CODE OF PRACTICE 4
GAS SUPPLY AND DISTRIBUTION SYSTEMS
(EXCLUDING ACETYLENE)
REVISION 5: 2020

British Compressed Gases Association
CODE OF PRACTICE 4

GAS SUPPLY AND DISTRIBUTION SYSTEMS
(EXCLUDING ACETYLENE)

REVISION 5: 2020

Copyright © 2020 by British Compressed Gases Association. First printed 1986. All rights reserved. No part of this publication may be reproduced without the express permission of the publisher:

BRITISH COMPRESSED GASES ASSOCIATION
Registered office: 4a Mallard Way, Pride Park, Derby, UK. DE24 8GX
Company Number: 71798, England

Website:
www.bcga.co.uk

ISSN 2398-9440
PREFACE

The British Compressed Gases Association (BCGA) was established in 1971, formed out of the British Acetylene Association, which existed since 1901. BCGA members include gas producers, suppliers of gas handling equipment and users operating in the compressed gas field.

The main objectives of the Association are to further technology, to promote safe practice and to prioritise environmental protection in the supply, use, storage, transportation and handling of industrial, food and medical gases, and we produce a host of publications to this end. BCGA also provides advice and makes representations on behalf of its Members to regulatory bodies, including the UK Government.

Policy is determined by a Council elected from Member Companies, with detailed technical studies being undertaken by a Technical Committee and its specialist Sub-Committees appointed for this purpose.

BCGA makes strenuous efforts to ensure the accuracy and current relevance of its publications, which are intended for use by technically competent persons. However this does not remove the need for technical and managerial judgement in practical situations. Nor do they confer any immunity or exemption from relevant legal requirements, including by-laws.

For the assistance of users, references are given, either in the text or Appendices, to publications such as British, European and International Standards and Codes of Practice, and current legislation that may be applicable but no representation or warranty can be given that these references are complete or current.

BCGA publications are reviewed, and revised if necessary, at five-yearly intervals, or sooner where the need is recognised. Readers are advised to check the Association’s website to ensure that the copy in their possession is the current version.

This document has been prepared by BCGA Technical Sub-Committee 1. This document replaces BCGA CP 4, Revision 4: 2012. It was approved for publication at BCGA Technical Committee 161. This document was first published on 14/02/2020. For comments on this document contact the Association via the website www.bcga.co.uk.
# CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>TERMINOLOGY AND DEFINITIONS</td>
<td>1</td>
</tr>
<tr>
<td>1. INTRODUCTION</td>
<td>7</td>
</tr>
<tr>
<td>2. SCOPE</td>
<td>7</td>
</tr>
<tr>
<td>3. INITIAL CONSIDERATIONS</td>
<td>9</td>
</tr>
<tr>
<td>3.1 Roles and responsibilities</td>
<td>9</td>
</tr>
<tr>
<td>3.2 Competence</td>
<td>9</td>
</tr>
<tr>
<td>3.3 Legal framework</td>
<td>10</td>
</tr>
<tr>
<td>4. THE PRESSURE SYSTEM – DESIGN CONSIDERATIONS</td>
<td>12</td>
</tr>
<tr>
<td>4.1 The gas source</td>
<td>13</td>
</tr>
<tr>
<td>4.2 Supply pipework</td>
<td>14</td>
</tr>
<tr>
<td>4.3 The control system</td>
<td>14</td>
</tr>
<tr>
<td>4.4 Distribution system</td>
<td>15</td>
</tr>
<tr>
<td>5. THE DUTIES OF THE DESIGNER</td>
<td>16</td>
</tr>
<tr>
<td>5.1 Component selection</td>
<td>20</td>
</tr>
<tr>
<td>5.2 Material selection</td>
<td>24</td>
</tr>
<tr>
<td>6. THE DUTIES OF THE INSTALLER</td>
<td>26</td>
</tr>
<tr>
<td>7. TESTING</td>
<td>27</td>
</tr>
<tr>
<td>7.1 Verification of the installation</td>
<td>29</td>
</tr>
<tr>
<td>7.2 Pressure testing</td>
<td>30</td>
</tr>
<tr>
<td>7.3 Electrical safety testing</td>
<td>35</td>
</tr>
<tr>
<td>7.4 Inspection body involvement</td>
<td>35</td>
</tr>
<tr>
<td>8. COMMISSIONING AND HANDOVER</td>
<td>35</td>
</tr>
<tr>
<td>8.1 Purging</td>
<td>36</td>
</tr>
<tr>
<td>8.2 Final checks</td>
<td>37</td>
</tr>
<tr>
<td>8.3 Handover</td>
<td>38</td>
</tr>
</tbody>
</table>
9. PUTTING INTO SERVICE 39
10. SECURITY 39
11. REFERENCES *

APPENDICES:
APPENDIX 1 CONTROL SYSTEMS - LOCATION 48
APPENDIX 2 LEAK PATHS 54
APPENDIX 3 PIPEWORK 55
  A3.1 Material selection 56
  A3.2 Plastic pipework 57
  A3.3 Cryogenic pipework 58
  A3.4 Articulation, vibration, expansion and contraction 59
  A3.5 Bends 62
  A3.6 Pressure drop 62
  A3.7 Velocity 63
  A3.8 Preparation for jointing 64
  A3.9 Jointing methods 64
  A3.10 Routing 69
  A3.11 Supports 75
  A3.12 Cleaning 77
APPENDIX 4 VENT SYSTEMS 78
APPENDIX 5 COMPONENTS 80
APPENDIX 6 ELECTRICAL COMPONENTS AND SYSTEMS 87
APPENDIX 7 EXTERNAL PROTECTION 89
APPENDIX 8 IDENTIFICATION 91
APPENDIX 9 CONSIDERATIONS FOR SOME COMMON GASES 93

* Throughout this publication the numbers in [ ] brackets refer to references in Section 11.
Documents referenced are the edition current at the time of publication, unless otherwise stated.
TERMINOLOGY AND DEFINITIONS

Adiabatic compression  Occurs when there is no heat transfer during the compression of a gas, either because of perfect insulation or because the change in pressure is so rapid that there is insufficient time for the heat, which is generated, to dissipate. This may happen if a valve in a system is opened too quickly, leading to rapid pressurisation of a system. This results in elevated temperatures and can lead to ignition in some cases, for example, in oxygen systems.

Assemblies  Several items of pressure equipment assembled to constitute an integrated and functional whole.

Auto change unit  A device used to ensure continuity of supply between dual system gas supplies, normally situated in the manifold header and set to automatically change from the service bank to the reserve bank at a predetermined pressure. This device commonly has integral pressure regulators. However where pressure regulators are not an integral part of the unit a main pressure regulator is still required.

Bundle (of cylinders) / Manifolded Cylinder Pallet (MCP)  An assembly of cylinders that are fastened together and which are interconnected by a manifold and carried as a unit. The total water capacity shall not exceed 3000 litres except that bundles intended for the carriage of toxic gases of Class 2 (groups starting with letter T according to ADR [17] 2.2.2.1.3) shall be limited to 1000 litres water capacity.

Bursting disc  A relief device designed to operate in the event of over-pressure, and thereby protect a specific pressure system or part of a system. Bursting discs are set to operate (i.e. burst) at a specific set pressure, within a closely-defined tolerance. Unlike a pressure relief valve, a bursting disc cannot re-seat after operation; the stored contents will be released.

Channel  A narrow channel, of rigid construction, located in the ground with a cover at ground level, to accommodate the passage of pipework, cables, etc. The cover may consist, for example, of a grating or masonry slabs.

Composite safety device  A unit which embodies a flame arrestor and one or more of these devices:

- Non-return valve
- Temperature sensitive cut-off valve
- Pressure sensitive cut-off valve
Confined space | Any place, including room, chamber, tank, vat, silo, pit, trench, pipe, sewer, flue, well, or other similar space in which, by virtue of its enclosed nature, there arises a reasonably foreseeable specified risk.

It has two defining features:

(i) It is a place which is substantially, (though not always entirely) enclosed;
(ii) There will be a reasonably foreseeable risk of serious injury from; flammable or toxic atmosphere, oxygen deficient or enriched oxygen atmosphere.

Refer to the *Confined Spaces Regulations* [5].

Cylinder | A transportable pressure receptacle of a water capacity not exceeding 150 litres.

Detonation | A flame front which travels into the unreacted gas usually several times the speed of sound. Detonation involves a sharp difference in pressure between the reacted and unreacted gas. The change from low pressure of the unreacted gas to the high pressure produced by the reacted gas takes place in a shock wave at the front of the flame.

Duct | An enclosed space formed for the passage of pipework, cables, etc.

Filter | An element capable of restraining particles which may interfere with the operation of downstream equipment.

Flame arrestor | A device which arrests a flame front (caused by flashback or decomposition) and which is suitable for the most severe type of flame which may occur, i.e. detonation.

It shall be effective in stopping a flame coming from either one or both directions depending upon the application and design. Flashback may occur in systems using flammable gases and, other than in acetylene systems, will normally require a mixture of the flammable gas and oxygen, or the flammable gas and air to occur.

Flexible hose | A flexible connection between two components in the system.

Flow meter | A device for measuring gas flow by mass or volume.
<table>
<thead>
<tr>
<th><strong>Gas</strong></th>
<th>the purpose of this Code of Practice the term gas refers to gases that are cryogenic, liquefied or compressed.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Compressed gas</strong></td>
<td>A gas which when packaged under pressure (for transport) is entirely gaseous at -50 °C; this category includes all gases with a critical temperature less than or equal to -50 °C.</td>
</tr>
<tr>
<td><strong>Cryogenic gas</strong></td>
<td>A gas which is made partially liquid because of its low temperature. Temperatures below 120 K (-153 °C) are referred to as cryogenic temperatures.</td>
</tr>
<tr>
<td><strong>Flammable gas</strong></td>
<td>Gases which at 20 °C and a standard pressure of 101.3 kPa:</td>
</tr>
<tr>
<td></td>
<td>- are ignitable when in a mixture of 13 % or less by volume with air; or</td>
</tr>
<tr>
<td></td>
<td>- have a flammable range with air of at least 12 percentage points regardless of the lower flammability limit.</td>
</tr>
<tr>
<td><strong>Inert gas</strong></td>
<td>A gas that is neither toxic nor flammable, but which does not support human life and which reacts scarcely or not at all with other substances.</td>
</tr>
<tr>
<td><strong>Liquefied gas</strong></td>
<td>A gas which when packaged under pressure (for transport) is partially liquid at temperatures above -50 °C.</td>
</tr>
<tr>
<td></td>
<td>High pressure liquefied gas: a gas with a critical temperature above -50 °C and equal to or below +65 °C.</td>
</tr>
<tr>
<td></td>
<td>Low pressure liquefied gas: a gas with a critical temperature above +65 °C.</td>
</tr>
<tr>
<td><strong>Oxidising gas</strong></td>
<td>Gases which may, generally by providing oxygen, cause or contribute to the combustion of other material more than air does.</td>
</tr>
</tbody>
</table>
Heater
A device to maintain gases and/or equipment above the minimum required process temperatures.

Sometimes referred to as a ‘Trim Heater’, ‘Process heater’ or a ‘Trace Heater’.

May
An option available to the user of this Code of Practice.

Outlet point
An assembly including an isolation valve, together with other features identified in Section 5.1, fitted at the termination of the distribution pipework for connection of the user equipment.

Pipeline
A pipe or system of pipes used for the conveyance of relevant fluid across the boundaries of premises, together with any apparatus for inducing or facilitating the flow of relevant fluid through, or through a part of, the pipe or system, and any valves, valve chambers, pumps, compressors and similar works which are annexed to, or incorporated in the course of, the pipe or system.

Pressure

<table>
<thead>
<tr>
<th><strong>Pressure unit</strong></th>
<th>1 bar = 100 kPa = 0.1 MPa = (10^5) N/m(^2) = 0.1 N/mm(^2) = 14.5 psi</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pressure drop</strong></td>
<td>The loss of pressure through the system due to frictional forces and restrictions under flow conditions.</td>
</tr>
<tr>
<td><strong>Design pressure</strong></td>
<td>For the purpose of this document the design pressure is equivalent to the MAWP. Refer to Figure 1.</td>
</tr>
<tr>
<td><strong>Operating pressure (OP)</strong></td>
<td>The operating pressure is the pressure the system will routinely operate at and should not exceed 90% of MAWP.</td>
</tr>
</tbody>
</table>

**NOTE:** Each section of the pressure system may have a different operating pressure. Refer to Figure 1.

<table>
<thead>
<tr>
<th><strong>Maximum allowable working pressure (MAWP)</strong></th>
<th>The maximum allowable working pressure is the maximum pressure for which the system is designed. The primary protective device(s) set-point shall not exceed this pressure.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NOTE:</strong> Each section of the pressure system may have a different maximum allowable working pressure.</td>
<td>Refer to Figure 1.</td>
</tr>
</tbody>
</table>

BCGA CP 4 – Revision 5
Pressure equipment
Means any component, assembly or sub-assembly designed, incorporated or intended for use in a pressure system, such as vessels, piping, safety accessories, or pressure accessories.

Pressure receptacle
A collective term that includes cylinders, tubes, pressure drums, closed cryogenic receptacles, metal hydride storage systems, bundles of cylinders and salvage pressure receptacles.

Pressure regulator
A self-governing device for regulating a variable inlet pressure to the required outlet pressure.

When used to regulate pressure from a high pressure gas source, it is normal practice to use a multi-stage regulator.

Pipework / piping
A pipe or system of pipes together with associated valves, pumps, compressors and other pressure containing components such as hoses or bellows, intended for the transport of gases when connected together for integration into a pressure system.

This does not include a pipeline.

Pipework, header
Pipework for collecting gas pressure from one or more pressure source(s).

Distribution pipework
The pipework downstream of the pressure source(s) or primary control system pressure regulator.

Protective device
Devices designed to protect the pressure system against system failure and devices designed to give warning that system failure might occur, this includes bursting discs.

Safe operating limits
Means the operating limits, which may incorporate a suitable margin of safety, beyond which system failure is liable to occur.

These limits are defined by the Designer and include parameters such as pressure (which relates to MAWP, refer to Figure 1) or temperature, or other such parameter requiring limitation.

Shall
Indicates a mandatory requirement for compliance with this Code of Practice and may also indicate a mandatory requirement within UK law.

Should
Indicates the preferred requirement but is not mandatory for compliance with this Code of Practice.

Valves
Non-return valve
A self-actuating valve which prevents the passage of gas in the opposite direction to the design flow direction.

Isolating valve
A valve which gives positive shut-off.
Pressure relief valve  A device which automatically vents gas from a pressure system in order to prevent over pressure in that system. The pressure relief valve should automatically reseat when the condition(s) causing the over-pressure is corrected and when the pressure itself reduces.

Vaporiser  A device for converting liquid to gas by heat transfer.

Well ventilated  Adequate ventilation that prevents the unsafe accumulation of any foreseeable release of gas. Refer to BCGA GN 11 [93].

Figure 1: Visualisation of various pressures
CODE OF PRACTICE 4

GAS SUPPLY AND DISTRIBUTION SYSTEMS
(EXCLUDING ACETYLENE)

1. INTRODUCTION

This Code of Practice covers the design, installation, commissioning and handover of gas supply and distribution systems (pipework). This will comprise of one or more pressure systems.

A pressure system consists of a number of components which are assembled together using piping and piping components. Pressure systems used within the work environment shall comply with the Health and Safety at Work etc. Act \[1\] as well as all applicable legislation, including the requirements of the Pressure Equipment (Safety) Regulations \[14\], the Pressure Systems Safety Regulations (PSSR) \[9\] and the Provision and Use of Work Equipment Regulations PUWER \[6\].

The integrity of a pressure system is the primary safety requirement and this will be dependent on various considerations and principles that should be observed during its design and installation.

Pressure system designs will vary, for example, by the selection of the gas, pressure, temperature, flow rate, gas quality and the control required. This will affect the choice of materials and components, as well as the location(s) in which they can be installed.

The roles and responsibilities of individuals involved in the design and installation of a pressure system are detailed in the main body of the document, whilst information on design elements and the methodology for installing a pressure system are incorporated into the appendices.

This document is not a design code; reference shall be made to appropriate design codes and standards.

This code of practice is intended for use in conjunction with current guidance and information produced by the Health and Safety Executive (HSE) and other related bodies and trade associations.

2. SCOPE

This Code of Practice provides the minimum safety practices and principles for the selection and assembly of pressure equipment to control and distribute gases. It includes the design, construction, installation and putting into service of such assemblies.

This document is for the installation of a new pressure system and for where there is a modification (including an addition) to an existing system.
For the in-service requirements of such assemblies refer to BCGA CP 39 [88], *In-service requirements of pressure equipment (gas storage and distribution systems)*.

This Code of Practice shall be used for all gas supply systems (unless excluded below).

This code excludes:

- acetylene gas. Requirements for acetylene gas control systems are given in BCGA CP 5 [79], *The design and construction of manifolds using acetylene gas from 1.5 bar to 25 bar*. Requirements for acetylene distribution are given in BCGA CP 6 [80], *The safe distribution of acetylene in the pressure range 0 - 1.5 bar*;

- closed-loop systems which do not release their gas charge under normal conditions of use, for example, in refrigeration and air conditioning systems;

- compressed air systems, not supplied by a transportable pressure receptacle. Refer to publications produced by the British Compressed Air Society (BCAS);

- transmission pipelines which are within scope of the *Pipelines Safety Regulations* [4], and pipelines as defined in the PSSR [9];

- pressure assemblies associated with the propulsion of any type of vehicle, for example, cars, ships, trains, planes, etc.;

**NOTE:** Pressure assemblies used for the operation of on-board ancillary equipment, for example, fire suppression systems, cooling systems etc. are in scope of this code of practice.

- domestic use;

- gases and their applications as defined in *Gas Safety (Installation and Use) Regulations* [7].

Some gas applications may have specific requirements, such as:

- food gases, refer to BCGA GN 14 [95], *Production, storage, transport and supply of gases for use in food*;

- specialty gases, refer to BCGA CP 18 [82], *The safe storage, handling and use of special gases*;

- medical gases, for information on medical gas pipework refer to the Department of Health, Health Technical Memorandum HTM 02-01 [29], *Medical gas pipeline systems*, and BS EN ISO 7396 [50], *Medical gas pipeline systems*. For pharmacopeia gases, refer to medical good manufacturing practice (GMP) guidance.
3. INITIAL CONSIDERATIONS

The foremost principle to follow when designing any gas control and distribution system is that it can be installed, commissioned, operated and maintained safely, with minimum effect on the environment.

3.1 Roles and responsibilities

The roles and responsibilities of the key personnel involved shall be established at the beginning of the project. For the purposes of this document there are three roles to be fulfilled:

1) User. The User has the requirement and becomes the ultimate user of the pressure system. The User will be responsible for putting the pressure system into service and will have to ensure compliance with the PSSR[^9][9], including the appointment of a Competent Person, refer to Section 9.

The User shall communicate the key requirements to the Designer. These should include:

- purpose of the pressure system;
- compatibility to process equipment;
- desired location of equipment, including the routing of pipework.

Where the User does not have the necessary knowledge then they should seek advice from a person with relevant competency.

2) Designer. The Designer takes the (User) requirement and prepares a design specification. In particular refer to Section 5.

3) Installer. The Installer installs the pressure system in accordance with the design specification. In particular refer to Section 6.

The Designer, Installer and User shall agree who is responsible for managing the testing (Section 7), commissioning and handover (Section 8) as well as on-site activities, taking into consideration all legal obligations.

Compliance will be required with a variety of Regulations, refer to Section 3.3.

An individual or body may fulfil one or more of these roles.

3.2 Competence

All persons involved in the design, installation, commissioning and testing of pressure systems shall be competent in the work they are undertaking.

Competence requires that personnel have the appropriate level of skills, knowledge and experience, including a thorough knowledge of the relevant parts of this Code of Practice.
BCGA define competence within BCGA GN 23\textsuperscript{[96]}, Gas safety information, instruction and training.

NOTE: Under the PSSR\textsuperscript{[9]} there is a specific role of ‘Competent Person’ which is laid out within HSE L122\textsuperscript{[22]} Safety of pressure systems. Pressure Systems Safety Regulations 2000. Approved Code of Practice and guidance.

### 3.3 Legal framework

The principal legislation covering the design, installation and subsequent use of pressure systems is the Health and Safety at Work etc. Act\textsuperscript{[1]}, which places duties on organisations and employers to protect the health and safety of employees and others (who may be affected). The duties include the provision and maintenance of plant and systems of work that are, so far as is reasonably practicable, safe and without risks to health. This includes pressure equipment.

There are several Regulations which further define legal requirements, these include:

- The *Provision and Use of Work Equipment Regulations* (PUWER)\textsuperscript{[6]} which requires that work equipment should not result in health and safety risks, regardless of its age, condition or origin. The PUWER\textsuperscript{[6]} requires that the employer selects suitable equipment and carries out appropriate maintenance, inspection, identifies any specific risks and provides suitable information, instructions and training.

  The HSE provide further guidance on the PUWER\textsuperscript{[6]} within HSE L22\textsuperscript{[19]}, Safe use of work equipment. Provision and Use of Work Equipment Regulations 1998. Approved Code of Practice and guidance.

- The *Pressure Equipment (Safety) Regulations*\textsuperscript{[14]}, for pressure equipment operating above 0.5 bar, which shall be complied with during the design and installation of all new pressure systems.

  Guidance is available from the HSE at: [http://www.hse.gov.uk/pressure-systems/index.htm](http://www.hse.gov.uk/pressure-systems/index.htm) and for customer sites refer to BCGA CP 34\textsuperscript{[86]}, The application of the Pressure Equipment Regulations to customers sites.

- The *Pressure Systems Safety Regulations*\textsuperscript{[9]} includes design and construction requirements as well as in-use gas pressure equipment operating above 0.5 bar. It requires that such equipment is examined and maintained. It should be noted that the overall intention of the PSSR\textsuperscript{[9]} is to prevent serious injury from the hazard of stored energy, as a result of the failure of a pressure system or one of its component parts. The primary responsibility for compliance lies with the User of the pressure equipment and it is the User’s responsibility to enlist any assistance required to comply with the Regulations.

  The HSE provide guidance on the PSSR\textsuperscript{[9]} in HSE L122\textsuperscript{[22]}.

- The *Construction (Design and Management) Regulations*\textsuperscript{[13]} govern the way construction projects are managed. The design, installation and maintenance of pressure systems are included. The key elements, include:
° managing the risks by applying the general principles of prevention;

° appointing the right people and organisations at the right time;

° making sure everyone has the information, instruction, training and supervision they need to carry out their jobs in a way that secures health and safety;

° duty-holders cooperating and communicating with each other and coordinating their work; and

° consulting workers and engaging with them to promote and develop effective measures to secure health, safety and welfare.


- The *Dangerous Substances and Explosive Atmospheres Regulations* (DSEAR) \[[11]\] places obligations on operators of sites where hazardous atmospheres (for example, flammable or oxidant) could be present or created. The regulations are concerned with protection against the risks from fire, explosion or substances corrosive to metals. Gases that are under pressure may present a risk of rupture which may lead to an explosion if not correctly handled in the workplace. Substances that can corrode metals could cause structural damage reducing integrity of structures if not suitably contained. *The Dangerous Substances and Explosive Atmospheres Regulations* \[[11]\] places a formal requirement on employers to assess the risks and put in place suitable control and mitigation measures.

As necessary, equipment and protective systems shall comply with the *Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres Regulations* \[2\]. Areas where hazardous explosive atmospheres may occur have to be classified into zones and only equipment suitable for that zone shall be located within it. These hazardous areas may occur at several locations around and/or on the route of a pressure system. For further information refer to:


° BS EN 60079, Part 10 \[76\], *Explosive atmospheres. Classification of areas. Explosive gas atmospheres.*

° BCGA GN 13 \[94\], *DSEAR Risk Assessment.*

- The *Confined Spaces Regulations* \[5\] which regulates those involved in managing work within confined spaces, those who employ or train such people and those that represent them. For further information refer to HSE L101 \[21\], *Safe...*

- The Regulatory Reform (Fire Safety) Order \(^{12}\) requires that a responsible person shall carry out a Fire Safety Risk Assessment within the workplace. This shall include an assessment of the impact from an installed pressure system and its associated gas source. The findings from which shall be incorporated into the Site Fire Safety Management Plan. Appropriate fire-control and other risk management measures, as determined by the Fire Safety Risk Assessment, shall be provided.

- The Control of Substances Hazardous to Health Regulations (COSHH) \(^{10}\), requires employers to either prevent or reduce workers’ exposure to substances that are hazardous to their health.

For further information refer to HSE L5 \(^{18}\), Control of substances hazardous to health. The Control of Substances Hazardous to Health Regulations 2002 (as amended). Approved Code of Practice and guidance.

- The Management of Health and Safety at Work Regulations \(^{8}\), as well as other legislation, require employers to conduct risk assessments to ensure the health and safety of all those who may be exposed to hazards due to the employer’s activities.

4. THE PRESSURE SYSTEM - DESIGN CONSIDERATIONS

Gas supply and distribution systems are assemblies of individual components which will form a pressure system when joined together.

A typical pressure system is divided into distinct areas:

- the gas source, refer to Section 4.1.
- the supply pipework, refer to Section 4.2.
- the control system, refer to Section 4.3.
- the distribution system, refer to Section 4.4.

Figure 2 provides a schematic representation of a pressure system.
Deciding on the selection and assembly of individual components, which may or may not be ‘off-the-shelf’, is a design activity and shall be carried out by a person(s) with the relevant competencies, the ‘Designer’.

The general requirements for the Designer of a pressure system are detailed in Section 5.

Section 5.1 provides guidance and requirements for the selection of components within a pressure system.

Section 5.2 provides guidance on the selection of materials for use in a pressure system.

4.1. The gas source
The gas may be stored and / or supplied from a variety of sources, for example, a cryogenic storage tank, a pressure receptacle (such as a gas cylinder), manufactured on site by a gas generation system, delivered via pipeline, etc.

Where the gas source supply conditions, at the outlet point of the gas source, match the specified User requirements and cannot vary beyond the safe operating limits of the pressure system(s) downstream, it may be connected directly to the distribution system (refer to Section 4.4) with no need for further control.

For the design and installation of a liquid storage tank, as appropriate, refer to:

- BCGA CP 26 [83], *Bulk liquid carbon dioxide storage at users’ premises*.
- BCGA CP 36 [87], *Cryogenic liquid storage at users’ premises*.
- BCGA CP 46 [92], *The storage of cryogenic flammable fluids*. 

---

**Figure 2:** Schematic of a pressure system

For transportable vacuum insulated containers refer to:

- BCGA CP 27 \(^{[84]}\), *Transportable vacuum insulated containers of not more than 1000 litres volume*.

For tube trailers, refer to:

- BCGA CP 33 \(^{[85]}\), *The bulk storage of gaseous hydrogen at users’ premises*.

For gas cylinders and bundles:

- for the principles of locating in-use gas cylinders, refer to BCGA CP 44 \(^{[91]}\), *The storage of gas cylinders*, but for the minimum recommended separation distances refer to Appendix 1 of this document.

For connections to pipelines, refer to the pipeline operator.

BCGA CP 44 \(^{[91]}\) details the requirements for the storage of gas cylinders, but its principles and practices shall also be followed when locating gas cylinders for use with a pressure system. The demarcation point from the gas source will be at the gas outlet of the valve assembly fitted directly to the gas cylinder.

4.2 Supply pipework
The supply pipework, where applicable, connects the gas source(s) to the control system, refer to Figure 2.

The supply pipework shall have a maximum allowable working pressure (MAWP) as defined below:

- where the gas supply is from cylinders the MAWP shall be at least equal to the developed cylinder pressure at 60 °C; this information may be obtained from the gas cylinder supplier;

- where the gas supply is from a tank or gas generator the MAWP of the supply system shall be at least equal to or above the set pressure of the primary protective device of the tank, or gas generator outlet;

- where the gas supply is from a pipeline, the MAWP of the supply system shall be at least equal to or above the MAWP of the pipeline as advised by the pipeline operator.

The supply pipework shall have the appropriate permanent end fittings to connect direct to the gas source. Additional adapters shall not be used.

4.3 The control system
Where the gas source supply conditions, at the gas source outlet point, do not match the specified User requirements, a control system is required.
The primary control system receives the gas from the gas source, via the supply pipework where applicable, and then changes and controls the output gas to that required.

Additional (secondary) control systems can be incorporated downstream, as necessary, to provide specific control to the point of use.

A control system can be as simple as a single pressure control regulator (with over pressure protection), fitted to the gas source connection point, to a much more complex arrangement incorporating, for example, multiple gas sources, safety devices, blenders, temperature, pressure and flow control systems.

Where the output gas pressure required is higher than the pressure at the gas source then the control system may include compression equipment complete with relevant safety protection devices to prevent over-pressurisation of the gas source.

The inlet to the control system shall be capable of withstanding the pressure and temperature limits of the gas source so as not to give rise to danger.

Where failure of the control system can lead to danger through malfunction or other abnormal circumstances, the design shall ensure the distribution system is adequately protected from exceeding its safe operating limits.

NOTE: The term ‘manifold’ refers to the connection of multiple gas paths to and from a pipework header or pressure source. However, this term is also commonly used to refer to a complete control system assembly, i.e. a collection of components contained within a single ‘off-the-shelf’ proprietary product which will typically provide a combination of the basic controls necessary for a pressure system, such as safety devices, pressure reduction, pressure indication, flow control and connections to the gas supply and distribution pipework.

Each gas control system shall be located in an area where it is adequately protected from potential external hazards. The location shall take account of any hazards produced by a release of gas. Refer to Appendix 1 for information on locating gas control systems.

4.4 Distribution system

The distribution system is that part of an installation that delivers the gas from the outlet of the primary control system, or directly from the gas source where a primary control system is not required, to the point(s) of use; refer to Figure 2. Where the distribution system connects directly to the gas source, the principals outlined in Section 4.2 shall apply to the pipework elements of the distribution system.

The distribution system comprises of pipework and may feature a number of additional (secondary) control systems, providing specific control for onwards distribution or for the point of use, refer to the principles outlined in Section 4.3.

Downstream systems and equipment shall be adequately protected from exceeding safe operating limits. For each part of the distribution system, the protective device set point shall not exceed the MAWP of the lowest rated pressure of any component in that part of the system.
For additional information on the requirements of oxy-fuel systems refer to BCGA CP 7 [81], *The safe use of oxy-fuel gas equipment (individual portable or mobile gas supply)*.

5. **THE DUTIES OF THE DESIGNER**

The Designer is responsible for the design of the pressure system, taking into account the many variables, and needs to be competent for this role. Where the Designer does not have all the necessary competences then specialist advice shall be sought. The Designer shall take the User requirement and convert it into a design specification.

Working with the User, the Designer should understand the application and shall establish the required gas(es), pressure, temperature, flowrate, quality requirements, the physical state (solid, liquid and / or gas), the characteristics of the local environment and location, and ensure compatibility with the gas(es) and the end process equipment.

As applicable, the Designer shall take into account interfaces with other systems, including pressure systems, as well as any specific local design or environmental features that have been incorporated.

The Designer shall ensure the design will comply with the requirements of applicable legislation, refer to Section 3.3.

The Designer shall base the system design on the requirements of applicable industry standards, with respect to mechanical, electrical and process design, and implement sound engineering design practices including the output from any appropriate risk assessments. For example, refer to Safety Assessment Federation (SAFed) IMG 1 [118], *The mechanical integrity of plant containing hazardous substances. A guide to periodic examination and testing*.

Pressure systems shall be designed to avoid mechanical damage and minimise external stresses. The Designer should ensure that phenomena known to cause problems in pipework systems are considered and allowed for in the mechanical design, or designed out where practicable. These can include:

- pressure surge;
- cavitation;
- pulsations / vibrations;
- cyclic loadings;
- temperature gradients and cycling;
- unintended reverse flows.

The design shall prevent the potential for a liquefied or cryogenic gas to become trapped between two closed valves, commonly referred to as ‘liquid lock’. Liquid lock can result in
rapid pressure rise due to thermal expansion and phase change into a gas. A pressure relief device shall be interposed between any two stop valves where liquid may be trapped.

Section 5.1 provides guidance and requirements for the selection of components within a pressure system.

Section 5.2 provides guidance on the selection of materials for use in a pressure system.

The Designer will draw up a design specification which shall address all the relevant requirements of this Code of Practice.

The Designer shall ensure that:

- the intended operation of the pressure system is clearly understood and defined for normal and other reasonably foreseeable conditions including those conditions arising during start up, shutdown and as a result of process upsets;
- modifications or additions to an existing pressure system shall be carried out to a modern equivalent or a higher design and construction standard(s) than the original system, so as not to reduce its integrity. Full testing of the modified system will be required on completion;
- the pressure system is designed to be operated at the lowest possible pressure to meet the user requirement and with a restricted flow-rate suitable for the intended operation;
- the gas(es) are correctly specified in accordance with the User’s requirements, and all its properties and hazards have been taken into consideration. Refer to the Safety Data Sheet and, as needed, seek advice from the gas supplier;
- the type and location of the gas source(s) is specified, is compatible with the intended pressure system, and all the gas source(s) hazards have been taken into consideration. Refer to Section 4.1;
- where there is a requirement to mix oxidising and flammable gases together, the mixing process shall take place at the point of ignition or at a point specifically designed for this purpose. The resulting oxy-fuel gas shall not be conveyed in pipework;
- the safe operating pressure limits of the system are defined.
  - The Designer shall define the operating pressure (OP) of each part of the pressure system, which is the highest pressure at which the system will safely and routinely operate.
  - The Designer shall define the MAWP for each part of the pressure system, which is the maximum pressure at which the safety relief devices shall be set. The MAWP should be a minimum of 10% above the operating pressure;
- the safe operating temperature and any other relevant limits of the system are defined;
• appropriate safety devices are included to ensure the pressure system design limits are never exceeded, refer to Section 5.1;

• the temperature, pressure and flow characteristics have been assessed, are appropriate for the design of the pressure system and provide the output required by the end user, taking into consideration the pressure drop (refer to Appendix 3, A3.6) and the velocity (refer to Appendix 3, A3.7) of the gas flow;

• the correct components have been identified and their sequence in the pressure system is specified (typically by way of a process diagram) to meet the minimum safety requirements and the operational needs of the User, refer to Section 5.1;

• all materials exposed to the gas stream, including those within proprietary or ‘off-the-shelf’ components, have been selected to be compatible with the gas, as well as the pressure, temperature, flow requirements and the operating environment, refer to Section 5.2;

• the design is ergonomic and takes into account human factors, for example, in providing accessibility to allow valves and other controls to be operated, allows visibility of indication devices and enables all necessary examinations, inspections and maintenance requirements to be undertaken;

• where the pressure system may be managed under a Permit to Work / Lock Out-Tag Out procedure, that (isolation) valves incorporate design features which allow them to be physically secured;

• where pipework bends are necessary then they do not adversely impact the flow and velocity. The bend specification shall be provided, refer to Appendix 3, A3.5;

• the type of joints and the methodology for preparing and jointing pipework and components is defined as well as any quality control measures. This may include: the competence of the installer, alignment tolerances, defect limits, the extent of visual and non-destructive testing, jointing material specification, etc. Refer to Appendix 3, A3.9;

• where a gas may be released (for example, from safety devices), that it is only released into an area that has been assessed as safe. The design specification shall include either specific locations for discharge or the general characteristics that will determine a safe location. Where a vent system is required, refer to Appendix 4;

• any interface with or requirement for electrical equipment is identified, including the requirement for earth bonding, and that appropriate electrical equipment is specified, refer to Appendix 6;

• pipework is designed for ease of cleaning and purging where this is a User or critical design requirement, for example, for oxidising or toxic gases. An appropriate cleaning standard shall be specified, refer to Appendix 3, A3.12.
• Pipework dead legs should be avoided where possible. Dead legs are sections of pipework branched away from the main flow path, under stagnant or low flow conditions. The hazard from dead legs could include accumulation of contaminants, increased risk of ignition from foreign matter accumulation or adiabatic compression (for example, in oxygen systems), accelerated internal corrosion, ineffective purging, etc.;

• The location for the control system(s), is identified. Refer to Appendix 1;

• The routing of the pipework and the mounting of components is identified and, as necessary, additional information and design considerations are provided, for example, constraints on locations for joints and potential leak paths (refer to Appendix 2), if the route requires to pass other hazards, go through enclosed spaces, go underground, etc. Refer to Appendix 3, A3.10;

• Potential leak paths, are identified, and appropriate design measures are taken to minimise the impact from a leak, refer to Appendix 2;

• The specification includes the type, location and required quantity of pipework supports to be used, refer to Appendix 3, A3.11;

• Measures to protect the pipework, including any protective finish necessary, to maintain the pipework in a serviceable condition is specified, refer to Appendix 7;

• The marking and identification requirements for the pressure system, including on individual components and pipework is specified, refer to Appendix 8;

• The initial and in-service tests and the testing regime for components, as well as the completed pressure system, is specified, refer to Section 7.

Particular equipment design codes may have specific pressure testing requirements, and the equipment may also be required to comply with applicable legislation, for example, The Pressure Equipment (Safety) Regulations [14];

• The requirements for commissioning the pressure system are specified, refer to Section 8;

• Certification requirements are specified;

• Appropriate drawings and Bill of Materials are produced which identify the pressure system, its control systems, components and associated pipework;

• The specification provided to the User includes any necessary installation information, operating instructions, limitations and maintenance requirements;

• The completed pressure system design is suitable for the stipulated purpose and will not cause danger.
The completed design specification shall provide all necessary information to allow the pressure system to be installed, refer to Section 6. This shall be provided to the Installer; this may be directly from the Designer or via the User.

### 5.1 Component selection

Table 1 provides guidance and requirements for the selection of various components and their location within a pressure system. For additional information refer to Appendix 5 – *Components*.

<table>
<thead>
<tr>
<th>COMPONENT *</th>
<th>FUNCTION</th>
<th>LOCATION</th>
<th>Requirements &amp; comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas source connector.</td>
<td>Physical connection.</td>
<td>At start of system.</td>
<td>Mandatory.</td>
</tr>
<tr>
<td></td>
<td>Prevent incorrect gas / class connection.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flexible hose / pig tail.</td>
<td>Flexible movement to allow two systems to connect.</td>
<td>Following gas source connector.</td>
<td>Mandatory when directly connected to a transportable pressure receptacle or a tube trailer.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Between end of gas distribution system and process.</td>
<td>To suit process requirement.</td>
</tr>
<tr>
<td>Non return valve</td>
<td>Prevent flow from an unconnected gas source connector.</td>
<td>Each inlet point on a multiple cylinder manifold.</td>
<td>Required where there is a risk of having unconnected hoses or a risk of transfer of liquefied gas product.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Where gas sources are intentionally left unconnected a further means of isolation, such as an isolation valve or blanking plug shall be fitted.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Close to connector.</td>
<td>May be required, to maintain quality control and to minimise any contamination.</td>
</tr>
<tr>
<td></td>
<td>Maintain gas quality in system during changeover of cylinders.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>To prevent gas migration between liquefied gas cylinders.</td>
<td>Each inlet point on a multiple cylinder manifold.</td>
<td>Mandatory where liquid withdrawal liquefied gas cylinders are manifòled.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Minimise gas loss in the event of upstream loss of containment.</td>
<td>May be required dependant on process, location or gas.</td>
</tr>
<tr>
<td>COMPONENT *</td>
<td>FUNCTION</td>
<td>LOCATION</td>
<td>Requirements &amp; comments</td>
</tr>
<tr>
<td>-------------</td>
<td>----------</td>
<td>----------</td>
<td>------------------------</td>
</tr>
<tr>
<td>Valve</td>
<td>Isolation: To isolate the gas source from the distribution system.</td>
<td>Close to gas connector.</td>
<td>Mandatory, where not incorporated within the gas source. Appendix 5 – A5.3</td>
</tr>
<tr>
<td></td>
<td>Isolation: Operational isolation.</td>
<td>At diversions within the system.</td>
<td>As required, to suit operational requirements. Appendix 5 – A5.3</td>
</tr>
<tr>
<td></td>
<td>At the end use point(s).</td>
<td></td>
<td>Mandatory. Appendix 5 – A5.3</td>
</tr>
<tr>
<td></td>
<td>At sample / analysis point(s).</td>
<td></td>
<td>Mandatory. Appendix 5 – A5.3</td>
</tr>
<tr>
<td></td>
<td>Isolation: Emergency isolation.</td>
<td>Determined by risk assessment.</td>
<td>Mandatory, this function may be achieved by the valve isolating the gas source. The type and method of activation to be determined by risk assessment. Appendix 5 – A5.3</td>
</tr>
<tr>
<td></td>
<td>Isolation: Prevent flow from an unconnected gas source connector.</td>
<td>Each inlet point on a multiple cylinder manifold.</td>
<td>Mandatory Either a non-return valve is required or an isolation valve is required. Appendix 5 – A5.3</td>
</tr>
<tr>
<td></td>
<td>Vent: To depressurise or purge the distribution system.</td>
<td>As determined by operational requirements.</td>
<td>Appendix 4.</td>
</tr>
<tr>
<td></td>
<td>Flow control: To manage the flow to meet operational requirements.</td>
<td>As determined by operational requirements.</td>
<td>Excess flow control valves are also available to prevent maximum flow conditions being exceeded.</td>
</tr>
<tr>
<td></td>
<td>Diverter: To facilitate alternative directions of gas flow.</td>
<td>As determined by operational requirements.</td>
<td>If used for multiple pressure relief devices to facilitate inspection / maintenance, it shall be ensured the pressure system cannot be isolated from the pressure relief devices.</td>
</tr>
<tr>
<td>User outlet point connection</td>
<td>To connect pressure system to user equipment.</td>
<td>At the outlet point.</td>
<td>Mandatory. 1. Quick release connectors are not deemed to be a method of positive isolation. Each quick release point shall be accompanied by an isolation valve in the immediate vicinity.</td>
</tr>
<tr>
<td>COMPONENT *</td>
<td>FUNCTION</td>
<td>LOCATION</td>
<td>Requirements &amp; comments</td>
</tr>
<tr>
<td>-------------</td>
<td>----------</td>
<td>----------</td>
<td>-------------------------</td>
</tr>
</tbody>
</table>
| Pressure indication.  
*Appendix 5 – A5.6* | To provide an indication of the pressure within a specific part of the system. | Between gas source and pressure regulator. | Recommended if the gas source(s) does not have pressure indication incorporated. |
| Pressure regulator / reduction valve  
*Appendix 5 – A5.2* | Primary regulation:  
To reduce the gas source pressure to the required operating pressure. | At the transition between the gas source pressure and the lower pressure system. | Mandatory where the distribution system and / or the end use process is not capable of withstanding the pressure limits of the gas source. To minimise high pressure pipework it is recommended that the regulator is located as close as reasonably practical to the gas source. |
|  | Secondary regulation:  
To further reduce pressure and / or provide more stable pressure to meet operational requirements. | As determined by operational requirements. | Mandatory where the secondary distribution system and / or the end use process is not capable of withstanding the outlet pressure limits of the primary regulation system. |
| Pressure relief device  
*Appendix 5 – A5.1* | Overpressure protection:  
Ensures that the safe operating pressure of the pressure system is not exceeded under fault conditions. | After a pressure regulator. | Mandatory where the downstream system and/or the end use process is not capable of withstanding the upstream pressure limits. Equally this can be achieved by the use of a safety instrumented system which would isolate the source gas. NOTE: An integral pressure relief device fitted to a pressure regulator is not designed to protect downstream equipment. It is only designed to protect the regulator assembly. |
<table>
<thead>
<tr>
<th>COMPONENT *</th>
<th>FUNCTION</th>
<th>LOCATION</th>
<th>Requirements &amp; comments</th>
</tr>
</thead>
</table>
|             | Thermal protection for liquid sources; preventing liquid lock. | Wherever there is the potential for a liquefied or refrigerated gas to be trapped. | Mandatory.  
The set point should be set to relieve at a higher pressure than any other relief device in that part of the system.  
A bursting disc shall not be used. |
| Particulate filter. | To trap particulates within the gas stream. | Upstream of equipment or process. | Mandatory, on systems that can be affected by particulates.  
NOTE: Typically pressure regulators have these incorporated in the inlet stem. |
| Flame arrestor. | To prevent a flame progressing along pipework in the event of ignition of a flammable gas / oxidising gas mixture. | At the user end of the pipework, prior to torch / blender / process i.e. close to the point of use. | Mandatory in oxygen and flammable gas pipework when the system is supplying oxy-fuel gas equipment.  
May also be located downstream of the primary regulator and / or where pipework branches from a main distribution line.  
A flame arrestor may be incorporated in a composite safety device.  
A flame arrestor should be incorporated in all flammable gas outlet points where combustion is part of the process. |
| Heater. | To warm and maintain the gas above minimum process temperature. | As determined by process requirements. | Consider installing an over temperature control device if one is not already incorporated. |
| Vaporiser. | To convert a liquid to gas by heat transfer. | Between the gas source and the pressure regulation. | Mandatory for CO₂ dip tube cylinders supplying gas applications.  
For a bulk tank the vaporiser is usually included as part of the gas source. |
| Low temperature protection device. | To protect pipework and equipment from low temperatures. | Downstream of any heaters or vaporisers. | Mandatory if temperature limits of downstream materials / equipment are not compatible with foreseeable operating or fault conditions. |
### Table 1: Pressure system components

<table>
<thead>
<tr>
<th>COMPONENT *</th>
<th>FUNCTION</th>
<th>LOCATION</th>
<th>Requirements &amp; comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow meter.</td>
<td>To indicate and/or measure flow. For indication, fiscal measurement or process control.</td>
<td>As determined by operational requirements.</td>
<td>Determine accuracy requirements. Compensation may be required for pressure, temperature or gas.</td>
</tr>
<tr>
<td>Alarm.</td>
<td>To alert to a deviation from predetermined limits which may require an intervention.</td>
<td>As determined by operational requirements.</td>
<td>To be considered where a fault or deviation could give rise to danger. An alarm should require an action to be taken!</td>
</tr>
<tr>
<td>Auto change unit.</td>
<td>To ensure continuity of supply between dual system gas supplies.</td>
<td>Normally part of the primary control system.</td>
<td>As required.</td>
</tr>
<tr>
<td>Back contamination device.</td>
<td>Prevent back-feed from downstream system into gas source.</td>
<td>At the outlet from the gas source.</td>
<td>May be required dependant on process. For CO₂ applications refer to BCGA CP 42.</td>
</tr>
</tbody>
</table>

* A component may fulfil more than one function

#### 5.2 Material selection

The correct selection and use of materials for the construction of a pressure system is essential for the safe operation of the system and for maintaining the quality of the gas it contains, over the design life of the pressure system.

Materials shall be compatible with the particular gas, foreseeable environmental conditions, operating conditions and ageing mechanisms, for example, corrosion, fatigue and creep. Additional guidance is available on the material requirements of some common gases in Appendix 9. The following standards and industry documents provide guidance, refer to:

- BS EN 1797[^39], *Cryogenic vessels. Gas / material compatibility*.
- BS ISO 21010[^72], *Cryogenic vessels. Gas / material compatibility*.
- European Industrial Gases Association (EIGA) 13[^98], *Oxygen pipeline and piping systems*.
- EIGA 73 \[102\], *Design considerations to mitigate the potential risks of toxicity when using non-metallic materials in high pressure oxygen breathing gas systems.*

Table 2 is for guidance only and gives information on some common materials used with pipes and seals.

<table>
<thead>
<tr>
<th>Gas</th>
<th>Common materials</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Pipes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Copper or Copper Alloys</td>
<td>Steel</td>
<td>Stainless steel</td>
<td>Plastic</td>
<td>Sealants</td>
<td>PTFE</td>
<td>Compressed fibre</td>
<td>Copper washers</td>
<td>Viton bonded seals</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inert gaseous</td>
<td></td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inert cryogenic</td>
<td></td>
<td>Y</td>
<td>N</td>
<td>NOTE 8</td>
<td>N</td>
<td>NOTE 5</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inert liquefied (e.g. Liquid CO₂)</td>
<td></td>
<td>Y</td>
<td>NOTE 8</td>
<td>Y</td>
<td>NOTE 7</td>
<td>NOTE 5</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flammable gaseous</td>
<td></td>
<td>NOTE 2 &amp; 9</td>
<td>NOTE 2</td>
<td>NOTE 2</td>
<td>NOTE 7</td>
<td>Y</td>
<td>Y</td>
<td>NOTE 2 &amp; 9</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flammable cryogenic (e.g. Liquid H₂, LNG)</td>
<td></td>
<td>Y</td>
<td>N</td>
<td>NOTE 2 &amp; 8</td>
<td>N</td>
<td>NOTE 7</td>
<td>NOTE 5</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flammable liquefied (e.g. LPG, ammonia)</td>
<td></td>
<td>NOTE 9</td>
<td>NOTE 8</td>
<td>Y</td>
<td>NOTE 7</td>
<td>Y</td>
<td>Y</td>
<td>NOTE 9</td>
<td>NOTE 9</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oxidiser gaseous</td>
<td></td>
<td>Y</td>
<td>NOTE 4</td>
<td>NOTE 4</td>
<td>NOTE 7</td>
<td>NOTE 6</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oxidiser cryogenic</td>
<td></td>
<td>Y</td>
<td>N</td>
<td>NOTE 4 &amp; 8</td>
<td>N</td>
<td>NOTE 6</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oxidiser liquefied (e.g. N₂O)</td>
<td></td>
<td>Y</td>
<td>N</td>
<td>NOTE 4 &amp; 8</td>
<td>N</td>
<td>NOTE 6</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Guidance on material selection

NOTES (for Table 2):

1. Within the limitations of plastic pipework, refer to Appendix 3, A3.2.
2. For hydrogen, take into consideration the problem of embrittlement of some metallic materials under cyclic conditions, especially at elevated temperatures and pressures, refer to ISO TR 15916 \[70\]. *Basic considerations for the safety of hydrogen systems.*
3. For liquefied petroleum gas (LPG), refer to publications produced by Liquid Gas UK.

4. For pipework made of ferrous materials, (for example, stainless steel, carbon steel) the gas velocity shall be restricted to limited values. For the recommended limiting velocities for oxygen, refer to EIGA 13 [98].

5. PTFE tape may be used as a thread sealant. Glass filled PTFE should be used for gaskets and washers. Refer to Appendix A3.9.5.

6. Only use PTFE grades compatible for use with oxygen

7. Refer to manufacturer for gas compatibility and operational limitations.

8. Use an appropriate grade which is suitable for the foreseeable operating temperatures.

9. Not to be used with ammonia.

6. THE DUTIES OF THE INSTALLER

The Installer shall ensure that the pressure system is installed in accordance with the design specification and any other applicable legislation or requirements, in particular that:

- only the specified materials and components are used;
- the components are in the correct order and lay-out;
- pipework is prepared ready for installation;
- pipework and components are cleaned to the specified level of cleanliness;
- components are securely mounted in their designated location and orientation, with connecting pipework appropriately routed, refer to Appendix 3, A3.10;
- pipework and component supports are suitable and sufficient, refer to Appendix 3, A3.11;
- only specified jointing methods are used;
- areas where potential leak paths that have been identified are installed as required by the Designer, refer to Appendix 2;
- all pipework bends meet the requirements set by the Designer;
- only specified electrical equipment is installed;
- all vents or exhausts discharge into a safe area;
- where specified, a protective finish is applied in accordance with the manufacturer’s instructions;
- components and pipework are marked and identified.
Where a pressure system is undergoing modification or having additions, then the Installer shall ensure the existing pressure system has been made safe and the change is carried out under a safe system of work.

If any aspects of the design are identified by the Installer as being missing, incorrect or inadequate, the Installer shall clarify with the Designer.

The Installer shall not deviate from the design specification. If the Installer identifies or proposes deviations then these should be discussed with the Designer. If the deviation is approved the Designer shall amend the design specification, other relevant documentation and conduct appropriate hazard and risk assessment(s) for all agreed deviations.

Any deviations made by the Installer without obtaining the Designers written approval will automatically transfer the responsibility of the design for the deviation(s) onto the Installer, including responsibility over any impact that the deviation(s) may have on the whole pressure system. In this case, the Installer shall have the competency requirements of the Designer, refer to Section 5. All deviations shall be documented as above.

All documents, certificates, operating instructions, etc. associated with individual components and equipment shall be provided to the User, refer to Section 8.

Where the Gas Safety (Installation and Use) Regulations [7] apply, such work shall only be carried out by persons registered as competent on the Gas Safe Register.

NOTE: Persons with the Gas Safe registration do not automatically demonstrate competence with regard to the requirements of this Code of Practice.

On completion of the installation the pressure system shall be tested in preparation for commissioning, refer to Section 7.

7. TESTING

Testing is carried out to ensure the pressure system (from the gas source connector to the end user outlet point) is safe, meets the design specification and meets the User requirement.

The pressure system shall be tested in accordance with the design specification and this section before being commissioned.

This section details the minimum testing requirements for the entire system prior to introduction into service. These requirements shall also be followed for the testing of any sub-assemblies, where applicable.

The person responsible for managing the testing shall ensure that a specific risk assessment is carried out for testing and that subsequently a written testing plan is produced, that details:

- the required tests in accordance with the design specification and any applicable legislation, for example, the Pressure Equipment (Safety) Regulations [14];

- the testing procedure(s);
• roles and responsibilities;

• the necessary precautions to ensure the pressure system, or specific parts of the system, are not over-pressurised;

• the significant risks and the associated required risk control measures, including exclusion zones;

• all affected persons, for example, site duty holder, stakeholders;

• Inspection Body involvement, refer to Section 7.4;

• the required test equipment.

Ensure pressure test equipment, including all associated flexible hose assemblies, instrumentation and connections, are serviceable, pressure rated for the system under test and calibrated as required. Consideration should be given to the use of safety whip lines.

Where proprietary or ‘off-the-shelf’ components are supplied any testing that may have been already carried out shall be verified with the supplier so that, if required, any proof testing requirements can be carried out before fitting into the final pressure system.

Testing activities shall only be carried out by persons with adequate competency.

Where the gas source is installed in accordance with the referenced documents in Section 4.1, then ensure the testing and commissioning requirements of these documents complement the testing and commissioning of this pressure system. The gas source will not require further testing (as it will be subject to its own testing regime).

Testing shall include the following:

• verification of the installation prior to testing commencing, refer to Section 7.1;

• pressure testing, refer to Section 7.2;

• electrical testing (where incorporated), refer to Section 7.3;

• Inspection Body involvement (if applicable), refer to Section 7.4;

Prior to handling or using any test fluid ensure it has been correctly identified and appropriate safety precautions have been taken to manage any associated hazards. Ensure each test fluid used and any cleaning materials are compatible with each other as well as the final service gas. Refer to the Safety Data Sheet. As necessary, seek the advice of your gas supplier.

All testing shall be documented and documents should be retained. Refer to Section 8.3.
On completion of satisfactory testing, the pressure system can be commissioned ready for service, refer to Section 8.

7.1 Verification of the installation
Before conducting any testing, the pressure system (or sub-systems) shall be inspected to ensure it meets the design specification, including any agreed deviations.

The following documentation shall be available:

- a copy of the final design specification;
- a piping and instrumentation diagram (P&ID);
- the testing and commissioning procedures and associated risk assessments;
- where applicable, testing documentation for proprietary or ‘off-the-shelf’ components;
- where applicable, electrical installation certificates.

The following visual checks shall be carried out, ensuring that:

- the installation conforms to the P&ID, the correct components are fitted, are in the right order, are in the appropriate orientation and are installed in accordance with the design specification;

NOTE: Certain components may not be fitted at this preliminary stage, such as, pressure indicators, safety relief devices, analysers, etc., as the testing regime may cause damage or contaminate sensitive components. However, where a component is not yet fitted, its final location is to be confirmed.

- for cryogenic and liquefied source installations, liquid cannot become trapped in any part of the pressure system which is not protected by a thermal pressure relief device. Liquids which are at low temperatures cannot reach parts of the pressure system not designed for low temperature use and that there are appropriate controls in place;

- correct jointing method(s) have been used, joints are correctly made and meet the Designer’s quality requirements;

- instrumentation and controls are accessible and easily visible to the operators, for example, without the need to climb through pipes or struggle through structures to gain access;

- all relief devices and / or the vent system, discharge into a safe area;

- as required, the facility is earthed and bonded including, where applicable, the gas supply delivery location. Refer to Appendix 6;
• access is readily available to all areas of the pressure system required for normal operation, testing (and commissioning) activities.

NOTE: When in-service some areas may not be easily accessible.

7.2 Pressure testing
There are various tests involving applying pressure to the pressure system (or sub-assembly) that can be performed depending on the materials used, the method of construction and the design of the pressure system.

The purpose of pressure testing is to apply stored energy to an assembly in order to verify its strength, its integrity and/or its functionality.

For the purposes of this document the various types of pressure testing include a:

• **Standard pressure test.** This test is used when the safe working limits of all of the pressure components are known.

  When the test medium is hydraulic then the *Pressure Equipment (Safety) Regulations* [14] require a minimum pressure of 1.43 x MAWP. Refer to the European Pressure Equipment Directive [16], (Annex 1 – 7.4) and BS EN 13445-5 [63], *Unfired pressure vessels. Inspection and testing.*

  Due to the impracticalities of hydraulic testing (as discussed below) the standard pressure test is typically pneumatic. Due to the absence of any specific requirements for pneumatic testing within the *Pressure Equipment (Safety) Regulations* [14], the requirements of ASME B31.3 [117], *Process piping guide*, should be followed. Therefore, a pneumatic test should be carried out at a minimum of 1.1 times the MAWP. Refer to Figure 1.

  NOTE: When working to the requirements of a specific standard or design code then the test requirements of this will take precedence.

  Pass criteria: Test pressure reached. No evidence of defects.

• **Proof pressure test.** This test is carried out when the safe working limits of any of the components under pressure cannot be accurately calculated or is in doubt, for example, where an existing pressure system is modified. To be in-line with the Design Code, as necessary, the advice of a competent specialist shall be sought. Refer to Figure 1.

  This test is not normally applicable to new pressure systems as all components should be suitable for the design pressure.

  Proof pressure testing should ideally be carried out hydraulically and the pressure applied gradually until the specified test pressure is reached. If any yielding of any part of the pressure equipment occurs the test shall immediately be stopped, the pressure system de-pressurised and measures taken to prevent the pressure system being re-pressurised.
WARNING: If a pneumatic test is necessary additional safety procedures and safety / exclusion zones will be necessary.

Pass criteria: Test pressure reached. No evidence of defects.

- **(Final) Leak test.** This test is performed after a successful standard or proof test has been carried out. All components that were removed (due to incompatibility with the previous test procedure) shall be refitted in preparation for the final leak test. This test shall be performed at a minimum pressure of 90 % of the MAWP.

The leak test may be carried out with the final service gas or, if required for safety or quality reasons, an appropriate inert gas should be used, such as nitrogen, helium or helium mixtures.

**NOTE:** Using an inert test gas with or containing a molecule size smaller than the final service gas will allow the gas to leak from positions that a gas with larger molecules will not. Helium, an inert gas with the smallest atomic size, is commonly used as a ‘searching’ gas which can be detected using an external sensor. The use of pure helium also has the advantage of inerting high purity pressure systems prior to first fill.

The purpose of the final leak test is to ensure the pressure system is ready for service. Particular attention shall be given to ensuring that any joints that have been disturbed during the testing process are leak free.

Pass criteria: No leaks.

For information on leak detection fluids refer to EIGA 78 [104], *Leak detection fluids cylinder packages*.

- **Pressure retention test.** A pressure retention test (also referred to as a pressure drop test) is a methodology which may be used as part of the standard pressure test and the leak test. This test is used to determine if there is a pressure drop over a defined time period. The pressure system is pressurised to the appropriate test pressure, typically for a period of 30 minutes, with the gas source supply isolated. After taking into account any changes in ambient conditions, the pressure variation of the system during this period will be measured. If this variation meets the design specification / is acceptable to the Designer, the pressure system may be commissioned; if not further investigation and rectification will be required, followed by further testing.

Pass criteria: Pressure drop within acceptable limits as defined by the Designer.

The pressure system will require either a standard or a proof pressure test to prove the mechanical integrity of the system. However, individual items of equipment, components or sub-assemblies within the pressure system which have previously been pressure tested (with certification and have appropriate documentation) and remain valid, may not require further pressure testing.
On completion of standard or proof pressure testing the pressure system will be fully assembled and the complete assembly will then be subject to leak testing.

The test methods to be applied shall be specified by the Designer.

**WARNINGS:**

1. Pressure testing is a hazardous activity and requires suitable and sufficient risk management. When applying stored energy to an assembly, especially for the first time, there is potential for an unintended or premature pressure release while people are in the danger zone. An exclusion zone may be required.

2. The rate of pressure increase shall be controlled so that pressure is gradually increased and/or increased in incremental steps, checking continuously for untoward developments (leaks, distortion, loosening of fasteners and supports, etc.), to the required test pressure.

3. Gases may be released into the local atmosphere during pneumatic testing. Where the gas is unavoidably released into an enclosed area then a risk assessment shall be conducted to establish any necessary control measures. Refer to BCGA GN 11 [93], *The management of risk when using gases in enclosed workplaces*.

Safety devices will normally be tested and set prior to installation by the manufacturer.

Aside from the final leak test the equipment should be hydraulically tested wherever practicable, as the energy released in the event of a failure compared with a pneumatic test is considerably lower. If hydraulic testing, water with a chloride content of less than 50 ppm should be used. When hydraulic testing is complete all moisture shall be removed from the pressure system (to the Designer’s specification).

Hydraulic testing is not usually practical on gaseous pressure systems for the following reasons:

- gaseous components are not designed for the efficient movement of liquid through them, liquid can become trapped in small cavities;

- gases are manufactured to a high quality specification. The process of removing contaminants (remaining in the residue of fluid used in hydraulic testing) from a pressure system to meet the cleanliness specification is complex and time consuming;

- the contamination introduced can create additional hazards, for example, with incompatibility;

- if contamination is not fully removed then this could lead to long term corrosion, and subsequent service and maintenance issues with equipment;

- it can be difficult to remove trapped air during a hydraulic test;
• it can be impractical to remove all liquid from the pressure system. As an example, if any water remains it can freeze and cause blockages or prevent the correct operation of controls and/or safety devices.

• pipework and component supports may not be rated for the additional weight of adding a liquid.

The pressure test shall be performed with a medium that is compatible with the final service gas, the materials the pressure system is manufactured from, and any chemicals which may have been used during the construction and cleaning of the pressure system.

When pneumatic testing an inert gas shall be used. The density of the inert gas shall not be greater than the final service gas.

Before testing commences, the person responsible for carrying out the testing shall ensure that all relevant personnel are aware of the testing and commissioning activities, including any control measures in force, have the relevant competencies, refer to Section 3.2, and have adequate information and instruction on the actions to be taken in the event of an incident.

Before conducting a standard or proof pressure test, control measures identified in the written testing plan shall be implemented, such as:

• checking to ensure all components to be included in the pressure test(s) are compatible with the test pressure;

• checking that the source which is to be connected is correct for the pressure system prior to introducing a medium into the pressure system, for example, the gas, pressure and temperature;

• checking there are appropriate controls in place to ensure the target test pressure is not exceeded;

• checking there is adequate ventilation around the pressure system, paying particular attention to potential leak paths, and the gas source location to ensure a hazardous atmosphere is not created through leakage or venting during the testing. Particular care is required in areas designated as enclosed or confined spaces;

• excluding all personnel from within the test area (exclusion zone) during the pressure test. Where it is not possible to exclude all personnel, then only personnel directly involved in the testing, who have been authorised to do so, shall be permitted within the exclusion zone. Such personnel may enter after a successful test and only when the test pressure has been reduced to MAWP or lower;

NOTE: Other personnel may enter the test area (exclusion zone) once the pressure test is completed and it has been confirmed that all pressure has been released.
• providing protection for personnel in the test area (exclusion zone). Suitable shielding from a potential energy release shall be provided. For example:

  o a brick or concrete wall (not breeze block);
  o fixed plant, such as a steel tank of at least 3 mm thickness which provides protection from floor to above head height;
  o installed barriers made from steel of at least 3 mm thickness which provides protection from floor to above head height;
  o specialist blast protection, such as curtains / blankets.

NOTE: The suitability of any shielding will be dependent upon the pressure, volume and the test medium employed.

• carrying out the pressure test outside normal work hours;

• testing remotely;

• isolating and testing smaller sub-sections to minimise the risks, prior to testing larger sections of systems;

• applying incremental pressure increases, including intermediate leak testing;

• ensuring the system is protected from over-pressure during testing. Where the test pressure exceeds the rated pressure of individual propriety pre-tested components, for example, pressure indicators, safety devices and other components fitted for normal operation of the pressure system, these may have to be removed / omitted from the pressure system before testing and, as necessary, open pipework is to be appropriately blanked or capped-off. Where safety devices have been removed measures shall be taken to prevent over-pressurising the pressure system during testing, for example, higher rated pressure relief devices installed which have a flow capacity rated above the supply capacity;

• setting out the procedure to be followed in the event of an unsuccessful pressure test, as an example:

  o de-pressurise the system;
  o carry out a visual inspection of the pressure system (before any further pressure is introduced into the system);

  ▪ if a defect is found, rectify before further testing takes place;

  ▪ if no defects are found pressure can then be applied incrementally until a leak is identified or MAWP is reached. The pressure system shall be de-pressurised and the gas source pressure isolated before any rectification work takes place;
• if still no visual defects or leaks are identified, no further testing shall be carried out without consultation and agreement with the Designer of the action to take;

Rectification of defects shall be agreed with the Designer.

○ once rectified, a pressure test may be re-attempted.

For further guidance on pressure testing refer to:

• HSE RR 168 \[26\], *Pressure test safety*.
• HSE GN GS4 \[28\], *Safety requirements for pressure testing*.

### 7.3 Electrical safety testing

All electrical components shall be tested for correct operation and to ensure electrical safety.

Electrical continuity checks shall be carried out, including continuity over flanges and joints and earth bonding.

Electrical systems shall be certified by a competent person.

For further information, refer to Appendix 6.

### 7.4 Inspection Body involvement

If the pressure system is categorised as Sound Engineering Practice (SEP) or Category 1 according to the *Pressure Equipment (Safety) Regulations* \[14\], a Notified Body is not required. If it is categorised as Category 2 or above then a Notified Body shall need to be involved.

### 8. COMMISSIONING AND HANDOVER

Commissioning is carried out to check that the pressure system is fully serviceable, meets the design specification and is in working order in preparation for handover to the user.

The person responsible for carrying out commissioning shall ensure there is a written document that defines the commissioning regime, that commissioning is as specified by the Designer, that the related risk assessment(s) have been carried out and all required control measures are implemented.

All persons conducting the commissioning activities shall be competent, refer to Section 3.2.

Where the gas source is a liquid storage tank refer to the appropriate document for its commissioning requirements, refer to Section 4.1.

Commissioning of the pressure system (excluding the gas source) includes the following:

• purging, refer to Section 8.1;
• final checks, refer to Section 8.2;

Each of these activities should be documented.

Following commissioning the pressure system can then be handed over to the User, refer to Section 8.3.

8.1 Purging

Purging is carried out to remove from the pressure system any contaminants or fluids which are incompatible with the service gas that were introduced during the assembly and testing processes and that may cause safety and / or quality issues.

The Designer shall specify the purging requirement and method.

There are different methods for purging, such as, pressure vent, blow through, etc.

Generally purging is a two-stage process, an inert purge, followed by a purge with the final service gas.

• Inert purging. This involves flushing the pressure system with an inert gas of a known specification, including being dry, oil-free and compatible with the service gas. This is a recommended process for all gas installations.

Inert purging is typically carried out by the Installer.

Before introducing a flammable fluid it is mandatory that the whole pressure system shall be purged with an inert gas. This will ensure that oxygen is reduced to a safe level to prevent a dangerous flammable oxygen mixture occurring. A flammable gas shall not be introduced into the pressure system until the oxygen level is verified as being below the minimum level for combustion to occur.

Inert purging may be used when high purity is required.

NOTE: The use of compressed air is not usually suitable as a purging gas. Compressed air contains oxygen, and, dependant on the specification of the air, may contain moisture and other contaminants, such as oil.

• Product purging. Introduces the service gas into the pressure system to remove the inert purging gas and to ensure product quality throughout the pressure system.

Product purging is usually carried out by the Installer, but may be carried out by another party. The responsibility for product purging should be determined prior to commencement of the in-service use of the installation.

When purging, any gas released should be vented through the vent system or through dedicated discharge points which vent into a safe area. There may be occasions where purging is required through other points in the system, for example, gauge lines, dead legs, etc. where a gas will be released into the local atmosphere. Where this may create a hazard and / or the gas is unavoidably released into an enclosed area or confined space,
then a risk assessment shall be conducted and any necessary control measures implemented, refer to BCGA GN 11 [93].

8.2 Final checks
Final checks of a pressure system are carried out to ensure the pressure system functions in-line with the Designer’s specification. The pressure system components shall be checked under normal operating conditions to verify safe and correct operation.

These checks should include:

- the actuation of moveable parts, such as the opening and closing of valves;
- a flow test which measures a quantity of a gas passing through a point per unit of time (for example, litres of gas per minute);
- closure tightness and gland leakage of non-return valves and valves;
- correct operation of automatic changeover devices, alarms and cut-off devices;
- correct set-point and correct operation of alarms and safety devices;
- correct operation of gauges and indicating devices;
- that the control system logic reflects the logic sequence specified by the Designer;
- that at each gas inlet / outlet the gas is correctly identified and that the correct connector is fitted;
- that all exhaust gases from pressure relief devices, vents, drains, etc. discharge to a safe place;
- that all open ends and / or redundant outlets, other than designated exhaust or vent points, are appropriately blanked or capped off;
- that there is no cross-connection of the pipework. Where, for any reason, cross-connection of the pipework is possible, the following anti-confusion check shall be made:
  i) Isolate the pipework from all gas supplies except the one under test;
  ii) Check that gas is supplied at each outlet point of the pipework under test;
  iii) Ensure no gas is supplied into the pressure system or from the outlet points of any other system;
iv) Prove each pipework supply and distribution system in turn with all other systems isolated.

Additional checks may be carried out with the User to ensure that the pressure system is providing the correct pressure, temperature, flow rates and quality requirements for the User end-process.

Checks should be carried out to ensure the system remains safe during start up and shutdown, as well as from a result of process upsets.

### 8.3 Handover

This is the point when all installation, testing, and commissioning activities are complete and the pressure system is ready to be put into service either for the first time or following completion of modification (or additions).

Before the pressure system (or part of a pressure system) is put into service the User shall ensure a Written Scheme of Examination is in place and, if applicable, the initial examination completed, or if PSSR [9] is not applicable a documented inspection and maintenance regime is in place in accordance with PUWER [6], refer to BCGA CP 39 [88].

The following technical and safety documentation shall be handed over to the User for the safe operation of the pressure system.

The Designer shall provide the User with the following:

- safe operating limits to allow safe use, for example, for pressure and temperature;
- operating instructions, including emergency shut-down;
- drawings (P&ID, electrical circuit diagrams, etc.);
- information to allow a Written Scheme of Examination to be drawn up in accordance with the PSSR [9];
- information to allow an Ageing Pressure Equipment Assessment to be drawn up in accordance with BCGA CP 39 [88];
- inspection and maintenance requirements, including instructions and, where applicable, testing requirements, for example, of safety shut off systems. Refer to BCGA CP 39 [88];
- any additional information to allow the User to conduct appropriate risk assessment to meet legal duties and to implement a safe system of work;
- decommissioning requirements (not required by the User if they are not the owner of the equipment).

The Installer shall provide the User with the following:
• test certificates for any testing carried out by the Installer;
• any accompanying documentation provided with any proprietary pressure equipment;
• a demonstration of the correct operation of the pressure system.

The above list is not exhaustive and further documentation may be required to comply with legislation, for example, those associated with CE marked equipment and the Construction (Design and Management) Regulations \[13\].

The User should retain all documentation, as necessary, to comply with legislation.

9. PUTTING INTO SERVICE

Before the pressure system is put into service the User shall ensure there are safe systems of work in place and the requirements of BCGA CP 39 \[8\] are complied with, relating to the safe operation, examination, inspection and maintenance of the pressure system.

Putting into service for the first time means pressurising the pressure system for use by the User following commissioning. Where, at the end of the commissioning process, the pressure system is to remain pressurised, it will be considered to be in-service. Where the requirements of BCGA CP 39 \[8\] are not met then the pressure system cannot be put into service and shall be left depressurised at or below 0.5 bar(g).

10. SECURITY

Access to, and operation of, a pressure system, shall only be by authorised personnel.

Particular care should be taken during the installation, testing and commissioning phases.

The gas source may require separate security arrangements, refer to Section 4.1.
11. REFERENCES

<table>
<thead>
<tr>
<th>Document Number</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>The Health and Safety at Work etc. Act 1974</td>
</tr>
<tr>
<td>5. SI 1997: No. 1713</td>
<td>The Confined Spaces Regulations 1997</td>
</tr>
<tr>
<td>10. SI 2002 No 2677</td>
<td>The Control of Substances Hazardous to Health Regulations (COSHH).</td>
</tr>
<tr>
<td>13. SI 2015 No. 51</td>
<td>The Construction (Design and Management) Regulations 2015</td>
</tr>
<tr>
<td></td>
<td>The Classification, Labelling and Packaging Regulations (CLP).</td>
</tr>
<tr>
<td></td>
<td>The Pressure Equipment Directive (PED).</td>
</tr>
</tbody>
</table>
17. ECE/TRANS/275 The European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR) (as amended).


25. HSE HSG 85 Electricity at work. Safe working practices.


27. HSE INDG 459 Oxygen use in the workplace. Fire and explosion hazards

28. HSE Guidance Note GS4 Safety requirements for pressure testing.

29. HTM 02-01 Health Technical Memorandum. Medical gas pipeline systems

30. BS EN ISO 228 Pipe threads where pressure-tight joints are not made on the threads.

31. BS 341 Part 3 Transportable gas container valves.

32. BS 476 Fire tests on building materials and structures.

33. BS EN 751 Part 3 Sealing materials for metallic threaded joints in contact with 1st, 2nd and 3rd family gases and hot water.

3. Unsintered PTFE tapes.
34. BS EN 837  Pressure gauges.
35. BS 1306  Specification for copper and copper alloy pressure piping systems.
36. BS EN 1515  Flanges and their joints. Bolting.
37. BS 1710  Specification for identification of pipelines and services.
38. BS EN 1759  Flanges and their joints. Circular flanges for pipes, valves, fittings and accessories, class-designated.
39. BS EN 1797  Cryogenic vessels. Gas / material compatibility.
40. BS EN ISO 2503  Gas welding equipment – Pressure regulators and pressure regulators with flow-metering devices for gas cylinders used in welding, cutting and allied processes up to 300 bar (30 MPa).
41. BS EN ISO 3821  Gas welding equipment. Rubber hoses for welding, cutting and allied processes.
42. BS EN ISO 3834  Quality requirements for fusion welding of metallic materials.
43. BS EN ISO 4126  Safety devices for protection against excessive pressure.  
Part 1: Safety valves  
Part 2: Bursting disc safety devices.
44. BS 4800  Schedule of paint colours for building purposes.
45. BS EN ISO 5171  Gas welding equipment. Pressure gauges used in welding, cutting and allied processes.
46. BS EN ISO 5175  Gas welding equipment. Safety devices.  
Part 1: Devices incorporating a flame (flashback) arrestor.  
Part 2: Devices not incorporating a flame (flashback) arrestor.
47. BS 5499  Safety signs, including fire safety signs.
48. BS 6031  Code of practice for earthworks.
49. BS EN ISO 7291  Gas welding equipment. Pressure regulators for manifold systems used in welding, cutting and allied processes up to 30 MPa (300 bar).
50. BS EN ISO 7396  Medical gas pipeline systems.
51. BS 7430  Code of practice for protective earthing of electrical installations.
52. BS 7671  Requirements for electrical installations. IET Wiring Regulations.
53. BS 7786 Specification for unsintered PTFE tape for general use.
54. BS 8313 Code of Practice for accommodation of building services in ducts.
55. BS 9999 Code of Practice for fire safety in the design, management and use of buildings.
56. BS EN 10226 Pipe threads where pressure tight joints are made on the threads. Taper external threads and parallel internal threads. Dimensions, tolerances and designation
57. BS EN ISO 10380 Pipework. Corrugated metal hoses and hose assemblies.
   Part 2 1: Metallic materials.
   Part 2 2: Non-metallic materials.
59. ISO 12170 Gas welding equipment. Thermoplastic hoses for welding and allied processes.
60. BS EN 12434 Cryogenic vessels. Cryogenic flexible hoses.
61. BS EN 13348 Copper and copper alloys, seamless, round copper tubes for medical gases and vacuum.
62. BS EN 13371 Cryogenic vessels. Couplings for cryogenic service.
63. BS EN 13445 Unfired pressure vessels. Part 5 5. Inspection and testing
64. BS EN 13480 Metallic industrial piping. Inspection and testing
   Part 1 1. General
   Part 2 2. Materials
   Part 3 3. Design and calculation
   Part 4 4. Fabrication and installation
   Part 5 5. Inspection and testing
   Part 6 6. Additional requirements for buried piping
   Part 7 7. Guidance on the use of conformity assessment procedures
   Part 8 8. Additional requirements for aluminium and aluminium alloy piping
   Part 9 9. Additional requirements for nickel and nickel alloys piping
65. BS EN 13585 Brazing. Qualification test of brazers and brazing operators.
66. BS EN ISO 14113  Gas welding equipment. Rubber and plastic hose and hose assemblies for use with industrial gases up to 450 bar (45 MPa).

67. BS EN 15001  Gas infrastructure. Gas installation pipework with an operating pressure greater than 0.5 bar for industrial installations and greater than 5 bar for industrial and non-industrial installations.

68. BS EN ISO 15494  Plastics piping systems for industrial applications. Polybutene (PB), polyethylene (PE), polyethylene of raised temperature resistance (PE-RT), crosslinked polyethylene (PE-X), polypropylene (PP). Metric series for specifications for components.

69. BS EN ISO 15609  Specification and qualification of welding procedures for metallic materials.

70. ISO TR 15916  Basic considerations for the safety of hydrogen systems.

71. BS ISO 16964  Gas cylinders. Flexible hoses assemblies. Specification and testing.

72. BS ISO 21010  Cryogenic vessels. Gas/material compatibility.

73. BS EN ISO 21012  Cryogenic vessels. Hoses.

74. BS ISO 22688  Brazing. Quality requirements for brazing of metallic materials.

75. BS EN ISO 23208  Cryogenic vessels. Cleanliness for cryogenic service.

76. BS EN 60079.  Explosive atmospheres.


77. BS EN 60529  Specification for degrees of protection provided by enclosures.

78. BS IEC 60877  Procedures for ensuring the cleanliness of industrial process, measurement and control equipment for oxygen service.

79. BCGA Code of Practice 5  The design and construction of manifolds using acetylene gas from 1.5 bar to 25 bar.

80. BCGA Code of Practice 6  The safe distribution of acetylene in the pressure range 0 - 1.5 bar.
<table>
<thead>
<tr>
<th>No.</th>
<th>Code of Practice</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>81.</td>
<td>BCGA Code of Practice 7</td>
<td>The safe use of oxy-fuel gas equipment (individual portable or mobile cylinder supply).</td>
</tr>
<tr>
<td>82.</td>
<td>BCGA Code of Practice 18</td>
<td>The safe storage, handling and use of special gases.</td>
</tr>
<tr>
<td>83.</td>
<td>BCGA Code of Practice 26</td>
<td>Bulk liquid carbon dioxide storage at users’ premises.</td>
</tr>
<tr>
<td>84.</td>
<td>BCGA Code of Practice 27</td>
<td>Transportable vacuum insulated containers of not more than 1000 litres volume.</td>
</tr>
<tr>
<td>85.</td>
<td>BCGA Code of Practice 33</td>
<td>The bulk storage of gaseous hydrogen at users’ premises.</td>
</tr>
<tr>
<td>86.</td>
<td>BCGA Code of Practice 34</td>
<td>The application of the Pressure Equipment Regulations to customers’ sites.</td>
</tr>
<tr>
<td>87.</td>
<td>BCGA Code of Practice 36</td>
<td>Cryogenic liquid storage at users’ premises.</td>
</tr>
<tr>
<td>88.</td>
<td>BCGA Code of Practice 39</td>
<td>In-service requirements of pressure equipment (gas storage and distribution systems).</td>
</tr>
<tr>
<td>89.</td>
<td>BCGA Code of Practice 41</td>
<td>The design, construction, maintenance and operation of filling stations dispensing gaseous fuels.</td>
</tr>
<tr>
<td>90.</td>
<td>BCGA Code of Practice 42</td>
<td>Implementation of EIGA carbon dioxide standards.</td>
</tr>
<tr>
<td>91.</td>
<td>BCGA Code of Practice 44</td>
<td>The storage of gas cylinders.</td>
</tr>
<tr>
<td>92.</td>
<td>BCGA Code of Practice 46</td>
<td>The storage of cryogenic flammable fluids.</td>
</tr>
<tr>
<td>93.</td>
<td>BCGA Guidance Note 11</td>
<td>The management of risk when using gases in enclosed workplaces</td>
</tr>
<tr>
<td>94.</td>
<td>BCGA Guidance Note 13</td>
<td>DSEAR Risk Assessment.</td>
</tr>
<tr>
<td>95.</td>
<td>BCGA Guidance Note 14</td>
<td>Production, storage, transport and supply of gases for use in food.</td>
</tr>
<tr>
<td>96.</td>
<td>BCGA Guidance Note 23</td>
<td>Gas safety information, instruction and training.</td>
</tr>
<tr>
<td>97.</td>
<td>BCGA Guidance Note 30</td>
<td>The safe use of gases in the beverage dispense industry.</td>
</tr>
<tr>
<td></td>
<td>EIGA</td>
<td>Description</td>
</tr>
<tr>
<td>---</td>
<td>------</td>
<td>-------------</td>
</tr>
<tr>
<td>98.</td>
<td>EIGA 13</td>
<td>Oxygen pipeline and piping systems.</td>
</tr>
<tr>
<td>99.</td>
<td>EIGA 30</td>
<td>Disposal of gases.</td>
</tr>
<tr>
<td>100.</td>
<td>EIGA 33</td>
<td>Cleaning of equipment for oxygen service.</td>
</tr>
<tr>
<td>101.</td>
<td>EIGA 42</td>
<td>Flexible connections in high pressure gas systems</td>
</tr>
<tr>
<td>102.</td>
<td>EIGA 73</td>
<td>Design considerations to mitigate the potential risks of toxicity when using non-metallic materials in high pressure oxygen breathing gas systems.</td>
</tr>
<tr>
<td>103.</td>
<td>EIGA 75</td>
<td>Determination of safety distances.</td>
</tr>
<tr>
<td>104.</td>
<td>EIGA 78</td>
<td>Leak detection fluids cylinder packages.</td>
</tr>
<tr>
<td>105.</td>
<td>EIGA 85</td>
<td>Noise management.</td>
</tr>
<tr>
<td>106.</td>
<td>EIGA 133</td>
<td>Cryogenic vapourisation systems - Prevention of brittle fracture of equipment and piping.</td>
</tr>
<tr>
<td>107.</td>
<td>EIGA 154</td>
<td>Safe location of oxygen and inert gas vents.</td>
</tr>
<tr>
<td>108.</td>
<td>EIGA 200</td>
<td>The safe design, manufacture, installation, operation and maintenance of valves used in liquid oxygen and cold gaseous oxygen systems.</td>
</tr>
<tr>
<td>109.</td>
<td>EIGA 211</td>
<td>Hydrogen vent systems for customer applications.</td>
</tr>
<tr>
<td>110.</td>
<td>EIGA 217</td>
<td>Vacuum-jacketed piping in liquid oxygen service.</td>
</tr>
<tr>
<td>111.</td>
<td>EIGA 909</td>
<td>EIGA cryogenic gases couplings for tanker filling.</td>
</tr>
<tr>
<td>113.</td>
<td>EIGA Safety Information 15</td>
<td>Safety principles of high pressure oxygen systems.</td>
</tr>
<tr>
<td>114.</td>
<td>Liquid Gas UK Code of Practice 1</td>
<td>Bulk LPG storage at fixed installations.</td>
</tr>
<tr>
<td>115.</td>
<td>Liquid Gas UK Code of Practice 7</td>
<td>Storage of full and empty LPG cylinders and cartridges.</td>
</tr>
<tr>
<td>116.</td>
<td>Liquid Gas UK Code of Practice 22</td>
<td>LPG piping system design and installation.</td>
</tr>
</tbody>
</table>
117. ASME B31.3 Process piping guide.

118. SAFed IMG 1 The mechanical integrity of plant containing hazardous substances. A guide to periodic examination and testing.

119. Energy Institute Guidelines for the management of flexible hose assemblies

Further information can be obtained from:

UK Legislation  www.legislation.gov.uk
Health and Safety Executive (HSE)  www.hse.gov.uk
British Standards Institute (BSI)  www.bsigroup.co.uk
International Organization for Standardization (ISO)  www.iso.org
Energy Institute  www.energyinst.org
European Industrial Gases Association (EIGA)  www.eiga.eu
British Compressed Gases Association (BCGA)  www.bcga.co.uk
Safety Assessment Federation (SAFed)  www.safed.co.uk
Liquid Gas UK - The UK LPG trade association  www.liquidgasuk.org
British Compressed Air Society (BCAS)  www.bcas.org.uk
American Society of Mechanical Engineers (ASME)  www.asme.org
CONTROL SYSTEM(S) - LOCATION

Control systems need to be sited in an appropriate safe location.

Where the primary gas control system is co-located with the gas source then the general requirements for the location should be satisfied by the appropriate Code for the gas source, refer to Section 4.1.

Considerations to be taken into account when deciding on a location for a gas control system are:

- the primary gas control system should be close to the gas source, therefore minimising the amount of high pressure pipework;

- the primary gas control system should be in an outdoor area. Where there is a requirement for a gas control system to be located indoors or in an enclosed space then additional control measures may be necessary to mitigate the hazards;

- there is good natural ventilation which will prevent the build-up of gases in the event of a leakage. Gas may potentially be released into the local environment through pressure system safety devices, purge valves, from leaks, the disconnection and / or connection to the gas source, etc.;

If natural air ventilation is inhibited then the location is considered as being indoors or in an enclosed space. Before siting a gas control system(s) indoors, a risk assessment shall be carried out to determine the level of risk in the event of a leak. BCGA GN 11 [93] provides guidance that can be used in the assessment of risk associated with gases indoors or in enclosed workplaces, it assists in identifying where hazardous atmospheres may occur and the sets out appropriate control measures;

- the location is restricted to authorised persons;

- access is available to operate controls, including access in the event of an emergency;

- the potential fire risk. Be aware of sources of ignition and keep away from combustible products;

- local environmental conditions, for example, temperature, moisture, etc.;

- protection from mechanical damage, for example, impact from vehicle(s), cylinder / bundle(s), tampering, etc.;

- adequate lighting.

There may be some special cases where there is a requirement for a high pressure ring-main. The Designers risk assessment shall take into account the additional hazard(s).
Where you have more than one gas being supplied and there are more than one primary control systems, then there are additional considerations. These include:

- compatibility of the gases alongside their properties;
- the risk of different gases mixing together, for example:
  - leak paths, refer to Appendix 2;
  - release points;
  - changing over of the gas source;
  - cross-product connection.

NOTE: The risks relating to the storage of the gas at its source are of a lower order than those where gas is in use. This should be reflected in the risk assessment for the installation.

The primary control system shall be mounted on a permanent structure, such as a building wall. Such walls shall be constructed of fire resistant materials to BS 476 [32], *Fire tests on building materials and structures*.

For a primary control system connected in close proximity to gas cylinders, a wire mesh cage or similar well-ventilated security enclosure may be adequate. For information on such enclosures, refer to BCGA CP 44 [91].

The use of a specialist fire safety storage cabinet for gas cylinders or control systems is not recommended for general gases but may be appropriate for some specialty gas uses, refer to BCGA CP 44 [91].

Where the primary control system is located within a security enclosure, then take into account the safety of personnel who require to enter the enclosure. The gates should not be self-locking, they should be outward opening and provide easy access and egress, with, as appropriate, consideration given to the manual handling requirements for moving equipment, for example, gas cylinders. If emergency exits are provided they should comply with the requirements of BCGA CP 44 [91].

Safety signs and warning notices. The installation shall be clearly identified with the product name(s) and hazard(s) in accordance with the requirements of the *Health and Safety (Safety Signs & Signals) Regulations* [3], either on, or adjacent to the outside wall.

**Minimum recommended separation distances**

Minimum recommended separation distances are intended to:

a) protect personnel from exposure to hazardous atmospheres and to help reduce the effects from any hazardous situation that may develop, for example, oxygen enrichment and an increased fire risk;
b) protect the installation from the effects of thermal radiation or jet flame impingement from fire hazards;

c) protect the installation from physical impact damage.

The distances are based upon industry standards as published by the BCGA, HSE guidance notes and upon calculations based on physical tests or upon computer modelling of minor releases. The distances given are not intended to protect against catastrophic failure of the installation.

Distances are measured from any point on the system where in normal operation product release may occur.

Shorter distances may be used if a site specific risk assessment in line with the EIGA methodology, refer to EIGA 75[^103]. *Determination of safety distances*, (using HSE fatality rates) indicates an acceptable level of risk.

Where there are space restraints a permanent physical partition may be used to help achieve the required minimum recommended separation distances. The height of the partition should be relevant to the hazard, however it should be not less than 2 metres high, unless for non-fire hazards a lower partition can be justified through risk assessment. The required minimum recommended separation distance can include the length of the sides of the partition, as shown in Figure A1-1. Such partitions should be imperforate and constructed of suitable materials, for example, solid masonry or concrete. Where protecting against fire hazards they should be constructed to achieve at least 30 minutes’ fire-resistance. Refer to HSE L138[^23] and BS 476[^32].

Where the wall separates vulnerable populations from the gas containers (not including inert gases), the fire resistance provided should be a minimum of 60 minutes.

![Figure A1-1: Use of a partition to achieve the minimum recommended separation distances](image-url)
Distance (in metres) between oxygen or inert gas control systems and typical hazards.

**Figure A1-2:** Minimum distances – oxygen or inert gases
Distance (in metres) between flammable gas control systems and typical hazards.

**Figure A1-3:** Minimum distances – flammable gases
NOTES on Figure A1-2 and Figure A1-3:

1) The minimum distances used for LPG are based upon those given in Liquid Gas UK CP 1[114], Bulk LPG storage at fixed installations, and Liquid Gas UK CP 7[115], Storage of full and empty LPG cylinders and cartridges. Where there is any discrepancy between the advice given here and the Liquid Gas UK Codes, the latter shall take precedence.

2) Where the quantity of LPG in cylinders is greater than 50 kg these shall be stored a minimum of 3 metres from bulk LPG installations of up to 5,000 litres and 7.5 metres from bulk storage of greater than 5,000 litres.

3) Where the quantity of LPG in cylinders is greater than 50 kg they should be not less than 7.5 metres from bulk liquid oxygen storage.

4) Storage of compressed flammable gas cylinders with up to 70 (normal) $m^3$ capacity shall be a minimum distance of 5 metres from bulk liquid oxygen storage and 8 metres where the quantity is in excess of this figure.

5) Minimum distances for the siting of dissolved acetylene cylinders in relation to other gases and hazards are contained in BCGA CP 6[80].

Within Figure A1-1 the minimum recommended separation distances may include the distance measured around the sides of the partition by determining the sum of A + B + C.

Where flammable gas containers are stored against a building wall the area up to 2 m either side of the storage area and up to 9 m above ground should be imperforate and of a minimum of 30 minutes fire resisting construction.

Figure A1-2 displays the minimum distances for oxygen or inert gases and Figure A1-3 displays the minimum distances for flammable gases. The minimum distances in Figure A1-2 and Figure A1-3 shall be observed.
LEAK PATHS

A leak path is defined as a point in a pressure system where, unintentionally, the gas may leak.

Leaks can occur on a pressure system from several sources, for example, failure of a component, during connection / disconnection, through corrosion, from abrasion, etc., however, experience indicates that the most likely source of leaks is through leak paths from non-permanent pipe joints, non-permanent joints to components and non-permanent joints on components.

The following should be considered during design and installation:

- Pipework should be installed such that the number of leak paths is kept to a minimum. Less leak paths equates to less opportunity for leaks to be created. This becomes more relevant at elevated pressures and variations in temperature and pressure (cyclic conditions) and with gases which have a very small molecular size, for example, hydrogen and helium;

- Permanent joints should be installed in areas such as conduits, ducts, underground, at height, across roof / ceiling spaces, alongside other hazardous products, electrical cables / equipment where there is a potential source of ignition, for example, switching gear, lighting, indication systems, etc.

- Stagger joints, especially at high levels. Where multiple pipework follow the same route, staggering the joints can prevent gas mixtures forming, however, there may be benefits in having potential leak paths located in a common area;

- Use components made to an appropriate specification and install in accordance with the manufacturer’s recommendations. Force fitting and surface defects can increase the likelihood of leaks occurring, especially when used with gases, such as hydrogen and helium which have a very small molecular size;

- Locate potential leak paths (components and joints) in accessible areas for ease of future inspection and maintenance;

- Locate potential leak paths in well-ventilated areas. As necessary, provide additional control measures, such as atmospheric monitoring equipment, refer to BCGA GN 11 [93].
APPENDIX 3
Sheet 1 of 23

PIPEWORK

Pipework is used throughout a pressure system to contain and convey a gas, whilst connecting the various items within the pressure system together.

The general principles to observe during the design, installation, operation and maintenance of pipework include:

- ensuring that the User requirement is met, i.e. flow, pressure, temperature, etc.;
- pipework generally should be as straight as possible, following the most direct path that avoids any reasonably foreseeable hazards;
- appropriate material selection, refer to Appendix 3, A3.1;
- articulation, vibration, expansion and contraction, refer to Appendix 3, A3.4;
- bends within design limits, refer to Appendix 3, A3.5;
- pressure drop considerations, refer to Appendix 3, A3.6;
- velocity, refer to Appendix 3, A3.7;
- preparation of pipework for jointing, refer to Appendix 3, A3.8;
- appropriate jointing methods, refer to Appendix 3, A3.9;
- identification of potential leak points, refer to Appendix 2;
- appropriate routing, refer to Appendix 3, A3.10;
- adequate supports, refer to Appendix 3, A3.11;
- cleaning, refer to Appendix 3, A3.12;
- safe venting, refer to Appendix 4;
- where required, electrical safety, refer to Appendix 6;
- where required, appropriate external protection, refer to Appendix 7;
- pipework identification, refer to Appendix 8;
- allowance for safe operation and future examination, inspection and maintenance.
A3.1 Material selection.
Also refer to Section 5.2.

When selecting piping material the following variables shall be taken into account:

- the application, for example, industrial, medical, laboratory, food, etc.;
- the properties of the gas and state, for example, liquid or gas, for guidance refer to Appendix 9;
- pressure and temperature;
- flowrate;
- velocity, refer to Appendix 3, A3.7;
- gas purity and cleanliness requirements, refer to Appendix 3, A3.12;
- environmental conditions, for example, ambient temperature(s), corrosive environments, exposure to weather, UV light, etc.;
- the expected life of the pressure system;
- cyclic conditions, vibration, temperature or pressure fluctuations;
- the routing of the pipework, for example, under-ground, over-ground, etc., refer to Appendix 3, A3.10;
- jointing method(s), especially at pressure system boundary, refer to Appendix 3, A3.9;
- electrical conductivity, with consideration for earth bonding, refer to Appendix 6;
- fire resistance and local heat sources;
- requirements for pipework protection, refer to Appendix 7;
- corrosion allowance;
- permeability of the material;
- the hazard of adiabatic compression and appropriate mitigation measures, for example, the use of a heat sink, valve design, etc. This is especially important for pipework in oxygen and high pressure air service.

Pipework should meet the requirements of relevant standards, for example:
It is recommended that rigid metallic materials are used for permanently installed pipework. Semi-rigid or alternative materials may be used where a comprehensive design review has confirmed their suitability, any special installation requirements are met and they are specifically included in the examination, inspection and maintenance regime to ensure their on-going safety.

For information on plastic pipework refer to Section A3.2.

For information on pipework used in cryogenic applications refer to Section A3.3.

Flexible hose assemblies should only be used for the connection between the pipework and the gas source or process equipment where articulation is a requirement. They may also be used within a pressure system at a specific location to allow articulation and / or to prevent the transmission of vibration where this may be a concern. Refer to Section A3.4.

### A3.2 Plastic pipework

Only plastic pipe that is specifically designed for the transmission of gases may be used for pipework.

Plastic pipework should be:

- used within the pressure limitations specified by the manufacturer, and in any case less than 10 bar;
- used within the temperature limitations specified by the manufacturer, and in any case between -20 °C and 50 °C.

Most plastics become embrittled at low temperatures and should not therefore be used where foreseeable temperatures below –20 °C are likely to be encountered.

The mechanical strength of plastic reduces as the local and / or operating temperature increases, this may affect the level of pressure that can be safely contained. The operating environment should be taken into account in order to ensure that the working pressure does not exceed the design pressure at the operating temperature;

- only considered for the types of gases specified by the manufacturer, typically only for inert gases;
- used for low flow applications;
- kept to the minimum practical length;
- limited to ≤10 mm internal diameter;
- replaced at the end of its design life. The design life shall be specified. This is a maintenance activity and should be identified as such within the maintenance requirements for the pressure system, refer to BCGA CP 39 [88].

Plastic pipework shall comply with appropriate standards, for example:

- BS EN ISO 15494 [67], *Plastics piping systems for industrial applications. Polybutene (PB), polyethylene (PE), polyethylene of raised temperature resistance (PE-RT), crosslinked polyethylene (PE-X), polypropylene (PP). Metric series for specifications for components.*

Most plastics degrade in the presence of ultra violet (UV) light and this should be taken into account, with consideration for the environment in which the pressure system is to operate.

Plastic pipework will be more susceptible to failure in the event of a fire. The risk of a fire and the potential failure of plastic pipework in a fire incident should be considered during the design. Where plastic pipework is in use it should be included in the fire safety risk assessment carried out in compliance with *The Regulatory Reform (Fire Safety) Order* [12].

**A3.3 Cryogenic pipework**

Due to the temperature difference of cryogenic liquids from ambient (for example, liquid nitrogen is -196 °C) ice will form and build up on uninsulated pipework. Even if the pipework is insulated, frosting and ice may still develop. It is most likely to occur close to areas which are difficult to insulate, such as pipe ends, valves, controls and vaporisers.

There are safety considerations related to the formation of ice, these include:

- preventing access to, or operation of, the controls;
- preventing operation of safety devices;
- brittle fracture of pipework or components;
- creating excessive loads on the pipework;
- the hazard from ice breaking off and falling;
- the management of water run-off following melting.
The design and selection of pipework and components will need to allow for the potential formation of ice, for example, consider the use of extended spindle valves, remotely locating safety devices and pressure indicators, etc.

A thermal pressure relief device shall be fitted wherever there is the potential for liquid to be trapped between two isolations, commonly referred to as ‘thermal lock’.

Pipework used for the transfer of cryogenic liquid may need to be insulated. Where liquid is required at the point of use then insulation is required. There are two methods of insulation, conventional and super insulated (known as super insulated vacuum line (SIVL)).

NOTE: SIVL are up to 30 times more efficient in reducing thermal losses. They are primarily manufactured of high grade stainless steel and consist of an inner pipe for the cryogenic liquid, covered by insulation (consisting of a combination of multi-layer super insulation, or cryosorption material, low conductivity supports and a vacuum) which is then all enclosed in an outer pipe. The outer pipe remains at ambient temperature, whilst the inner pipework is at cryogenic temperatures.

The choice between the use of a conventional insulated line or a SIVL will depend on the length of the pipework, the frequency of use, the time required to achieve the cold gas or liquid at the point of use at the expected quality and the volume required.

When designing pipework for cryogenic liquids the Designer should take into consideration the liquefaction of air. This can occur when air comes into contact with articles which are at a temperature below the boiling point of an air gas, for example, oxygen (-183 °C). When transferring a colder gas, such as liquid nitrogen (-196 °C), through uninsulated pipework contact with the pipework by ambient air can result in the unexpected production of liquid oxygen, as this changes state back into a gas it will enrich the immediate atmosphere and therefore increase the fire risk.

For further information, refer to EIGA 217 [110], Vacuum-jacketed piping in liquid oxygen service.

Where cryogenic pipework is provided to connect to cryogenic transport tanks for filling purposes a standardised filling coupling system is used, refer to EIGA 909 [111], EIGA cryogenic gases couplings for tanker filling.

A3.4 Articulation, vibration, expansion and contraction

The coefficient of expansion of the material shall be taken into account.

A3.4.1 Pigtail
Pigtails are usually manufactured from solid tube with a mechanical connection at each end that connects two high-pressure systems. Pigtails are semi-flexible and are used in applications where a flexible hose is unsuitable, for example, in applications using corrosive gases, or the permanent installation of gas cylinders.
A3.4.2 Flexible hose assemblies

Flexible pipework assemblies shall be suitable for the design pressure and be compatible with the service gas.

Their length and diameter shall be kept to a minimum. They shall have end fittings permanently attached. Re-usuable worm-drive clamps shall not be used.

During installation, ensure the hose is fitted in such a way that it prevents bending of the hose along the non-flexible length, therefore avoiding unnecessary stress at the couplings, and that it avoids unnecessary stress to the hose assembly core construction, refer to Figure A3-1. To achieve this:

- there is a non-flexible length attached to each coupling. This should remain straight. This length should be specified by the manufacturer. Where not specified, as a minimum this should be a length equivalent to six times the outside diameter of the hose;

- there is a minimum bend radius for the remained of the hose. Typically this is expressed as a ratio of bending radius to hose diameter, for example, 12:1. This should be specified by the manufacturer.

![Figure A3-1: Flexible hose](image)

Where used on flammable gas pressure systems flexible hoses shall be electrically conductive with a resistance not exceeding $10^6$ ohms to give protection against electrostatic charging.

To prevent injury to personnel in the event of a hose failure, anti-whip wires should be fitted where the pressure exceeds 40 bar(g). The restraining wire prevents the hose from flailing in the case of a fitting failure. The securing point shall have adequate strength with the wire securely fastened at each end, but shall not be attached at the crimp area. Some hoses are provided with an internal restraining wire, this should only be used when it is certain that the wire will be compatible with the gas being carried through the hose, particularly oxygen. Ensure that any manufacturing process does not
leave contaminants on the wire, which could react with the gas, and that the wire does not restrict flow.

For certain gases there is a colour code system applied to the external surface of the hose which is used to identify the gas. For example, this is common on oxy-fuel applications, refer to BCGA CP 7\textsuperscript{[81]}. 

Flexible hose assemblies shall conform to appropriate standards, such as:

- BS EN ISO 3821\textsuperscript{[41]}, \textit{Gas welding equipment. Rubber hoses for welding, cutting and allied processes}. 
- BS EN ISO 10380\textsuperscript{[57]}, \textit{Pipework. Corrugated metal hoses and hose assemblies}. 
- ISO 12170\textsuperscript{[59]}, \textit{Gas welding equipment. Thermoplastic hoses for welding and allied processes}. 
- BS EN ISO 14113\textsuperscript{[66]}, \textit{Gas welding equipment. Rubber and plastic hose and hose assemblies for use with industrial gases up to 450 bar (45 MPa)}. 
- BS ISO 16964\textsuperscript{[71]}, \textit{Gas cylinders. Flexible hoses assemblies. Specification and testing}. 

For further information refer to:

- Energy Institute, \textit{Guidelines for the management of flexible hose assemblies}\textsuperscript{[119]}; 
- EIGA 42\textsuperscript{[101]}, \textit{Flexible connections in high pressure gas systems}. 

For cryogenic applications, additionally hose assemblies shall conform to appropriate standards, such as:

- BS EN 1797\textsuperscript{[39]}, \textit{Cryogenic vessels. Gas / material compatibility}. 
- BS ISO 21010\textsuperscript{[72]}, \textit{Cryogenic vessels. Gas / material compatibility}. 
- BS EN 12434\textsuperscript{[60]}, \textit{Cryogenic vessels. Cryogenic flexible hoses}. 
- BS EN 13371\textsuperscript{[62]}, \textit{Cryogenic vessels. Couplings for cryogenic service}. 
- BS EN ISO 21012\textsuperscript{[73]}, \textit{Cryogenic vessels. Hoses}. 

BCGA CP 4 – Revision 5
APPENDIX 3
Sheet 8 of 23

For additional information refer to:

- EIGA 133 \(^{[106]}\), *Cryogenic Vaporisation Systems - Prevention of Brittle Fracture of Equipment and Piping.*
- EIGA Technical Bulletin 26 \(^{[112]}\), *Cryogenic flexible hoses.*

**A3.5 Bends**

Where a bend is required it shall be formed using appropriate methods. Bends:

- shall not reduce the mechanical strength or the integrity of the pipework outside of the safe operating limits of the pressure system;
- within pipework should have a minimum bend radius in-line with applicable design codes and material specification, typically a minimum of 3D (where D = the nominal pipework bore);
- when fabricated shall show no signs of buckling, cracking or other defects.

**A3.6 Pressure drop**

When fluid flows through pipework there will be a pressure drop that occurs as a result of resistance to flow.

For most conditions and gases within the scope of this Code, pressure drop (at 15 °C) can be estimated from the formula:

\[
\Delta P = P_1 - \sqrt{P_1^2 - \frac{32 Q^2 L S_g}{d^5}}
\]

where:

- \(\Delta P\) = pressure drop (bar)
- \(P_1\) = inlet pressure (bar absolute)
- \(Q\) = flow (m\(^3\)/h measured at 15 °C & 1013 mbar)
- \(L\) = pipework length (m)
- \(S_g\) = specific gravity (air = 1)
- \(d\) = internal diameter of pipework (mm)

Pressure drop may be affected by changes in direction of the gas flow, fittings and components installed in the pressure system. The usual method of calculating pressure drop, due to fittings and components, is to increase theoretically the pipework length to account for the fittings as shown in Table A3.6-1.
Allowance should be made at the design stage for future extensions.

NOTE: The calculations for pressure drop are applicable to metallic pipework only and provide indicative values.

| Pipe size (mm) nominal |  |  |  |
|-----------------------|-----------------|---------------|
|                       | Valves (wide open) | Fittings |
|                       | Ball | Globe or Diaphragm | Angle | Tee (Through) | Tee (Branch) | Elbow |
| 10                    | 0.3 | 4.0 | 2.5 | 0.2 | 0.9 | 0.4 |
| 12                    | 0.3 | 4.0 | 2.5 | 0.2 | 0.9 | 0.4 |
| 15 / 16               | 0.3 | 6.0 | 3.1 | 0.3 | 1.0 | 0.5 |
| 20 / 22               | 0.6 | 6.0 | 4.0 | 0.6 | 1.9 | 0.7 |
| 25 / 28               | 0.9 | 9.0 | 5.0 | 0.6 | 1.9 | 0.9 |
| 42                    | 1.2 | 14.0 | 7.5 | 0.9 | 3.0 | 1.2 |
| 54                    | 1.4 | 16.0 | 9.0 | 1.1 | 3.5 | 1.4 |

**Table A3.6-1:** 
Calculating pressure drop due to fittings and components installed

**A3.7 Velocity**
The pipework should be designed such that the velocity is compatible with the pressure drop and remains within acceptable limits. Certain gases have velocity limitations related to their properties and/or materials of construction of the pipework.

For pressure systems containing oxidising gases the velocity of the gas shall be kept below a defined value, refer to Appendix 9.

For most gases and conditions covered by this code, velocity may be calculated using the following formula:

\[ V = \frac{358 Q}{D^2 (P + 1.013)} \text{ m/s} \]

where:
- \( V \) = the velocity (m/s)
- \( Q \) = the gas flow-rate in cubic metres per hour measured at 15 °C, 1013 mbar
- \( D \) = the internal diameter of the pipe (mm)
- \( P \) = the inlet pressure (bar(g))
A3.8 Preparation for jointing

Pipe work ends should be cut square with the pipe axis using suitable tools.

All cuttings and burrs (both internal and external) shall be removed. Finally the pipe shall be cleaned, refer to Appendix 3, A3.12.

Expanded joints should be made using the appropriate tools and dies. Only tools and dies free from oil and grease should be used.

Pipe work fabrication (bend angles and measured lengths) shall be sufficient to ensure the pipe end enters the fitting in proper alignment with full penetration into the fitting (where applicable). Do not force an improperly fitted pipe into the fitting.

A3.9 Jointing methods

The design of a pressure system and the choice of joints shall take into consideration the potential stresses, reactions and movement of the pipe work. Correctly installed and jointed pipe work should not leak throughout its lifetime, however, pipe work joints are often the point where a leak path occurs within a pressure system. Consequently, the number of joints in a pressure system should be kept to the minimum. This becomes more important where pipe work contains gas at very high pressures, refer to Appendix 2.

All joints shall be rated to be equal to or greater than the pressure system MAWP.

All of the considerations relevant to pipe work material selection (refer to Appendix 3, A3.1) shall be taken into account when choosing the jointing materials and shall be compatible with the pipe work material.

When selecting a jointing method, reference shall be made to the constraints detailed in the following sections:

- routing, refer to Appendix 3, A3.10;
- leak paths, refer to Appendix 2.

Examples of jointing techniques include:

- welding, refer to Appendix 3, A3.9.1;
- brazing, refer to Appendix 3, A3.9.2;
- soldering, refer to Appendix 3, A3.9.3;
- mechanical joints, for example, screw threads, flanges, compression fittings, push-fittings, connections, etc. refer to Appendix 3, A3.9.4;
Jointing techniques not mentioned above shall be used only after detailed evaluation and risk assessment. For example, plastic pipework may include solvent-welded, screwed, fusion-welded, flanged, hose fittings and clips, push-in or compression fittings.

High integrity joints, of a permanent nature, such as a brazed or welded joint, should be used in preference to non-permanent joints. Non-permanent joints have a greater propensity to leak.

NOTE: A permanent joint is defined as a joint which cannot be disconnected except by destructive methods.

Joints and adjacent zones shall be free of any surface or internal defects detrimental to the safety of the joint.

Where additional joint sealing materials are necessary, refer to Appendix 3, A3.9.5.

A3.9.1 Welding
Welding creates a permanent joint.

Welding shall be carried out by qualified personnel according to qualified welding procedure specifications (WPS). For example, refer to:

- BS EN ISO 15609 [69], *Specification and qualification of welding procedures for metallic materials*;

- BS EN ISO 3834 [42], *Quality requirements for fusion welding of metallic materials*.

For information on oxy-fuel equipment refer to BCGA CP 7 [81].

A3.9.2 Brazing
Brazing creates a permanent joint.

Brazing shall be carried out by qualified personnel according to qualified brazing procedure specifications (BPS). For example, refer to:

- BS EN 13585 [65], *Brazing. Qualification test of brazers and brazing operators*;

- BS ISO 22688 [74], *Brazing. Quality requirements for brazing of metallic materials*.

In cases where flux residues are not acceptable, for example, medical, some laboratory and food applications, copper phosphorus rod may be used for fluxless brazing of copper to copper using a suitable purge.

For information on oxy-fuel equipment refer to BCGA CP 7 [81].
A3.9.3 Soft soldering

Soft soldering creates a permanent joint.

Soft solder is a jointing technique which uses a filler material that has a melting point lower than the material being joined and is typically less than 400 ºC.

Soft solder may be capable of creating a joint in a pipework system, and is commonly used in, for example, water and low pressure natural gas systems (at mbar pressures). However there are limitations for its use in any other pressure systems. Therefore the use of soft soldered joints is limited to a very narrow range of applications. Its use is not endorsed by BCGA for the following reasons:

- the strength of the joint is significantly lower than a brazed joint;
- the strength of the joint is affected by both high and low temperatures, as well as by temperature variations;
- there are limitations regarding temperature and pressure;
- the lack of qualified personnel according to a qualified soldering procedure specification;
- the difficulty in distinguishing the difference between a soft soldered joint and a brazed joint when assessing a pressure system limitations, when considering a change of service conditions, or when modifying an existing pressure system;
- flux products can present compatibility issues with gas wetted components.

Soft solder joints shall not be used for pressure systems containing gases that are toxic, corrosive, flammable, oxidising, cryogenic applications, or where there are pressure and/or temperature variations. If soft solder joints are to be specified, the Designer shall conduct and document a full technical design appraisal to demonstrate suitability and shall provide the Installer with a documented soldering procedure. The User shall keep the technical design appraisal for the life of the pressure system.

A3.9.4 Mechanical joints

Mechanical joints are non-permanent joints. Gas tightness is achieved by compression, with or without a seal, and the joint can be disassembled and reassembled.

For information on joint sealing materials, refer to Appendix 3, A3.9.5.

NOTE: Pressure systems with gases with a small molecular size, for example, hydrogen and helium, are more likely to find a leak path when using a mechanical joint and the use of a permanent joint may be more appropriate, especially at high pressures.
**Screw threads.** Threads shall be clean cut and the calculated strength of the threaded joints shall be adequate for the pressure and other service loading of the pipework in which they are installed. The number of joints shall be kept to a minimum.

Taper and parallel threads shall not be mismatched, unless the joint is specifically designed by the manufacturer for this purpose.

Threads of different forms shall not be mismatched.

Joint sealing materials, such as PTFE tape, shall only be used on taper threads, refer to Appendix 3, A3.9.5.

Where the pressure seal is made on the thread, screw threads shall conform to appropriate standards, for example:

- BS EN 10226\(^{[56]}\), *Pipe threads where pressure tight joints are made on the threads.*

Where the seal is not made on the thread, screw threads shall conform to appropriate standards, for example:

- BS EN ISO 228\(^{[30]}\), *Pipe threads where pressure-tight joints are not made on the threads.*

**Flanges and fixings.** Flanges, in respect of material, dimensions and drilling, shall be suitable for the duty for which they are installed. Nuts and bolts shall be suitable for the duty for which they are installed. Bolts and stud bolts shall extend completely through the nuts. They shall conform to appropriate standards, for example:

- BS EN 1515\(^{[36]}\), *Flanges and their joints. Bolting.*

- BS EN 1759\(^{[38]}\), *Flanges and their joints. Circular flanges for pipes, valves, fittings and accessories, class designated.*

Where electrical continuity is required across the joint refer to Appendix 6.

**Compression, push and crimp / press-fit fittings**

Only fittings designed for the intended gas service and operating conditions shall be used.

Domestic plumbing fittings are normally not designed for gas service and should not be used.

Manufacturer’s installation and use instructions shall be followed when fittings of any type are used.
Connections
Connections are joints that routinely need to be connected and dis-connected, normally by the user.

Types of connections include:

- quick release couplings;
- cylinder connections (for example, a BS 341-3, Transportable gas container valves. Valve outlet connections, No.3 bull nose connector);
- the gas dispensing nozzle and its associated receptacle (for example, gas dispenser nozzles referenced in BCGA CP 41, The design, construction, maintenance and operation of filling stations dispensing gaseous fuels).

Only connections designed for the intended gas service shall be used.

Where there is the potential to make an incorrect connection the use of anti-confusion connectors, or specially designed mechanical inter-locks, should be installed. For example:

- flammable gases shall terminate in a left hand thread;
- non-flammable gases shall terminate in a right hand thread.

Connections shall be clearly labelled for their intended use and gas service, refer to Appendix 8.

Manufacturer’s installation, use and maintenance instructions shall be followed when connections of any type are used.

A3.9.5 Joint sealing materials
Sealing materials come in a variety of forms, for example, seals, tapes, paste, gaskets, metallic rings, etc.

Sealing materials, although they may be in contact with the gas, shall not protrude in the gas stream.

All sealing materials shall be compatible with the application, for example, meeting the quality and specification requirements for gases used in food, medical, etc. Where the hazard of ignition is present, further consideration should be given to the by-products of combustion from the sealing material(s) on the downstream application.

Asbestos based materials shall not be used.
**PTFE tape.** Polytetrafluoroethylene (PTFE) tape for use in oxygen service shall be of degreased quality. PTFE tape shall comply with appropriate standards, for example, refer to:

- BS 7786[^53], *Specification for unsintered PTFE tapes for general use.*
- BS EN 751-3[^33], *Sealing materials for metallic threaded joints in contact with 1st, 2nd and 3rd family gases and hot water. Unsintered PTFE tape.*

PTFE tape should only be used on taper threads to form the seal. PTFE tape should not be used to achieve a gas tight seal on other mechanical joints.

PTFE tape should only be applied sparingly and start at least one thread back from the start of the thread form moving away from the gas stream.

**NOTES:**

1. Incorrectly applied PTFE tape can enter the gas system, fragments can block downstream components and present a fire hazard with high-pressure oxidising gases.

2. Some sites have a restriction on the use of PTFE tape and its use should be checked with any site specific requirements.

**Sealants.** Only sealants designed and tested for the joint method and the intended gas service shall be used.

Manufacturer’s installation and use instructions shall be followed when sealants of any type are used.

Sealant should only be applied sparingly and at least one thread back from the start of the thread form away from the gas stream.

**NOTE:** Incorrectly applied sealant can enter the gas system, block downstream components and present a fire hazard with high-pressure oxidising gases.

Sealant should not be used to achieve a gas tight seal on joints, other than those for which the sealant has been designed.

**A3.10 Routing**

Pipework should, wherever practical, be located outdoors.

Pipework generally should be as short and straight as possible, avoiding any reasonably foreseeable hazards.
Where direct access to the pipework is not required, pipework should be located in areas where it is unlikely to be accidently damaged or where it is not easily accessible to unauthorised personnel, for example, at height (approximately 2 m).

Pipework should be routed away from potential hazards (to or from the pipework), for example, anything that may cause mechanical or chemical damage, excessive temperatures, vibration, corrosion, other hazardous substances, other utilities, high fire risk areas, lift shafts, etc. Where the installation of pipework in such areas is unavoidable, then the pipework should be protected, for example, by enclosing in non-combustible, non-corrosive materials that will not chemically react with the material the pipework is constructed from, including any electrolytic reaction.

Where it is necessary for pipework to pass over exits, particularly emergency exits, suitable materials for the pipework, supports and any conduits shall be used to prevent their premature collapse in the event of an incident, for example, a fire.

NOTE: Non-metallic pipework, supports, conduit, etc. are more easily damaged and are more susceptible to failure in the event of a fire than if manufactured from metallic materials.

Pipework should be routed away from, and separated from, electrical services to prevent induced current, damage to the pipework from an electrical energy release and to minimise the fire risk. When it is necessary to route pipework in close proximity to electric services, the electrical cables and the pipework should be continuous. If pipework joints are necessary permanent joints should be used.

Where it is essential that pipework has to cross electrical services, other pipework, etc. the pipework should be supported either side of the crossing to prevent contact. Refer to Appendix 3, A3.11.

Provision shall be made for access to allow for any future maintenance and inspection activities.

The route for pipework shall be surveyed to identify:

- any potential site hazards which may affect the external integrity of the pipework;
- any hazards that may be created in the event of a gas leak, for example, a heavier than air gas will sink to floor level and collect in pits, cellars etc., a lighter than air gas will rise up to the roof spaces. Available local ventilation should be taken into account and consideration given to any changes necessary to provide adequate ventilation requirements for the area, refer to BCGA GN 11 \(^{(93)}\);
- a route to minimise the length of the pipework;
- locations for pipework supports and (existing) structures to which the pipework supports can be fixed, refer to Appendix 3, A3.11;
APPENDIX 3
Sheet 17 of 23

- safe access for installation, testing, operations (of valves, controls, etc.), examination, inspection and maintenance;

- the type and suitability of joints at specific locations, with due consideration to potential leak paths, refer to Appendix 2;

- location of operational equipment;

- the need for, and the potential location of, expansion and contraction;

- the need for and location of any electrical supplies, cable routes, bonding, earthing, etc., refer to Appendix 6;

- pipework routes indoors and in enclosed areas. All such routes should be well-ventilated, refer to BCGA GN 11 [93]. Routing pipework in enclosed spaces (roof and floor spaces, ducts, etc.) should be avoided. Routing pipework may change the space into a Confined Space;

Where pipework has to be routed through indoors or in enclosed spaces, refer to Appendix 3, A3.10.1.

Where pipework has to be routed outdoors below ground level refer to Appendix 3, A3.10.3.

- locations where pipework makes a building fabric transit (for example, through a wall, a ceiling, a floor, a fence, cladding, etc.).

Where the pipework has to make a building fabric transit a sleeve shall be used to protect the exterior of the pipework. There shall be no joints within the sleeve. A sleeve should:

- protrude from either side of the obstacle;

- take the shortest route possible, usually perpendicular to the fabric surface;

- have materials of construction compatible with the pipework and the obstacle through which it passes, for example, fire resistance, electrical potential difference, etc.;

- be fixed to the structure using suitable building materials;

- as necessary, fill one end with a compatible sealant. Where the pipework passes from an external to an internal area, then the seal shall be on the internal side.

Where multiple pipework needs to transition, a single sleeve may be used providing each pipe is appropriately supported, separated and the sleeve effectively sealed.
A3.10.1 Routing indoors or in enclosed spaces
Where pipework is routed through an indoor or enclosed space then:

- leak paths should be minimised. Permanent joints are preferred;
- the length of pipework should be kept to a minimum;
- the area shall be well ventilated, refer to BCGA GN 11 [93];

Where pipework is to be subject to direct visual inspection it should not be concealed such that it cannot be accessed, for example, within ducts, stud walls, by boxing in, etc.

Where it is necessary to route pipework in a duct, refer to Appendix 3, A3.10.2.

A3.10.2 Routing in a duct
Pipework shall not be routed in or through a duct provided for heating, ventilation and air conditioning (HVAC) purposes, refer to BS 9999 [55], *Fire safety in the design, management and use of buildings. Code of practice*.

Pipework should not be run in any other duct unless there is no safe practical alternative. Where it is necessary to route pipework in a duct or other enclosures, such as ceiling, floor or wall voids and cavities, comply with the requirements of BS 8313 [54], *Code of practice for accommodation of building services in ducts*.

BS 8313 [54] provides guidance on topics, including:

- access;
- protection of services in ducts;
- ventilation;
- fire and safety precautions;
- inspection, maintenance and testing;
- separation distances;
- material considerations.

The principles to follow when considering installing pipework in a duct are:

- leak paths should be avoided, refer to Appendix 2. Where jointing is necessary then it shall be a permanent joint;
• the duct shall be well ventilated, refer to BCGA GN 11\textsuperscript{93}. Where it is not possible to ventilate ducts, pipework shall be run within an outer, larger diameter pipe (that is, sheathed), both ends of the outer pipework being open to well-ventilated positions;

• flammable pipework shall not be installed in the same duct as any other services except inert gases, cold water or steam;

• the duct shall not contain materials which are incompatible with the gas or the pipework, and shall protect from the accumulation of dirt, contaminants, detritus, etc.

A3.10.3 Routing outdoors below ground level
Pipework should only be installed underground where there is no alternative, for example, in order to cross pathways, roads and railway lines. Several different methods, in order of preference, may be used:

• pipework installed on pipework racks or supports inside concrete or metal channels, which may be closed by the use of masonry slabs or which may be covered with open grid covers. This is the preferred method as it allows for relatively easy access to allow examination, inspection, maintenance, etc. However consideration should be given to the effects of corrosion, for example from salting in winter conditions, additional external protection of the pipework may be required, refer to Appendix 7;

• pipework laid in trenches and backfilled;

• pipework laid in trenches and encased in concrete.

NOTE: Some materials may chemically react with concrete.

In all cases ensure that all pipework below ground level is included within the pressure system examination, inspection and maintenance regime, refer to BCGA CP 39\textsuperscript{88}.

Flammable and oxidising gases should not be run in the same channel or trench unless:

• the ventilation is adequate, for example, in a large ventilated channel; or

• the trench is back filled with an inert non corrosive material and the oxygen and flammable gas pipework has a minimum separation distance of 500 mm; or

• the pipework is encased in concrete and the minimum separation distance is 300 mm.

Inert gases may be run in the same trenches as either oxidising or flammable gases.
Electrical power cables. Electrical power cables should be run in a separate channel / trench. If there is no option, only inert gas pipework may be run in the same trench provided it is encased in plastic coated tube, fitted in a single section with no joints.

All underground pipework should be continuous with no joints. Where a joint is necessary, the number of joints shall be kept to the minimum and be of a permanent design. High integrity joints, for example, flanges, shall only be permissible when they are essential for assembly and disassembly.

Pipework shall be supported in such a way that, during its lifetime, the pipework will not move with respect to its initial installed position, except for foreseen permitted displacements.

Where pipework is to enter a building, the entry point should be above ground wherever this is practicable. Pipework shall not pass under the foundations of the building, under the base of a wall or under the footings.

At the point it enters / leaves the ground, pipework shall be adequately protected to prevent damage. This may require a sleeve. At this point the pipework shall include appropriate identification and signage, refer to Appendix 8.

Consider the long term effects of corrosion and the use of external protection for pipework laid below ground, refer to Appendix 7. The use of pipework manufactured from metals may be particularly susceptible to corrosion underground. Plastic pipework shall not be laid in chemically corrosive soils containing tars, oils or other acidic type residues. Manufacturers of such pipework should be consulted where there is any doubt.

In a channel, drainage shall be provided to prevent the accumulation of water or other fluids. Drains should be of a design to prevent escaping gas entering.

To provide additional protection, or where there is a particular hazard from a gas leak underground, consider installing a pipe within a pipe. Therefore if there is a leak then the gas will escapes at either end.

Where valves are required to be fitted to underground pipework, they shall be of a high integrity leak tight design. They should be accessible from the surface, via a suitable access pit, this should be of solid construction, for example, concrete or brick lined. Where necessary, valves and pipe fittings shall be anchored such that no unacceptable stresses can be transmitted to the pipework during normal operation or during the actuation of the valve. Valves (and their access pits) should be appropriately identified with the gas they control, their purpose and their method of operation, refer to Appendix 8. As necessary, consider appropriate security measures to manage access and to allow the operation of the valve.
Where the pipework is to be buried underground and where there is a likelihood of traffic over that area, a Civil Engineer shall be consulted to determine the required depth, backfill and support requirements, to ensure the continued integrity of the pipework. Further information is available, refer to BS 6031 [48], *Code of practice for earthworks*. It is recommended that a Civil Engineer is consulted for all other buried pipework scenarios.

Where pipework is based in a channel, and there is the likelihood of traffic, a Civil Engineer shall be consulted for advice.

When the pipework is buried, it shall be protected from impact from, for example, by stones, by a layer of a protective material, such as washed (sweet) sand.

All required testing should take place prior to back-filling, although this is not essential if all joints and connections are left exposed for such tests. Refer to Section 7.

Identification. All buried pipework shall be identified with its contents, refer to Appendix 8. Identification markings should be manufactured from material which will not deteriorate whilst underground. The use of a continuous marker tape indicating the presence of pipework, laid a minimum of 0.3 m above the pipework, is recommended.

Where pipework is buried consideration should be given to providing markers on the surface to indicate that pipework is routed below. This may be beneficial in places, such as a footpath or road, where, for example, the surface may be re-laid.

**A3.11 Supports**

All pipework shall be adequately supported.

Individual supports shall have sufficient mechanical strength to withstand the loads exerted on them.

Supports shall be adequately secured to structures which are capable of carrying all foreseeable loads.

**NOTE:** Some building construction materials may not have sufficient strength, for example, plasterboard lined walls.

Take into consideration:

- the weight of the pipework, including flexible assemblies;
- the weight of the liquid and / or gaseous product contained in the pipework;
- any components being supported, including the concentrated loads imposed by valves, regulators, pressure relief devices and other associated equipment;
- any additional loads imposed, for example, by:
When choosing supports and fixings take into account their properties and their capability to withstand an external incident, particularly fire. Where pipework is routed over access and egress routes and its collapse could cause obstruction, the integrity of the supports shall retain the piping in position. Metallic clamps, metallic clamps with plastic inserts, pipework contained within and above metal tray or ladder, or the use of metallic tie wraps securing pipes to the underside of metallic tray are examples of fixings that will prevent collapse.

Supports shall be spaced such that the pipework does not sag or distort. BS EN 15001 [67], *Gas infrastructure. Gas installation pipework with an operating pressure greater than 0.5 bar for industrial installations and greater than 5 bar for industrial and non-industrial installations*, provides a methodology for determining the distances between supports.

For convenience, using this methodology, the distances between supports for copper pipework containing a compressed gas are provided in Table A3-2.

<table>
<thead>
<tr>
<th>Nominal pipe outside diameter (mm)</th>
<th>Support spacing (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>0.9</td>
</tr>
<tr>
<td>22</td>
<td>1.3</td>
</tr>
<tr>
<td>28</td>
<td>1.7</td>
</tr>
<tr>
<td>42</td>
<td>1.7</td>
</tr>
<tr>
<td>54</td>
<td>2.2</td>
</tr>
</tbody>
</table>

**Table A3-2: Support spacing for copper pipework**

Where flexible plastic pipework is used, supporting on cable trays rather than on standard support systems may be a preferable alternative.
Where conduits are used, they shall be fabricated from materials which are the same as, or are compatible with, the pipework they support. Conduits shall be adequately supported.

Supports and other permanent attachments which are connected directly to the pipework shall be fabricated from materials which are the same as, or are compatible with, the pipework they support. All clamping parts shall fit closely around the pipework.

Supports may require addition protection to prevent corrosion etc., refer to Appendix 7.

**A3.12 Cleaning**

Before working with any hazardous substances a suitable and sufficient risk assessment should be carried out in accordance with the Control of Substances Hazardous to Health Regulations [10] and appropriate control measures implemented.

Before erection, pipework, fittings and equipment should be fully cleaned and degreased and cleanliness maintained thereafter, for oxidising gases this is mandatory.

Pipework required for high quality (low contamination) applications or in oxygen / oxidising gas service will require special cleaning methods. It is recommended that all pipework, valves and fittings exposed to these gases are procured and are certified as being suitable for, and cleaned for, oxygen service. The cleaning shall be to an appropriate standard and all products packaged to ensure there is no contamination in transit or storage and labelled accordingly.

For further information refer to:

- EIGA 33 [100], Cleaning of equipment for oxygen service.
- BS IEC 60877 [78], Procedures for ensuring the cleanliness of industrial process, measurement and control equipment for oxygen service.
- BS EN ISO 23208 [75], Cryogenic vessels. Cleanliness for cryogenic service.

Site cleaning of pipework should be limited to re-cleaning ends of pipework / valves and fittings which may have been contaminated during the pressure system erection process.

If not required for immediate use, then after cleaning, items shall be protected to maintain their clean condition and to prevent the ingress of any contaminants. Sections of pipework should be capped. Any packaging, plugs, etc. that can contact the clean surfaces shall be clean and removable without leaving any residue. External packaging material shall be strong enough to resist the expected handling and storage conditions, be able to be sealed and be capable of providing protection from local environmental conditions, for example, be waterproof.

Completed pipework shall be flushed until all foreign matter is removed. This will normally be achieved by passing clean, dry, oil-free nitrogen or air through the pipework at high velocity.
VENT SYSTEMS

Any gas that is automatically or manually vented shall be dispersed safely to an external area where there is no risk of creating a local hazardous environment, or where the gas will not impinge on personnel, equipment and buildings in an unsafe way. This may require a remote discharge point, often at a high level.

Vent systems shall be made of materials compatible with the gases being vented. Consideration should also be given to change of phase or any reactions that may occur when the gas comes into contact with air or moisture, for example, combustion, formation of corrosive by-products, etc.

The vent pipework generally should be as short and straight as possible, avoiding any reasonably foreseeable hazards.

All vent pipework shall be designed and installed in such a way so there is no reduction in pipe diameter, no unacceptable back-pressure or potential for obstruction. The outlets shall prevent the ingress of contaminants including water, for example, from snow, rain and condensation. Water accumulation may lead to the formation of ice, which could potentially cause blockages.

All vent systems shall be adequately supported to cope with the loads created during discharge (to resist reaction force), as well as those created by the weather, for example, wind, snow, etc.

For flammable gases a flame arrestor or a flare stack is not normally required. If there is a local requirement then this shall be subject to an independent assessment.

Incompatible gases shall not be discharged into a single vent system.

Where a number of outlets are connected into a single vent system, the common outlet vent pipework shall be sized sufficiently to accommodate a number of simultaneous discharges (to be determined via an appropriate risk assessment) whilst not exerting any unacceptable backpressure on any connected outlet. This should not impair the safe and full operation of any connected equipment. Consideration shall also be given to the need for future inspection and maintenance operations, noting that all systems of connected outlets may require depressurisation during those operations.

Noise hazards should be considered and appropriate means installed to direct or reduce any noise to acceptable levels. Refer to EIGA 85 [105], *Noise management*.

All vent outlets shall be identified by an appropriate warning sign highlighting the hazard(s) from the discharged gas. For example, identifying that it is a vent discharge point and the hazard from the individual gas, refer to Appendix 8.
For flammable gases, there is a risk of the creation of an explosive atmosphere and therefore a risk assessment is required in accordance with The Dangerous Substances and Explosive Atmospheres Regulations \[11\], it may be necessary to display the explosive atmosphere ‘EX’ sign.

For further information on the venting of gases refer to:

- EIGA 30 \[^{99}\] , Disposal of gases.
- EIGA 154 \[^{107}\] , Safe location of oxygen and inert gas vents.
- EIGA 211 \[^{109}\] , Hydrogen vent systems for customer applications.
A pressure system will comprise of many components. For component selection refer to Section 5.1.

For additional information on:

- pressure relief devices, refer to Appendix 5, A5.1;
- regulators, refer to Appendix 5, A5.2;
- isolation valves (including emergency isolation valves), refer to Appendix 5, A5.3;
- non-return valves, refer to Appendix 5, A5.4;
- flame arrestors, refer to Appendix 5, A5.5;
- pressure indicators, refer to Appendix 5, A5.6;
- filters, refer to Appendix 5, A5.7.

**A5.1 Pressure relief devices**

There are a variety of pressure relief devices available. There is a choice between reseating and non-reseating relief devices and their means of activation, for example, pressure, temperature.

The key considerations are that the pressure release device:

- is compatible with the gas, phase, the operating temperatures and all foreseeable environmental conditions;
- relieves at or below the pressure of the lowest rated component within the section of the pressure system being protected;
- has adequate flow capacity to cope with all anticipated fault conditions;
- outlets shall be sited to discharge in a safe area. Where they connect into a vent system, the relief devices shall be adequately sized to relieve the flow rate (through the vent system), refer to Appendix 4;
- shall be properly secured, including being securely anchored to prevent movement from any loads imposed by the vent system;
- should be located and orientated in accordance with the manufacturer’s instructions;
APPENDIX 5
Sheet 2 of 7

- shall be supplied with appropriate certification and have a useful remaining service life.

Pressure relief devices require routine examination, inspection and maintenance. The service life should be recorded. This is a maintenance activity and should be identified as such within the maintenance requirements for the pressure system, refer to BCGA CP 39 [88].

As pressure relief devices require periodic examination, inspection and maintenance they shall be located accordingly to allow access, etc.

Some proprietary pressure equipment may incorporate a pressure relief device (fitted by the manufacturer), these only protect the specific equipment from over-pressure, they are not designed to protect downstream equipment.

Bursting discs should only be used as a secondary pressure relief device, typically as the final safety device, as following operation they cannot be reset resulting in the entire pressure system depressurising (including the source gas).

Pressure relief valves and bursting discs shall conform to an appropriate standard, such as:

- BS EN ISO 4126 [43], Safety devices for protection against excessive pressure.

A5.2 Regulators
The primary pressure regulator reduces the pressure of the gas from the gas source pressure to the required lower operating pressure and then maintains it within prescribed limits.

Additional regulators may be incorporated to provide secondary regulation, to further reduce pressure and / or provide more stable pressure to meet operational requirements.

Regulators shall be designed and be suitable for the particular gas service, the design pressure and flow rate.

Pressure reduction within the regulator may be in one or two stages (single or two stage regulators).

Some pressure regulators may incorporate a pressure relief device (fitted by the manufacturer), these only protect the regulator from over-pressure, they are not designed to protect downstream equipment.

Where downstream pipework and equipment is not rated to the pressures upstream of the regulator, a pressure relief device should be fitted. Where a pressure relief device is not fitted the pressure regulator becomes the primary pressure protection device and shall be included in the examination, inspection and maintenance regime, as an item requiring periodic replacement, refer to BCGA CP 39 [88]. If a separate pressure relief device is not to be fitted this should be justified by a separate risk assessment.
Pressure regulators should comply with an appropriate standard, such as:

- BS EN ISO 2503[^40], *Gas welding equipment. Pressure regulators and pressure regulators with flow-metering devices for gas cylinders used in welding, cutting and allied processes up to 300 bar (30 MPa)*; or

- BS EN ISO 7291[^49], *Gas welding equipment. Pressure regulators for manifold systems used in welding, cutting and allied processes up to 30 MPa (300 bar)*.

In the absence of an appropriate standard then seek the advice of a manufacturer who can provide a pressure regulator that meets the essential safety requirements of the above standards.

The pressure regulator shall be designed for use with the intended gas. Some regulators are designed for multiple gas use (for example, inert gas service). Best practice is that once a pressure regulator has been in service with a particular gas it should remain in that gas service for the remainder of its life.

It is recommended that the following is clearly and permanently marked on the pressure regulator body or cover:

- gas service. In many cases the gas service will be identified by the manufacturer. Where there is an option to use a regulator designed for a range of gases, the Installer shall label the regulator at first use;

- maximum inlet pressure (bar);

- maximum outlet pressure (bar);

- the name or trademark of the manufacturer and / or distributor;

- a date mark showing either the date of manufacture or a date when the regulator is to be replaced or refurbished.

NOTE: The manufacturer / supplier can advise on the life of a pressure regulator.

Pressure regulators for industrial use shall not be CE marked in accordance with the European Directives.

Pressure regulators should be treated as precision instruments and should be protected from, for example, being jarred or knocked.

Regulators require routine examination, inspection and maintenance. Damaged, contaminated or life-expired pressure regulators shall not be used. This is a maintenance activity and should be identified as such within the maintenance requirements for the pressure system, refer to BCGA CP 39[^88].

[^40]: BS EN ISO 2503
[^49]: BS EN ISO 7291
[^88]: BCGA CP 39
A5.3  **Isolation valves**  
Isolation valves shall be designed to interrupt the gas flow in pipework and provide positive shut-off. They may be required to isolate a part of the pressure system, for maintenance or for emergency purposes.

When specifying ball valves careful consideration should be given to the orientation of the operating handle and the potential consequences of an accidental change of position. Ball valves should be avoided in systems containing oxidising gases due to the risk of high velocities and adiabatic compression.

Other than vent valves, pipework downstream of an isolation valve that is not connected / in-use, shall be blanked or capped-off to prevent accidental release.

Following the closure of an isolation valve the Designer should take into account the potential velocity of the gas flow as the isolation valve is re-opened.

Each isolation valve is to be identified with its purpose and method of operation, refer to Appendix 8.

Some isolation valves may be designed and configured for use when Permit to Work / Lock Out Tag Out procedures are required, for example, they can be secured by the use of a padlock.

When used as an emergency shut-off valve they are to be located where they are easily accessible by persons exiting an area in an emergency situation. They shall be able to be reached without the use of access equipment, such as ladders, and shall not require a key, card, or code to operate.

In a basic pressure system an emergency shut-off valve may provide instant isolation, however, in more complex pressure systems they may be designed to consolidate and control equipment emergency power off in a timely, efficient and co-ordinated manner.

Some isolation valves may require electrical services, refer to Appendix 6.

Some isolation valves may be connected into pneumatic systems.

Some isolation valves, both for normal use and for emergency use, may be operated remotely. Following remote operation appropriate safety checks may be required before the pressure system is re-set. This is a maintenance activity and should be identified as such within the maintenance requirements for the pressure system, refer to BCGA CP 39[88].

A5.4  **Non-return valves**  
A non-return valve is a self-actuating valve which prevents the passage of gas in the opposite direction to the normal flow.
Non-return valves should be:

- capable of passing the required flow rate without oscillation or excessive pressure drop;
- capable of preventing backflow of gases, both at low and high reverse pressures;
- marked with the direction of flow.

Consideration shall be given to the required performance capability of a non-return valve with respect to the specific application including cracking pressure, seat leakage and reseating pressure. This is especially important where cross or back-feed contamination can occur. Where non-return valves are used, for example in multi-cylinder manifolds, primarily as safety devices to prevent high pressure gas flowing back through open-ended flexible hoses, absolute leak-tightness against back flow may not be required.

A non-return valve may be supplied as an element within a composite safety device.

Non-return valves shall conform to an appropriate standard, such as:

- BS EN ISO 5175\footnote{\textsuperscript{[46]}}, Part 2, Gas welding equipment. Safety devices. Devices not incorporating a flame (flashback) arrestor.

A5.5 Flame arrestors

A device which extinguishes a flame front (for example, caused by a flashback). Often referred to as a flashback arrestor. It may be supplied as an element within a composite safety device.

Flame arrestors are mandatory when used within an acetylene pressure system. They are advisable for use with oxidising and other flammable gases, where the gas, or gas mixture, has the potential to create a flammable atmosphere. Flame arrestors are not required for:

- Single gas pressure systems, where the gas will not form a flammable atmosphere;
- Inert gases, or mixtures of inert gases.

Flame arrestors shall be:

- compatible with the gas service;
- suitable for the required flow requirements;
- marked with the direction of gas flow;
- marked with a date showing either the date of manufacture or a date when the flame arrestor is to be replaced;
- marked with the manufacturing standard.
Flame arrestors require examination, inspection, maintenance and at end of life, replacement. Some flame arrestors have to be replaced following activation, some have a facility for resetting. These are maintenance activities and should be identified as such within the maintenance requirements for the pressure system, refer to BCGA CP 39 [88].

Flame arrestors shall conform to an appropriate standard, such as:


**A5.6 Pressure indication**

A pressure gauge is an instrument for measuring the pressure of a gas or liquid.

The Designer shall determine the accuracy requirements of each pressure gauge. There is a choice between an indicator and a calibrated pressure gauge:

- an indicator provides an indication of the pressure, it is not calibrated and requires no routine maintenance;
- a calibrated pressure gauge is accurate within a defined tolerance and will require periodic maintenance, including calibration. This is a maintenance activity and should be identified as such within the maintenance requirements for the pressure system, refer to BCGA CP 39 [88].

Mechanical and / or electrical gauges are available. Where an electrical input is required refer to Appendix 6.

Pressure gauges shall be compatible with the operating requirements of the pressure system and the particular gas service. Once in service with a specific gas, the gauge should continue in that gas service for the remainder of its service life.

The gauge should be located where it is easy to view.

The scale on the dial of pressure gauges used in the UK should be indicated in ‘bar’ as well as any other units.

NOTE: Within the International System of Units (SI), adopted for use within Regulations and by Standards Bodies, the unit of pressure is the Pascal (Pa), for pressure systems this is conveniently converted into ‘MPa’. However, an acceptable alternative unit of pressure is ‘bar’. As is custom and practice in many countries, the UK uses ‘bar’ as the primary unit for pressure.
Pressure gauges shall conform to an appropriate standard, such as:

- BS EN 837[^34], *Pressure gauges*.
- BS EN ISO 5171[^45], *Gas welding equipment. Pressure gauges used in welding, cutting and allied processes*.

### A5.7 Filters

A filter is an element capable of restraining particles which may interfere with the operation of downstream equipment.

Filters shall be compatible with the gas, pressure and flow requirements. Oxidising gas pressure systems may require additional filtration requirements to prevent the possibility of loose particles forming ignition sources through impingement or frictional heating.

The cleaning and / or replacement of filters is a maintenance activity and should be identified as such within the maintenance requirements for the pressure system, refer to BCGA CP 39[^88].
ELECTRICAL COMPONENTS AND SYSTEMS

Some control systems may incorporate electrical equipment.

Pipework may also be affected by an electrostatic charge, which may have the potential to cause ignition, for example, where a flammable gas is venting to atmosphere.

An electrostatic charge(s) can build up where fluid flows through the pipework, for example, as a result of friction. The conductive properties of the fluid and the pipework system affect the charging process and in some cases it may be necessary to restrict flow rates to control static generation. As such, the pressure system and the facility where it is located may require to be earthed, including, where applicable, the gas supply delivery location. Relevant pipework shall be adequately earth bonded, for example, flammables and pipework incorporating electrical equipment. Earthing arrangements shall not inter-act with any instrument earthing or cathodic protection arrangements. Routine inspection to ensure the integrity of electrical earthing and bonding systems is essential. Refer to:

- BS 7430[^51], *Code of practice for protective earthing of electrical installations.*
- PD CLC/TR 60079-32-1[^76], *Explosive atmospheres. Electrostatic hazards, guidance*

Only persons who are competent shall install, connect and test electrical components.

All electrical installations shall, as a minimum, conform to BS 7671[^52], *Requirements for electrical installations. IET wiring regulations.*

Where protection from, for example, external weather conditions, is necessary, electrical equipment shall conform to BS EN 60529[^77], *Specification for degrees of protection provided by enclosures*, as a minimum protection class IP54.

Areas where hazardous explosive atmospheres may occur have to be classified into zones and only equipment suitable for that zone shall be used within it (refer to Section 3.3). Within the hazardous zone all equipment and protective systems shall comply with the *Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres Regulations[^2].*

Electrical equipment in a hazardous zone shall comply with BS EN 60079[^76], Part 14, *Explosive atmospheres. Electrical installations design, selection and erection.*

The electrical installation shall be certified by a competent person.

Once installed, all electrical components shall be tested for correct operation and to ensure electrical safety. Electrical continuity checks shall be carried out, including continuity over flanges and joints as well as earth bonding.

All documentation for electrical installation work, including, on completion, electrical circuit diagrams and electrical installation certificates (EICs), shall be retained, refer to Section 8.
NOTE: Electrical continuity checks and the routine inspection and testing of electrical components is a maintenance activity and should be identified as such within the maintenance requirements for the pressure system, refer to BCGA CP 39 \[^{[88]}\].

Further guidance is available in HSE HSG 85 \[^{[25]}\], *Electricity at work. Safe working practices.*
EXTERNAL PROTECTION

All pipework shall be adequately protected. In many cases pipework provided by the manufacturer will not need additional protection. In some cases, for example, to protect from local environmental conditions, a number of protection options are available.

Pipework that is protected may need additional identification marking on the external surface, refer to Appendix 8.

Where pipework is covered by a protective layer there may be the potential for corrosion to occur, out of sight, between the pipework and the protective layer. For this reason additional examination, inspection and maintenance programmes may be necessary. The HSE provide advice on corrosion under insulation within SPC/TECH/GEN/18, a copy is available on their website:


Where protection is applied to pipework below ground, particularly when a trench is backfilled or encased in concrete, consider the long term life of the protection provided, its potential degradation and any reaction it may have with the pipework as it degrades.

Options for providing protection include:

- **Painting**
  Pipework laid in open trenches shall be painted. In other locations it will depend on local requirements.

  Painting should be done in accordance with manufacturers recommendations on clean, dry and corrosion-free surfaces. The durability of the paint finish is largely dependent on the quality of the surface preparation. When considering a colour, refer to Appendix 8.

- **Wrapping**
  For underground pipework or for pipework in corrosive atmospheres, a protective wrapping may be applied.

  The protection shall be applied as a continuous wrap with sufficient overlap to prevent exposure of the pipework surface. Wrapping shall be compatible with the material of the external pipework as well as the service gas.

- **Lagging**
  Lagging can be used to provide insulation and a cover for the lagging can also protect against the weather.

  Lagging should be protected from water contact and other sources of contamination. Lagging on external pipework should be weatherproofed.
**Cathodic protection**
For underground pipework a cathodic protection system may be installed to counteract the corrosive nature of the terrain. Cathodic protection is a technique used to control the corrosion of a metal surface by making it the cathode of an electrochemical cell.

Cathodic protection is usually installed by a specialist contractor and should take into account the requirement for electrical fittings, refer to Appendix 6.

**Galvanic corrosion protection**
Galvanic corrosion (sometimes called ‘dissimilar metal corrosion’) occurs when there is accelerated corrosion of a metal following electrical contact with a more noble metal or a non-metallic conductor (a cathode) in a corrosive electrolyte.

Protection from galvanic corrosion can be provided by:

- avoiding the use of dissimilar metals, particularly at joints and supports. Use only materials which are very similar in the galvanic series;
- insulating dissimilar metals;
- keeping pipework pressure systems, and other services, with dissimilar metals separated;
- avoiding the creation of a local electrochemical cell, particularly one with a small anode and a large cathode.

**Sleeving**
Pipework can be protected by the use of:

- a sleeve, refer to Appendix 3, Section A3.10;
- a pipe within a pipe.
IDENTIFICATION

HSE L64, Safety Signs and Signals. The Health and Safety (Safety Signs and Signals) Regulations. Guidance on the Regulations, recommends that pipework containing hazardous chemical substances and mixtures should be labelled in accordance with the Classification, Labelling and Packaging of Chemicals (CLP) Regulations.

Each pressure system shall be clearly identified with the gas that it contains. Individual pipework requires identification, unless the pipework is short and the contents are clearly identifiable by the gas source to which it is connected.

Individual pipework shall be identified in accordance with the particular industry guidance relevant to the gas application, for example, for food gases used in the beverage gas industry BCGA GN 30. The safe use of gases in the beverage dispense industry, for medical gases refer to the HTM series of documents. For other applications which do not have specific industry guidance it is recommended that the information displayed on pipework includes:

- gas or gas mixture (this may include the chemical symbol). Colour: black, for example, RAL 9005; BS 4800 [44], 00 E 53;
- background colour code. Colour: yellow ochre, for example, RAL 1024; BS 4800 [44], 08 C 35;
- where appropriate, flow direction (using arrows). Colour: black, for example, RAL 9005; BS 4800 [44], 00 E 53.

Figure A8.1 gives examples of labels that may be used on pipework.

![Figure A8.1: Examples of pipework identification labels](image)

All text shall be legible and the size appropriate to the diameter of the pipework.

Optional additional information may include:

- hazard pictogram, conforming to the CLP Regulations (Annex V);
- maximum and minimum pressure (bar);
- temperature (especially cryogenic).

Pipework identification labels should be attached:

- at least once in each room they pass through;

Figure A8.1: Examples of pipework identification labels

All text shall be legible and the size appropriate to the diameter of the pipework.

Optional additional information may include:

- hazard pictogram, conforming to the CLP Regulations (Annex V);
- maximum and minimum pressure (bar);
- temperature (especially cryogenic).

Pipework identification labels should be attached:

- at least once in each room they pass through;
• at appropriate intervals not exceeding 5 m;
• at any significant change of direction of the pipework or branches;
• where the pipework passes through walls, floors (including underground) and roofs;
• close to any points where people are likely to be exposed to the contents of the pipework, for example, points of use, sampling or filling points, drain valves, and joints which are likely to need periodic breaking.

Where there are multiple pipes for different services it is recommended that each service is identified at a similar location.

Additional information may be required on individual components, in particular where there is more than one similar component, for example, valves. This may include:

• a reference number aligning with the P&ID, written scheme of examination, etc.;
• the purpose of an individual component;
• the direction of turn for opening / closing a valve.

Where different users have responsibilities for separate parts of the pressure system, for example, the gas supplier (the gas source) and their customer, then a label (or other appropriate means) shall be applied to identify the demarcation point. Where there may be several separate legal entities sharing a common gas source, then each demarcation point shall be identified.

Components installed for isolation or emergency operation shall be identified by a clearly visible sign explaining their purpose and method of operation. Each should be suitably identified by type for pressure rating, direction of flow and gas service.

Identification should be applied such that the information it contains remains visible, any overlap should be on the blind side of the pipework. Care is to be taken to ensure that the method of fixing the labels, for example, clips, adhesive, etc. is compatible with the pipework and does not cause damage or corrosion. Where pipework is protected, for example, by insulation materials, then the identification markings are also to be located on the external cover.

Where the pipework is in an external location, suitable weatherproof labels should be applied.

For further information refer to:

• BS 1710[^37], Specification for identification of pipelines and services.
• BS 5499[^47], Safety signs, including fire safety signs.
CONSIDERATIONS FOR SOME COMMON GASES

Safety and product information is available in each Safety Data Sheet, further advice can be obtained from your gas supplier.

Where there is the potential for a gas release to take place this may result in a change to the local atmosphere, for example, by creating an asphyxiant or a flammable atmosphere, guidance is available in BCGA GN 11 [93]. This may necessitate additional requirements, for example, increased ventilation, the use of intrinsically safe equipment, displaying appropriate safety signs and warning notices, etc. In particular, where lighter than air gases are in-use, consider the potential for the gas to collect at high levels, such as in roof spaces.

For additional information on specialty gases, refer to BCGA CP 18 [82].

The properties of some common gases are detailed below.

Inert gases:

- Argon (Ar)
  - Density 1.6903 kg/m³ (at 1.013 bar & 15 °C)
  - Specific gravity 1.38 (therefore heavier than air)

- Carbon dioxide (CO₂)
  - Density 1.8714 kg/m³ (at 1.013 bar & 15 °C)
  - Specific gravity 1.53 (therefore heavier than air)

- Helium (He)
  - Density 0.1692 kg/m³ (at 1.013 bar & 15 °C)
  - Specific gravity 0.14 (therefore lighter than air)

- Nitrogen (N₂)
  - Density 1.1848 kg/m³ (at 1.013 bar & 15 °C)
  - Specific gravity 0.97 (therefore lighter than air)

Flammable gases:

- Hydrogen (H₂)
  - Density 0.0853 kg/m³ (at 1.013 bar & 15 °C)
  - Specific gravity 0.07 (therefore lighter than air)

- Propane (C₃H₈)
  - Density 1.8988 kg/m³ (at 1.013 bar & 15 °C)
  - Specific gravity 1.55 (therefore heavier than air)
Butane (C\textsubscript{4}H\textsubscript{10})
- Density: 2.5346 kg/m\textsuperscript{3} (at 1.013 bar & 15 °C)
- Specific gravity: 2.08 (therefore heavier than air)

Methane (CH\textsubscript{4})
- Density: 0.6797 kg/m\textsuperscript{3} (at 1.013 bar & 15 °C)
- Specific gravity: 0.56 (therefore lighter than air)

Oxidising gas:
- Oxygen (O\textsubscript{2})
  - Density: 1.354 kg/m\textsuperscript{3} (at 1.013 bar & 15 °C)
  - Specific gravity: 1.11 (therefore heavier than air)

**Carbon dioxide**
Carbon dioxide is usually considered as an inert gas but under certain conditions of temperature and pressure it will react with certain other substances which are themselves highly reactive.

Pipework, valves and fittings for use with liquid carbon dioxide may require low temperature properties and impact tested materials.

High tensile brass is not a recommended material for valves and other components.

Discharge of liquid carbon dioxide can generate static electricity and it should be avoided in or near flammable gas mixtures.

Pipework shall have a minimum separation distance of 50 mm from electrical systems.

Pipework should be segregated from other pipework carrying oxidising gases and sources of ignition to prevent combustion occurring.

**Hydrogen**
Although most commonly used materials are suitable with hydrogen, the problem of embrittlement under cyclic conditions with steel shall be taken into account, especially at elevated temperatures and pressures.

The use of bursting discs is not recommended on hydrogen pressure systems.

Pipework shall be purged out of service with inert gas until the residual hydrogen concentration is below 1 %.

Hydrogen may spontaneously ignite in the event of a leak or in the event of a relief device opening. Hydrogen flames are almost invisible and produce no radiant heat. Approach with caution.
LPG
Liquefied petroleum gas (LPG) is much heavier than air and will collect in low-lying positions where it will remain for long periods before it is dissipated. Storage areas and vent positions should be selected with this point in mind.

For above ground liquid duty carbon steel seamless pipe is used and the joints can be either flanged or welded. Screwed fittings are only permissible on pipe diameters up to 50 mm and compression fittings cannot be used. Copper and polyethylene pipework are not permitted on liquid duty but copper can be used on vapour duty for pipes of up to 15 mm diameter in conjunction with compression fittings.

Liquid Gas UK provide additional information on managing LPG systems, for example, Liquid Gas UK CP 22[^116], *LPG piping system design and installation*.

Oxygen
Oxygen is non-flammable but supports combustion vigorously, combining with all other elements except inert gases.

Only components compatible with oxygen shall be used. As necessary seek advice from the manufacturer. At pressures higher than 230 bar materials may require special consideration.

For the design of oxygen pressure systems refer to EIGA Safety Information 15[^113], *Safety principles of high pressure oxygen systems*.

Ball valves should be avoided in systems containing oxidising gases due to the risk of high velocities and adiabatic compression.

For information on valves in oxygen service, refer to EIGA 200[^108], *The safe design, manufacture, installation, operation and maintenance of valves used in liquid oxygen and cold gaseous oxygen systems*.

For oxygen service the use of materials, lubricants and greases shall be restricted to oxygen compatible types only. Readily combustible substances, including most oil, grease and organic solvents, shall not be allowed to come into contact with oxygen or oxygen-containing equipment. Scrupulous cleaning, degreasing and freeing from solvents is of prime importance with oxygen. Refer to Appendix A3.12.

For additional information on the use of non-metallic materials in oxygen service refer to EIGA 73[^102].

For pipework made of ferrous materials, for example, stainless steel or carbon steel, the gas velocity shall be contained within limited values. The recommended limiting velocity for oxygen in ferrous distribution pipework is 15 m/sec maximum at 20 bar. Refer to EIGA 13[^98].
Rapid pressurisation of flexible hoses on oxygen manifolds, for example, by fast opening of the cylinder valve, may cause an ignition in a plastic lined hose or in the seat of the non-return valve because of adiabatic compression. In these circumstances adiabatic compression occurs because the change in pressure is so rapid that there is insufficient time for the heat which is generated to dissipate. Protective measures as described in EIGA 42 \[101\] should be considered to prevent such an ignition resulting in a hose or valve failure with consequent risk of injury, for example, provision of a suitable metallic ‘heat sink’ at the hose end adjacent to the pipework header.

Oxygen pipework should be separated from pipework containing flammable gases and from sources of ignition, such as electrical systems, to prevent the possibility of combustion occurring.

NOTE: Separation distances will vary according to the degree of precaution taken, for example, ventilation, sleeving, separation barriers.

For general information on oxygen refer to HSE INDG 459 \[27\], Oxygen use in the workplace. Fire and explosion hazards.

**Mixed gases**
Contact the mixture supplier for full details of the physical properties, potential hazards, safety precautions and operating procedures for the particular gas mixture to be used. Refer to the safety data sheet.

When these facts are known, identify what materials can safely be specified for pipework, hoses and other equipment used in the supply and distribution system and design the pressure system on this basis, also taking into account the operating and design pressure requirements.

Establish safe procedures for the installation, operation and maintenance of the pressure system and agree emergency procedures to cover any potentially hazardous incidents which may occur.

Consideration should be given to withdrawal rates from the pressure system; this will affect sizing of the manifold and pipework and, in the case of liquefied gases in cylinders, the number of cylinders required. The possibility of freezing up of pressure regulators should also be considered (for example, methane / natural gas mixtures).

Identify if, under certain conditions, condensable products can be obtained in the pressure system from the mixture, and establish any precautions or modifications which may be required, for example, drainage points, trace heating, etc.

For flammable mixtures understand the flammability range and ensure that cylinders, control systems, equipment and pipework are adequately and continuously earthed, refer to Appendix 6.

Consideration shall be given to the withdrawal to ensure the mixed gas is delivered at the usage point in the correct ratio.