TECHNICAL ASSOCIATION
OF THE EUROPEAN NATURAL GAS INDUSTRY

Guidelines for Industrial Gas Installations

FINAL

Version 17

Exploration&Production → Processing → Transmission → Distribution → END USERS

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1. INTRODUCTION

Gas industry leaders acknowledge the strategic role of European and National Standards. They are making their research, expertise and experience available by sending their experts to Technical Committees in order to participate in elaborating functional and detailed standards.

European, national legislation and the related framework of standards are complex and changing at an ever increasing pace. For industrial plant engineers, finding these standards can be a difficult task, demands specific knowledge and can consume a considerable amount of time. This guideline has been compiled by a Marcogaz Technical Committee to give the reader a clear understanding of the different sections of an industrial gas installation and the related European standards to be applied.

As designers and installers apply the prevailing standards for design, construction, testing, commissioning and operation of an industrial gas installation, safety not only increases but also the full energy efficiency potential of industrial thermal processes are utilised. As a result, customers are being stimulated to increase adoption and use of natural gas as the fuel of choice in place of alternative energy sources.

1.1 Marcogaz

Created in 1968, Marcogaz has developed over the years a very good reputation with the official bodies in the European Union and other industry partners. Marcogaz chief mission is to serve its members as the European window for most of the technical issues regarding natural gas.

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As the representative organisation of the European Natural Gas Industry, it aims at monitoring and contributing to European technical regulation, standardisation and certification with respect to safety and integrity of gas systems and equipment, and rational use of energy. Environment, Health and Safety issues related to natural gas systems and efficient utilisation are of paramount importance for Marcogaz and its members.

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1.2 Scope

Industrial Gas Installations (I.G.Is):

The scope of this document covers Industrial Gas Installations (I.G.I.) from gas pipework downstream of the “point of delivery” up to and including the “industrial thermal process” (that is, gas consuming equipment that falls outside the scope of the Gas Appliances Directive).

The term, “point of delivery” is the isolation valve (or combination of regulator and isolation valve) located before or after the metering station, as defined by the particular EU member state national legislation.

Industrial thermal processes are those processes that fall outside the scope of the Gas Appliance Directive. The range of industrial thermal process equipment is significant providing energy solutions to customers for a diverse range of applications, a sample including:

Examples of natural gas application by branch

Metal industry
Blast-furnace
Calcining furnace
Casting furnace
Crucible furnace
Forge
Hardening furnace
Melting furnace
Reverberatory furnace
Tempering furnace

Chemical / Process industry
Afterburner
Calcination drum
Catalytic afterburner
Cracking unit
Fermentation
Fluid bed combustor
Incinerator
Perlite furnace
Refinery waste gas flare
Spray dryer
Sterilization food-/pharmaceutical products

Central heat and power
Gas turbine
Gas motor
Reciprocating engine
Shell boiler
Wast gas boiler
Water tube boiler

Brickyard
Brick kiln
Dry chambers (driers)
Progressive kiln
Round down-draft kiln
Tunnel furnace

Miscellaneous
Asphalt cooking still (vertical tube type)
Carbon black applications
Continuous band oven
High temperature cement kiln
Make-up air
Rock wool melting furnace
Roll heating (roofing machinery rolls, paper mill rolls)
Rotary oven

Paint drying
Chamber kiln

Ceramic
Dryer
Heating furnace
Annealing furnace
Decorating kiln
Firing furnace

Glass
Melting furnace
Feeder
Decorating arch
Glassware flamework

Commercial Gas Installations, within the context of this document, are non-domestic in application, gas pipework operating at a pressure equal to or less than 0.5 bar while utilising gas consuming equipment that falls within the scope of the Gas Appliance Directive (G.A.D.).

1.3 Objective and aim of the document

This guideline has been compiled by a Marcogaz Technical Committee to give the reader a clear understanding of the different possible component parts of an industrial gas installation and the related European directives and standards to be applied.

This document delves into the specific areas of the industrial gas installation: directives and standards, safety, quality management & assessment, gas quality and the environment.

This document is neither exhaustive, nor categorical, nor definitive. No liability can be assumed by Marcogaz for any damage or less by application of this recommendation.

2. THE INDUSTRIAL GAS INSTALLATION

Down-stream of the "point of delivery", depending on the complexity of the installation and volume of gas being consumed, normally comprises of pipework, regulator(s), slam-shut(s) and industrial thermal process equipment. See figure 1 for illustrative details.

Note: The term "point of delivery" is the end of the network. This can be isolation valve (or combination of regulator and isolation valve) located before or after the metering station, as defined by the particular EU member state.

2.1 Gas Installation Components and Safety Devices

Each industrial gas installation may consist of a number of the listed items below:

- Gas Pressure Regulator, Metering device, Pipework, Compressor, Ancillaries

- Gas Detection & Automatic Shut-Off Valve, Gas Proving System and Thermal Process Safety Devices [e.g. Burner Control Units (EN 298)].

Figure 1: example of an industrial gas installation

2.2 European Standards

Industrial installations are affected during their design, construction, operation and maintenance by a variety of directives, regulations and technical standards. Though every effort has been made to include all related E.N. standards, the below listing is not exhaustive.

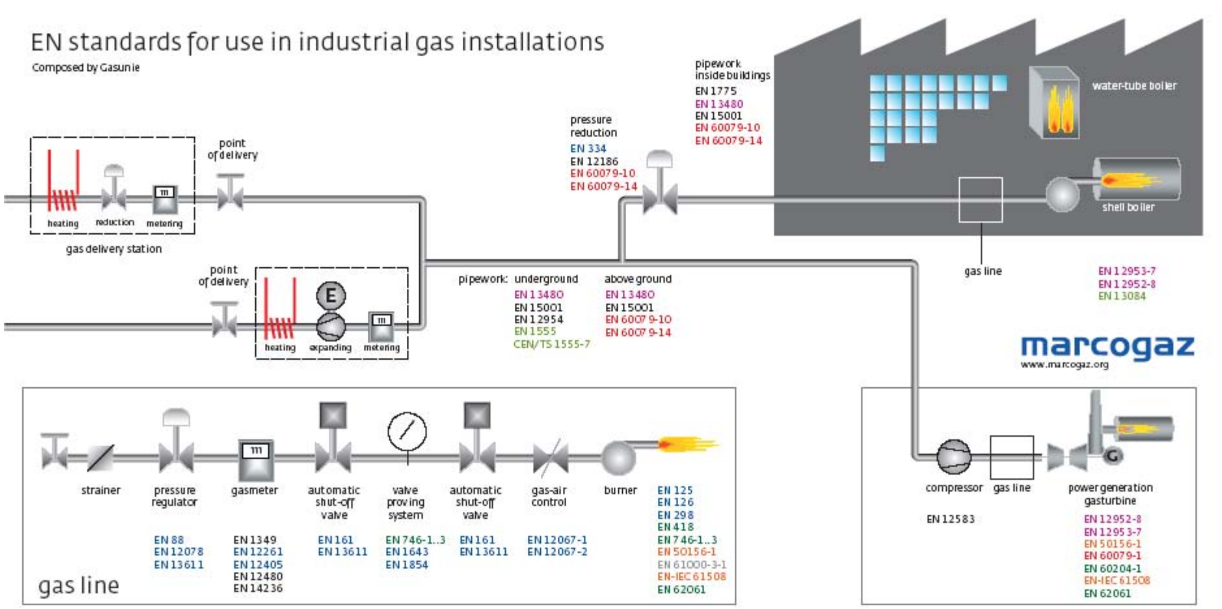


Figure 2: The Gas Installation,

Downstream of the Point of Delivery

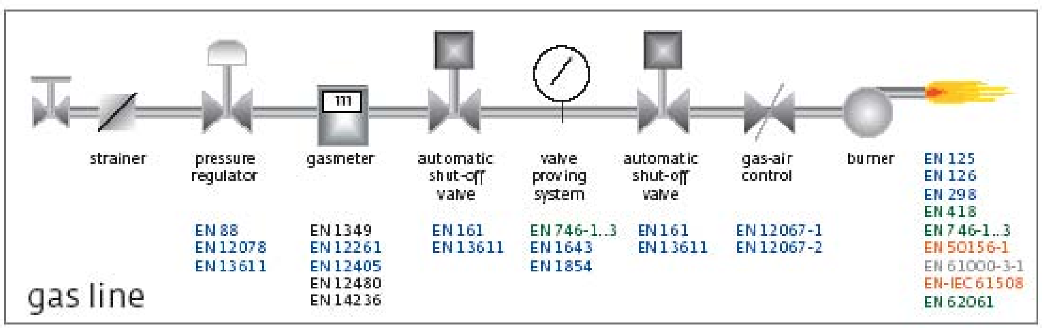


Figure 3: Description of the Gas Train (or Line)

Directive/ Standard	Description
98/37/EC MD	**Machinery**
EN 418	Safety of machinery - Emergency stop equipment, functional aspects - Principles for design
EN 746-1	Industrial thermo processing equipment - Part 1: Common safety requirements for industrial thermo processing equipment
EN 746-2	Industrial thermo processing equipment - Part 2: Safety requirements for combustion and fuel handling systems
EN 746-3	Industrial thermo processing equipment - Part 3: Safety requirements for the generation and use of atmosphere gases
EN 60204-1	Safety of machinery - Electrical equipment of machines - Part 1: General requirements (IEC 60204-1:1997)
EN 62061	Safety of machinery - Functional safety of safety-related electrical, electronic and programmable electronic control systems (IEC 62061:2005)
2004/108/EC EMC	**Electromagnetic compatibility (EMC)**
EN 61000-3-1	Electromagnetic compatibility (EMC)
94/9/EC ATEX	**Equipment explosive atmospheres (ATEX)**
EN 50154	Electrical installation in explosive atmospheres
EN 60079-10	Electrical apparatus for explosive gas atmospheres - Classification of hazardous areas
EN 60079-14	Electrical apparatus for explosive gas atmospheres - Electrical installations in hazardous areas
97/23/EC PED	**Pressure Equipment**
EN 12583	Compressor stations
EN 12952-8	Water-tube boilers and auxiliary installations - Part 8: requirements for firing systems for liquid and gaseous fuels for the boiler
EN 12953-7	Shell boilers - Part 7: Requirement for firing systems for liquid and gaseous fuels for the boiler
EN 13480-1	Metallic industrial piping - Part 1: General
EN 13480-2	Metallic industrial piping - Part 2: Materials
EN 13480-3	Metallic industrial piping - Part 3: Design and calculation
EN 13480-4	Metallic industrial piping - Part 4: fabrication and installation
EN 13480-5	Metallic industrial piping - Part 5: Inspection and testing

2004 / 22 / EEG	**Measuring instruments**
EN 1359	Gas meters - Diaphragm gas meters
EN 12261	Gas meters - Turbine gas meters
EN 12405	Gas meters - Conversion devices - Part 1: Volume conversion
EN 12480	Gas meters - Rotary displacement gas meters
EN 14236	Ultrasonic domestic gas meters

Directive/ Standard	Description
90 / 396 / EEC GAD	**Appliances burning gaseous fuels**
EN 88	Pressure governors for gas appliances for inlet pressures up to 200 mbar
EN 125	Flame supervision devices for gas burning appliances - Thermo-electric flame supervision devices
EN 126	Multifunctional controls for gas burning appliances
EN 161	Automatic shut-off valves for gas burners and gas appliances
EN 298	Automatic gas burner control systems for gas burners and gas burning appliances with or without fans
EN 676	Automatic forced draught burners for gaseous fuels
EN 1643	Valve proving systems for automatic shut-off valves for gas burners and gas appliances
EN 1854	Pressure sensing devices for gas burners and gas burning appliances
EN 12067-1	Gas/air ratio controls for gas burners and gas burning appliances - Part 1: Pneumatic types
EN 12067-2	Gas/air ratio controls for gas burners and gas burning appliances - Part 2: Electronic types
EN 12078	Zero governors for gas burners and gas burning appliances
EN 13611	Safety and control devices for gas burners and gas-burning appliances - General requirements
89 / 106 / EEC CPD	**Construction Products**
EN 1856	Chimneys - Requirements for metal chimneys
EN 12583	Gas supply systems - Compressor stations. Functional requirements
EN 12954	Cathodic protection of buried or immersed metal structures. General principles and application for pipelines
EN 13084	Free-standing chimneys
EN 15001	pipework MOP 0,5 up to 60 bar for industrial gas installations

2006/95/EC LVD	**Low Voltage**
EN IEC 61508	Functional safety of electrical/electronic/programmable electronic safety related systems - Part 5: Examples of methods for the determination of Safety Integrity Levels
EN IEC 61511	Functional safety - Safety instrumented systems for the process industry sector
EN 50156-1	Electrical equipment for furnaces and ancillary equipment Part 1: Requirements for application design and installation
92/42/EEC	**Efficiency Requirements for new hot-water boilers fired with liquid or gaseous fuels**
EN 303-3	Heating boilers - Part 3: Gas-fired central heating boilers - Assembly comprising a boiler body and a forced draught burner
EN 303-7	Heating boilers - Part 7: Gas-fired central heating boilers equipped with a forced draught burner of nominal heat output not exceeding 1000 kW
EN 656	Gas-fired central heating boilers - Type B boilers of nominal heat input exceeding 70 kW but not exceeding 300 kW
EN 677	Gas-fired central heating boilers - Specific requirements for condensing boilers with a nominal heat input not exceeding 70 kW
EN 13836	Gas fired central heating boilers - Type B boilers of nominal heat input exceeding 300 kW, but not exceeding 1000 kW

Fig. 4: list of EU standards affecting Industrial Installations

2.3 The European Directives and Gas System Related Thresholds

Industry has to comply with essential safety requirements specified in a lot of European Directives. Those Directives were written to improve safety at work in Europe. They could be split in two categories: Directives for manufacturers and Directives for end-users.

2.3.1 Safety Directives for manufacturers of equipments used at works

For any equipment designed for use at work and covered by a Directive, the manufacturer should draw up a CE declaration of conformity for certifying the compliance of the equipment to the Directive requirements and affix the CE marking to guarantee this conformity. Generally, specific “harmonized” standards (that give a presumption of conformity) are available for helping the manufacturer to meet safety requirements. This type of Directive concerns only new equipments placed on the market and/or put into service.

Some of the “Manufacturers” Directives concern industrial equipments using natural gas or equipment that are part of gas system installations. Notably, the following Directives should be considered:

Machinery Directive 2006/42/EC: 3rd Safety Directive (after those released in 1989 and 1998) fixing safety requirements for designing, constructing, installing and commissioning machineries used in industry. All industrial thermal equipments (ovens, kilns, furnaces for drying, heating, melting, annealing, firing , . . . etc.), except boilers and building heating systems, are considered as machinery. The standard EN 746 part 1 to 8 gives to the manufacturer’s technical specifications harmonised with the Directive. As far as combustion and gas fuel handling systems are concerned, the reference is EN 746 part 2. Gas pipeworks (and components fitted on them) when they are parts of the thermal equipment shall comply with this standard.

Gas Appliances Directive 90/396/EEC: because appliances designed for uses in industrial processes carried out on industrial premises are out of its scope, this Directive is not directly applied in industry. Nevertheless, automatic forced draught burners and many components used for the safety or the control of gas system installations are designed and constructed in compliance with European Standards harmonised with the G.A.D. Directive. Examples: automatic forced draught burners for gaseous fuels (EN 676), safety shut off valves (EN 161), burner control units (EN 298), air gas ratio controllers (EN 12067), zero governors (EN 12078), valve proving systems (EN 1643) and pressure switches (EN 1854).

Pressure Equipment Directive 97/23/EC: this Directive applies to the design, manufacture and conformity assessment of pressure equipment and assemblies with a maximum allowable pressure greater than 0.5 bar. Gas pipeworks (if pressure > 0.5 bar) and gas-fired boilers (steam boilers with pressure > 0.5 bar and water boilers with temperature > 105°C) are part of the scope of the Directive.

Regarding gas pipeworks:

- If DN < 25 mm, the only requirement is to be designed and manufactured in accordance with the sound engineering practice of a Member State in order to ensure safe use. There is no CE marking.
- If 25 < DN < 100 mm and pressure < 1000/DN, gas pipes shall be designed and manufactured in accordance with a conformity assessment procedure “Module A “ (internal production control). The CE marking is requested except if the gas pipework is part of an industrial thermal equipment compliant with Machinery Directive, because then it is supposed to meet the PED requirements.
- In other cases, the conformity assessment procedure is more constraining and depends on the diameter and the pressure.

- The harmonised reference standard is EN 15001 part 1 and 2.

Regarding gas-fired boilers:

- For generators of water steam higher than 0.5 bar or super-heated water at temperatures higher than 100 °C but having a volume V smaller than 2 litres, the only requirement is to be designed and manufactured in accordance with the sound engineering practice of a Member State in order to ensure safe use. There is no CE marking.
- If 2 < V < 100 litres and pressure < 50/V, steam boilers shall be designed and manufactured in accordance with a conformity assessment procedure "Module A " (internal production control). The CE marking is requested.
- In other cases, the conformity assessment procedure is more constraining and depends on the volume and the pressure.
- The harmonised reference standards are EN 12952 parts 2, 3, 5, 6, 8 and 10 (water-tube boilers) and EN 12953 parts 2, 3, 5, 7 and 8 (shell boilers).

Other Directives applicable to manufacturers in industries using natural gas:

- Directive 94/9/EC concerning equipments and protective systems intended for use in potentially explosive atmospheres.
- Directive 2004/108/EC relating to the Electro Magnetic Compatibility of equipments.
- Directive 2006/95/EC relating to Low Voltage electrical equipments.

For more details see annex II of the guidelines

2.3.2 Safety Directives for industrial end-users of equipments used at work

For complying with this kind of Directive, the employer shall take the measures necessary to ensure that the work equipment is suitable for the work to be carried out and may be used by workers without impairment to their safety or health. There is neither conformity declaration nor CE marking. Generally, there are no harmonized standards related to these Directives.

Any equipment or workplace covered by a Directive and in operation at the date of application of the Directive is concerned, whatever the date of its first use in the undertaking. It means that sometimes equipments shall be put in conformity with a new "End-User" Directive. The Directive is obviously applicable for any new equipment used at work. Note that the date of application for existing installations already in use may be later than for new ones.

The main "End-User" Directives that concern employers in gas-fired thermal process industries are the following:

Directive 89/391/EEC introduces measures to encourage *improvements in the safety and health of workers at work* and applying to all sectors of activity, especially industrial. According to the Directive, the employer shall take the measures necessary for the safety and health protection of workers, on the basis of general principles of prevention: avoiding risks, evaluating the risks which cannot be avoided, reducing the risks at the source, giving appropriate instructions and training to the workers.

Obviously, any gas-fired thermal equipment or gas system installed in industrial premises is concerned by this very general safety Directive. Article 16 provides a procedure for adopting individual Directives, in defined areas, that complete this general Directive.

Directive 89/655/EEC concerns *the minimum safety and health requirements for the use of work equipment by workers at work* (2^{nd} individual Directive within the meaning of Article 16 of Directive 89/391/EEC). It provides general minimum requirements applicable to work equipments. In particular, all work equipment must be appropriate for protecting workers against the risk of fire or overheating, or of discharges of gas, dust, liquid, vapour or other substances used in the work equipment, *for preventing the risk of explosion* of the work equipment or of substances used in the work equipment. It must be fitted with a control to stop it completely and safe. Any industrial thermal equipment, considered as work equipment, shall comply with these safety requirements.

Directive 1999/92/EC provides *the minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres* (15th individual Directive within the meaning of Article 16 of Directive 89/391/EEC). According to this Directive, the employer shall take technical and/or organisational measures appropriate to the nature of the operation, in order of priority and in accordance with the following basic principles:

- the prevention of the formation of explosive atmospheres, or where the nature of the activity does not allow that,
- the avoidance of the ignition of explosive atmospheres; and
- the mitigation of the detrimental effects of an explosion so as to ensure the health and safety of workers.

As it is said, in this explosion risks assessment prescribed by the Directive, the priority for the employer is to take measures preventing everywhere the formation of explosive atmospheres rather than trying to avoid the ignition of likely explosive atmospheres inside classified hazardous zones, zones where a combustion activity would be hard to carry out! These preventive measures could lean on technical specifications that have been already applied for a long time. But, because there are no harmonised European standards related to the Directive, these technical specifications may differ from one country to another. Nevertheless, some general rules can be considered:

- The Directive does not apply to the use of appliances burning gaseous fuels in accordance with Gas Appliances Directive 90/396/EEC unless being used for non domestic purposes.
- Industrial thermo processing equipments shall comply with Machinery Directive 98/37/EC and the prevention of the risk of explosion is one of the Essential Safety Requirements of this Directive. Use EN 746 as reference.
- Industrial boilers and gas pipes with pressure greater than 0.5 bar shall comply with Equipment under pressure Directive 97/23/EC; Notably, they shall be designed to avoid a dangerous accumulation of ignitable mixtures of combustible substances and air. For steam boilers, use EN 12952 and 12953 as references.
- Gas pipeworks designed and constructed in compliance with the relevant standards (EN 1775, prEN 15001) and maintained to these standards are presumed to be tight. They must be subjected to regular checks.
- Industrial premises must be correctly ventilated. The ventilation must be reliable, or any malfunctions must be controlled by technical and/or organisational means.

It is generally considered that the risk of formation of explosive atmospheres can be controlled by applying these technical rules and good practice (for pipework, combustion equipment and ventilation) so that it is unlikely that a dangerous explosive atmosphere could form.

More detailed information about these Directives is given in section 2.3.3.

The main Directives related to the safety of the work place and gas installations and their link to the official website are listed below:

G.A.D. – Gas Appliance Directive	http://ec.europa.eu/enterprise/gas_appliances/index_en.htm
P.E.D. – Pressure Equipment Directive	http://ec.europa.eu/enterprise/pressure_equipment/ped/index_en.html
AT.EX. 95 & 137 – Atmosphere Explosive	http://ec.europa.eu/enterprise/atex/indexinfor.htm
M.D. – Machinery Directive	http://ec.europa.eu/enterprise/mechan_equipment/machinery/index.htm
L.V.D. – Low Voltage Directive	http://ec.europa.eu/enterprise/electr_equipment/lv/index.htm
E.M.C. – Electro Magnetic Compatibility	http://ec.europa.eu/enterprise/electr_equipment/emc/index.htm

C.E. – Conformité Européenne	http://www.ce-marking.org/directive-9368eec-ce-marking.html
89/391/EEC & 89/655/EEC	Per table below

2.3.3. Synthesis of Directives

Industrial installations are affected during their design, construction, operation and maintenance by a variety of directives, regulations and technical standards. The table below aims at helping to understand the main features of the most relevant Directives and the most relevant parameters associated with it.

Directive TAG	**GAD 90/396/EEC**	**PED 97/23/EC**	**ATEX95 94/9/EC**	**ATEX137 1999/92/EC**	**MD 2006/42/EC**	**LVD 2006/95/EC**	**EMC 2004/18/EC**	**89/391/EEC**	**89/655/EEC**
Directive Name	Gas Appliances Directive	Pressure Equipment Directive	Manufacturer Explosive Atmosphere	End-User Explosive Atmosphere	Machinery Directive	Low Voltage Directive	Electro Magnetic Compatibility	Safety & Health of Workers at Work	Work Equipments
Previous Directives				Related to 89/391/EEC	89/392/EEC 98/37/EC	73/23/EEC 93/68/EEC	89/336/EEC		Related to 89/391/EEC
Date of application	July 1990	May 2002	July 2003	New : 07/03 Existing: 07/06	December 2009	January 2006	July 2007	June 1989	December 89
Application of the 1st Directive					January 1993	August 1974	January 1992		
Scope	Gas appliances, forced draught burners, safety and control devices	Vessels, Piping, Generators of steam or super heated water with P>0.5 bar	Any equipment or protective system intended for use in potentially explosive atmospheres.	Any industrial workplace with potential risk from explosive atmosphere	Machinery Partly completed machinery Safety components of machinery	Electric equipments with voltage 50<AC<1000 or 75<DC<1500	Appliances liable to generate electromagnetic disturbance or to be affected by such disturbance	All sectors of activity	Any work equipment used by workers at work
Main concerned industrial	Forced draught burners and few components for	Gas pipes, Steam boilers	when there are ATEX zones : equipments	Workplaces with gas pipeworks and/or	Industrial furnaces, ovens,	Electric equipments (safety and	Electric equipments (safety and	Any industrial premise	Industrial gas-fired thermal

gas equipments or components	gas pipeworks		installed in these zones	atmosphere generators	kilns, dryers Gas turbines Gas engines	control devices)	control devices)		equipments
Main harmonised standards for gas equipments and components	EN 676 EN 161 EN 298 EN 12067 EN 12078 EN 1643	EN 15001 parts 1 and 2 EN 12952 EN 12953	EN 1127 part 1 EN 60079 parts 1 to 10	No harmonised standards	EN 746 parts 1 to 8 EN 1539	Many standards for electric devices are harmonised with 73/23/EEC	EN 61000-6-2 EN 61000-6-4	No harmonised standards	No harmonised standards
Liability	Manufacturer	Manufacturer	Manufacturer	End-User (employer)	Manufacturer	Manufacturer	Manufacturer	End-User (employer)	End-User (employer)
CE marking	Yes	Yes except if DN<25 (pipes) V<2L (boilers)	Yes	No	Yes	Yes	Yes	No	No

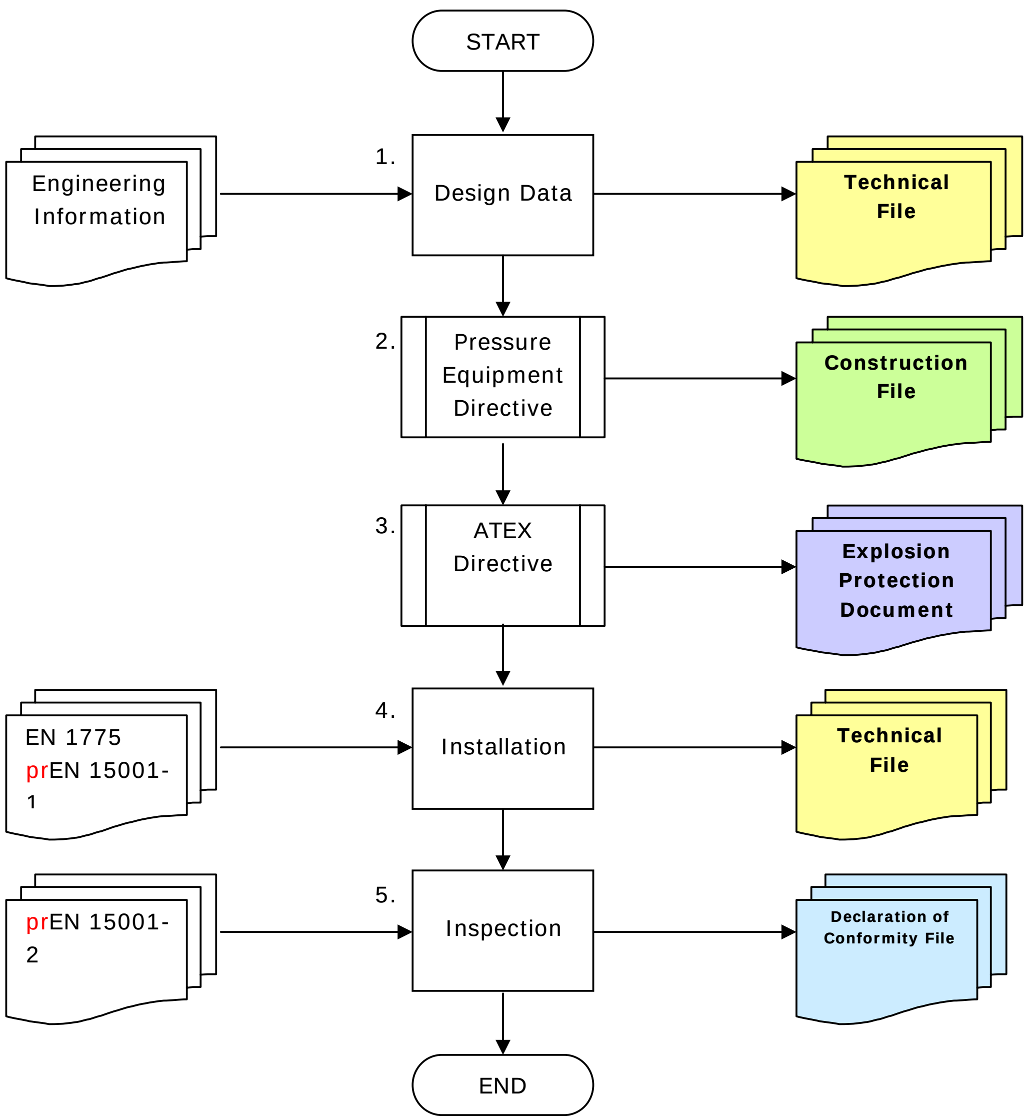
3. DOCUMENT MANAGEMENT

3.1 Scope

The scope of section 3 is from the "point of delivery", as defined by each member state to the last manual isolation valve before the thermal process equipment.

3.2 Maintaining Records of Completed Gas Work

In the context of Quality Management, it is important that the Technical File, Construction File, Explosion Protection Document and Conformity File are maintained and updated regularly to match with activities concerning the industrial gas installation.



3.3 The Technical File

The user should ensure that a technical file is available and that it contains the following information (with parts list where appropriate):

- gas composition;
- the location (route) of the installation pipe work;
- gas supply line diagram and/or Piping and Instrumentation Diagram;
- normal operating gas pressure, Design Pressure DP, Maximum Incidental Pressure MIP;
- pipe line diameter(s);
- calculation of flow, pressure drop, velocity and discharge capacities;
- list of used materials and components;
- details of design standards used, evidence of testing of materials and components together with any Certificates issued by test bodies/manufacturers;
- the location and design of supports;
- the location and design of wall and floor transits, points where pipe work crosses or runs parallel with other systems, etc.;
- location of ancillaries, stating the make, type, connection sizes and type of material;
- joints, gaskets, bolts, etc.;
- location and layout of internal gas pressure regulating systems, stating the required settings for regulators and safety devices;
- the location and sizes of valved points for testing and purging; and
- Cathodic protection system, where fitted.

The thermal process equipment/gas appliances to be connected to the system shall be specified separately, stating:

- supplier/make and type;
- maximum flow, in m^3/h under normal conditions of fuel gas; and
- Minimum and maximum operating pressure.

3.4 The Construction File

The user should ensure that a Construction File is available and that it contains the following information (with parts lists where appropriate):

- Type of pressure equipment, phase condition and physical properties;
- design pressure(s) PS, temperature(s) maximum and minimum and nominal size diameter;
- conformity assessment, declaration of conformity;
- welders qualification (EN 287-1);
- specification and qualification of welding procedures (EN-ISO 15607);
  (CR-ISO 15608, EN-ISO 15609 up to EN-ISO 15614);
- specification and approval of welding procedures for metallic materials (EN 288-9);
- Non-Destructive Testing.

3.5 The Explosion Protection File

The user should ensure that an Explosion Protection File is available and that it contains the following information (with parts lists where appropriate):

- risk assessment;

- list of hazard sources;
- If necessary, zone classification of hazardous areas (EN 60079-10);
- Technical and organisational measures taken.
- Drawings with hazard sources and classified zones.

3.6 The Declaration of Conformity File

The user should ensure that a declaration of Conformity File is available and that it contains the following information (with parts lists where appropriate);

Gas pipe line:

- examination of joints;
- verification of materials and components;
- checking the route and construction of pipework;
- checking for the correct use of safety markings and signs;
- verification of corrosion protecting measurements;
- setting of pressure regulators and safety devices;
- test results (non-destructive tests, strength test, leakage test and visual inspection); and
- Inspection report(s) with the above mentioned check and tests.

Thermal process equipment / gas appliances:

- Boiler/furnace location (setting, combustion air intake, flue gas exhaust);
- setting of pressure regulator and safety devices;
- CE-marking burner and installation and there specifications;
- Start up sequence (purge-/ventilation time, ignition time, opening safety shut-off valves and flame detection);
- Safety times (safety time main/pilot burners, reaction time flame detection, closing time safety shut-off valves main burners);
- Control safeguarding (leak tightness check, gas-lock closed position, maximum gas pressure, minimum gas pressure, combustion air pressure/flow, maximum medium temperature, maximum medium pressure, minimum medium level, flame detection and E.S.D. (Emergency Shut Down);
- Execute measurements on four burner loads (minimum, maximum and two in between) measuring gas flow, gas supply pressure, gas pressure after reduction, burner pressure, combustion air pressure/flow; medium quantity (temperature, pressure), composition of the flue gas (O_2, CO_2, CO, temperature and NO_X); and
- Inspection report(s) with the above mentioned check and tests.

4 GAS COMPOSITION

4.1 Properties of Natural Gas

Natural gas is a mixture of light hydrocarbons including methane, ethane, propane, butane and pentanes. Other compounds found in natural gas include CO_2, helium, hydrogen sulphide and nitrogen.

The main component of natural gas is Methane, usually accounting for 70%–90% of the total volume produced. If gas contains more than 95% methane, it is sometimes termed dry or lean gas. Gas containing less than 95% methane and more than 5% of heavier hydrocarbon molecules (ethane, propane, and butane) is sometimes called rich gas or wet gas.

Natural gas is neither corrosive, nor toxic, its ignition temperature is high, and it has a narrow flammability range, making it an inherently safe compared to other fossil fuel sources.
In addition, because of its specifics gravity lower than that of air, natural gas rises if escaping, thus dissipating upwards from the site of the leak.

Always consult you Network Operator for the specific composition of the natural gas being delivered to the point of delivery of the industrial gas installation.

4.2 The Wobbe Index & non combustion parameters

The Wobbe Index is an indicator to compare the combustion energy output of different composition fuel gases in an appliance (fire, boiler, cooker, etc.).
If two fuels have identical Wobbe indices then for given pressure drop and valve settings the energy output will also be identical.

The Wobbe index is a critical factor to minimise the impact of the changeover when studying the use of different gases in a given appliance. That is called interchangeability of fuel gases and is frequently defined in the specifications of gas supply.

If ***Hs*** is the Gross Calorific Value of a gas, and **d** is its relative density, the gross Wobbe Index **W** is defined as:

$$Ws = Hs/\sqrt{d}$$

There are three ranges or "families" of fuel gasses that have been internationally agreed based on Wobbe Index. Natural gas belongs to the second family of gases (with high and low ranges).

Combustion equipment is typically designed to burn a fuel gas within one particular family and group: hydrogen-rich Town Gas, Natural Gas or LPG (commonly referred to as second family H-gas).

Summary of gas families and groups as a function of the Wobbe indices (EN 437:2003)

Gas families and groups	Gross Wobbe index at 15 °C and 1 013,25 mbar MJ/ m^3	
	Minimum	**Maximum**
Second family	39.1	54.7
- Group H	45.7	54.7
- Group L	39.1	44.8
- Group E	40.9	54.7

Wobbe number (or Wobbe Index)reflects gas composition and is a measure of Burner compatibility.

Two gases with the same Wobbe Index will give the same heat release at the burner tip for the same pressure drop across the burner orifice. It is widely used in Europe where the composition of the gas entering the transmission system can vary from location to location.

It is necessary to ensure that these new gas sources are interchangeable with existing supplies and that the established standards of appliance performance and safety can be maintained without, if possible, the need to adjust appliances and doing it in a non-disturbing way.

For the lower Hydrocarbons in natural gas the ratio of the heat of combustion to the stoechiometric air requirement is essentially constant. Since for all combustion equipment not having an air ratio control the flow of combustion air is constant when changing gas quality, the actual fuel-air ratio in industrial equipment also varies linearly with the Wobbe index.

In almost all gas appliances, the flow of gas is regulated by making it pass through a hole or orifice. The usefulness of the Wobbe number is that for any given orifice, all gas mixtures that have the same Wobbe number will deliver the same amount of heat.

4.2.1 Non – combustion parameters

Raw natural gas typically consists primarily of methane (CH_4), the shortest and lightest hydrocarbon molecule. It also contains varying amounts of:

- Pentanes and even higher molecular weight hydrocarbons. When processed and purified into finished by-products, all of these are collectively referred to Natural Gas Liquids (N.G.L.).
- Acid gases: carbon dioxide (CO_2), hydrogen sulfide (H_2S) and mercaptans such as methanethiol (CH_3SH) and ethanethiol (C_2H_5SH).
- Other gases: nitrogen (N_2) and helium (He).
- Water: water vapour and liquid water.
- Liquid hydrocarbons: perhaps some natural gas condensate and/or crude oil.

The raw natural gas is purified to meet the quality standards specified by the major pipeline transmission and distribution companies. Those quality standards vary from pipeline to pipeline and are usually a function of a pipeline system's design and the markets that it serves. In general, the standards specify that the natural gas:

- Be within a specific range of Gross Calorific Value.
- Be delivered at or above a specified hydrocarbon dew point temperature (below which some of the hydrocarbons in the gas might condense at pipeline pressure forming liquid slugs which could damage the pipeline).
- Be free of particulate solids and liquid water to prevent erosion, corrosion or other damage to the pipeline.
- Be dehydrated of water vapour sufficiently to prevent the formation of methane hydrates within the gas processing plant or subsequently within the sales gas transmission pipeline.
- Contain no more than trace amounts of components such as hydrogen sulphide, carbon dioxide, mercaptans, nitrogen, and water vapour.

An important variable to be controlled is the total sulphur and specially the hydrogen sulphide, a colourless, toxic gas with an odour similar to rotten eggs. It is an undesirable constituent of natural gas, and is reduced to tolerable concentrations through processing.

A low concentration of hydrogen sulphide provides safety personnel and customers, prevents corrosion in pipeline a distribution systems, prevents objectionable products of combustion, and protects sensitive industrial operations from corrosion.

CO_2 is another important component to have under controlled condition. CO_2 in the presence of free water can be an important cause of corrosion damage to pipelines, especially at high pressure.

In the European Gas Quality harmonisation process these variables are taking into account to set the tolerable thresholds (see EASEE gas CBP 2005-001-02 at http://www.easee-gas.org/common-business-practices/approved-CBPs)

4.3 Controlling air and gas flow rates and energy content to the gas equipment

4.3.1 Usual principles for the measurement of air and gas flows

The main measuring devices for air and gas flows are described in this document on the basis of principle of operation, values measured, accuracy and application.

Orifice plate systems

Orifice plate systems are frequently used to measure air flow or large gas quantities.

The principle of operation is based on the determination of flow by measuring differential pressure. The presence of an orifice in a pipe reduces the section thereby increasing the speed of the flow, to the detriment of static pressure. This will cause the pressure to drop in the orifice. This difference in pressure will depend on the speed of the flow and the thermodynamic properties of the fluid measured.

International and national standards (EN ISO 5167 & 5168) define construction specifications, conditions for use (mandatory lengths before and after the orifice) and calculation formulas. Calibration is not required in view of these standards.

The measuring unit includes:

- the primary unit consisting of the system (diaphragm, venturi, nozzle) and pressure devices,
- Secondary devices required for measuring (differential pressure sensor).

Other values such as downstream temperature and pressure in service conditions may be measured. All of these functions are integrated for certain suppliers.

The appropriate measurement scope, specified in the standard, is defined, for a given pressure and pipe diameter, on the basis of variation intervals for the diameter of the orifice and the measurable differential pressure. If the differential pressure is measured using a digital sensor, the accuracy of the flow measured by the diaphragm will be enhanced, particularly at low ΔP, and therefore low speeds. When using an accurate digital differential pressure sensor, and with the integration of the variation in Reynolds number in flow computing formulas, dynamics may reach 10.

The formula linking the flow across a plate with an orifice with differential pressure is :

$$Q = K.\sqrt{\frac{\Delta P}{\rho}}$$

- Q is the uncorrected volume flow rate in m3/s,
- ΔP is the differential pressure in Pa,
- ρ is the downstream density as per service conditions in kg/m3,
- K is a constant established during calibration or using a calculation based on physical and geometric properties and flow conditions.

Standards enable the determination of errors of approximately 1 – 1.5%. Prior calibration may reduce these errors to less than 1%.

Orifice plates or Venturi are easy to install and use. They do not require regular calibration and they enable the measuring of large quantities of gas at high pressures, exceeding the maximum flows which can be measured using turbine and rotating piston meters. They are inexpensive to run. However, they can cause a significant loss of pressure. It is also difficult to measure low speeds at high pressure. Straight legs must be fitted upstream and downstream from the orifice (minimum 10D downstream and 5D upstream, where D is the inner pipe diameter).

The use of a Venturi is preferable if only low load losses are acceptable.

Turbine meters

The principle of operation of flow meter turbines is based on the almost linear relation between the rotation speed of a rotor and volume flow rate. The turbine is inserted in the pipe and will rotate driven by the flow of the fluid.

Depending on the type of turbine used, measurements are obtained:

- either using pulses corresponding to the passage of the blades of the turbine wheel (high frequency), and /or
- using a mechanical index connected (magnetic coupling) to the turbine shaft, transforming the flow, via a set of gears, into volume (low frequency).

The calculation applies as follows: **Q = K x F x 3600**

- Q is the flow measured in m^3/h,
- K is a constant (m^3/puls),
- F is the number of pulses (puls/s) function of the speed of rotation of the turbine.

Turbines cause a low loss of load. They are however sensitive to the density and, to a lesser extent, to the viscosity of the fluid. Straight legs must be fitted upstream and downstream from the meter (minimum 10D upstream and 5D downstream, where D is the pipe diameter).

With careful calibration, these devices can guarantee an accuracy of between ± 0.25% and ± 0.6% of the value measured for flow equal to or exceeding 0.2 Qmax.

Turbines can cover a flow interval for diameters of between 50 & 750 mm, ranging from 1 m3/h to 40 000 m3/h, for absolute pressure of between 1 & 100 bar and fluid temperatures of between – 20 and + 50°C.

Rotating piston meters (roots)

The fluid flow rotates two pistons which mutually drive each other with minimal clearance. The fluid is hence carried to the chambers formed between the pistons (eight or oval format) and the meter core. During rotation, the fluid contained in the chamber is gradually transferred from downstream to upstream. The quantity transferred per rotation (cycle volume) is a constant which is determined using calibration and corresponds to four basic volumes. The volume measured in this way is proportional to the speed of rotation of the meter.

The volume or volume flow rate is obtained either using electric pulses supplying a pulse meter or frequency meter, or via a direct reading on a mechanical totaliser. The high frequency emitter is used for instantaneous flow and the low frequency emitter enables the measuring of volume.

The calculation applies as follows: **Q = K x F**

- Q is the flow measured in m3/h,
- K is a constant (which depends on the cycle volume),
- F is the speed of rotation of the pistons.

The gas must be filtered as input, oil level must be regularly checked and mechanical parts must be regularly maintained.

With a measurement scope of 5 – 100% of maximum flow, these meters provide an accuracy of ± 0.5%.

This type of meter causes a very low loss of load.

These meters can be used for flows ranging between 3 m3/h and 6 500 m3/h, for a maximum pressure of 80 bar. Acceptable fluid temperature variations are generally between 20° C and + 50° C.

Vortex flow meters

The principle of operation of these meters involves detecting the speed of formation of vortices upstream due to an obstacle placed in the flow. These vortices, created by the passage of the flow in the obstacle, create pressure in a piezo-electric sensor, at speeds which vary depending on the speed of the flow.

The calculation applies as follows: Q = K x F

- Q is the flow measured in m3/h,
- K is a constant,
- F is the frequency of the vortices.

Accuracy is approximately 1% and may reach 0.5% with special designs. Dynamics reach factor 15 – 20, and measurement scope = 10 – 16000 m3/h.

These flow meters are robust, low-cost, compact and reliable. However, they are sensitive to their conditions of installation (straight lenghts required: 15D upstream, 5D downstream) and no interferences (pulsed flow, noise, etc.). In addition, flow must be turbulent (Re > 2000).

Ultrasonic flow meter

These devices – known as transit time devices – measure the speed of propagation of a sound wave between an emitter A and an offset receiver B located on either side of the duct. These probes may both emit and receive ultrasound. If the fluid inside the duct is inactive, the time taken by an ultrasound wave to travel from probe A to probe B is identical to the time taken by a wave to travel the opposite route (from B to A). However, if the fluid is active, the speed vector of the fluid will combine with the speed vector of the ultrasound wave and the time taken for the wave to travel from A to B will differ from the time taken to travel from B to A. Measuring this time difference will identify the mean speed of the fluid over the distance AB (or several routes), and the flow. Probes may be placed inside (intrusive method) or outside (non-intrusive method) the pipe.

Accuracy is approximately ±1% and improves with multi-chord systems for gases of known composition. Repeatability = approx. 0.2%.

These 100% static devices have a short response time (1/10 sec.). They are two-way and cause no loss of load. This device may be used on ducts with diameters ranging between a few centimetres and several metres. The fluid temperature and flow conditions may have effect on the measurement.

Very rarely employed for gas metering on industrial plants, they are sometimes used for measuring large flow rates of dusty combustion air.

Mass flow meters

Two types of mass flow meters exist: thermal systems and Coriolis systems.

The operating mode of thermal flow meters is based on the measure of the transfer of calories by the fluid. The fluid for which the flow requires measurement enters a capillary tube. Temperature sensors are located at each end of the tube (heat detection resistances) and a heating coil is placed between the two sensors.

If flow is absent, the sensor will indicate the same temperature. Should flow exist, the movement of the heated gas will create a temperature difference. The latter creates a disequilibrium on the Wheatstone bridge. The final current is directly proportional to the temperature difference, and therefore the flow.

This type of flow meter has the advantage of low sensitivity to variations in gas temperature and pressure. However, use with natural gas is complex as the flow measured varies depending on the composition of the gas and properties (density and heat capacity Cp).

Measurement uncertainty for this meter, when using a gas of known composition, is approximately 1%. Dynamics reach 1 – 50. It enables the measuring of flows of less than 1000 kg/h.

Mass flow meters using Coriolis systems are traditionally used to measure liquids, and recent technological developments enable their use as a gas flow meter. The device consists of a metal U-shape or triangular tube, which is reverberated using an electro-magnetic system. The fluid in the tube is speeded up at the entrance to the tube and slowed down at the exit. The two forces induced by the fluid movement create torque whose angle is proportional to the mass flow of the fluid.

The accuracy announced by the manufacturers of this device varies between 0.5 and 1% for dynamics equal to or exceeding 50/1. They now cover a range of flows between 70 and 140 000 m3/h. Certain devices may be used to measure the density of the fluid.

4.3.2. Corrected flow calculation

The measurements of air or gas flow rates should be corrected to enable comparison with similar data. The flow Q measured at pressure P and T is converted for a standard pressure (1013 mbar) and a reference temperature (0 °C in some countries, 15°C in others) using the following formula:

$$Qn = Q.\frac{P.T_0}{T.P_0}.\frac{Z_0}{Z}$$

- Q_n is the corrected volume flow rate (m3/h),
- Q is the measured volume flow rate (m3/h),
- T is the temperature (K),
- T_o is the temperature in standard conditions (273.15 or 288.15 K),
- P is the absolute pressure (bar),
- P_o is the absolute pressure downstream in standard conditions (1.01325 bar),
- Z is the compressibility factor which depends on P & T,
- Zo is the compressibility factor in standard conditions,
- Zo/Z approximates to 1 if P < 3 bar.

It is recommended to measure pressure 3D downstream from the meter as a minimum (particularly with orifice plates). D is the pipe diameter. Ideally speaking, the temperature should be measured at approximately 4D downstream.

4.3.3. Controlling energy content

Getting calorific flow rates released by burners from flow measurements requires information about gas quality. The main needed parameter is obviously the Gross Calorific Value. If the employed technique for flow metering allows getting the actual corrected volumetric flow rate of the natural gas (Qn in Nm3/h), it is easy to calculate the released thermal energy (Qc in kW):

$$Qc(kW) = Qn(Nm^3/s).GCV(kJ/Nm^3)$$

Warning: pressure and temperature references should be the same for corrected flow rate and GCV.

Flow metering techniques for which this simple method is appropriated are turbines, roots, vortex an ultrasonic.

Considering orifice plates or Venturi systems, the actual flow rate depends on the root square of the fluid density. Consequently, the energy content depends on the Wobbe index and not directly on the GCV.

Because Coriolis flow meters measure directly actual mass flows, you need GCV and gas density to calculate energy contents. In the same way, a thermal mass flow meter uses the heat capacity (Cp) to operate a flow measurement. And so you have to know this physical value to determine the energy flow.

4.3.4. Synthesis of flow metering and their main characteristics

Type of flow metering	Current accuracy of the flow rate measure	Usual range ability	Range of flow rate (m^3/h)	Pressure drop	Upstream straight length (xDiameter)	Downstream straight length (xDiameter)	Required gas parameters for controlling energy
Diaphragm with analogical ΔP sensor	1.5 to 3%	1/3	> 70	ΔP/2	> 10 D	> 5 D	Wobbe index
Diaphragm with digital ΔP sensor	1 to 2%	1/8	> 70	ΔP/2	> 10 D	> 5 D	Wobbe index
Venturi	1 to 3%	1/4	> 70	ΔP/5	> 10 D	> 5 D	Wobbe index
Turbine	1 to 2%	1/20	< 40000	small	15 D	6 D	GCV
Roots	1 to 2%	1/20	3-6500	small	2 D	2 D	GCV
Vortex	1%	1/15	13-16000	small	30 D	10 D	GCV
Ultrasonic	1 to 2%	1/30	> 6	≅ 0	20 D	10 D	GCV
Coriolis mass flow meter	0.5 to 1%	1/50	70-140000 (kg/h)	middle	2 D	2 D	GCV, density
Thermal mass flow meter	1% to 5% (if Cp is not accurately known)	1/50	< 1000 (kg/h)	small	0	0	GCV, heat capacity (Cp)

4.4 Industrial thermal processing equipment and sensitivity to variations in gas composition

It is recognised that variations in gas quality may cause inefficiencies for industrial end users. It is recommended that size and frequency of major variations within the ranges as above should be restricted in a reasonable way (e.g. limited to unavoidable technical problems) and in any case be notified to the relevant end users reasonably in advance. It is the common understanding that stability of the natural gas quality remains to be of outstanding importance.

Generally, effects of gas variations are not particularly noticeable on low temperature processes as long as a few precautions are taken when the initial adjustments are made. Hence, where a boiler is concerned, the burner must be adjusted with suitable excess air so that there is no risk of producing un-burnt particles when the gas enriches; any efficiency loss remains negligible.

However, some high temperature processes (>700°C) are more sensitive to these types of disturbances. In particular:

- Those processes where the flame is used as a tool (i.e.: bulbs or medical glassware),
- Processes where the regulated temperature is only slightly lower than flame temperature (i.e.: melting glass furnaces or glass feeders),
- Processes where combustion products are used in the processing (i.e.: direct contact firing and thermal treatment, in ceramics or for steel heat treatment),
- Processes where combustion sparks off a chemical reaction (i.e.: lime kilns).

For these special industrial processes, it is generally necessary to correct the adjustments on the facility, either by hand or automatically, every time the gas varies. Ignoring these variations can lead to manufacturing defects and to an increase in the production costs that are detrimental to the industrial customer.

In addition, efficiency losses will be present in systems without air-ration controls.

These industrial thermal processes are generally sensitive to variation in Wobbe index, except those where fuel gas flow rates are controlled by the mean of volumetric flow meters. In this particular case, the process is directly sensitive to variations in Gross Calorific Value.

Due to industrial thermal equipments are so varied, it is necessary to envisage detailed technological statements, sometimes very deep studies with the services of specialized personnel and sometimes with the advice of the qualified departments of the Distribution System Operator

Gas engines and gas turbines are also considered as sensitive to variations in gaseous fuels properties.

Gas engines are mainly sensitive to the knock phenomenon. Knock is caused by an abnormal combustion, with occurrence of a detonation that adversely affects performance, emissions, and service life of spark-ignited internal combustion engines. The occurrence of knock is dependent on many variables, including combustion chamber design, air gas ratio, and intake air temperature and pressure, and fuel properties.
As far as the fuel properties are concerned, the gas's tendency to resist detonation is characterised by a value experimentally related to the gas composition and called "Methane Number".
Comparable to the octane number for petrol, the Methane Number of a gaseous fuel is defined as the percentage by volume of methane blended with hydrogen that exactly matches the knock intensity of the fuel under specified operating conditions in a knock testing engine. A low Methane

Number can lead to detonation and damage to the gas engines if no adjustment is made to the engine's operation.. For most of natural gases supplied in Europe, Methane Number is varying from 75 to 90.

To operate in acceptable conditions, gas turbines and more specially those using lean premix combustor, require flame stability (risk of flashback), stable flame temperature (to prevent component overheating or excessive thermal stresses), small combustion dynamics (due to the coupling of pressure oscillations in the combustion system with the energy release within the flame) and finally have to produce low levels of pollutant emissions (particularly NOx and CO). To comply with these requirements, gas turbines are generally equipped with efficient combustion control systems that may involved gas quality measurements (e.g. by using chromatography). Nevertheless, too large variations in Wobbe index or in rate of some compounds (e.g. C2+) can affect the efficiency, the levels of pollutant emission and the reliability of the turbines. And because of the very high gas flow rates consumed by turbines, the rates of change of the Wobbe index are generally faster than for most industrial thermo-processes and may be also an issue (control system reaction slower than the rate of change).

The following table describes how Gas Quality variations can influence the performances in the thermal processes and the possible measures that it could be taken.

For further information on the subject the Marcogaz document "Effects of Gas Quality variation on appliances " is available on the Marcogaz website www.marcogaz.org

Main category	**Sub categories**		**Comment**	**Sensitive**	**Possible solution**
Low temperature (<700ºC) Industrial applications	Big boilers/large scale hot water & steam			Low for efficiency. May be high for NO_x emissions	Air gas control via measurement of the oxygen in combustion products.
	Food industry	Green houses	NO_2 is a problem when combustion products are in contact with food. NO_2 is a plant hormone, and can damage crops. NO_2 emissions can also increase with gases having higher hydrocarbons (with facilitate the conversion of $NO \rightarrow NO_2$)	High to NO_2 emissions	Adjustment of burners for reduced unburned fuel slippage (source of NO_2 production). New burners or air/ratio control
		Drying process			
				High to NO_2 emissions	
	Infra red	Drying	Low temp. combustion with potential presence of solvents. Radiant power/efficiency dependent on burning velocity.	High to burning velocity	In premixed radiant tiles, air/gas ratio and thermal input controls can minimize this effect.
		Heating			
High temperature (>700ºC) industrial applications	Ceramic/Glass	Bulk (melting feeders)		Soot formation often desired in bulk glass (heat transfer).	Gas quality (Wobbe Index, GCV) and air flow control. Air ratio and thermal input control should minimize effects. Air ratio control solves
			Sensitive to flame temperature and radiative power. Finished product is also sensitive to flame	High sensitivity to burning velocity	
		Finished product (bulbs, etc)		High sensitivity to air ratio (over/under stoechiometry).	

		Ceramic roofing tiles, bricks, etc	geometry. Finished glass products sensitive to flame length (burning velocity). Soot formation (composition) and increased NO_x emissions (Wobbe/calorific value) possible. Control of under-/overstoechiometric firing essential in ceramics.	High sensitivity to NO_x. High sensitivity to soot.	stoechiometry.
	Metal oven		General for metal industry. Air factor, soot formation and NO_x important issues.	High to soot and NO_x and oxygen in the oven atmosphere.	Solutions may be very specific according to the application
	Lime kilns		Quality of production (reject rate) sensitive to calorific flow rate	High sensitivity to Wobbe index or GCV variations	Gas quality (Wobbe Index, GCV) and air flow control
	Oxy-gas burners		More and more used on high temperature process in order to reduce NOx	Oxygen consumption very sensitive to gas variations	Gas quality (Wobbe Index, GCV) and oxygen flow control.
Engines	Fixed		Emissions and performances may vary. NO_x emissions and engine knock set boundary conditions for fuel sensitivity	High to NO_x High to knock	Air ratio control minimizes NO_x variations. Readjustment of engine necessary (with efficiency loss) for knock
Turbines	Pre-mixed		Control system and machine design limit Wobbe variations, both stationary (power modulation) and dynamic (oscillations); NO_x emissions and combustion instability issues.	High sensitivity to Wobbe variation (outside control range) Some machine have compositional limits (on higher hydrocarbons, e.g.) High to Wobbe/composition-induced oscillations	New control systems

	Non –pre-mixed	NO_x (also at constant Wobbe) issue	High to NO_x Thermal overload possible.	Readjust exhaust gas treatment; retrofit combustion chamber.

4.5 Industrial thermal processing equipment and Environmental issues

Industrial activities are producing gaseous emissions that are more and more regulated and controlled by national authorities. Among them, a full range of greenhouse gases is emitted from the combustion of fuels.

The combustion of natural gas is to be considered as a chemical reaction (oxidation) of the several hydrocarbons contained by the gas, with heat emission used for process purpose.

The general reaction of combustion is:

$$C_nH_m + O_2 + N_2 \rightarrow CO_2 + H_2O + O_2 + N_2 + OTHERS + HEAT$$

Where:

C_nH_m represents hydrocarbons of the fuel,
$O_2 + N_2$ represent the combustion air,
CO_2, H_2O, O_2 and N_2 are the main combustion products
OTHERS (NOx, CO, H_2, C...) are generally produced in very small quantities

(Note: some particular industrial thermal processes use only oxygen as combustion agent).

The products of the combustion that have not been oxidized completely (CO, H_2 and C) are denominated non-burned components

The greater is the proportion of non-burned components, the smaller is the amount of heat produced by the chemical reaction.

A **stoechiometric combustion**, is the one in which the relation between the amount of fuel and the amount of air is the minimum necessary for the complete oxidation of the fuel. For natural gas, the air gas ratio is approximately 10 m^3 of air to 1 m^3 of gas. (air factor n=1)

In the case of the methane:

$$CH_4 + 2\ O_2 + 8\ N_2 \rightarrow CO_2 + 2\ H_2O + 8\ N_2$$

In other words: for each unit of volume of methane (CH_4) is needed two units of oxygen(O_2).
Since the content of oxygen in the air is of 21%: to burn a cubic meter of methane we need 9.54 cubic meters of air.

Air supply less than needed for the complete combustion results an **under stoechiometric combustion** and consequently produces non-burned components: CO, H_2 and C, but no oxygen. This so called reducing type of combustion is sometimes used in some industrial processes (i.e. porcelain manufacturing).

Burner dysfunctions or too high air factors (n>>1) may lead to an **incomplete combustion** producing non-burned components (CO, H_2 and C) and oxygen (O_2). This bad combustion has highly negative effects on the safety and the efficiency of the thermal process.

A **complete combustion** with n>1 increases the thermal efficiency and ensures a safe combustion (no risk of CO emission). Because high combustion temperature can be reached in this case, it has as inconvenient the increase of nitrogen oxides. Also, the optimisation of the air/gas ratio may be seen as a compromise between several constraints: safety, efficiency and environment. This optimum is varying over the industrial thermal processes and is depending on the type of fuel, combustion technology, combustion chamber configuration, operating conditions, control technology, and on maintenance and ageing.

NOx emissions depend on the fuel composition but more strongly on other parameters (combustion temperature, length of stay in the combustion chamber, burner design). For the last 30 years, the gas companies research centres, combustion laboratories and burners manufacturers have developed a lot of techniques to reduce the nitrogen oxides emissions of industrial burners (low-NOx burners, ultra low-NOx burners, flameless combustion, oxy-gas burners,..).

Sulphur that is added to the natural gas to give the gas the special smell (odorisation), the so called THT, is to be considered as negligible (about tens of milligrams per cubic meter).

Nevertheless, if higher concentrations of sulphur are present in the gas, it can cause problems of corrosion in the appliances by condensation of H_2SO_4.

Carbon dioxide (CO2) emissions are mainly related to the fuel composition but also to those factors which affects fuel efficiency. For natural gas, the CO2 emission factor is far below in comparison with other types of energy.

Emission factors for CO_2 (from 1996 IPCC data used as references in the 2003/87/EC Directive)

- Biomass: 400 g/kWh (average value)
- Solid fuels: 350 g/kWh (average value)
- Liquid fuels: 260 g/kWh (average value)
- LPG: 225 g/kWh
- Natural gas : 205 g/kWh

4.6 Biogas

Biogas is a gas mixture that comes from the biological degradation of the organic components in anaerobic conditions. The degradation of organic matters happens spontaneously in the nature or as the result of the human activities. The conditions for the methane production are in natural habitats like marshes, lakes and salt marshes. The microbiological natural process of anaerobic degradation is applied by the humans to the organic matter of the garbage dumps and the plants of production of biogas. In Europe that utilization is regulated by 99/31/EEC Directive.

The composition of biogas can vary considerably, per following:

Density:	1.0 – 1.4 kg/Nm^3	(Methane	0,717 kg/Nm^3)
Net Calorific Value:	17000 -25000 kJ/Nm^3	(Methane	35882 kJ/Nm^3)
Gross calorific value:	18000-32000 kJ/Nm^3	(Methane	39819 kJ/Nm^3)
Wobbe Index:	20000 – 30000 kJ/Nm^3	(Methane	54.720 kJ/Nm^3)

The components of biogas which can cause corrosion are the hydrogen sulphide (H_2S) and Carbon Dioxide (CO_2)[1]. The hydrogen sulphide can be highly corrosive for metals particularly the copper, iron and steel. During combustion, the H_2S is oxidized to form sulphur oxides SO_2 and SO_3 that lead to the highly corrosive sulphuric acid formation in the ducts of combustion gases.

Carbon dioxide also can be corrosive in particular under conditions of high pressure and presence of water, since the CO_2 in dissolution takes to the carbonic acid formation H_2CO_3.

[1] ***CO_2 reduces the burning velocity of natural gas flames and biogases (methane/CO_2 mixtures) have lower burning velocities than the equivalent natural gas flames. This is a concern for the stability of all burner systems.***

Regarding the effects on combustion, the CO2 reduces the burning velocity of natural gas flames, and biogases in general have lower burning velocities than the equivalent natural gas flames. This is a concern for the stability of all burner systems.

In addition biogas normally is saturated with water steam and the humidity favours corrosion.
The methane contained in biogas is a gas of powerful effect conservatory ($1tCH_4=21tCO_2$). The mitigation of the environmental impact attributable to the gas discharge of effect conservatory to the atmosphere of the garbage dumps is a preventive measure against global warming, for that reason its use is fomented to avoid its emission to the atmosphere.

There are four basic applications for biogas:

1. Production of electricity: using a gas motor or a gas turbine.
2. Thermal use: combustion of biogas for production of steam, hot water or hot gases.
3. Production of gas to be commercialized like fuel for vehicles.
4. Production of gas to be sold to a network of gas distribution natural gas.

The option of electricity production is the most independent alternative, since the incidences of internal operation, do not repel in the use and later utilisation.

The option of use like combustible gas, to be sold to the network of natural gas or to be commercialized like fuel for vehicles, implies the necessity of the CO_2 purification, H_2S and of the humidity for its adaptation to the conditions of the network.

Its functionality also depends on the facilities location with respect to the possible connections to the natural gas network.

Considering the variable characteristics of the gases from non renewable sources and the possible technical problems arising from its injection into gas grids, Marcogaz decided to prepare a recommendation on the injection of such gases into gas grids which should serve as a guideline for grid operators and producers for better technically managing the injection of gases into the grid.
The recommendation is freely downloadable from the Marcogaz website www.marcogaz.org

5 THE ENVIRONMENT

5.1 Emission Trading Directive

Following the adoption of the Kyoto protocol in 1997, the European Commission put in place the Emissions Trading Scheme in 2005 by the adoption of the Directive 2003/87/EC entered into force in 2003. For the ETS each Member State receives a certain amount of CO2 allowances which are further allocated to the undertakings falling under the scope of the Directive mentioned before.
The amount of allowances is revised periodically. If the undertaking needs more than the available allowances it has to buy the excess in special auctions. More details on the ETS functioning can be found in the following link http://ec.europa.eu/environment/climat/emission/index_en.htm .

5.1.1 CO2 measurement

CO2 determination should be done accordingly to the guidelines established by the EU Commission. These guidelines, established with a Commission Decision 2007/589/EC in 2007 can be downloaded at the following link

http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2007:229:0001:0085:EN:PDF

Annex IV to the Directive 2003/87/EC permits a determination of emissions using either:

- a calculation-based methodology ("calculation")

- a measurement-based methodology ("measurement").

The operator may propose to measure emissions if he can demonstrate that:

- it reliably gives higher accuracy than the relevant calculation applying a combination of the highest tiers, and

- the comparison between measurement and calculation is based on an identical list of sources and emissions.

The operator may, with the approval of the competent authority, combine measurement and calculation for different sources belonging to one installation. The operator shall ensure and demonstrate that neither gaps nor double counting concerning emissions occur.

Calculation of emission data can be done with the following formula:

$$CO_2 \text{ emissions} = \text{activity data} * \text{emission factor} * \text{oxidation factor}$$

Measurement shall be done accordingly to relevant standards.

5.2 Measures to reduce emissions (CO2, CO, NOx, CH_4)

The Best Available Techniques Reference Documents (B.A.T.) detail the most common measures put in place to reduce emissions, divided per type of machinery and harmful emissions type (CO_2, CO, NO_x, CH_4). Many of them are part of the so called Best Available Techniques (BAT) that can be used to reach the emission levels foreseen by the Large Combustion Plant Directive (L.C.P.) and Integrated Pollution Prevention and Control (I.P.P.C.). For more detailed information on these measures B.R.E.F. (Best Available Techniques Reference Documents) documents for the different kind of installations exist and can be downloaded from the following link of the EU Commission website http://eippcb.jrc.es/pages/FActivities.htm

5.3 Integrated Pollution prevention & Control Directive (IPPC), Large Combustion Plants Directive (LCP)

Among the most relevant Directives for Industrial Gas Installations it must be mentioned Directive 2001/80/EC on Large Combustion Plants and Directive 96/61/EC on Integrated Pollution Prevention&Control. They both deal with the pollutants arising from industrial activities and in particular with their limitation.
The LCP Directive applies to combustion plants with rated thermal input of which is equal to or greater than 50 MW.
Regarding the IPPC Directive it applies to the activities listed in Annex I of the Directive itself.
The link with the EU Official website for downloading the Directives are the following:

http://europa.eu/legislation_summaries/environment/air_pollution/l28028_en.htm

http://ec.europa.eu/environment/air/pollutants/stationary/ippc/index.htm

To be noted that these two Directives, together with others like incineration of waste Directive, Titanium Dioxide industry waste Directive etc, is being recasted in one unique Directive which is at the moment under discussion in the EU Parliament and Council.

6. REFERENCES

1) EU Directives http://eur-lex.europa.eu

2) Marcogaz: "*recommendation on the injection of gases from non conventional sources into gas networks"*

3) European Turbine network: position paper "*The impact of natural Gas Quality on Gas Turbine Performance"*

4) Marcogaz: "main effects of gas quality variations on applications"

APPENDIX

Appendix I: Glossary of Terminology / Definitions

air gas ratio
The ratio between the mass flow of combustion air and the mass flow of the fuel gas.

air factor
The ratio between the actual mass flow of combustion air and the stoechiometric mass flow of combustion air.

gas appliances
Appliances burning gaseous fuels used for cooking, heating, hot water production, refrigeration, lighting or washing and having, where applicable, a normal water temperature not exceeding 105°C, except those specifically designed for use in industrial processes carried out on industrial premises.

pressure
Gauge pressure of the fluid inside the system, measured in static conditions

design pressure (DP)
Pressure at which the design calculations are based. This is equivalent to the maximum allowable pressure (PS) as given in the PED.

maximum allowable pressure (PS)
Maximum pressure for which pipework is designed in accordance with the strength requirements in this document.

maximum incidental pressure (MIP)
Maximum pressure at which a system can experience during a short time, limited by the safety devices

Operating pressure (OP)
Pressure which occurs within a system under normal operating conditions

maximum operating pressure (MOP)
Maximum pressure at which a system can be operated continuously under normal operating conditions
Note: Normal operating conditions are: no fault in any device or stream.

tightness test pressure (TTP)
Pressure applied to a system during tightness testing

strength test pressure (STP)
Pressure applied to a system during strength testing

combined test pressure (CTP)
pressure applied to a system during combined testing

components
Any item from which a gas supply system or installation is constructed. A distinction is drawn between the following groups of components:
- ancillaries (for example; pressure regulators, valves, safety devices, expansion joints, and insulating joints);
- pipes, including bends made from pipe;
- instrumentation pipework;
- fittings (for example; reducers, tees, factory-made elbows, flanges, dome ends, welding stubs, and mechanical joints)

flexible appliance connector

Fitting of flexible pipe to be fitted between the end of fixed pipework and the appliance inlet connection

point of delivery
The point of transfer of ownership of gas from the supplier to the customer.
NOTE 1 This can be at a means of isolation or at the meter outlet connection
NOTE 2: This can be isolation valve (or combination of regulator and isolation valve) located before or after the metering station, as defined by the particular EU member state.

user(s)
Person (s) responsible for the safety of the gas installation and associated risks on a site
NOTE Normally the user will be the site occupier or owner. It should be assumed that every user has a responsibility for work performed on their site, whether or not the work is performed directly for the user or not. This does not mean that they cannot take advice from an independent specialist.

pipework
Assembly of pipes and fittings

installation pipework
Pipework downstream of the point of delivery terminating at the appliance inlet connection
NOTE This pipework is normally the property of the customer.

ventilated space
Space where the air is continuously changed by natural or mechanical means

safety zone
Area around the pipework from which persons who are not involved in the strength test are excluded during testing

equipotential bond
Means of ensuring that metallic gas pipework and other metallic parts of the building are at the same electrical potential
NOTE :For safety reasons, this equipotential bonding is connected to earth.

duct
Space specifically designed and constructed for the passage of building services
EXAMPLE Building services include gas pipework, water systems, power and telecommunication cables.

ventilation duct
Duct forming part of the structure of the building and intended exclusively for ventilation purposes

means of isolation
Device which is intended to interrupt the gas flow in pipework
EXAMPLE: Manually operable valve.

DEFINITIONS RELATING TO JOINTING METHODS

joint
Means of connecting elements of a gas installation

flanged joint
Joint in which gas tightness is achieved by compression of a gasket between the faces of two flanges

threaded joint
Joint in which gas tightness is achieved by metal-to-metal contact within threads with the assistance of a sealant

mechanical joint
Joint in which gas tightness is achieved by compression, with or without a seal and which can be disassembled and reassembled
NOTE: This definition includes twin ferrule type joints

pressed joint
Joint in which tightness is achieved by using a specific tool for either compressing a fitting to form the joint or expanding a pipe to enable forming the joint

brazed joint
Joint formed by brazing

welded joint
Joint formed by welding

electro fusion joint
Joint formed between polyethylene components using fittings which have an integrated electric heating element

butt fusion joint
Joint formed between polyethylene components where the two pipe ends are heated and brought together to be fused directly without the use of a separate fitting or filler material

compression joint
Type of joint in which gas tightness is achieved by compression within a socket with or without a seal

DEFINITIONS RELATING TO COMPONENTS

regulator
Device which reduces the gas pressure to a set value and maintains it within prescribed limits

appliance connection
Flexible pipe or length of rigid pipework connecting an appliance's means of isolation with the appliance inlet connection

insulating joint
fitting installed to insulate electrically one section of pipework from another

sleeve
Protective pipe through which a gas pipe passes

vent pipe
Pipework connected to a safety or control device to release gas at a safe location

creep relief valve
Device designed to release a limited flow of gas in the event of an unacceptable pressure being detected within the system it protects.

safety slam-shut device
Device designed to quickly shut off the gas flow in the event of an unacceptable pressure being detected within the system it protects

instrumentation pipework
Pipework required for the proper functioning of the ancillaries installed within the pressure regulating
installation
EXAMPLE: Sensing, measuring, auxiliary and sampling lines.

DN

Alphanumeric designation of size for components of a pipework system, which is used for reference purposes.
It comprises the letters DN followed by a dimensionless whole number, which is in directly related to the physical size, in millimetres, of the bore or outside diameter of the end connections
NOTE 1: The number following the letters DN does not represent a measurable value and should not be used for calculation purposes except where specified.
NOTE 2: Where DN designation is used, any relationship between DN and component dimensions are given, e.g. DN/OD or DN/ID.

safety system
System which ensures, independent of the pressure regulating system, that the outlet pressure of that system does not exceed the safety limits

DEFINITIONS RELATING TO TESTS

strength test
Specific procedure intended to verify that the pipework meets the requirements for mechanical strength

tightness test
Specific procedure intended to verify that the pipework meets the requirements for tightness

combined test
specific procedure to verify that the pipework and/or installation meets the requirements for mechanical
strength and tightness

leak detection fluid
Specially formulated fluid and foaming product that gives a clear indication that a leak exists when applied to an element of pipework

DEFINITIONS RELATING TO ASSEMBLY PROCESSES FOR METALLIC MATERIALS

welding
Joining (union) of two or more parts by heat or pressure or a combination of both, (fusion, arc or oxy-acetylene) such that the materials form a continuity. A filler metal having a melting point similar to that of the materials to be welded can be used

brazing
Operation in which metal parts are joined by means of capillary action of a filler metal in the liquid state with a melting temperature, higher than 450 ° C, lower than that of the parts to be joined and wetting the parent metal(s), which does not participate in the making of the joint
NOTE This is often referred to as hard soldering.

hot tapping
Procedure involving the safe use of heat, e.g. welding or fusion, to affix an attachment to a section of pipework containing gas at pressure

DEFINITIONS RELATING TO PRESSURE REGULATING AND METERING

compressors
A complete unit for raising the gas pressure within installation pipework above 0.5 bar to an OP greater than 5 bar.

station
Gas pressure regulating and/or metering system including (where applicable) the housing, the odorisation facilities and the fenced site

gas pressure regulating and metering system
System comprising all equipment, together with inlet and outlet pipework up to and including the isolating valves, which together performs the functions of pressure regulation, pressure safety

and/or quantitative gas measurement, whether or not including pressure boosting and/or gas mixing facilities

monitor
Second regulator used as a safety device in series with the active regulator which assumes control of the pressure at a higher set value in the event of the active regulator failing open

Appendix II: Directive PED. Conformity Assessment tables

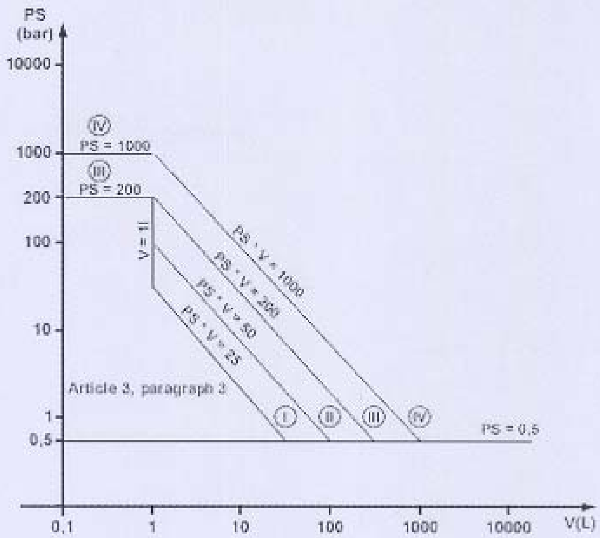


Table 1

Vessels referred to in Article 3, Section 1.1 (a), first indent. (*See Guidelines*: 2/21)

Exceptionally, vessels intended to contain an unstable gas and falling within categories I or II on the basis of table 1 must be classified in category III.

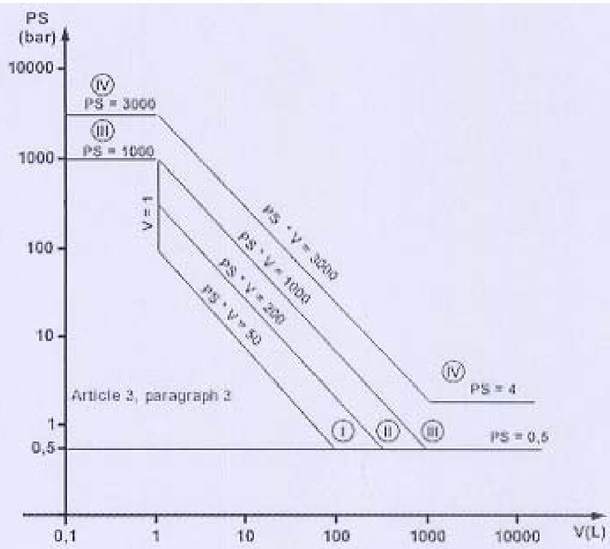


Table 2

Vessels referred to in Article 3, Section 1.1 (a), second indent. (*See Guidelines*: 1/1,1/36,1/52,2/14)

Exceptionally, portable extinguishers and bottles for breathing equipment must be classified at least in category III.

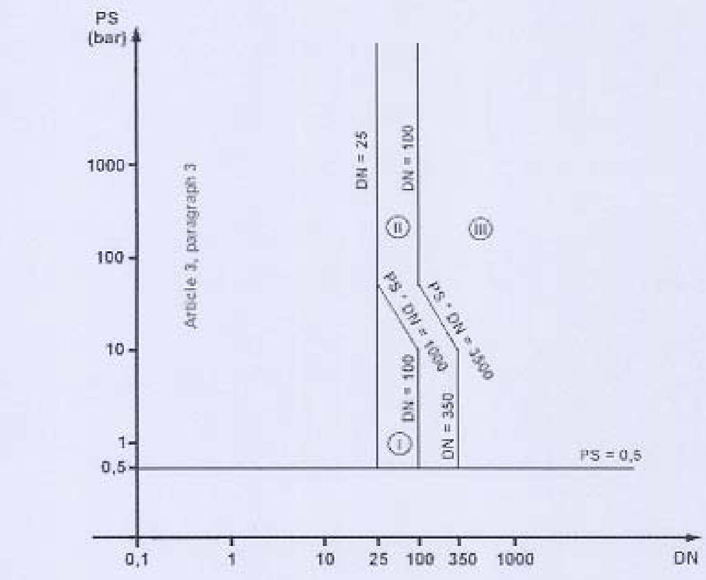


Table 6

Piping referred to in Article 3, Section 1.3 (a), first indent. (*See Guidelines*: 2/21)

Exceptionally, piping intended for unstable gases and falling within categories I or II on the basis of Table 6 must be classified in category III.

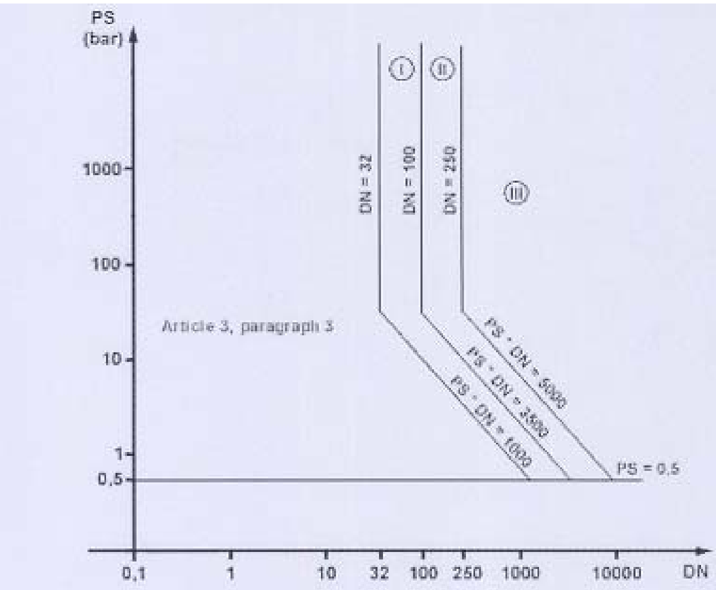


Table 7

Piping referred to in Article 3, Section 1.3 (a), second indent. (*See Guidelines*: 1/38)

Exceptionally, all piping containing fluids at a temperature greater than 350 °C and falling within category II on the basis of Table 7 must be classified in category III.

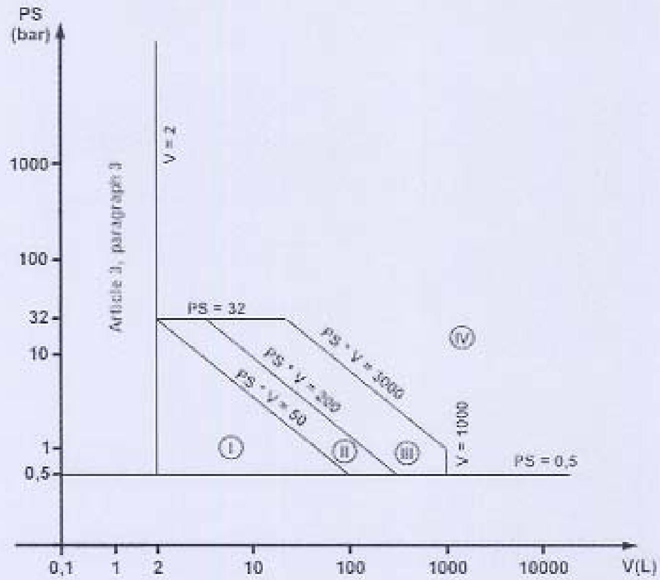


Table 5

Pressure equipment referred to in Article 3, Section 1.2. (*See Guidelines*: 2/15,2/5)

Exceptionally, the design of pressure-cookers must be subject to a conformity assessment procedure equivalent to at least one of the category III modules.

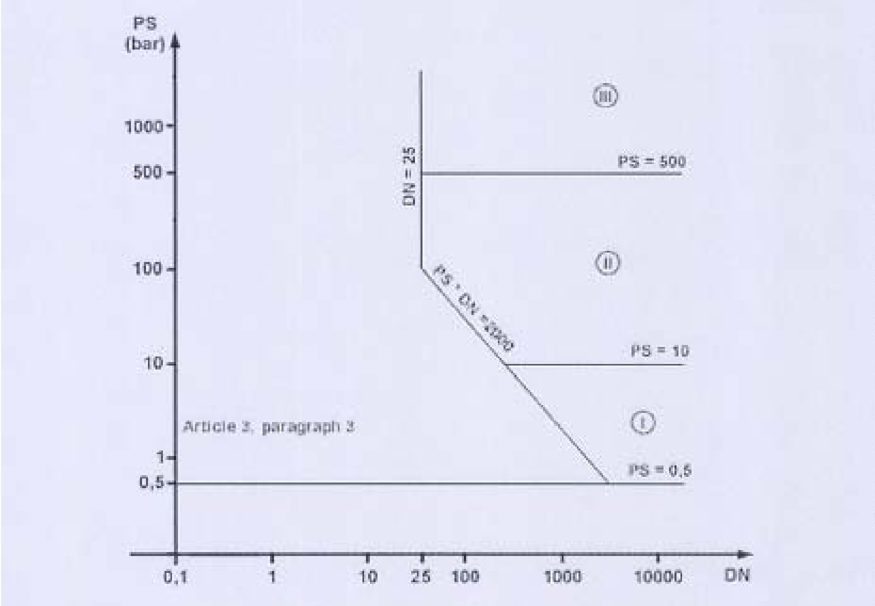


Table 8

Piping referred to in Article 3, **Section 1.3 (b), first indent.** (*See Guidelines*: 1/38)

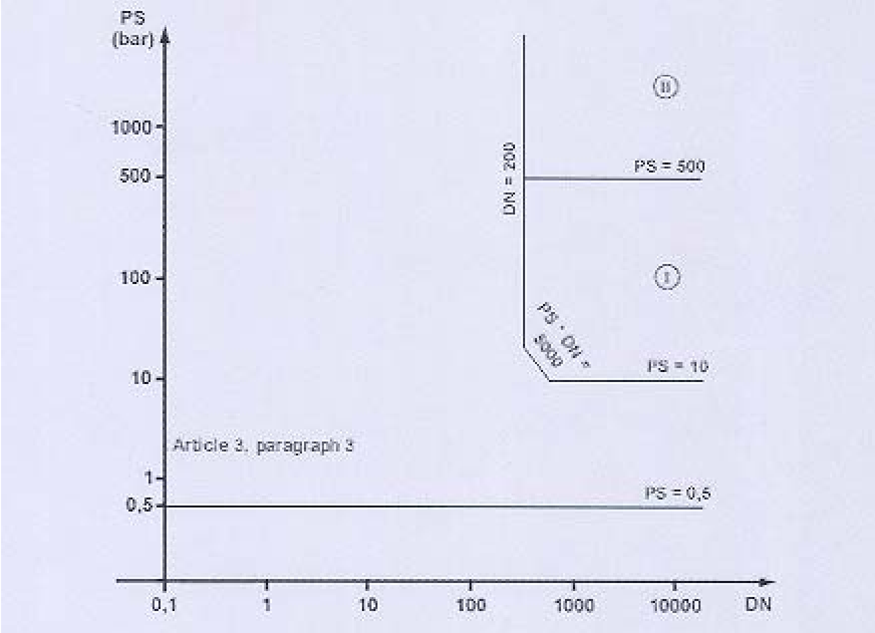


Table 9

Piping referred to in Article 3, **Section 1.3 (b), second indent.** (*See Guidelines*: 1/38)