction handbook shall provide information on special allowances or requirements for:

— pre-purge, e.g. deviation of pre-purge times from standardized conditions in justified cases or waiting time between ignition attempts in the case of natural draught burners;

— the exhausting of combustion products;

— the conditions for automatic restart, if applicable;

— the conditions for, and the number of permitted recycles.

6.3.5 Shutdown procedures

The instruction handbook shall provide information on any special requirements necessary before fuel shut-off (e.g. evacuation or combustion of flammable atmospheres), and after fuel shut-off (e.g. continuous venting to avoid overheating or blocking of flue dampers in the open position), together with a description of measures to be taken in the event of a safety shutdown.

The instruction handbook shall set down any special requirements for lock-out and/or emergency shutdown and any special measures for subsequent restart.

An information sheet containing the information required by this subclause shall be provided for display at the equipment control panel or at a defined nearest place.

6.3.6 Maintenance procedures

The instruction handbook shall contain details of the maintenance intervals and procedures for all parts that require maintenance, replacement and/or repair of items of safety equipment.

Safety equipment shall be replaced before its useful life time has expired.

The instruction handbook shall specify the suitable cleaning methods and agents for the cleaning of oxygen systems.

Documentation forms with dates of last and next maintenance and the contact information (such as addresses, telephone, fax numbers, e-mail, website and helpdesk coordinates) of maintenance and repair services shall be provided.

6.3.7 Documentation

Provision shall be made for recording revisions to the instruction handbook in the event of modification of the equipment (e.g. by repair, modernisation or replacement of parts, change of operating conditions).

Annex A
(informative)

List of significant hazards

Table A.1 — List of significant hazards

1	2	3	4	5
Cl.	**Hazards**	**Location**	**Relevant clauses of** ISO 13577-1:2016	**Relevant clauses of this document**
	Hazards, hazardous situation and hazardous events			
1	**Mechanical hazards**			
1.1	High-pressure fluid injection or ejection hazard	Pipework	4.2.7	4.2.1, 4.2.2, 4.2.5, 4.2.7, 4.2.11, 4.3.3, 4.5.3, 4.5.4, 4.5.5
2	**Electrical hazards**			
2.1	Electrical contact direct or indirect with live parts	Control system, power supply to the machine and connectors	4.3.1	4.1.1
2.2	Electrostatic phenomena		4.3.1.1	
3.	**Thermal hazards**, resulting in:			
3.1	Burns and other injuries by a possible contact of persons with objects or materials with an extreme high-temperature, by flames or explosions and also by the radiation of heat sources	Burners Environment of the TPE	4.4.1, 4.4.4	
3.2	Damage to health by hot working environment	Environment of the TPE	4.4.5, 4.9	
4	**Hazards caused by interruption of energy supply**			
4.1	Malfunction or break up of components	Burner and accessories		4.3.6; 4.5.8
4.2	Malfunction or break down of control system	Control system	4.11.3	
4.3	unexpected start-up	Control system	4.12.2	
5	**Hazards caused by (temporary) missing and/or incorrectly positioned safety related measures/means**			
5.1	Specific hazard of maintenance and adjusting	Burners, fans, piping, duct, control system		4
6	**Hazards generated by materials and substances processed or used by the machinery**			
6.1	Hazards from contact with or inhalation of harmful fluids, gases, mists, fumes, and dusts	Exhaust gases evacuating system Combustion chamber		4.2.12, 4.3.4, 4.3.5, 4.6.3, 4.9.6, 4.2.1, 4.2.2, 4.6.3, 4.9.6, 4.12.5, 4.13.1

Table A.1 *(continued)*

1	2	3	4	5
Cl.	**Hazards**	**Location**	**Relevant clauses of** ISO 13577-1:2016	**Relevant clauses of this document**
6.2	Fire or explosion hazard	Burners, fans, piping, duct, control system, combustion chamber	4.4.3.1, 4.4.3.2	4
7	**Hazards generated by neglecting ergonomic principles in machinery design, as e.g. hazards from:**			
7.1	Hazard of mismatch of design, location or identification of manual controls	Pipework Control system	4.12.2	4.3.1, 4.5.1

Annex B
(informative)

Examples of fuels

B.1 General

The fuels below are given as typical examples only and should not be considered as limitations to this document where all gaseous and liquid fuels apply.

B.2 Gaseous fuels

Gases fuels likely to be used can be classified in accordance with their Wobbe index and composition:

— manufactured gases: e.g. town gas (1st family);

— natural gases (2nd family);

— liquefied petroleum gases (3rd family);

— hydrogen and hydrogen containing fuel gases;

— other gaseous fuels.

NOTE EN 437:2021 includes information about 1st, 2nd and 3rd gas family.

B.3 Liquid fuels

Liquid petroleum fuels likely to be used can be classified into different categories in accordance with the value of their viscosity:

— gas-oil fuel-oils;

— light fuel-oils;

— medium fuel-oils;

— heavy fuel-oils;

— very heavy fuel-oils;

— other liquid fuels.

Annex C
(normative)

Maximum allowed pressure

This document covers the pressure hazard of piping forming an integral part of combustion and fuel handling systems of TPE intended to be subjected to a maximum allowable pressure of not more than 50 kPa.

For piping with a maximum allowable pressure of more than 50 kPa, the pressure hazard is covered in the following cases:

a) gases, liquefied gases, gases dissolved under pressure, vapours and also those liquids whose vapour pressure at the maximum allowable temperature is greater than 50 kPa above normal atmospheric pressure, (101,3 kPa) at the following limits:

— for Group 1:

  — DN 25 and included;

  — DN × PS (kPa) = 1,0 × 10^5 kPa for DN 25 up to 100 and included (see Figure C.1),

— for Group 2:

  — DN 100 and included;

  — DN × PS (kPa) = 3,5 × 10^5 kPa for DN greater than 100 (see Figure C.2);

b) liquids having a vapour pressure at the maximum allowable temperature of not more than 500 kPa above normal atmospheric pressure (101,3 kPa) at the following limits:

— for Group 1;

  — DN 25 and included;

  — DN × PS (kPa) = 2,0 × 10^5 kPa for DN 25 up to 200 and included;

  — PS (kPa) = 1,0 × 10^3 kPa for DN greater than 200 (see Figure C.3);

— for Group 2:

  — DN 200 and included;

  — PS (kPa) = 5,0 × 10^4 kPa for DN greater than 200 (see Figure C.4).

Group 1 comprises the following fluids:

— explosive;

— extremely flammable;

— highly flammable;

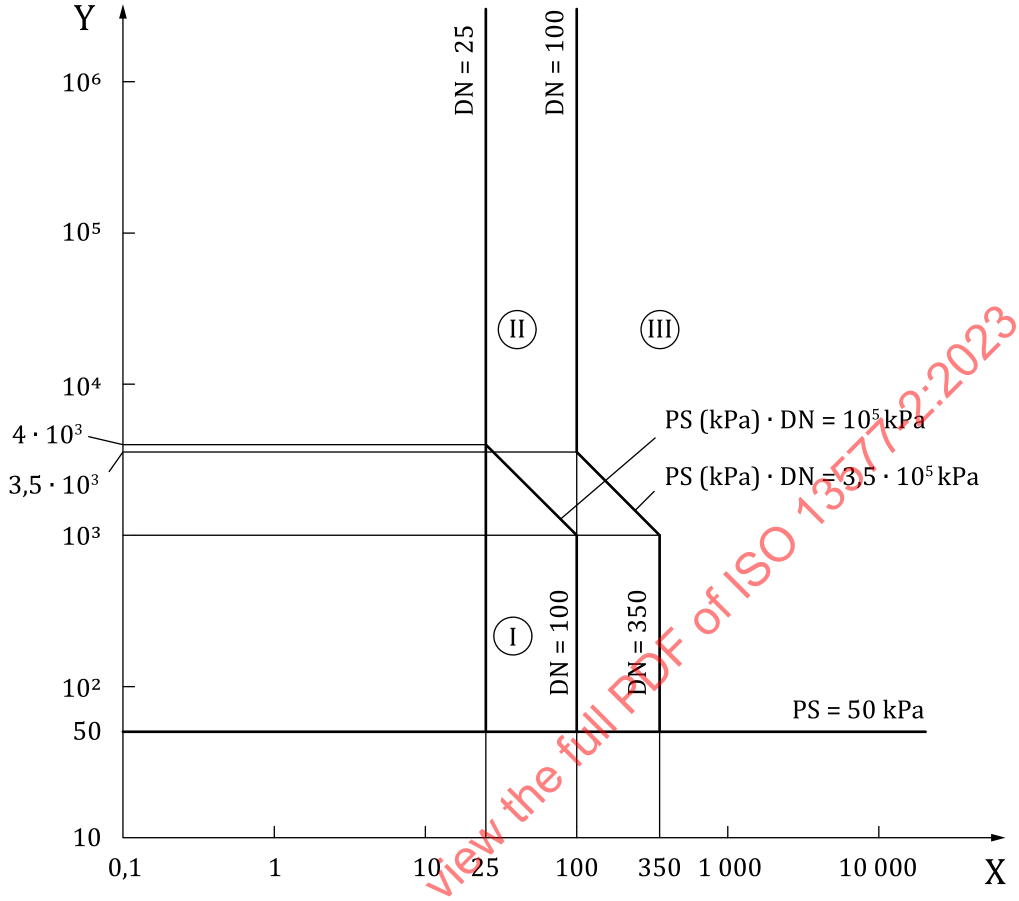
— flammable (where the maximum allowable temperature is above flashpoint);

— very toxic;

— toxic;

— oxidizing.

Group 2 comprises all other fluids.



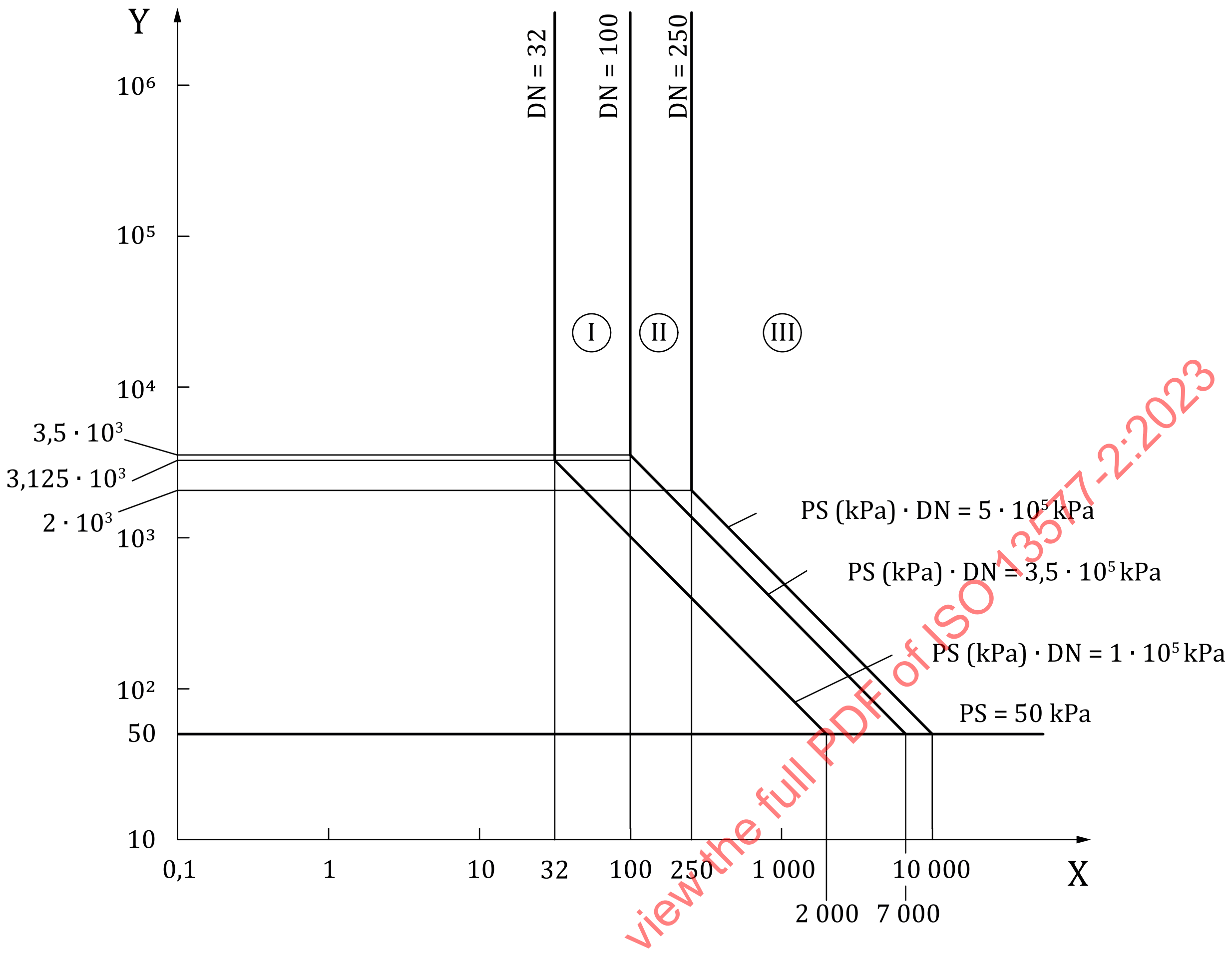
Key

X DN

Y PS (kPa)

Figure C.1 — Piping referred to clause a) group 1 of Annex C

NOTE 1 References to category II and III of this annex are mentioned for information only.



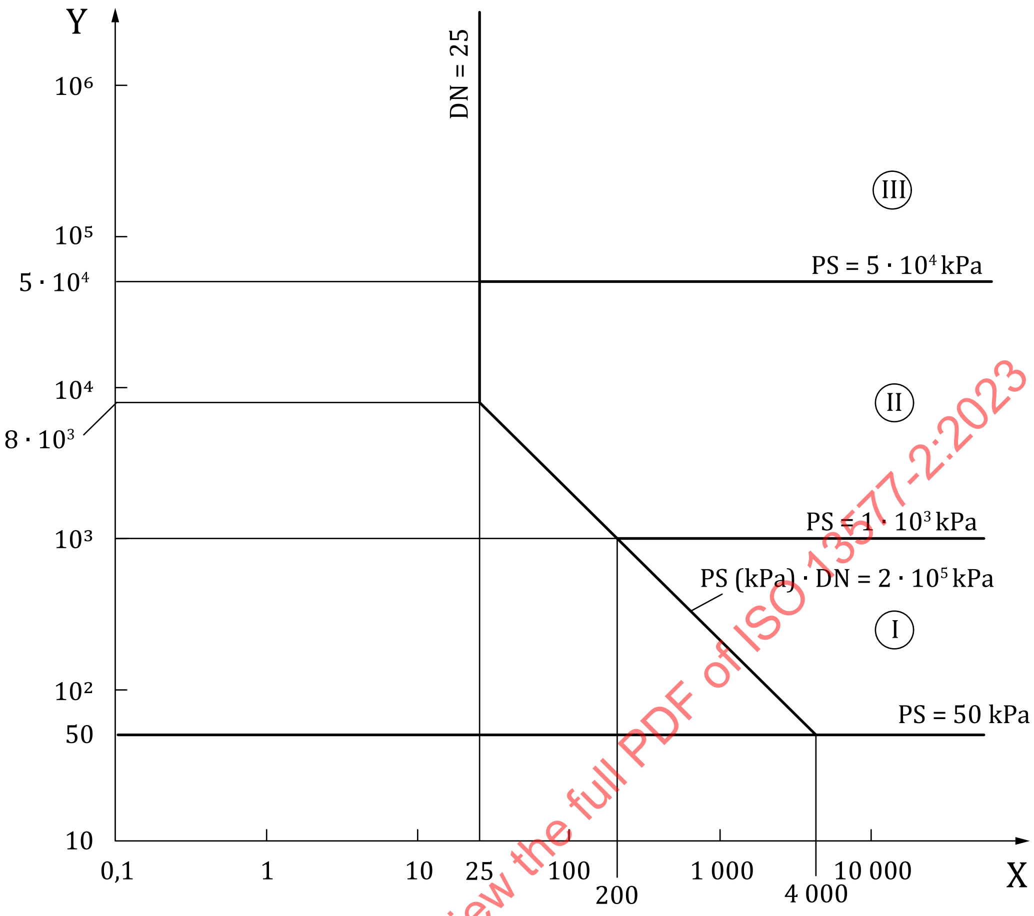
Key

X DN

Y PS (kPa)

Figure C.2 — Piping referred to clause a) group 2 of Annex C

NOTE 2 References to category II and III of this annex are mentioned for information only.



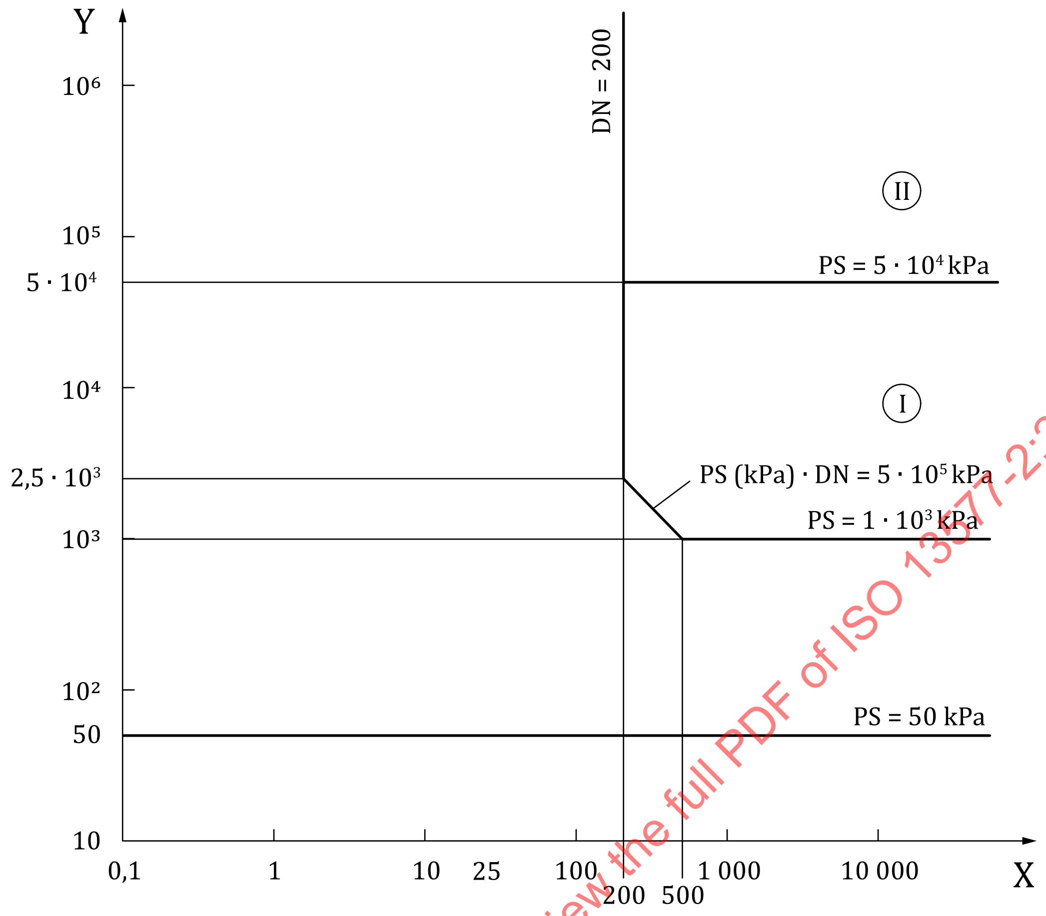
Key

X DN

Y PS (kPa)

Figure C.3 — Piping referred to clause b) group 1 of Annex C

NOTE 3 References to category II and III of this annex are mentioned for information only.



Key

X DN

Y PS (kPa)

Figure C.4 — Piping referred to clause b) group 2 of Annex C

NOTE 4 References to category II of this annex are mentioned for information only.

Annex D
(informative)

Examples for the determination of safety integrity level (SIL) or performance level (PL) using the risk graph method

Several International Standards may be used for determination of the required safety integrity level (SIL)/performance level (PL). For machinery, IEC 62061:2021 was developed to determine the SIL while IEC 61511-1:2016, IEC 61511-2:2016 and IEC 61511-3:2016 were developed to determine the required SIL for process industry. Risk graph methods for determining the SIL are given in both IEC standards. In addition, ISO 13849-1:2015 covers the determination of a PL and also includes a method to determine PL from SIL (ISO 13849-1:2015, Table 3).

Table D.1 shows an example of SIL/PL determination according to IEC 62061:2021/ ISO 13849-1:2015, Table 3. This SIL determination is done according to IEC 62061:2021, Figure A.3. The PL is determined in accordance with ISO 13849-1:2015, Table 3 which shows the relationship between PL and SIL.

Table D.2 shows an example of SIL determination according to IEC 61511-3:2016.

The values given in Table D.1 and Table D.2 refer to typical TPE. The required SIL/PL levels might vary dependent on the individual risk assessment.

Table D.1 — Example of SIL/PL determination in accordance with IEC 62061:2021 and ISO 13849-1:2015, Table 3

		Risk assessment and safety measures						Document No.:				
								Part of:				
Project: Example of typical SIL determination							☐	Pre risk assessment				
Issued by:							☐	Intermediate risk assessment				
Date:							☐	Follow up risk assessment				
Revision: 2012/12/13												
		Black area = Safety measures required										
		Grey area = Safety measures recommended										
Consequences	Severity Se	Class Cl					Frequency and duration, Fr		Probability of hzd. event, Pr		Avoidance Av	
		3 – 4	5 – 7	8 – 10	11 – 13	14 – 15						
Death, loss of an eye or arm	4	SIL 2	SIL 2	SIL 2	SIL 3	SIL 3	< = 1 h	5	Very high	5		
Permanent, loss of fingers	3		OM	SIL 1	SIL 2	SIL 3	> 1 h - < = day	5	Likely	4		
Reversible, medical attention	2			OM	SIL 1	SIL 2	> 1 day - < = 2 weeks	4	Possible	3	Impossible	5
Reversible, first aid	1				OM	SIL 1	> 2 weeks - < = 1 year	3	Rarely	2	Possible	3
							> 1 year	2	Negligible	1	Likely	1

Table D.1 *(continued)*

SRCF	Hazardous event	Safety related control function (SRCF)	Consequences		Probability of occurrence			Class	Integrity		Comments
No.	Description	Description		Se	Fr	Pr	Av	Cl	SIL	PL	
01	Fuel gas supply pressure too low	Pressure switch or pressure transmitter is monitoring the gas pressure, and in combination with the logic circuit brings the plant to a safe state if the pressure decreases below a safe level.		4	5	2	1	8	2	d	4.3.4 Low gas pressure protection Hazards: explosion, fire, incomplete combustion
02	Fuel gas pressure too high, failure of upstream regulator	Pressure switch or pressure transmitter is monitoring the gas pressure, and in combination with the logic circuit brings the plant to a safe state if the pressure rises above a safe level.		4	5	2	3	10	2	d	4.3.5 High gas pressure protection Hazards: explosion, fire, poisoning (CO caused by lack of air operation), incomplete combustion
03	Liquid fuel pressure too high	Pressure switch or pressure transmitter is monitoring the liquid pressure, and in combination with the logic circuit brings the plant to a safe state if the pressure rises above a safe level.		4	5	2	3	10	2	d	4.5.6 Liquid fuel pressure protection Hazards: explosion, fire, poisoning, incomplete combustion
04	Liquid fuel pressure too low	Pressure switch or pressure transmitter is monitoring the gas pressure, and in combination with the logic circuit brings the plant to a safe state if the pressure decreases below a safe level.		4	5	2	3	10	2	d	4.5.6 Liquid fuel pressure protection Hazards: bad atomizing, soot, bad combustion, CO caused by excess air operation (light oil)
05	Liquid fuel temperature too high	Thermostat or temperature transmitter is monitoring the liquid temperature, and in combination with the logic circuit brings the plant to a safe state if the temperature rises above a safe level.		4	5	2	3	10	2	d	4.5.7 Liquid fuel temperature protection Hazards: explosion, fire, poisoning, incomplete combustion

Table D.1 *(continued)*

SRCF	Hazardous event	Safety related control function (SRCF)	Consequences		Probability of occurrence			Class	Integrity		Comments
No.	Description	Description		Se	Fr	Pr	Av	Cl	SIL	PL	
06	Liquid fuel temperature too low	Thermostat or temperature transmitter is monitoring the liquid temperature, and in combination with the logic circuit brings the plant to a safe state if the temperature decreases below a safe level.		2	5	2	3	10	OM	-	4.5.7 Liquid fuel temperature protection Hazards: bad atomizing, soot, bad combustion
07	Atomizing fluid pressure outside safe operating range	A pressure sensing device is monitoring the atomizing fluid pressure, and in combination with the logic circuit brings the plant into a safe state if the pressure is outside the tolerable pressure range.		4	5	2	1	8	2	d	4.5.8 Automatic shut-off valves Hazards: explosion, fire, bad atomizing, bad combustion
08	Failure of heat transfer fluid	Flow, pressure, temperature, position or level sensing devices in combination with a logic system are detecting if the heat transfer fluid is sufficient. If not, the plant is brought into a safe state.		4	5	2	3	10	2	d	4.3.6/4.5.8 Automatic shut-off valves Hazards: overheating, poisoning, fire
09	Failure of power supply and/or other utilities used for operating valves and other equipment essential for bringing the plant into a safe state (e.g. compressed air, steam)	A sensing device for pressure, flow, voltage, etc. in combination with a logic bringing the plant into a safe state.		4	5	2	3	10	2	d	4.3.6/4.5.8 Automatic shut-off valves Hazards: explosion, fire, poisoning
10	Plant temperature exceeding the maximum allowable operating temperature	A temperature sensing device in combination with a logic system is monitoring the process temperature. If the temperature rises above the safe level, it shall be brought into a safe state.		4	5	2	3	10	2	d	4.3.6/4.5.8 Automatic shut-off valves Hazards: fire, mechanical breakdown, injuries from hot parts

Table D.1 *(continued)*

SRCF	Hazardous event	Safety related control function (SRCF)	Consequences		Probability of occurrence			Class	Integrity		Comments
No.	Description	Description		Se	Fr	Pr	Av	Cl	SIL	PL	
11	Failure of valve proving	A pressure sensing device or position device combined with a logic system is detecting if the gas system has a tolerable low leakage. If not, the start is prevented.		4	5	1	1	7	2	d	4.3.7 Valve proving Hazards: explosion, explosive atmosphere
12	Combustion air pressure / flow too low	Pressure switch, pressure transmitter or flow meter is monitoring the air pressure / flow, and in combination with the logic circuit brings the plant to a safe state if the pressure / flow decreases below a safe level.		4	5	2	3	10	2	d	4.6.2 Air flow and pressure sensing devices Hazards: explosion, fire, poisoning, incomplete combustion
13	Air / gas ratio outside safe operating range	The correct air / gas ratio is controlled by mechanical, pneumatic or electric systems. The electric ratio sensing device combined with a logic system shall bring the ratio to a safe level.		4	5	4	5	14	3	e	4.6.3 Air/fuel ratio Hazards: explosion, fire, poisoning
14	Combustion chamber pressure too high, failure of flue gas venting	A pressure sensing device combined with a logic system is detecting if the combustion chamber pressure leads to a harmful flue gas escape and brings the plant into a safe state.		3	5	2	3	10	1	c	4.9.6 Flue gas venting Hazards: poisoning, inhalation of harmful fluids
15	Flame failure	Each burner is supervised by a flame sensing device, which in combination with a logic system is bringing the burner or the plant into a safe state if the flame extinction is unwanted.		4	5	4	5	14	3	e	4.10 Automatic burner control system Hazards: explosion, fire

Table D.1 *(continued)*

SRCF	Hazardous event	Safety related control function (SRCF)	Consequences		Probability of occurrence			Class	Integrity		Comments
No.	Description	Description		Se	Fr	Pr	Av	Cl	SIL	PL	
16	Temperature monitoring for high temperature operation	A temperature sensing device combined with a logic system is detecting when the limit for high temperature equipment has been reached. Only above this limit the high temperature equipment functions are released.		4	5	4	5	14	3	e	4.10.3 High temperature equipment Hazards: explosion, fire
17	Air flow too low during purge	Flow meter, differential pressure switch or transmitter is monitoring the air flow, and in combination with the logic circuit brings the plant to a safe state if the flow decreases below a safe level.		4	5	2	3	10	2	d	4.11.1 Pre-purge Hazards: explosion, insufficient purging
18	Start fuel flow rate too high	The position or state of a limiting device ensuring a safe burner ignition is monitored for correct position. If not start is prevented.		3	5	2	1	8	1	c	4.11.2 Start fuel flow rate Hazard: hard or failed burner start with possible high impact of the construction

Table D.2 — SIL determination under different risk environment in accordance with IEC 61511-3:2016

Project:	Example of typical SIL determination	Process:	
Issued by:		SIF:	
Date:		Plant:	
Revision		Risk:	

Consequence parameter / Risk graph matrix

Severity level		C	Likelihood sum (F+P+W) 1–2	3–4	5–6	7–8	9–10	11–12
C_F	Catastrophic	F	a	SIL 1	SIL 2	SIL 3	SIL 4	b
C_E	Extensive	E	OK	a	SIL 1	SIL 2	SIL 3	SIL 4
C_D	Serious	D	OK	OK	a	SIL 1	SIL 2	SIL 3
C_C	Considerable	C	OK	OK	OK	a	SIL 1	SIL 2
C_B	Marginal	B	OK	OK	OK	OK	a	SIL 1
C_A	Negligible	A	OK	OK	OK	OK	OK	a

Occupancy parameter

Frequency of human presence in the hazardous zone. Credit for limited occupancy shall not have been taken choosing consequence categories!

Exposure rate			F
F_D	Permanent	100 %	2
F_C	Frequent	10 % –100 %	2
F_B	Occasionally	1 % – 10 %	1
F_A	Rare	< 1 %	0

Avoidance parameter

Probability of avoiding the hazardous event **if the SIF fails on demand**. Implies **independent** facilities provided to "shut down" so hazard can be avoided or enable all persons to escape to a safe area.

Conditions to be fulfilled:

— Facilities to alert operator that the SIS has failed

— Independent facilities to bring process to safe state

— Time between operator alert and hazardous event > 1 h

Avoidance probability		P
P_B	Avoidance condition is not fulfilled.	1
P_A	All avoidance conditions are fulfilled.	0

Demand rate parameter

Estimated SIF demand rate			W
W_9	Often	> 1/ years	9
W_8	Frequent	1/1–3 years	8
W_7	Likely	1/3 - 10 years	7
W_6	Probable	1/10–30 years	6
W_5	Occasional	1/30–100 years	5
W_4	Remote	1/100–300 years	4
W_3	Improbable	1/300–1 000 years	3
W_2	Incredible	1/1 000–10 000 years	2
W_1	Inconceivable	1/10 000–100 000 years	1

Table D.2 *(continued)*

SIF-	Hazardous event	Safety instrumented function (SIF)	Consequences		Influence		Demand	Likelihood	Integrity		Hazard description
No.	Description	Description	Harm	C	F	P	W	Sum	SIL	SIL	and comments
01	Fuel gas supply pressure too low	Pressure switch or pressure transmitter is monitoring the gas pressure, and in combination with the logic circuit brings the plant to a safe state if the pressure decreases below a safe level.	H	D	2	1	6	9	2	2	4.3.4 Low gas pressure protection Hazards: explosion, poisoning, CO caused by excess air operation of the burner
			E	B	1	1		8	-		
			F	E				8	2		
02	Fuel gas pressure too high, failure of upstream regulator	Pressure switch or pressure transmitter is monitoring the gas pressure, and in combination with the logic circuit brings the plant to a safe state if the pressure rises above a safe level.	H	D	2	1	6	9	2	2	4.3.5 High gas pressure protection Hazards: explosion, fire, poisoning, incomplete combustion
			E	B	1	1		8	-		
			F	E				8	2		
03	Liquid fuel pressure too high	Pressure switch or pressure transmitter is monitoring the liquid pressure, and in combination with the logic circuit brings the plant to a safe state if the pressure rises above a safe level.	H	D	2	1	6	9	2	2	4.5.6 Liquid fuel pressure protection Hazards: explosion, fire, poisoning, incomplete combustion
			E	B	1	1		8	-		
			F	E				8	2		
04	Liquid fuel pressure too low	Pressure switch or pressure transmitter is monitoring the gas pressure, and in combination with the logic circuit brings the plant to a safe state if the pressure decreases below a safe level.	H	D	2	1	6	9	2	2	4.5.6 Liquid fuel pressure protection Hazards: bad atomizing, soot, bad combustion, CO caused by excess air operation (light oil)
			E	B	1	1		8	-		
			F	E				8	2		
05	Liquid fuel temperature too high	Thermostat or temperature transmitter is monitoring the liquid temperature, and in combination with the logic circuit brings the plant to a safe state if the temperature rises above a safe level.	H	D	2	1	6	9	2	2	4.5.7 Liquid fuel temperature protection Hazards: explosion, fire, poisoning, incomplete combustion
			E	B	1	1		8	-		
			F	E				8	2		

Table D.2 *(continued)*

SIF- No.	Hazardous event Description	Safety instrumented function (SIF) Description	Consequences Harm	 C	Influence F	 P	Demand W	Likelihood Sum	Integrity SIL	 SIL	Hazard description and comments
06	Liquid fuel temperature too low	Thermostat or temperature transmitter is monitoring the liquid temperature, and in combination with the logic circuit brings the plant to a safe state if the temperature decreases below a safe level.	H	B	2	1	6	9	a	0	4.5.7 Liquid fuel temperature protection Hazards: bad atomizing, soot, bad combustion
			E	C	1	1		8	a		
			F	B				8	-		
07	Atomizing fluid pressure outside safe operating range	A pressure sensing device is monitoring the atomizing fluid pressure, and in combination with the logic circuit brings the plant into a safe state if the pressure is outside the tolerable pressure range.	H	D	2	0	6	8	1	2	4.5.8 Automatic shut-off valves Hazards: explosion, fire, bad atomizing, bad combustion
			E	B	1	0		7	-		
			F	E				7	2		
08	Failure of heat transfer fluid	Flow, pressure, temperature, position or level sensing device in combination with a logic system are detecting if the heat transfer fluid is sufficient. If not, the plant is brought into a safe state.	H	D	2	1	6	9	2	2	4.3.6/4.5.8 Automatic shut-off valves Hazards: overheating, poisoning, fire
			E	B	1	1		8	-		
			F	D				8	1		
09	Failure of power supply and/or other utilities used for operating valves and other equipment essential for bringing the plant into a safe state (e.g. compressed air, steam)	A sensing device for pressure, flow, voltage, etc. in combination with a logic bringing the plant into a safe state.	H	D	2	1	6	9	2	2	4.3.6/4.5.8 Automatic shut-off valves Hazards: explosion, fire, poisoning
			E	B	1	1		8	-		
			F	E				8	2		

Table D.2 *(continued)*

SIF- No.	Hazardous event Description	Safety instrumented function (SIF) Description	Consequences Harm	 C	Influence F	 P	Demand W	Likelihood Sum	Integrity SIL	 SIL	Hazard description and comments
10	Plant temperature exceeding the maximum allowable operating temperature	A temperature sensing device in combination with a logic system is monitoring the process temperature. If the temperature rises above the safe level, it shall be brought into a safe state.	H	D	2	1	6	9	2	2	4.3.6/4.5.8 Automatic shut-off valves Hazards: fire, mechanical breakdown, injuries from hot parts
			E	B	1	1		8	-		
			F	D				8	2		
11	Failure of valve proving	A pressure sensing device or position device combined with a logic system is detecting if the gas system has a tolerable low leakage. If not, the start is prevented.	H	D	2	1	6	9	2	2	4.3.7 Valve proving Hazards: explosion, explosive atmosphere
			E	B	1	1		8	-		
			F	E				8	2		
12	Combustion air pressure/flow too low	Pressure switch, pressure transmitter or flow meter is monitoring the air pressure / flow, and in combination with the logic circuit brings the plant to a safe state if the pressure / flow decreases below a safe level.	H	D	2	1	6	9	2	2	4.6.2 Air flow and pressure sensing devices Hazards: explosion, fire, poisoning, incomplete combustion
			E	B	1	1		8	-		
			F	E				8	2		
13	Air/gas ratio outside safe operating range	The correct air / gas ratio is controlled by mechanical, pneumatic or electric systems. The electric ratio sensing device combined with a logic system shall bring the ratio to a safe level.	H	D	2	1	7	10	2	3	4.6.3 Air/fuel ratio Hazards: explosion, fire, poisoning
			E	B	1	1		9	a		
			F	E				9	3		
14	Combustion chamber pressure too high, failure of flue gas venting	A pressure sensing device combined with a logic system is detecting if the combustion chamber pressure leads to a harmful flue gas escape and brings the plant into a safe state.	H	D	2	0	6	8	1	1	4.9.6 Flue gas venting Hazards: poisoning, inhalation of harmful fluids
			E	A	1	0		7	-		
			F	D				7	1		

Table D.2 *(continued)*

SIF- No.	Hazardous event Description	Safety instrumented function (SIF) Description	Consequences Harm	Consequences C	Influence F	Influence P	Demand W	Likelihood Sum	Integrity SIL	Integrity SIL	Hazard description and comments
15	Flame failure	Each burner is supervised by a flame sensing device, which in combination with a logic system is bringing the burner or the plant into a safe state if the flame extinction is unwanted.	H	D	2	1	8	11	3	3	4.10 Automatic burner control systems Hazards: explosion, fire
			E	A	1	1		10	-		
			F	E				10	3		
16	Temperature monitoring for high temperature operation	A temperature sensing device combined with a logic system is detecting when the limit for high temperature equipment has been reached. Only above this limit the high temperature equipment functions are released.	H	D	2	1	7	10	2	3	4.10.3 High temperature equipment Hazards: explosion, fire
			E	B	1	1		9	a		
			F	E				9	3		
17	Air flow too low during purge	Flow meter, differential pressure switch or transmitter is monitoring the air flow, and in combination with the logic circuit brings the plant to a safe state if the flow decreases below a safe level.	H	D	2	1	6	9	2	2	4.11.1 Pre-purge Hazards: explosion, insufficient purging
			E	B	1	1		8	-		
			F	E				8	2		
18	Start fuel flow rate too high	The position or state of a limiting device ensuring a safe burner ignition is monitored for correct position. If not, start is prevented.	H	C	2	1	7	10	1	1	4.11.2 Start fuel flow rate Hazards: hard or failed burner start with possible high impact of the construction
			E	A	1	1		9	-		
			F	C				9	1		

Annex E
(normative)

Regional product standards

E.1 Product standards mechanical

E.1.1 Automatic shut-off valves

International	ISO 23551-1:2012	Safety and control devices for gas burners and gas-burning appliances — Particular requirements — Part 1: Automatic and semi-automatic valves
	ISO 23553-1:2014	Safety and control devices for oil burners and oil-burning appliances — Particular requirements — Part 1: Automatic and semi-automatic valves
Europe	EN 161:2013	Automatic shut-off valves for gas burners and gas appliances
	EN 16678:2016	Safety and control devices for gas burners and gas burning appliances — Automatic shut-off valves for operating pressure of above 500 kPa up to and including 6,300 kPa
USA + Canada	CSA/ANSI Z21.21–19/CSA 6.5-2019	Automatic valves for gas appliances
USA	UL 429:2013	Standard for Electrically Operated Valves
Japan	n.a.	

NOTE See 4.3.6, 4.5.8.

E.1.2 Pressure regulator

International	ISO 23551-2:2018	Safety and control devices for gas burners and gas-burning appliances — Particular requirements — Part 2: Pressure regulators
	ISO 23555-2:2022	Safety and control devices for operating pressures greater than 500 kPa — Part 2: Gas pressure regulators
Europe	EN 88-1:2016	Pressure regulators and associated safety devices for gas appliances — Part 1: Pressure regulators for inlet pressures up to and including 50 kPa
	EN 88-2:2015	Safety and control devices for gas burners and gas burning appliances — Part 2: Pressure regulators for inlet pressure above 50 kPa up to and including 500 kPa and associated safety devices
	EN 88-3:2017	Safety and control devices for gas burners and gas burning appliances — Part 3: Pressure and/or flow rate regulators for inlet pressures up to and including 500 kPa, electronic types
	EN 334:2019	Gas pressure regulators for inlet pressure up to 100 bar
USA + Canada	CSA/ANSI Z21.18-2019 /CSA 6.3-2019	Gas appliance pressure regulators
Japan	n.a.	

NOTE See 4.3.3.

E.1.3 Over-pressure cut-off devices

International	n.a.	
Europe	EN 88-2:2020	Pressure regulators and associated safety devices for gas appliances — Part 2: Pressure regulators for inlet pressures above 500 mbar up to and including 5 bar
	EN 14382:2019	Gas safety shut-off devices for inlet pressure up to 10 MPa (100 bar)
USA + Canada	n.a.	
Japan	n.a.	

NOTE See 4.3.3.

E.1.4 Pneumatic gas/air ratio controls

International	ISO 23551-2:2018	Safety and control devices for gas burners and gas-burning appliances — Particular requirements — Part 2: Pressure regulators
Europe	EN 88-1:2016	Pressure regulators and associated safety devices for gas appliances — Part 1: Pressure regulators for inlet pressures up to and including 50 kPa
USA + Canada	in preparation	
Japan	n.a.	

NOTE See 4.6.3.

E.1.5 Valve proving systems

International	ISO 23551-4:2018	Safety and control devices for gas burners and gas-burning appliances — Particular requirements — Part 4: Valve-proving systems for automatic shut-off valves
Europe	EN 1643:2014	Safety and control devices for gas burners and gas burning appliances – Valve proving systems for automatic shut-off valves
USA + Canada	n.a	
Japan	n.a.	

NOTE See 4.3.7.

E.1.6 Manual gas shut-off valves

International	ISO 23551-5:2014	Safety and control devices for gas burners and gas-burning appliances — Particular requirements — Part 5: Manual gas valves
Europe	EN 331:2015	Manual operated ball valves and closed bottom taper plug valves for gas installations for buildings
	EN 13774:2013	Valves for gas distribution systems with maximum operating pressure less than or equal to 16 bar — Performance requirements
USA + Canada	n.a	
Japan	n.a.	

NOTE See 4.3.1, 4.3.8.

E.1.7 Thermoelectric flame supervision devices

International	ISO 23551-6:2014	Safety and control devices for gas burners and gas-burning appliances — Particular requirements — Part 6: Thermoelectric flame supervision controls
Europe	EN 125:2010+A1:2015	Flame supervision devices for gas burning appliances — Thermoelectric flame supervision devices
USA + Canada	n.a	
Japan	n.a.	

NOTE See 4.3.6.

E.2 Product standards electrical

E.2.1 Automatic burner control systems

International	IEC 60730-2-5: 2013–11+A1:2017	Automatic electrical controls for household and similar use — Part 2–5: Particular requirements for automatic electrical burner control systems
Europe	EN 60730-2-5: 2015+A1:2019	Automatic electrical controls for household and similar use — Part 2–5: Particular requirements for automatic electrical burner control systems
	EN 298: 2012	Automatic burner control systems for burners and appliances burning gaseous or liquid fuels
USA + Canada	UL 60730-2-5: 2014	Automatic electrical controls for household and similar use — Part 2–5: Particular requirements for automatic electrical burner control systems
	UL 372: 2012	Automatic electrical controls for household and similar use — Part 2: Particular requirements for burner ignition systems and components
Canada	CAN/CSA-C22.2 No. 60730–2-5–14: 2019	Automatic electrical controls for household and similar use — Part 2–5: Particular requirements for automatic electrical burner control systems
	CAN/CSA-C22.2 No. 199-M89: 2004	Combustion Safety Controls and Solid-State Igniters for Gas- and Oil-Burning Equipment
Japan	JIS C 9730-2–5: 2010 eq. to IEC	Automatic electrical controls for household and similar use — Part 2–5: Particular requirements for automatic electrical burner control systems

NOTE See 4.10.1.

E.2.2 Electronic air/fuel ratio controls

International	ISO 23552-1:2007+A1: 2010	Safety and control devices for gas and/or oil burners and gas and/or oil appliances — Particular requirements — Part 1: Fuel/air ratio controls, electronic type
Europe	EN 12067-2:2004	Safety and control devices for burners and appliances burning gaseous or liquid fuels — Control functions in electronic systems — Part 2: Fuel/air ratio control/supervision of the electronic type
USA + Canada	n.a	
Japan	n.a.	

NOTE See 4.6.3.

E.2.3 Pressure sensing devices

International	IEC 60730-2-6: 2015+A1:2019	Automatic electrical controls — Part 2–6: Particular requirements for automatic electrical pressure sensing controls including mechanical requirements
Europe	EN 60730-2-6: 2016+A1:2020	Automatic electrical controls — Part 2–6: Particular requirements for automatic electrical pressure sensing controls including mechanical requirements
	EN 1854:2010	Pressure sensing devices for gas burners and gas burning appliances
USA	UL 60730-2-6: 2016	Standard for automatic electrical controls — Part 2–6: Particular requirements for automatic electrical pressure sensing controls including mechanical requirements
Canada	n.a	
Japan	n.a.	

NOTE See 4.3.4, 4.3.5, 4.5.6, 4.6.2.

E.2.4 Temperature sensing devices

International	n.a.	
Europe	n.a.	
USA	UL 353:2011	Limit Controls
	FM 3545:2013	Temperature limit and supervisory switches
Canada	n.a	
Japan	n.a.	

NOTE 1 See 4.1.2, 4.10.3.

NOTE 2 IEC 60730-2–9 including regional versions is considered not suited for safety functions in industrial environment.

Annex F
(informative)

Example for manual leak check of automatic shut-off valves

The following procedure is an example how to do a manual leak check of automatic shut-off valves using a setup according to Figure F.1.

1) Pressurize between SV2 and V2 and measure the pressure change. Back pressure resistance of automatic shut-off valves shall be taken into account.

2) Open V1 while keeping SV2 shut. Then by opening SV1 or connecting TV1 and TV2with a rubber tube, pressurize the upstream of SV2.

3) Open V2 to ventilate the downstream of SV2 to the atmospheric pressure. Then close V2 and connect another rubber tube at TV3. Submerge the other tip of the tube into the water filled in a basin/beaker at about 10 mm depth and open TV3 to observe if bubbles emerge. When bubbling continues at the tip of the tube, suitable action shall be taken. The precise measurement of the leak rate can be performed by collecting the bubbles in a measuring cylinder filled with water in a certain period of time measured with a stop-watch.

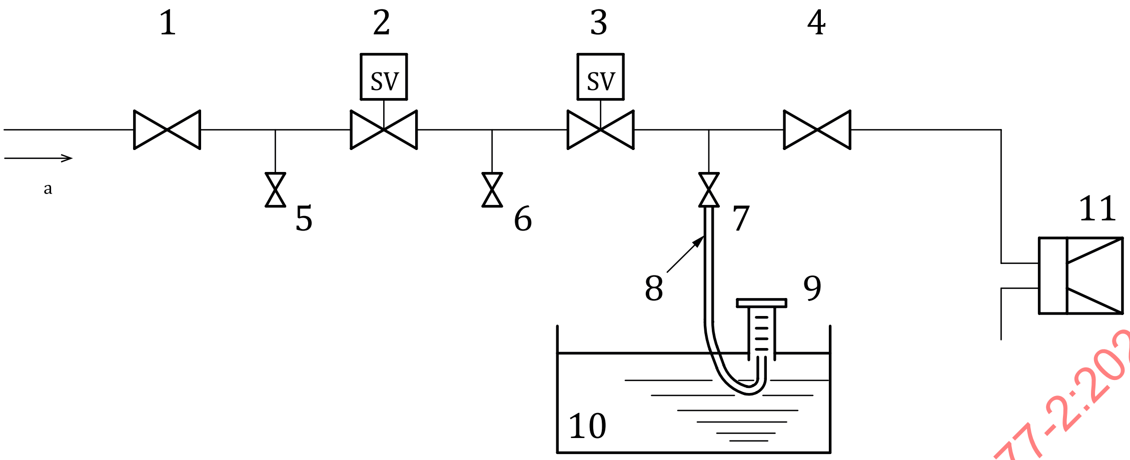
4) Same procedure is applied to check if there is a leakage in SV1 arranged at upstream of SV2.

5) When the test is done for three valves or more, the same test method shall be applied starting from the valve placed at the most downstream position.

6) When fuel gas pressure cannot be used for the test (e.g. central pipework for low cycling applications, see Figure G.8), supply high-pressure air from each check port TV1 just upstream of the examined automatic shut-off valve.

7) The leak rate shall be in accordance with the value specified in ISO 23550:2018, 7.2.

NOTE This is only one way to determine leak tightness and other techniques are available.



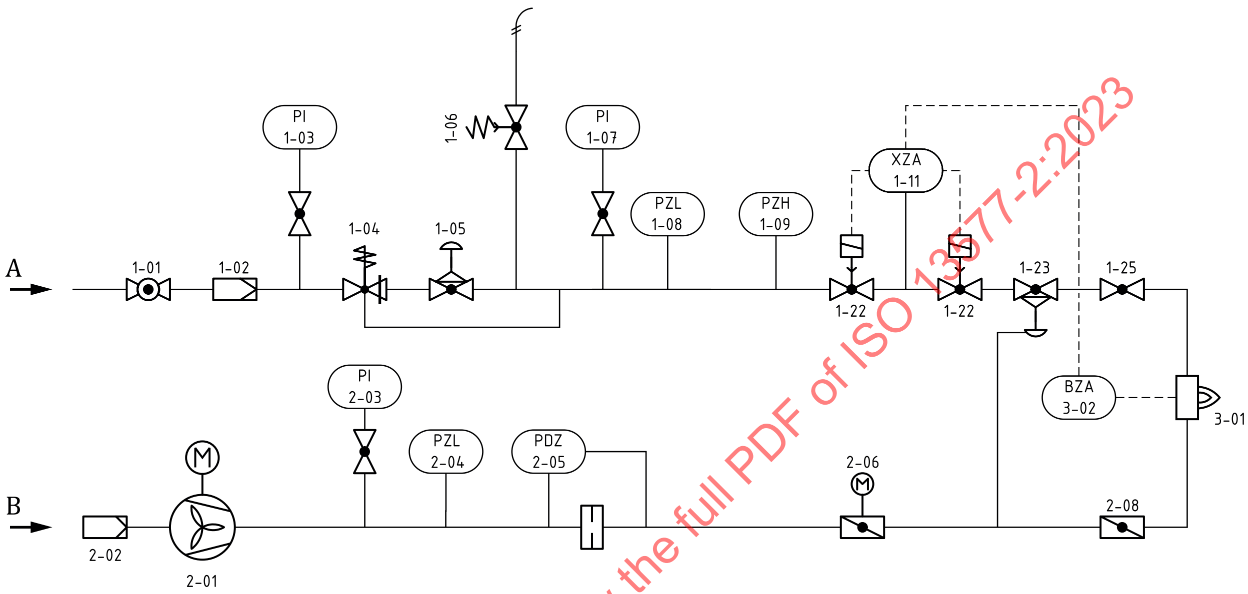
Key

1 burner manual shut-off valve 1 (V1)
2 automatic shut-off valve 1 (SV1)
3 automatic shut-off valve 2 (SV2)
4 burner manual shut-off valve 2 (V2)
5 test valve 1 (TV1)
6 test valve 2 (TV2)
7 test valve 3 (TV3)
8 flexible hose
9 measuring cylinder
10 water vessel
11 burner
[a] Fuel gas flow direction.

Figure F.1 — In piping diagram for valve tightness check

Annex G
(informative)

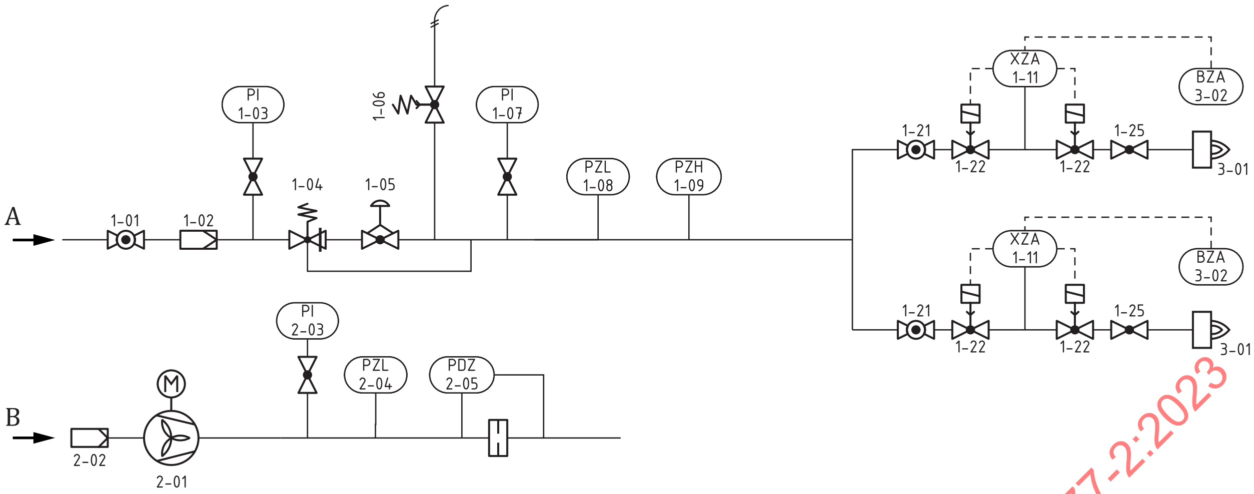
Example of piping and components



Key

1–01	manual isolating valve	2–01	combustion air fan
1–02	filter/strainer	2–02	air inlet filter
1–03	pressure indicator (PI) upstream with gauge cock	2–03	pressure indicator (PI) with gauge cock
1–04	overpressure cut-off device	2–04	low air pressure sensing device (PZL)
1–05	gas pressure regulator	2–05	air flow sensing device (PDZ)
1–06	relief valve, if applicable	2–06	air flow control valve with motor (M)
1–07	pressure indicator (PI) downstream with gauge cock	2–08	manual air flow adjustment valve for burner
1–08	low gas pressure sensing device (PZL)		
1–09	high gas pressure sensing device (PZH)	3–01	burner
1–11	automatic valve proving (XZA)	3–02	automatic burner control/automatic burner control system (BZA)
1–22	burner automatic shut-off valve with ability of adopting test point at inlet and outlet		
1–23	pneumatic air/gas ratio control	A	gas
1–25	manual gas flow adjustment valve for burner	B	air

Figure G.1 — Single burner equipment



Key

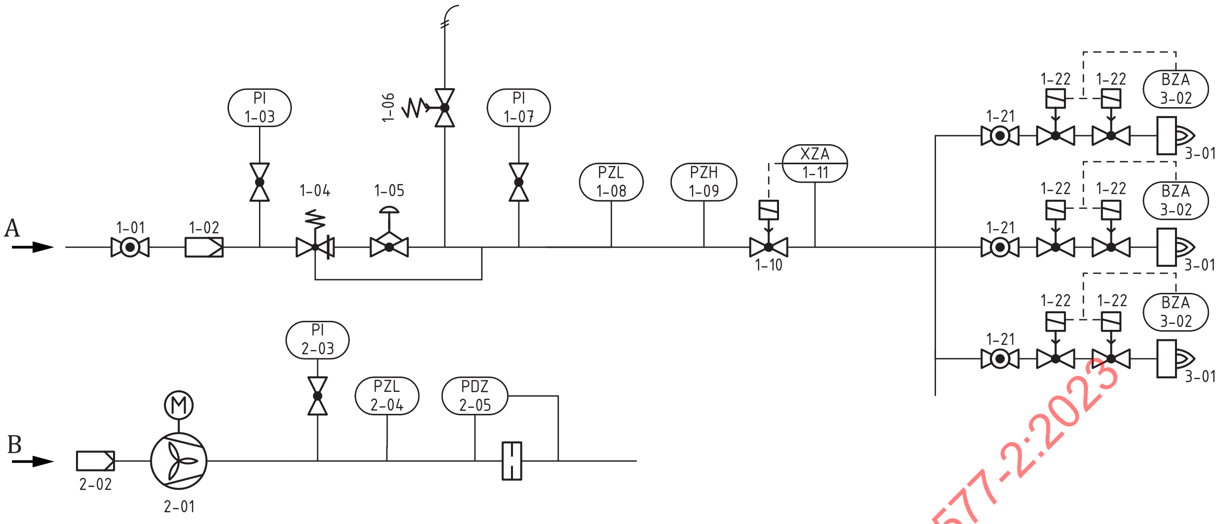
1–01 manual isolating valve
1–02 filter/strainer
1–03 pressure indicator (PI) upstream with gauge cock
1–04 overpressure cut off device
1–05 gas pressure regulator
1–06 relief valve, if applicable
1–07 pressure indicator (PI) downstream with gauge cock
1–08 low gas pressure sensing device (PZL)
1–09 high gas pressure sensing device (PZH)
1–11 automatic valve proving (XZA)
1–21 burner manual shut-off valve
1–22 burner automatic shut-off valve with ability of adopting test point at inlet and outlet
1–25 manual gas flow adjustment valve for burner

2–01 combustion air fan
2–02 air inlet filter
2–03 pressure indicator (PI) with gauge cock
2–04 low air pressure sensing device (PZL)
2–05 air flow sensing device (PDZ)

3–01 burner
3–02 automatic burner control/automatic burner control system (BZA)

A gas
B air

Figure G.2 — Multiple burner equipment –Central pipework – Example of a two burners system



Key

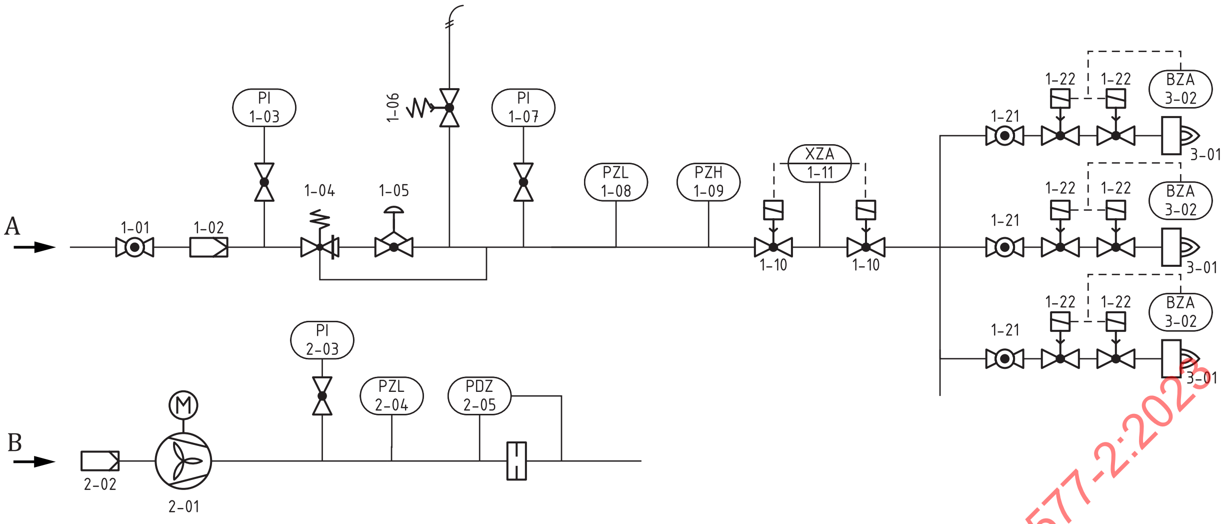
1–01 manual isolating valve
1–02 filter/strainer
1–03 pressure indicator (PI) upstream with gauge cock
1–04 overpressure cut-off device
1–05 gas pressure regulator
1–06 relief valve, if applicable
1–07 pressure indicator (PI) downstream with gauge cock
1–08 low gas pressure sensing device (PZL)
1–09 high gas pressure sensing device (PZH)
1–10 central automatic shut-off valve
1–11 automatic valve proving (XZA)
1–21 burner manual shut-off valve
1–22 burner automatic shut-off valve with ability of adopting test point at inlet and outlet

2–01 combustion air fan
2–02 air inlet filter
2–03 pressure indicator (PI) with gauge cock
2–04 low air pressure sensing device (PZL)
2–05 air flow sensing device (PDZ)

3–01 burner
3–02 automatic burner control/automatic burner control system (BZA)

A gas
B air

Figure G.3 — Multiple burner equipment – Central pipework – Example b



Key

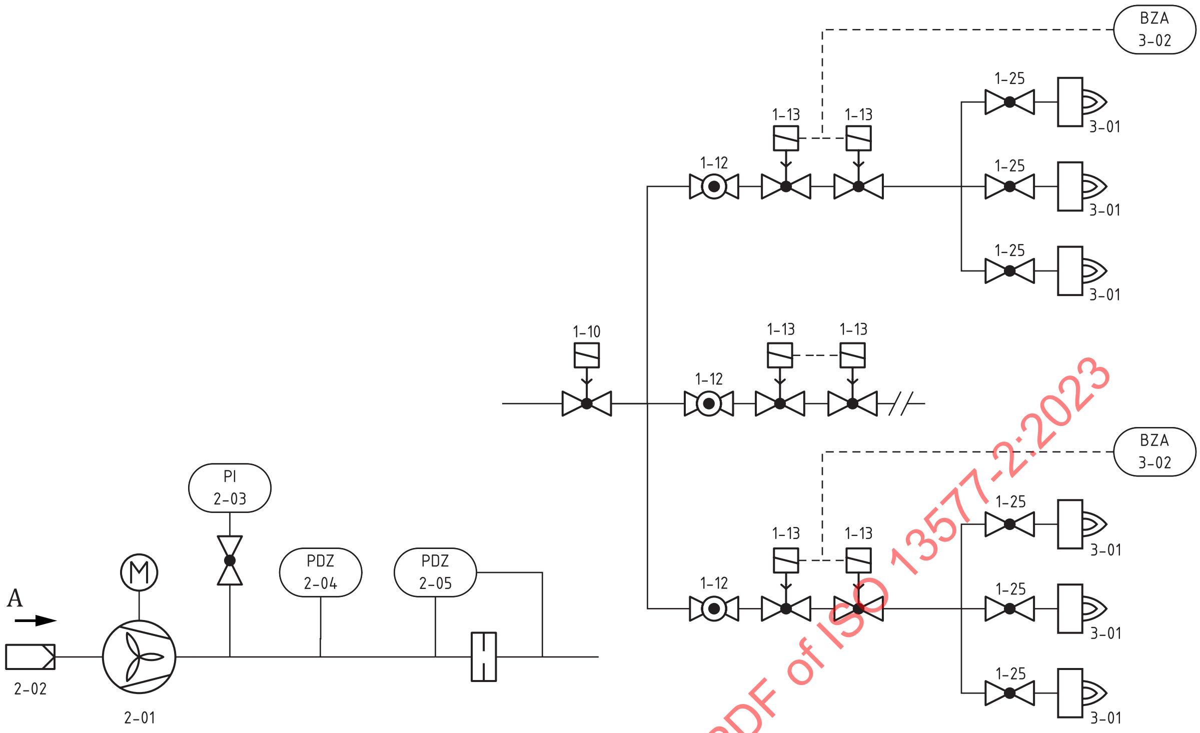
1–01 manual isolating valve
1–02 filter/strainer
1–03 pressure indicator (PI) upstream with gauge cock
1–04 overpressure cut-off device
1–05 gas pressure regulator
1–06 relief valve, if applicable
1–07 pressure indicator (PI) downstream with gauge cock
1–08 low gas pressure sensing device (PZL)
1–09 high gas pressure sensing device (PZH)
1–10 central automatic shut-off valve with ability of adopting test point at inlet and outlet
1–11 automatic valve proving (XZA)
1–21 burner manual shut-off valve
1–22 burner automatic shut-off valve with ability of adopting test point at inlet and outlet

2–01 combustion air fan
2–02 air inlet filter
2–03 pressure indicator (PI) with gauge cock
2–04 low air pressure sensing device (PZL)
2–05 air flow sensing device (PDZ)

3-01 burner
3-02 automatic burner control/automatic burner control system (BZA)

A gas
B air

Figure G.4 — Multiple burner equipment – Central pipework – Example c



Key

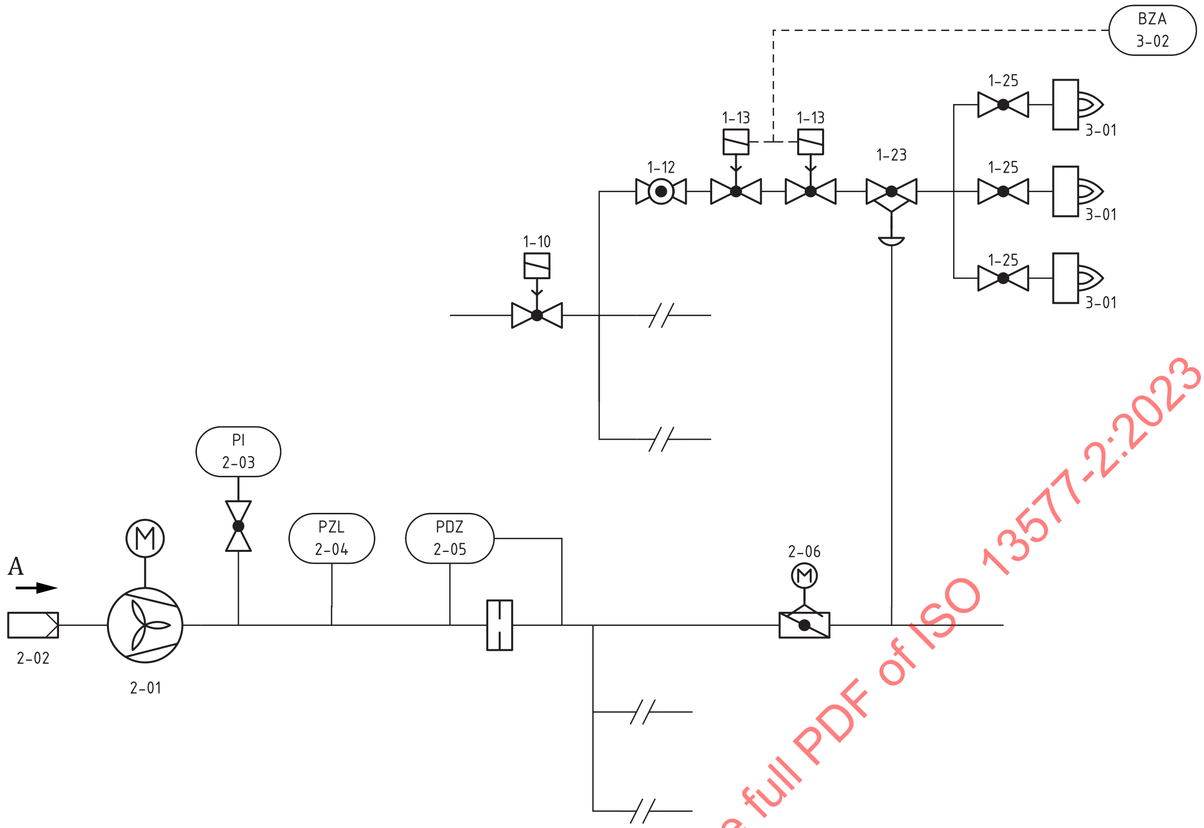
1–10 central automatic shut-off valve
1–12 zone isolating valve
1–13 zone automatic shut-off valve with ability of adopting test point at inlet and outlet
1–25 gas flow adjustment for burner

2–01 combustion air fan
2–02 air inlet filter
2–03 pressure indicator (PI) with gauge cock
2–04 low air pressure sensing device (PZL)
2–05 air flow sensing device (PDZ)

3–01 burner
3–02 automatic burner control/automatic burner control system (BZA)

A gas

Figure G.5 — Multiple burner equipment – Zone pipework – Example a



Key

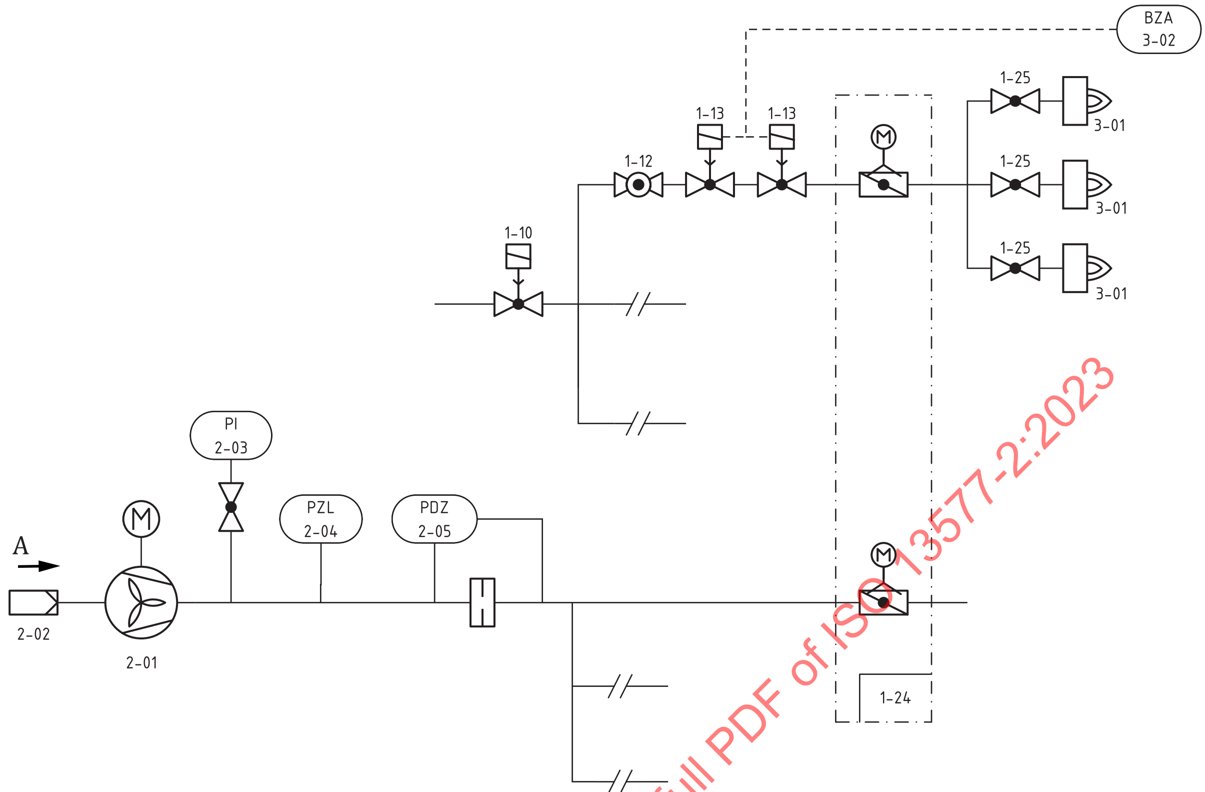
1–10 central automatic shut-off valve
1–12 zone isolating valve
1–13 zone automatic shut-off valve with ability of adopting test point at inlet and outlet
1–23 pneumatic air/gas ratio control
1–25 gas flow adjustment for burner

2–01 combustion air fan
2–02 air inlet filter
2–03 pressure indicator (PI) with gauge cock
2–04 low air pressure sensing device(PZL)
2–05 air flow sensing device (PDZ)
2–06 air flow control valve with motor (M)

3–01 burner
3–02 automatic burner control/automatic burner control system (BZA)

A gas

Figure G.6 — Multiple burner equipment – Zone pipework – Example b



Key

1–10 central automatic shut-off valve

1–12 zone isolating valve

1–13 zone automatic shut-off valve with ability of adopting test point at inlet and outlet

1–24 electronic air/gas ratio control

1–25 gas flow adjustment for burner

2–01 combustion air fan

2–02 air inlet filter

2–03 pressure indicator (PI) with gauge cock

2–04 low air pressure sensing device (PZL)

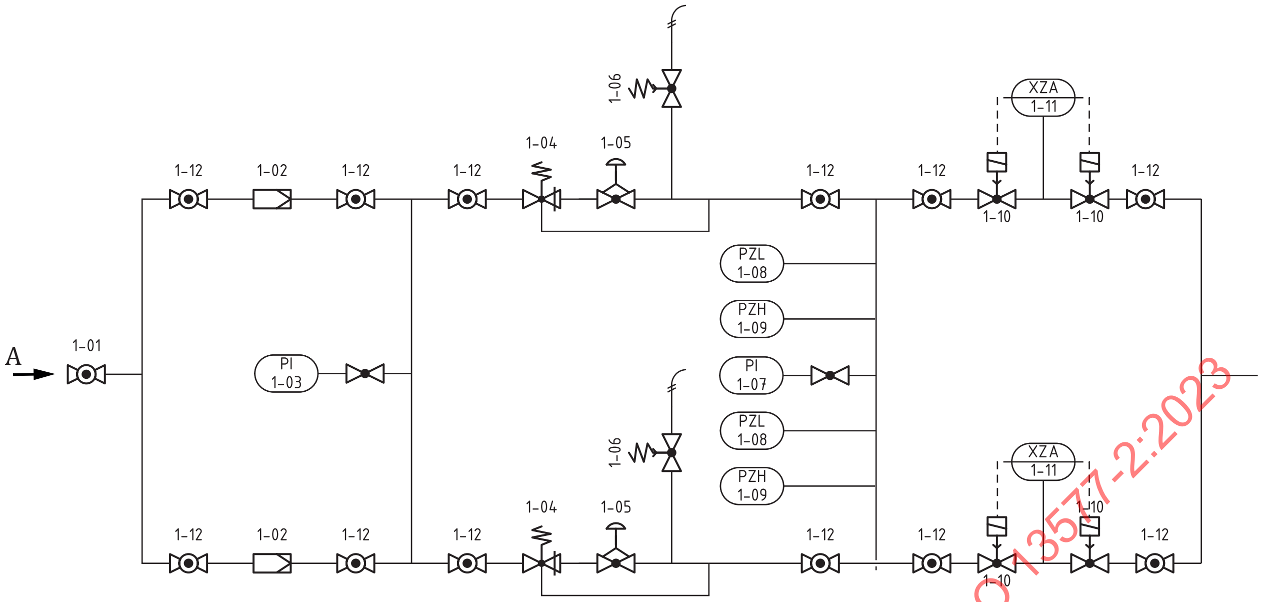
2–05 air flow sensing device (PDZ)

3–01 burner

3–02 automatic burner control/automatic burner control system (BZA)

A gas

Figure G.7 — Multiple burner equipment – Zone pipework – Example c

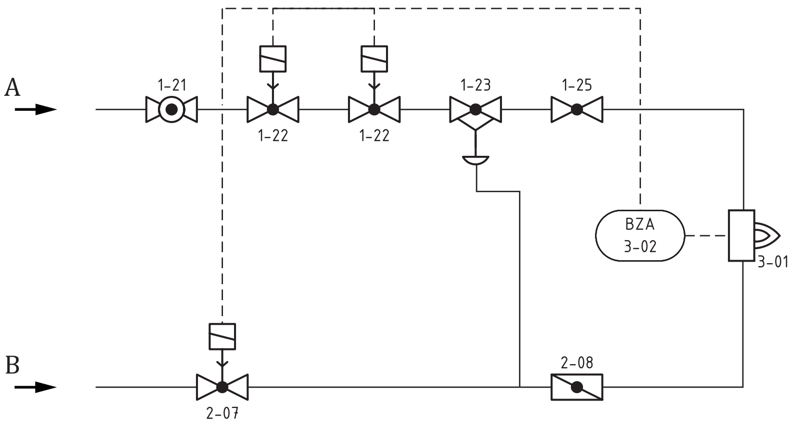


Key

1–01 manual isolating valve
1–02 filter/strainer
1–03 pressure indicator (PI) upstream with gauge cock
1–04 overpressure cut-off device
1–05 gas pressure regulator
1–06 relief valve, if applicable
1–07 pressure indicator (PI) downstream with gauge cock
1–08 low gas pressure sensing device (PZL)
1–09 high gas pressure sensing device (PZH)
1–10 central automatic shut-off valve with ability of adopting test point at inlet and outlet
1–11 automatic valve proving (XZA)
1–12 zone isolating valve

A gas

Figure G.8 — Redundant central pipework



Key

1–21 burner manual shut-off valve

1–22 burner automatic shut-off valve with ability of adopting test point at inlet and outlet

1–23 pneumatic air/gas ratio control

1–25 manual gas flow adjustment valve for burner

2–07 air flow valve for burner

2–08 manual air flow adjustment valve for burner (to ensure sufficient impulse pressure for the pneumatic regulator)

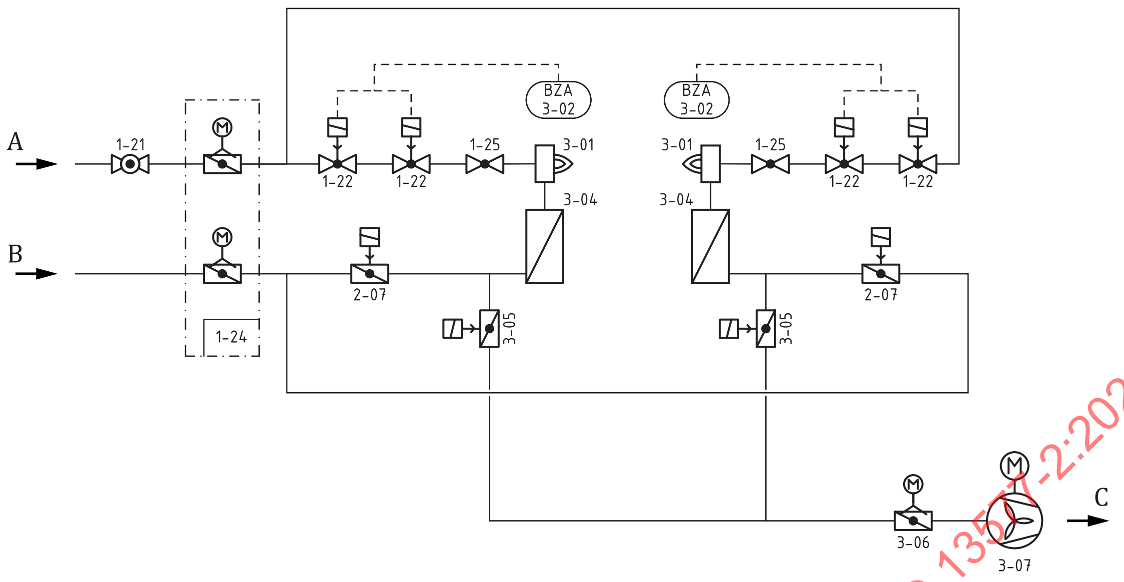
3–01 burner

3–02 automatic burner control/automatic burner control system (BZA)

A gas

B air

Figure G.9 — Impulse firing installation (burner pipework)



Key

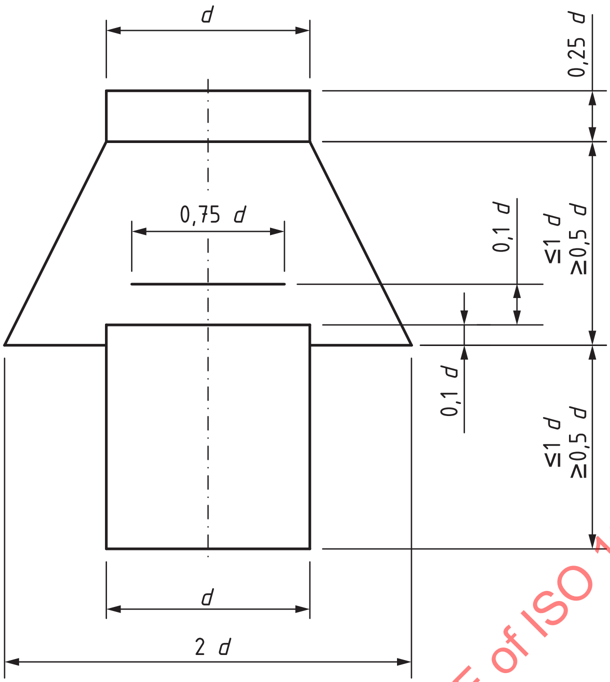
1–21 burner manual shut-off valve
1–22 burner automatic shut-off valve with ability of adopting test point at inlet and outlet
1–24 electronic air/gas ratio control
1–25 manual gas flow adjustment valve for burner

2–07 air flow valve for burner

3–01 burner
3–02 automatic burner control/automatic burner control system (BZA)
3–04 regenerator
3–05 flue gas valve
3–06 flue gas flow control valve with motor (M)
3–07 flue gas fan

A gas
B air
C flue gas

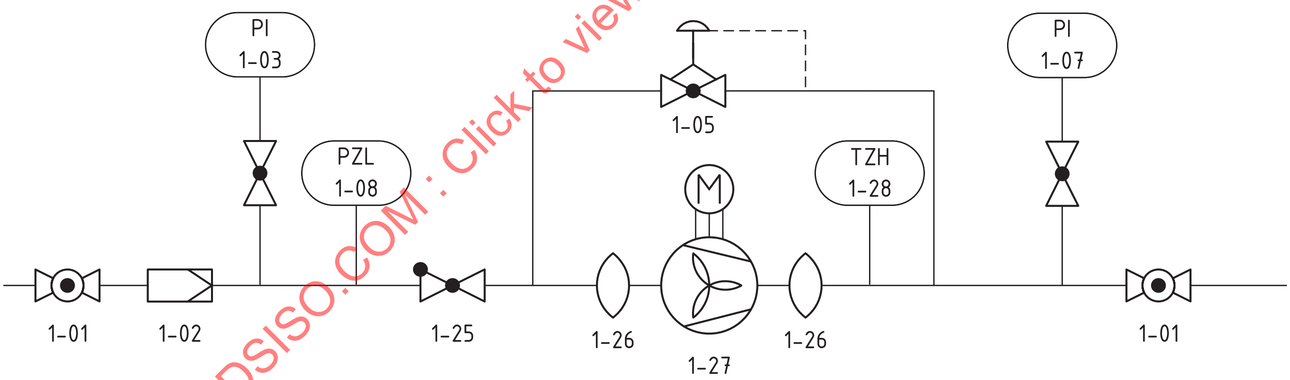
Figure G.10 — regenerative burner pipework



Key

d tube diameter

Figure G.11 — Draft breaks



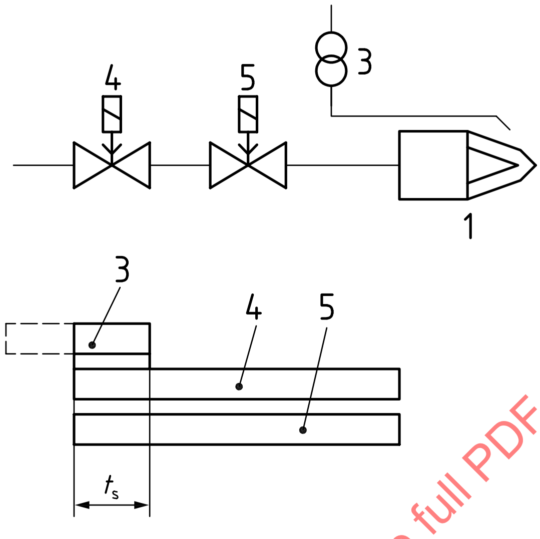
Key

1-01 manual isolating valve
1-02 filter/strainer
1-03 pressure indicator (PI) upstream with gauge cock
1-05 gas pressure regulator
1-07 pressure indicator (PI) downstream with gauge cock
1-08 low gas pressure sensing device (PZL)
1-25 non-return valve
1-26 flexible tubing
1-27 gas booster
1-28 high temperature sensing device (TZH)

Figure G.12 — Gas pressure booster system

Annex H
(informative)

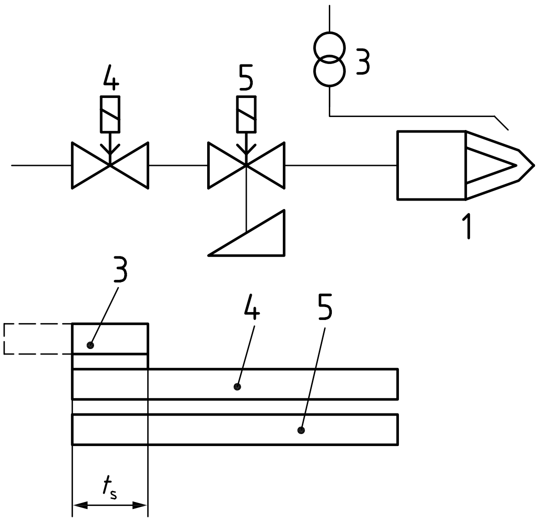
Methods for burner start-up



Key

1 burner
3 ignition
4 1st automatic shut-off valve
5 2nd automatic shut-off valve
t_S safety time

Figure H.1 — Direct main burner ignition at full rate (see Table 3, column 2, $Q_{F\ max}$ ≤ 120 kW)



Key

1 burner

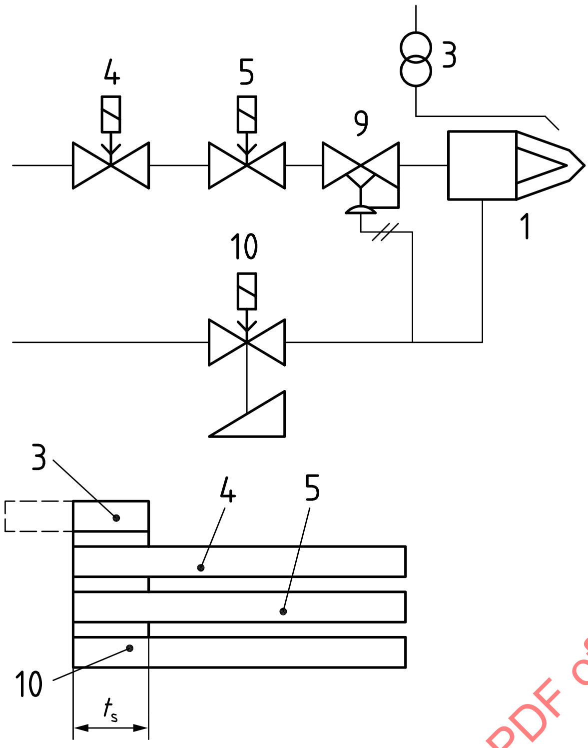
3 ignition

4 1st automatic shut-off valve

5 2nd automatic shut-off valve slow opening

t_S safety time

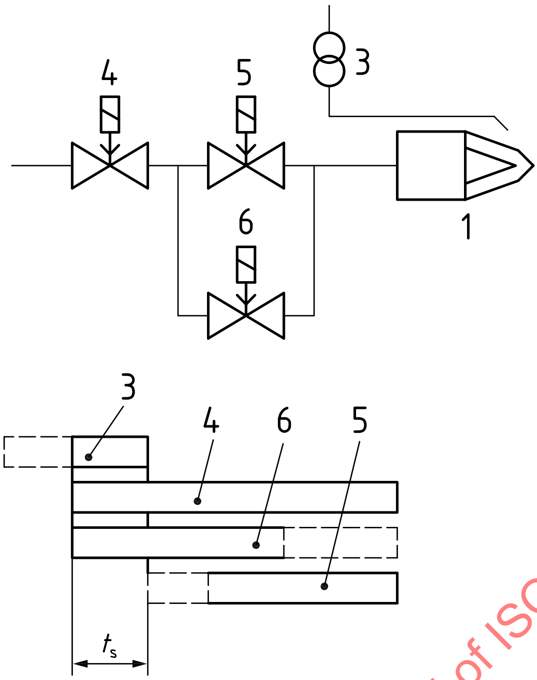
Figure H.2 — Direct main burner ignition at reduced rate with slow opening valve-1 (see Table 3, column 3, $Q_{F\ max} \leq 360$ kW)



Key

1 burner
3 ignition
4 1st automatic shut-off valve
5 2nd automatic shut-off valve
9 air/gas ratio control (PDCV)
10 air valve slow opening
t_S safety time

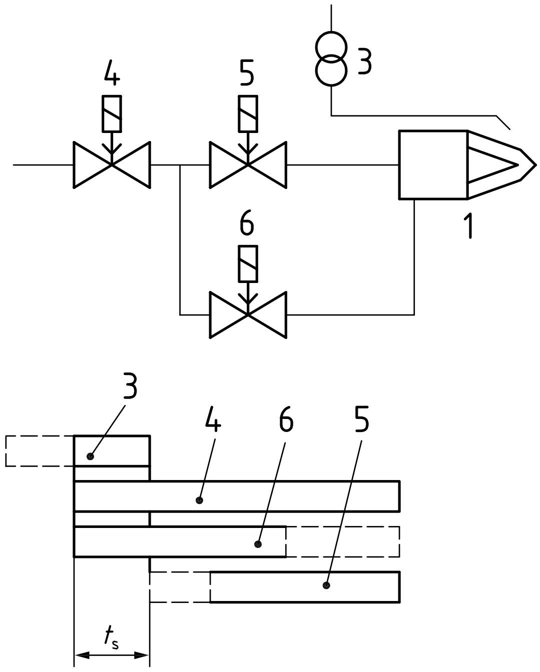
Figure H.3 — Direct main burner ignition at reduced rate with slow opening valve-2 (see Table 3, column 3, $Q_{F\ max}$ ≤ 360 kW)



Key

1 burner
3 ignition
4 1st automatic shut-off valve
5 2nd automatic shut-off valve
6 bypass shut-off valve
t_S safety time

Figure H.4 — Direct main burner ignition at reduced rate with bypass start gas supply (see Table 3, column 4)



Key

1 burner

3 ignition

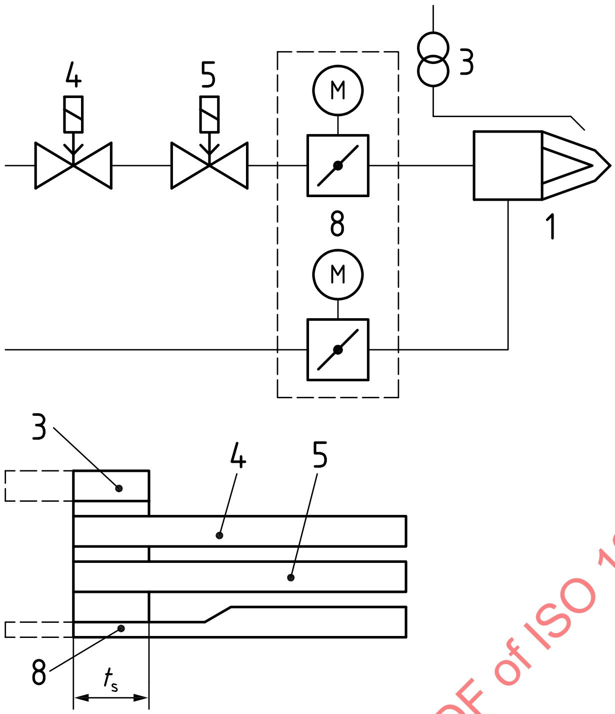
4 1st automatic shut-off valve

5 2nd automatic shut-off valve

6 bypass shut-off valve

t_S safety time

Figure H.5 — Direct main burner ignition at reduced rate with bypass start gas supply (see Table 3, column 4)



Key

1 burner
3 ignition
4 1st automatic shut-off valve
5 2nd automatic shut-off valve
8 electronic air/gas ratio control with motor (M)
t_S safety time

Figure H.6 — Direct main burner ignition at reduced rate with limited start gas input (see Table 3, column 4)