CODE OF PRACTICE 5

THE DESIGN AND CONSTRUCTION OF MANIFOLDS USING ACETYLENE GAS FROM 1.5 TO 25 bar

REVISION 3: 2016

British Compressed Gases Association

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PREFACE

The British Compressed Gases Association (BCGA) was established in l971, formed out of the British Acetylene Association, which existed since l901. 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 enhance safe practice, and to prioritise environmental protection in the supply and use 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 3. This document replaces BCGA Code of Practice 5, Revision 2: 2010. It was approved for publication at BCGA Technical Committee 153. This document was first published on 17/02/2016. For comments on this document contact the Association via the website www.bcga.co.uk.

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APPENDICES:

* Throughout this publication the numbers in brackets refer to references in Section 13. Documents referenced are the edition current at the time of publication, unless otherwise stated.

TERMINOLOGY AND DEFINITIONS

Acetylene manifold system	A system of interconnected pipework in which compressed acetylene gas is contained, and which connects to, but excludes, a cylinder. The manifold system will contain an assembly of devices delivering a regulated pressure under specified safe conditions, coupled to a user pipeline system.
Composite safety device (Flashback arrestor)	A unit which embodies 2 or more of the following devices: • Flame arrestor • Non-return valve • Temperature sensitive cut-off valve • Pressure sensitive cut-off valve
Cylinder bundle / Manifolded cylinder pallet (MCP)	An assembly of cylinders fastened together, interconnected by a manifold for collective filling and gas withdrawal, and intended to be transported as a single unit.
Decomposition	The breakdown of acetylene into carbon and hydrogen.
Deflagration	A flame produced by decomposition or combustion that travels into the unreacted gas at less than sonic velocity. The rate of propagation of a deflagration flame increases with the density, the temperature and the turbulence of the unreacted gas. Since these three parameters tend to increase as a deflagration progresses, the rate of propagation is usually not steady but tends to increase continually and sometimes leads to a detonation.
Detonation	A flame produced by decomposition or combustion that travels into the unreacted gas at a rate above sonic velocity, usually at several times the speed of sound. Unlike a deflagration, where the pressure in front of and behind the flame front rises at the same time, a detonation involves a sharp difference in pressure between the reacted and unreacted gas. The change from the low pressure of the unreacted gas takes place in a shock wave at the front of the flame.
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.
High-pressure hose assembly (pigtail)	A flexible connection between the cylinder valve and manifold header. It may be manufactured from tube or flexible elastomeric materials.

High pressure valves	*Automatic quick-acting shut-off device* A self-acting device which closes quickly, e.g. when triggered by acetylene decomposition in the high pressure manifold pipework.

Change-over unit
A device in a two sided system allowing switching of the supply of gas from the system to either of its bank of cylinders or bundles without interrupting the supply.

Decomposition blocker
A safety device which stops acetylene decomposition incorporating a thermal or pressure-sensitive cut-off valve.

High pressure filter
A device to retain particles with a size of 100 µm or greater.

High-pressure stop valve
A device to prevent, when closed, the flow of gas on the high pressure side.

Manual quick-acting shut-off valve
A manually activated device to quickly stop the gas flow.

Non-return valve
A device which prevents the passage of gas in the direction opposite to normal flow.

Pressure limiting device
A device which limits the pressure downstream of the manifold regulator in the event of regulator failure or malfunction.

Examples of such devices are: (1) relief valve; (2) pressure actuated shut-off valves; (3) manual or automatic systems to cut the flow; (4) pressure actuated venting device.

Pressure regulator for manifold systems
A device for regulating a generally variable inlet pressure to as constant as possible an outlet pressure when controlling the output of a manifold of cylinders.

Purge valve
A device which enables a pipework system to reach atmospheric pressure or eliminate undesirable gases or residues by flushing.

Quick-acting shut-off device
A safety device which prevents the continued withdrawal of acetylene and/or gaseous products of decomposition from the manifold system if an acetylene decomposition or a flashback occurs.

	Three way valve A device which allows gas flow from one side of the high pressure manifold to enter the regulator while isolating flow from the second side.
Low pressure valves	*Main shut-off valve* The main valve downstream of the system. *Pressure-sensitive cut-off device* A device which interrupts the gas flow in the event of a back pressure wave from the downstream side. *Temperature-sensitive cut-off device* A device which stops the gas flow when a predetermined temperature is reached.
Manifold high-pressure pipework	Pipework system extending from the outlet connection of acetylene cylinders or bundles at full cylinder charging pressure to the inlet of the pressure regulator, including as required hose assemblies or coiled metal pipes, piping and high pressure valves.
May	Indicates an option available to the user of this Code of Practice.
Pressure	Within this standard the 'bar' is used as the unit of pressure. 1 bar = 100 kPa = 10^5 N/m^2 = 14.5 lbf/in^2 Pressures used in this document are gauge pressures except where otherwise stated. High pressure: >1.5 bar and up to 25 bar. Low pressure: $\leq$1.5 bar
Reflection	During detonation, if the forward-moving shock wave hits an obstruction, such as the end of the pipework, a closed valve, a restriction or a sharp bend, the pressure increases considerably and the flame can travel back into the unburnt gas when reflected, considerably increasing the detonation energy.
Shall	Indicates a mandatory requirement for compliance with this Code of Practice and may also indicate a mandatory requirement within UK law.
Should	Indicates a preferred requirement but is not mandatory for compliance with this Code of Practice.

FOREWORD

This document supersedes BCGA CP 5, Revision 2: 2010.

Revision 2 allowed for a working pressure between 1.5 to 17 bar. Revision 3 increased the working pressure maximum limit from 17 bar to 25 bar. This was based on a practical reality. The following were taken into consideration:

- The working pressure of an acetylene cylinder is 19 bar.

- Potentially cylinders can vary in temperature and therefore pressure whist in-use, therefore a greater pressure than 19 bar may be introduced into the pressure system. The pressure system temperature will also vary and designing a system for 25 bar ensures a reasonable factor of safety.

- Although the pressure in filling manifolds is not likely to exceed 25 bar, the pressures generated in the event of an acetylene decomposition are accounted for in the design of manifolds and the associated components and pipes.

- BS EN ISO 14114 (22), *Gas welding equipment. Acetylene manifold systems for welding, cutting and allied processes. General requirements*, quotes high pressure as being between 1.5 bar and 25 bar, and all system components are expected to meet this upper limit.

- EIGA IGC Document 123 (27), *Code of Practice Acetylene*, quotes 25 bar as the high pressure limit.

CODE OF PRACTICE 5

THE DESIGN AND CONSTRUCTION OF MANIFOLDS USING ACETYLENE GAS FROM 1.5 TO 25 bar

1. INTRODUCTION

Acetylene has unique properties. Acetylene is an extremely flammable gas and can burn in the presence of air or oxygen. This generates very high flame temperatures, which is the reason why acetylene is so effective for cutting and welding. The acetylene (C_2H_2) molecule, however, if initiated by heat exposure of a cylinder in a fire, or through excessive fill pressure, can also decompose breaking up into one hydrogen molecule and two carbon atoms. This reaction delivers much less energy than combustion but can, in some circumstances, be strong enough to rupture a cylinder. Additionally, whereas acetylene is very soluble in the solvents used in dissolved acetylene cylinders, hydrogen, when released through decomposition, is much less soluble; giving a significant and irreversible pressure rise within the cylinder, which can be sufficient to cause its rupture. For these reasons the maximum working pressure of an acetylene cylinder is kept relatively low at 19 bar. Consequently, manifolds connected to an acetylene cylinder are designed and constructed to operate at pressures between 1.5 and 25 bar. In use, acetylene is delivered to the end user at pressures up to 1.5 bar.

NOTE: The design of a dissolved acetylene cylinder is also important. Each cylinder is filled with a porous material, which is a very effective obstacle for energy and fluid flow. A solvent is then added to the porous material, (typically acetone or dimethylformamide (DMF)), and the acetylene gas is then dissolved in this solvent. The dissolved acetylene cylinder is thus a complex system comprising a number of components interacting with each other. This system keeps acetylene in a safe condition inside the cylinder.

As a consequence of this potential hazard, acetylene is subject to specific legislation. Following a major review of legislation in 2014, acetylene was placed under The Acetylene Safety (England and Wales and Scotland) Regulations (6). This revision complies with these new regulations.

The manufacture of compressed acetylene gas; the compression of acetylene at pressures equal to or greater than 0.62 bar; or the filling of a cylinder with compressed acetylene gas cannot be carried out without a licence issued by the Health and Safety Executive (HSE). The licensee shall comply with the conditions of the licence and comply with the requirements of the Acetylene Safety (England and Wales and Scotland) Regulations (6), Schedule 1.

The content of this publication is in line with advice from the HSE. For more details refer to http://www.hse.gov.uk/fireandexplosion/acetylene.htm and leaflet HSE INDG 327 (10), *Working safely with acetylene.*

The Dangerous Substances and Explosive Atmospheres Regulations (DSEAR) (4) requires that employers undertake a risk assessment and put in place suitable controls where an explosive atmosphere may occur, such as where flammable gases are used or stored.

It is recommended that users of oxy-acetylene gas processes ensure that all new installations, or modifications to existing installations, comply with this Code of Practice for the products or services involved.

It is pointed out that this code represents the BCGA's views of minimum requirements for safe practices, reference should be made to Section 13 for further details on specific standards or Regulations.

2. SCOPE

This Code of Practice is for the design and construction of acetylene gas manifolds with a pressure range between 1.5 bar (21.8 lbf/in²) to a maximum working pressure of 25 bar (362.6 lbf/in²).

This code applies to acetylene cylinder manifold systems in which acetylene single cylinders or acetylene bundles are coupled for collective gas withdrawal. The manifold system extends from the cylinder outlet valve, or the bundle outlet connection, to the outlet connection of the main shut-off valve. It applies to the manifold and other sections of a total installation, which are within Working Range III, refer to Section 3.5.

The Code also makes recommendations for ancillary equipment normally associated with acetylene manifolds. Each manifold shall be installed in conjunction with the pressure control, safety devices and other equipment detailed in the BCGA CP 6 (29), *The safe distribution of acetylene in the pressure range 0 to 1.5 bar*.

This Code of Practice takes into account the requirements of the Pressure Systems Safety Regulations (3) and BS EN ISO 14114 (22), *Gas welding equipment. Acetylene manifold systems for welding cutting and allied processes. General requirements*.

The European Industrial Gases Association (EIGA) Document 123 (27), *Code of Practice Acetylene*, provides comprehensive guidance on the safety requirements for acetylene.

This Code of Practice excludes manifolds for acetylene cylinder filling, refer to EIGA Document 123 (27).

3. ACETYLENE GAS

3.1 General data

Chemical symbol	C_2H_2
Cylinder ground colour	Maroon (RAL 3007)
Flammable / non-flammable	Flammable
Lighter / heavier than air	Slightly lighter NOTE 1
Colour	Colourless
Odour	Some sources produce a slight odour NOTE 2
Taste	Tasteless
Toxicity	Non-toxic NOTE 2
Corrosivity	Non-corrosive

NOTES:

1. Mixtures of acetylene and acetone vapour can be heavier than air.
2. Commercial supplies of acetylene do contain trace impurities which are toxic and which can also give rise to a slight odour. Precautions should be taken to avoid inhaling acetylene gas.

3.2 Materials of construction

The properties of acetylene limit the choice of materials that can be used in the construction of its piping systems and components. Refer to Section 4.

3.3 Special conditions

Acetylene differs from other fuel gases, such as natural gas, propane and butane, because of its ability to decompose in the absence of air or oxygen, when initiated by a source of heat energy. This decomposition reaction may proceed through deflagration to detonation depending on the gas pressure and pipe dimensions. The effects of an acetylene decomposition are similar to fuel gas-oxygen explosions, resulting in a loud noise, bright flame, rise in temperature and pressure and soot formation.

The flammability range of acetylene in air is between 2.2 % to 85 %.

Decomposition in a gas cylinder will only occur after exposure to temperatures in excess of 350 °C. Factors, such as the presence of air, rust particles etc., can significantly lower this temperature in a manifold system.

NOTE: Mechanical shock alone to a cold acetylene cylinder, which remains intact and has not been exposed to fire, cannot initiate decomposition.

Some materials, even in small quantities, can form compounds with acetylene under certain conditions and pose a risk or are liable to initiate decomposition. Refer to Section 4.

3.4 Safety

As a flammable atmosphere may exist a risk assessment shall be carried out in compliance with DSEAR (4) and suitable controls put in place. If an explosive atmosphere may exist signage shall be displayed, refer to Section 6.9.

NOTE: Guidance on the preparation of Risk Assessments under DSEAR (4) is contained in BCGA GN 13 (32), *DSEAR Risk Assessment.* Additional guidance is provided by the HSE, refer to HSE L138 (9), *Dangerous substances and explosive atmospheres DSEAR 2002. Approved Codes of Practice and Guidance*, and HSE INDG 370 (11), *Controlling Fire & Explosion risks in the workplace. A brief guide to DSEAR.*

The Dangerous Substances (Notification and Marking of Sites) Regulations (1) require, that if you hold 25 tonnes or more of a dangerous substance then you are required to notify the enforcing authority and the local Fire and Rescue Service, and mark sites at the access points to warn of the presence or possible presence of dangerous substances.

Fire safety. A responsible person shall carry out a Fire Safety Risk Assessment on all storage sites and areas where acetylene is used, the findings from which are to be incorporated into the Site Fire Safety Management Plan that is to be implemented and maintained. As necessary, advice should be sought from the local fire authority. Each site should keep a record of the location of its hazardous store(s), this is to be made available to the emergency services in the event of an incident. Refer to The Regulatory Reform (Fire Safety) Order (5). Fire-fighting facilities as identified in the Site Fire Safety Management Plan shall be provided.

Although acetylene is non-toxic, acetylene-enriched atmospheres can cause asphyxiation through the depletion of oxygen.

Appropriate safety signs and warning notices shall be displayed, refer to Section 6.9.

Acetylene vented from safety / pressure relief devices and purge points should be discharged to an external area specifically classified for acetylene where there is no risk of ignition. All discharge pipes or orifices to the open air shall be designed and made in such a way as to avoid choking, obstruction or frictional pressure drop. Safety / pressure relief device discharge pipes should be separate and connection to a manifold should be avoided. The design of pipework shall take into account the working range of the acetylene for the pressures at the discharge point. The vent pipes and outlets shall prevent the ingress of contaminants and the accumulation of water, including that from snow, rain and condensation. Contaminants, as well as water accumulation that may lead to the formation of ice, could potentially cause blockages. Appropriate safety signs and warning notices shall be displayed at the vent outlet and drain points.

As a flammable atmosphere may exist at the vent outlet(s) a risk assessment shall be carried out in compliance with DSEAR (4) and suitable controls put in place.

Further information on venting is available in and EIGA Document 30 (25), *Disposal of gases*, and EIGA Document 123 (27).

Systems shall be effectively bonded and earthed against the build-up of static electricity, refer to BS 5958 (16), *Code of practice for control of undesirable static electricity.*

All piping and building components shall be protected from electrostatic charges by maintaining an electrical conductivity with a maximum resistance of 10^6 ohm.

The use of electrical equipment in an area where a flammable atmosphere may exist should be kept to the minimum necessary for the safe and practical operation of the installation. All such electrical equipment shall be suitable for use with acetylene [Gas Group IIC, Temperature Classification T2]. The equipment shall be designed, installed and maintained in accordance with BS EN 60079 (24), *Electrical apparatus for explosive gas atmospheres.*

The repair of electrical equipment within a hazardous area shall be carried out in accordance with BS EN 60079 Part 19 (24), *Electrical apparatus for explosive gas atmospheres. Repair and overhaul for apparatus used in explosive atmospheres (other than mines or explosives).*

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

Pipework shall be purged out of service with an inert gas, such as nitrogen, until the residual acetylene is below 0.6 %. Pipework shall be purged into service using an inert gas, such as nitrogen, until the oxygen level is less than 0.1 %. Carbon dioxide is not recommended due to the risk of a static charge.

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

Distribution pipework and associated safety components shall comply with BCGA CP 6 (29).

Decomposition can be initiated in the event of a flashback occurring. The cylinder / mass combination has been designed to contain and deal with a single flashback - but repeated flashbacks into a cylinder caused by faulty equipment or operation can ultimately lead to decomposition which could overcome the cylinder's ability to withstand such. A cylinder which is known to have suffered multiple flashbacks should be withdrawn from use and returned to the gas supplier with a clear notice as to what is known. To prevent a flashback the use of flashback arrestors is mandatory. They shall be fitted within 1 metre downstream of the regulator.

Each system shall be fitted with a non-return device, to prevent the flow of gas towards the cylinder, and a quick-acting shut-off device, both fitted as close as is reasonably practical to the acetylene manifold, or where no manifold is used, to the cylinder.

For further information on the safe distribution and use of acetylene refer to BCGA CP 6 (29).

3.5 Working ranges

(EIGA) Document 123 (27) identifies the types of hazard normally present in an acetylene installation. The type of hazard, under certain conditions, is determined by pressure, internal pipe diameter and pre-detonation distance. These hazards are categorised into three working ranges, which are simply identified by a graph relating pipeline pressure to pipe diameter, refer to Appendix 1.

- Working Range I
  Acetylene decomposition hazard is slight, but not impossible.

- Working Range II
  On ignition, acetylene decomposition in form of deflagration may occur.

- Working Range III
  On ignition, acetylene decomposition will start as a deflagration and in sufficiently long pipelines transition to detonation may occur.

The internal diameter of the pipe and the maximum gas pressure will place each pipeline into one of the Working Ranges. The material used in the construction and the size of the pipeline will depend on the Working Range.

4. MATERIALS

4.1 General

All materials used, including non-metallic parts for joints, seals, diaphragms, hoses, etc., shall conform to BS EN ISO 9539 (19), *Gas welding equipment. Materials for equipment used in gas welding, cutting and allied processes*, and be resistant to the action of the acetylene, its impurities and other substances (e.g. acetone or DMF, i.e. solvent from the acetylene cylinder) under the operating conditions (e.g. temperature, pressure) to which they are subjected and, where applicable, to atmospheric corrosion.

Materials which do not have adequate resistance may be used provided they are suitably protected (by coatings such as paint, baked enamel and sprayed metal) and provided that damage to or breakdown of the protection cannot give rise to the formation of dangerous compounds or conditions.

4.2 Recommended materials

A list of recommended materials are discussed below and are displayed in Table 1.

Component	Material
Pipe	Steel and stainless steel. Refer to Table 2.
Jointing	Requires special consideration. Refer to BCGA CP 6 (29).
Valves and other components	Requires special consideration. Refer to BCGA CP 6 (29).

Table 1: Recommended materials

Seamless carbon steel pipe is recommended as the material for acetylene header, valves, and fittings. Materials other than carbon steel (e.g. other metals, metal alloys) shall only be used in the construction of acetylene headers after they have been proved suitable for the operating conditions. Materials which are subject to brittle fracture shall not be used for Working Range III.

Headers, valves and fittings must withstand not only the stresses at maximum operating pressure but also the thermal and mechanical stresses resulting from explosive acetylene decomposition.

Steels conforming to the minimum requirements in Table 2 are recommended.

The construction rules for headers given in Section 5 are based on the use of carbon steels.

Other grades of steel, for example austenitic stainless steel, and other materials may be used provided the header is designed to the construction rules appropriate to the materials used and is suitable for the operating conditions.

For welded headers the materials chosen shall have suitable welding characteristics and the strength of the weld shall be not less than that of the material.

Minimum tensile strength (R_m)	Minimum % elongation after fracture
320 N/mm^2	$\frac{8400}{R_m}$ or 16 whichever is the greater

Table 2: Steel. Minimum requirements.

4.3 Materials not allowed or recommended only under certain conditions

Certain metals, such as copper, silver and mercury, can form compounds with acetylene under certain conditions that even in small quantities may explode when subjected to friction or shock.

This means that the unrestricted use of these metals even, for instance, as a brazing alloy, could introduce the possibility of acetylene decomposition.

Studies of the conditions of formation of the explosive acetylene compounds have shown that the likelihood of their formation increases with the copper or silver content of the alloy, together with flux residues in the presence of acetylene. Other metals, such as aluminium, magnesium or zinc, may suffer severe corrosion under the influence of the impurities that occur in un-purified acetylene.

For these or other reasons, the restrictions and conditions stated in Table 3 shall be observed.

Material	Conditions for use
Copper and Copper Alloys containing more than 70% of copper	Not allowed.
Mercury	Not allowed.
Copper Alloys containing up to 70 % copper	Permitted. Special consideration should be given to the use of copper alloy for filters, etc. in view of the large surface in contact with acetylene and for parts in contact with moist unpurified acetylene. Any heat or chemical / corrosion process which produces copper enrichment on the surface of the copper alloy shall be avoided, or copper alloy shall not be used.
Silver	Not allowed.
Silver Alloys	Suitable for brazing provided that the silver content does not exceed 43 % and the copper content does not exceed 21 % and that the gap between the two parts to be brazed does not exceed 0.3 mm. Special care shall be taken to minimise the area of filler metal exposed to acetylene and to remove as far as practical all traces of flux. For additional information refer to BS EN ISO 9539 (19).
Aluminium Aluminium Alloys Magnesium Alloys Zinc Alloys	Not recommended for components that come into contact with moist acetylene contaminated with lime or ammonia (un-purified generator gas).
Zinc	Suitable as external anti-corrosion protective coating.
Glass	Should generally be used only for sight glasses. Such devices should either be protected against external damage or designed so that breakage will not cause a hazard.
Organic materials	May be used if it has been proved that they are resistant against acetylene, solvents and impurities.
For fittings, valve housing and similar components, the ferrous materials listed below may be used: • Grey cast iron • Malleable cast iron • Spheroidal graphite cast iron • Wrought iron	

Table 3: Materials not allowed or recommended only under certain conditions

5. DESIGN OF MANIFOLDS

An acetylene manifold shall be designed, manufactured and subsequently operated to prevent, so far as is reasonably practical:

- The uncontrolled combustion of acetylene gas;
- The decomposition of acetylene gas; and
- The formation of acetylene-derived compounds that pose a risk or are liable to initiate decomposition of acetylene gas.

As such it shall take account of the Working Range; determined at Section 3.5

An acetylene manifold shall be designed and manufactured to:

- Withstand the thermal and mechanical stresses of any decomposition of the acetylene gas it contains; or
- Dissipate or direct the thermal and mechanical stresses of any decomposition of the acetylene gas that it contains.

The design of an acetylene manifold shall prevent the mixture of air, or oxygen, within the manifold. The filling manifolds and their ancillary equipment including valves, flexible hoses, and connections, shall be designed for safe operation in working range III (detonation resistance). In use, the manifold shall not be subjected to any pressure greater than that in the attached cylinder / bundle (maximum 25 bar).

EIGA Document 123 (27) covers the basic requirements for the safe and correct design and maintenance of an acetylene plant as well as customer installations and provides detailed information on the calculations referenced in Section 5.

5.1 Manifold high pressure pipework

Acetylene manifolds shall conform to the requirements of BS EN ISO 14114 (22) and this Code of Practice. The manifold shall, where practical, consist of rigid pipework. Refer to Section 5.9.

Pipelines or sections of pipelines used in the construction of the manifold shall be designed by calculation to withstand detonation. The length of manifolds, pipes and the overall manifold configuration shall be kept to a minimum and the design of the pipework should minimise the ingress of air into the system.

An acetylene detonation travels along the pipeline as a shock wave. Particularly high stresses are caused at or near those places of the pipeline where the shock wave will be reflected. Places of reflection may be sharp bends, valves and closed ends of pipes. Ring mains are not recommended.

There are two methods of designing a pipe system based upon calculated wall thickness:

(i) Designing the whole system to withstand reflection occurring at any point.

(ii) Designing straight parts of the line to withstand undisturbed detonation with increased wall thickness at places where reflection could occur.

To connect the cylinder or bundle outlet to the manifold inlet, all high pressure pipework or coiled metal pipe shall be in accordance with BS EN ISO 10961 (20), *Gas cylinders. Cylinder bundles. Design, manufacture, testing and inspection,* and high pressure hoses shall be in accordance with BS EN ISO 14113 (21), *Gas welding equipment. Rubber and plastics hose and hose assemblies for use with industrial gases up to 450 bar (45 MPa).*

5.2 Pipe bore

All pipe internal diameters shall be kept to the practical minimum necessary to sustain the flow rates required, and shall not exceed 25 mm for pressures above 1.5 bar.

5.3 System wall thickness to withstand detonation and reflection occurring at any point

Pipe wall thicknesses shall be determined according to the methods and calculations detailed in BS EN ISO 10961 (20). Specifically BS EN ISO 10961: 2010, Annex B 3.4.2.

5.4 System to withstand undisturbed detonation with reinforcements at reflection points

The wall thickness of the pipes is calculated by the method described in Section 5.3.

Pipes with wall thickness calculated in this way should be used only for straight parts of the line. Pipe bends with a bending radius of five times the internal diameter of the pipe or more, can be considered as straight lines if the strength of the bent pipe is comparable to that of the straight pipe.

Reinforcement of the wall thickness shall be employed at points of full reflection, e.g. blind bends, valves and bends with bending radius of less than five times the internal diameter (sharp bends). Tee junctions are points of partial reflection, not full reflection. The reinforcements shall increase the total wall thickness to at least twice the calculated wall thickness.

For blind bends and sharp bends the reinforcements must cover a pipe length at least equal to three times the internal diameter of the pipe. Where a point of reflection is protected by a flame arrestor which is within the pre-detonation distance from the point of reflection, reinforcement at that point is unnecessary.

There shall be no sudden change in the internal bore of the pipeline; this is particularly important when designing reinforcements.

All pipework shall be adequately supported and protected from damage or vibration. Acetylene pipelines shall not be used as an electrical earth or conductor and shall be separated from electrical installations by a minimum air gap of 50 mm.

5.5 Temperatures of formation of liquid acetylene

To prevent liquefaction (condensation) of acetylene, care shall be taken to ensure that the operating pressure in all parts of the high pressure system, for a given acetylene temperature, does not exceed the values given in Table 4. These values have been determined empirically to take in to account the cooling effect of gas expansion and the heat transfer to adjacent pipework resulting in progressive lowering of the gas temperature.

Maximum pressure (bar(g))	25	23	20	17	14.5	10
Gas temperature (°C)	8	5	0	- 5	- 10	- 20

Table 4: Temperature for the formation of liquid acetylene

5.6 Valves and seals

Valves shall be capable of withstanding the design pressure without catastrophic failure. If the bursting pressure of a valve body is not known, the following formula may be used to calculate whether the valve is suitable:

$$P_t = \frac{20(P_w + 1) - 1}{1.1}$$

Where:

P_t	=	Minimum test pressure (gauge) of the valve	bar
P_w	=	Maximum operating pressure (gauge)	bar

The design and installation of the valve shall be such as to minimise the risk of ignition due to friction. Filters may be used to prevent dirt reaching the valve seat. The valve design must ensure electrical continuity between its component parts.

Any type of seal and packing may be used provided the requirements of Section 4 are satisfied.

5.7 Pressure gauges

Pressure gauges shall conform to BS EN ISO 5171 (15) *Gas welding equipment. Pressure gauges used in welding, cutting and allied processes*, or BS EN 837 (13), *Pressure gauges*, and comply with the following:

(i) The pressure gauge shall withstand the pressures resulting from an acetylene decomposition without serious leakage; or

(ii) An adequate vent closed with a thin membrane is provided allowing the escape of gas and component parts in a safe direction away from the gauge window if the gauge ruptures. The inlet orifice to the gauge shall be limited to a maximum of 0.1 mm² (0.4 mm diameter); or

(iii) The pressure gauge is protected against over pressurisation by a gauge protector or similar device.

The dial shall be marked ‘ACETYLENE’.

5.8 Regulators

Regulators shall conform to BS EN ISO 7291 (18), *Gas welding equipment. Pressure regulators for manifold systems used in welding, cutting and allied processes up to 30 MPa (300 bar).*

They shall withstand the pressure resulting from acetylene decomposition without bursting of the body.

Special care shall be taken to ensure that the diaphragm and seat materials comply with Section 4.

When regulators do not have an integral filter then separate line filters shall be used.

5.9 High pressure hose assemblies

Flexible hoses shall only be used when rigid pipes are not practical. Where flexible hose is necessary, the length and diameter of the hose shall be kept to a minimum that is practical and the hose should be protected against external damage.

Hose fittings should be carefully designed to avoid sudden changes in diameter; where there is a change in diameter a gradual taper should be made.

Hoses shall have a minimum burst pressure of 1000 bar and they shall resist an acetylene decomposition of high pressure acetylene at an initial pressure of 25 bar.

When hoses are installed, the resistance between the two end fittings shall not exceed 10^6 ohms to give protection against electrostatic charging.

Hose assemblies shall conform to BS EN ISO 14113 (21), or an equivalent standard.

The hose shall consist of either:

(i) A rubber or plastics lining and reinforcement consisting of one or more layers and an outer protective cover of permeable material or perforated rubber or plastics; or

(ii) A rubber or plastics lining and reinforcement consisting of one or more layers of stainless steel wire braid and / or other corrosion and abrasion resistant material, which is also designed as an outer protective cover.

All hose shall be compatible with acetylene and resistant to solvent attack, from acetone or DMF.

5.10 Limitations on gas draw-off rate

If acetylene gas is drawn off from cylinders too rapidly there is a possibility of acetone or DMF being mixed with the gas, and then causing malfunction of downstream equipment. To avoid this the rate of withdrawal of gas should be restricted to the values given in Table 5. To use rates higher than those shown requires that more cylinders be manifolded together.

NOTE: The ability to draw off these volumes of gas will be dependent on the size of cylinder, the mass, the solvent used and ambient conditions.

Ambient temperature	**Max continuous withdrawal rate per cylinder**		**Cylinder pressure**	
^oC	m^3/h	ft^3/hr	bar	psi
-10	0.14	5	7.6	110
0	0.28	10	10.3	150
10	0.43	15	13.1	190
20	0.57	20	15.9	230

Table 5: Typical maximum continuous withdrawal rates per cylinder (dependant on cylinder type)

6. EQUIPMENT

Acetylene cylinder or bundle manifold systems shall be fitted with the following system components, refer to Appendices 4, 5, 6, and 7, and shall have the appropriate safety notices and warnings displayed.

6.1 High-pressure non-return valves

High-pressure non-return valves shall be located immediately downstream of the cylinder or bundle outlet to prevent the backflow of gas into the cylinders or bundle, or from one cylinder, or cylinder bundle to another. They shall also be fitted to prevent the air or moisture contamination of the manifold system. Refer to BS EN ISO 15615 (23), *Gas welding equipment. Acetylene manifold systems for welding, cutting and allied processes. Safety requirements in high-pressure devices*.

6.2 High-pressure hose assemblies

High-pressure hose assemblies shall be fitted between the cylinder and the high-pressure pipework.

A safety bundle connector may be used on the hose end that connects to a bundle. The safety connector incorporates a heat sink and non-return valve to reduce the risk of acetylene decomposition when changing a bundle of acetylene on the manifold system.

6.3 High-pressure stop valves

High-pressure stop valves shall be fitted to isolate one or more bundles of manifolded cylinders. For a one side system a single high pressure stop valve shall be used. For a two side system, a three way valve can be used instead of two high pressure stop valves. Refer to BS EN ISO 15615 (23).

6.4 Manual or automatic quick-acting shut-off device

A manual quick-acting shut-off valve, or an automatic quick-acting shut-off device, shall be fitted to prevent the continued withdrawal of acetylene and/or gaseous products of decomposition from the manifold system if an acetylene decomposition or flashback occurs. To be fitted upstream of the manifold regulator. Refer to BS EN ISO 15615 (23).

NOTE: Manual quick-acting shut-off valves can only be used on systems of up to 2 x 8 cylinders. Any system greater in capacity shall incorporate an automatic quick acting shut-off valve in accordance with BS EN ISO 15615 (23).

6.5 Pressure gauges

Pressure gauges shall be fitted on the upstream and downstream side of the pressure regulators. They may be an integral part of the regulator or separate devices.

6.6 Pressure sensitive shut-off device

A pressure sensitive shut-off valve, or a relief device, shall be fitted to limit the pressure downstream of the manifold regulator. Where this device is a pressure sensitive shut-off valve which is fitted in conjunction with a pressure differential auto-changeover manifold of two (separate) stages of regulation, it may be fitted after the primary regulator and before the secondary / final regulator.

6.7 Main pressure regulator

A manifold regulator shall be fitted to reduce the cylinder pressure to the distribution pipeline pressure. Refer to Section 5.8.

6.8 Other devices

Any device situated in the high-pressure system shall conform to the design requirements of this Code.

The items fitted to the low-pressure side of the manifold do not form part of this Code. They shall conform to the requirements of BCGA CP 6 (29).

6.9 Safety signs and warning notices

Gas cylinder stores, or stores where acetylene gas cylinders are connected to a manifold, shall have adequate signage to provide warnings and safety information, refer to BCGA GN 2 (31), *Guidance for the storage of gas cylinders in the workplace*. Outlets from manifolds and the distribution pipework shall be appropriately identified.

Signage shall comply with:

- The Health and Safety (Safety Signs and Signals) Regulations (2).
- BS ISO 7010 (17), *Graphical symbols. Safety colours and safety signs. Registered safety signs.*

For additional advice refer to HSE L64 (7), *Safety signs and signals. The Health and Safety (Safety Signs and Signals) guidance on regulations*.

Signs and pictograms shall be clearly displayed. As appropriate, signs for the following hazards should be displayed:

- NO SMOKING
- NO NAKED LIGHTS
- NO SOURCES OF IGNITION
- FLAMMABLE GAS
- ASPHYXIATION HAZARD

With flammable gases there is a risk of the development of an explosive atmosphere. In accordance with DSEAR (4) if an explosive atmosphere may exist display the explosive atmosphere "EX" sign.

The Dangerous Substances (Notification and Marking of Sites) Regulations (1) require that if you hold 25 tonnes or more of a dangerous substance then you are required to mark sites at the access points to warn of the presence or possible presence of dangerous substances.

Examples of signage are displayed in Figure 1.

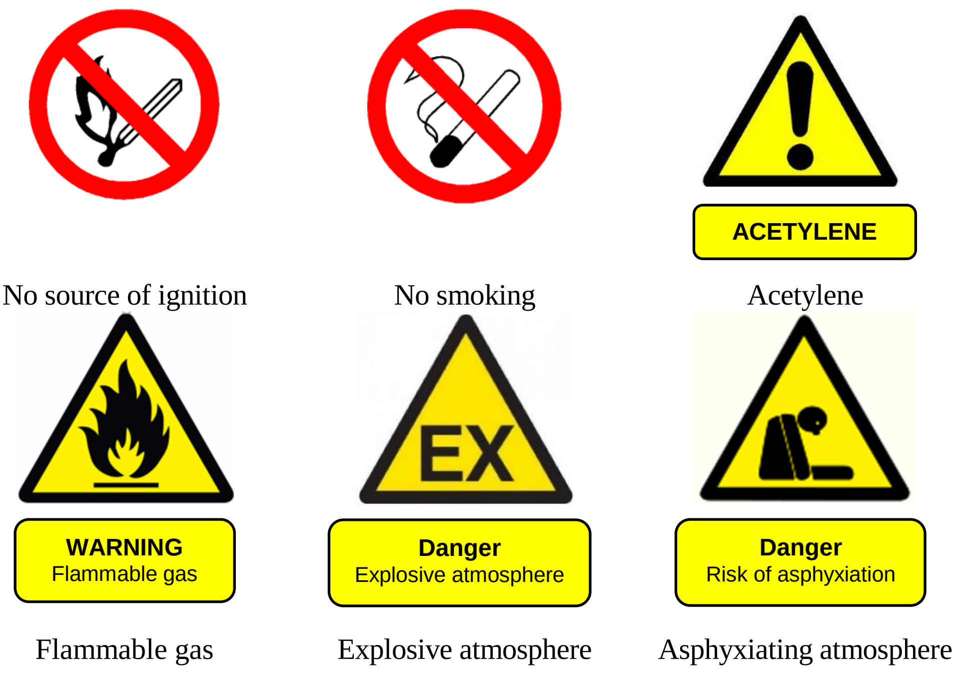


Figure 1: Examples of signage

Pipelines shall be clearly identified by the name 'ACETYLENE' or by colour coding, refer to BS 1710 (14), *Specification for identification of pipelines and services*. A combination of both methods is preferred. The identification markings shall be repeated as often as is necessary to ensure that the pipeline is clearly identified and will not be confused with adjacent pipelines carrying other substances.

In addition a notice shall be displayed showing:

(i) Actions to take in the event of an emergency.

(ii) The site operator's routine contact details.

(iii) Emergency contact information including an emergency phone number, for example of the gas supplier and/or the site operator.

(iv) The emergency services phone number.

This information should also be available at a control point, for example the site control room or site security.

7. PROTECTION

Acetylene manifolds are generally located in an external area and shall be designed for such use. Protection against external corrosion may be required.

8. CLEANING

Acetylene manifolds shall be cleaned internally during manufacture to remove all traces of mill scale and foreign matter.

9. IDENTIFICATION

Acetylene manifolds shall be clearly marked with the following information:

- Type of gas: Acetylene.
- Name, trademark or logo of manufacturer or distributor.
- Maximum regulated pressure (bar, MPa).
- Maximum flow of the system at 15 °C (m^3/h)
- Minimum and maximum operation temperature (-20 °C / +60 °C).
- Year and month of manufacture/installation.
- Reference to BS EN ISO 14114 (22)

10. TESTING OF INSTALLATION, COMPONENTS AND ASSEMBLIES

10.1 General

The installation shall be checked on completion to ensure that all connections are secure and that any blanks or fittings necessary for subsequent pressure testing are of adequate design and are securely fitted.

All high pressure and low pressure manifold components shall be tested for their resistance to the pressures likely to be encountered in acetylene service.

Pressure gauges and safety devices may have to be removed before testing.

Parts which have been tested prior to installation may be excluded from the pressure strength test.

10.2 Pressure testing

The completed system shall be pressure tested. Where practicable a hydraulic strength test should be carried out followed by a leak test. When a hydraulic test is not practicable or is precluded because of the design of the system, the strength test may be carried out pneumatically, commencing with a leak test.

NOTE: Hydraulic testing is considered to be a far safer method than pneumatic testing as the potential release of stored energy upon component failure is substantially less.

Guidance on pressure testing is given in HSE Guidance Note GS4 (12), *Safety in pressure testing*, and in BCGA CP 4 (28), *Industrial gas cylinder manifolds and distribution pipework (excluding acetylene)*.

10.2.1 Strength test

The system shall be hydraulically or pneumatically strength tested to a maximum pressure of 300 bar for five minutes. When strength testing pneumatically, the test shall be preceded with a leak test. There shall be no visible permanent deformation.

When carrying out a strength test refer also to ISO 14114 (22).

After hydraulic testing the system shall be thoroughly dried out to eliminate problems arising from trapped moisture and a pneumatic leak test carried out.

10.2.2 Leak test

Following the pressure strength test the system shall be depressurised and the pressure gauge and other components excluded from the pressure strength test replaced.

The system shall be pneumatically pressurised in stages to maximum working pressure and all joints tested with a suitable leak testing medium, commencing with an initial check at 1 bar. Any leaks shall be rectified before the test is continued. Leak test fluid shall, preferably, be a proprietary leak detecting fluid or foam, which is known to be compatible with the materials of construction of the equipment.

NOTE: Some leak detection fluids contain ammonia, and these will be unsuitable for many applications, particularly where brass components are involved. An alternative leak detection fluid is a 0.5 % solution (by volume) of Teepol in distilled water. Not acceptable are mixtures of household soap or detergent in water. For information on leak detection fluids refer to EIGA Document 78 (26), *Leak detection fluids cylinder packages*.

10.3 Function tests

Check non-return valves and stop valves for closure, tightness and gland leakage.

Check manifold change over valves for closure, tightness and gland leakage.

Automatic change over devices should be checked for correct operation.

11. PROVISION OF INFORMATION

The designer, supplier or the employer of a person who installs, modifies or repairs a pressure system shall provide sufficient written information to enable the user of a pressure system to determine the safe operating limits within his responsibility. Such information may include the following:

- Instructions for use (as detailed in BS EN ISO 14114 (22)).
- System flowsheets / schematics.
- Safe operating limits for pressure and temperature.
- Design pressure, refer to Section 5.
- Operating instructions (including emergency procedures).
- Written Scheme of Examination.
- Test Certificates.

Such information shall be included in the handover documentation or operating instructions supplied to the user.

12. PRESSURE SYSTEMS SAFETY REGULATIONS

In order to conform with the requirements of the Pressure Systems Safety Regulations (3), the user of an installed system shall not allow it to be operated without a Written Scheme of Examination certified by a Competent Person.

The Written Scheme should cover the following items as a minimum requirement:

(i) All protective devices.

(ii) All manifold pressure regulators (when they are a primary protective device).

(iii) All high pressure hoses and pigtails.

(iv) All pipework where a failure would give rise to danger

HSE L122 (8), *Safety of pressure systems. Pressure Systems Safety Regulations 2000. Approved Code of Practice*, provides guidance on the Pressure Systems Safety Regulations (3). Information for managing pressure systems, including guidelines on Written Schemes of Examination, are given in BCGA CP 39 (30), *In-service requirements of pressure equipment (gas storage and gas distribution systems).*

13. REFERENCES

	Document Number	Title
1.	SI 1990 No. 304	The Dangerous Substances (Notification and Marking of Sites) Regulations 1990.
2.	SI 1996 No 341	The Health and Safety (Safety Signs and Signals) Regulations 1996.
3.	SI 2000 No. 128	The Pressure Systems Safety Regulations 2000 (PSSR).
4.	SI 2002 No. 2776	The Dangerous Substances and Explosive Atmospheres Regulations 2002 (DSEAR).
5.	SI 2005 No. 1541	The Regulatory Reform (Fire Safety) Order 2005.
6.	SI 2014 No. 1639	The Acetylene Safety (England and Wales and Scotland) Regulations 2014.
7.	HSE L64	Safety signs and signals. The Health and Safety (Safety Signs and Signals) guidance on regulations.
8.	HSE L122	Safety of pressure systems. Pressure Systems Safety Regulations 2000. Approved Code of Practice.
9.	HSE L138	Dangerous substances and explosive atmospheres DSEAR 2002. Approved Codes of Practice and Guidance.
10.	HSE INDG 327	Working safely with acetylene.
11.	HSE INDG 370	Controlling fire and explosion risks in the workplace. A brief guide to DSEAR.

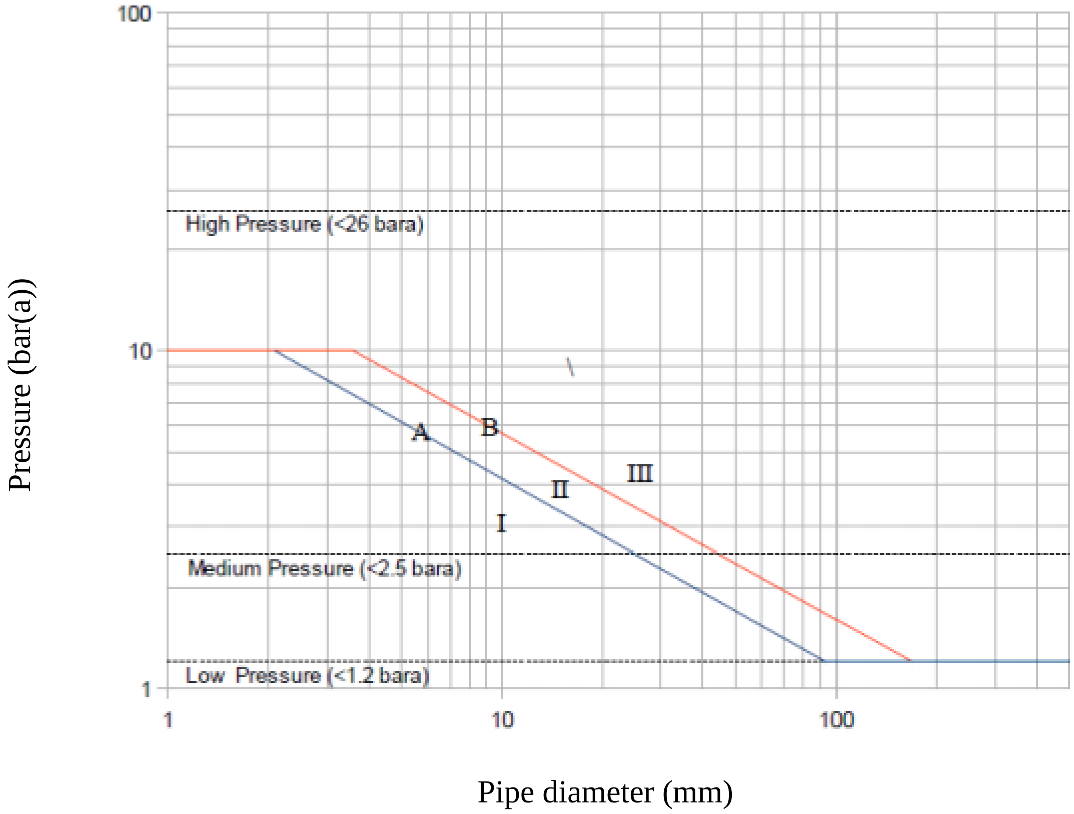
	Document Number	Title
12.	HSE Guidance Note GS 4	Safety in pressure testing.
13.	BS EN 837	Pressure gauges.
14.	BS 1710	Specification for identification of pipelines and services.
15.	BS EN ISO 5171	Gas welding equipment. Pressure gauges used in welding, cutting and allied processes.
16.	BS 5958: Part 1 Part 2	Code of practice for control of undesirable static electricity. 1. General requirements. 2. Recommendations for particular industrial situations.
17.	BS EN ISO 7010	Graphical symbols. Safety colours and safety signs. Registered safety signs.
18.	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).
19.	BS EN ISO 9539	Gas welding equipment. Materials for equipment used in gas welding, cutting and allied processes.
20.	BS EN ISO 10961	Gas cylinders. Cylinder bundles. Design, manufacture, testing and inspection.
21.	BS EN ISO 14113	Gas welding equipment. Rubber and plastics hose and hose assemblies for use with industrial gases up to 450 bar (45 MPa).
22.	BS EN ISO 14114	Gas welding equipment. Acetylene manifold systems for welding, cutting and allied processes. General requirements.
23.	BS EN ISO 15615	Gas welding equipment. Acetylene manifold systems for welding, cutting and allied processes. Safety requirements in high-pressure devices.
24.	BS EN 60079 Part 19	Electrical apparatus for explosive gas atmospheres. 19. Repair and overhaul for apparatus used in explosive atmospheres (other than mines or explosives).
25.	EIGA IGC Document 30	Disposal of gases.
26.	EIGA IGC Document 78	Leak detection fluids cylinder packages.

	Document Number	Title
27.	EIGA IGC Document 123	Code of Practice Acetylene.
28.	BCGA Code of Practice 4	Industrial gas cylinder manifolds and distribution pipework (excluding acetylene).
29.	BCGA Code of Practice 6	The safe distribution of acetylene in the pressure range 0 to 1.5 bar.
30.	BCGA Code of Practice 39	In-service requirements of pressure equipment (gas storage and gas distribution systems).
31.	BCGA Guidance Note 2	Guidance for the storage of gas cylinders in the workplace.
32.	BCGA Guidance Note 13	DSEAR Risk Assessment.

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
European Industrial Gases Association (EIGA)	www.eiga.eu
British Compressed Gases Association (BCGA)	www.bcga.co.uk

ACETYLENE WORKING RANGES



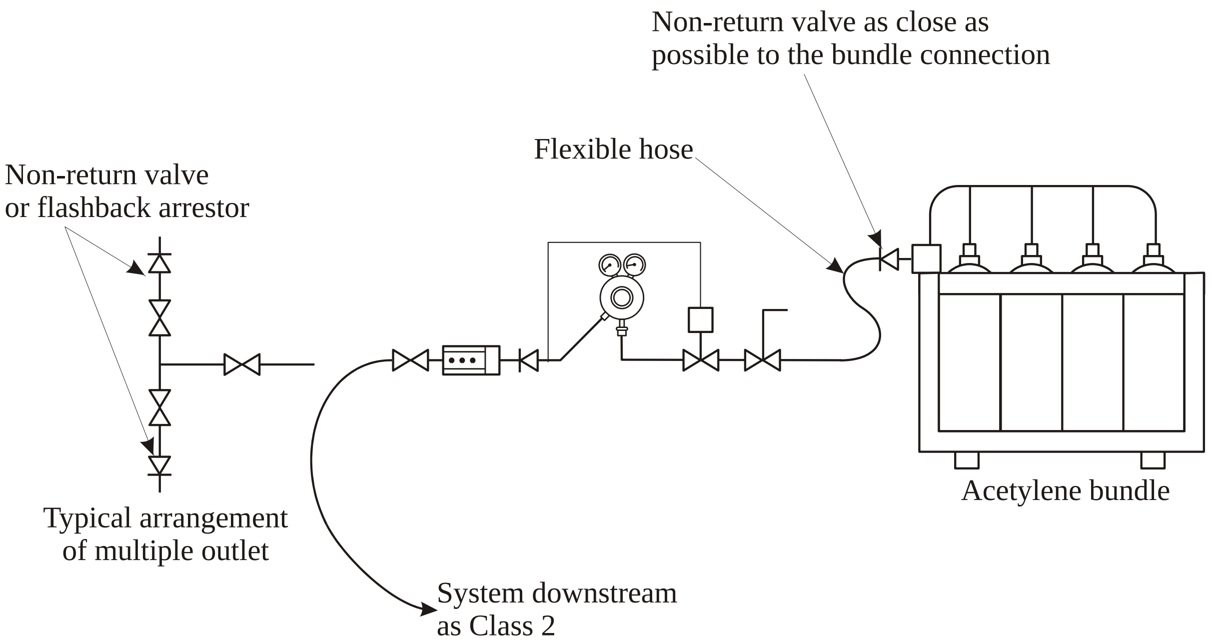
KEY:

Working Ranges I, II, III

A: Deflagration limit pressure line
B: Detonation limit pressure line

Source: EIGA Document 123 (27)

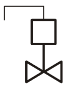
MOBILE INSTALLATION USING BUNDLE

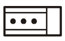


KEY

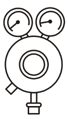
 Isolation valve

 Non-return valve

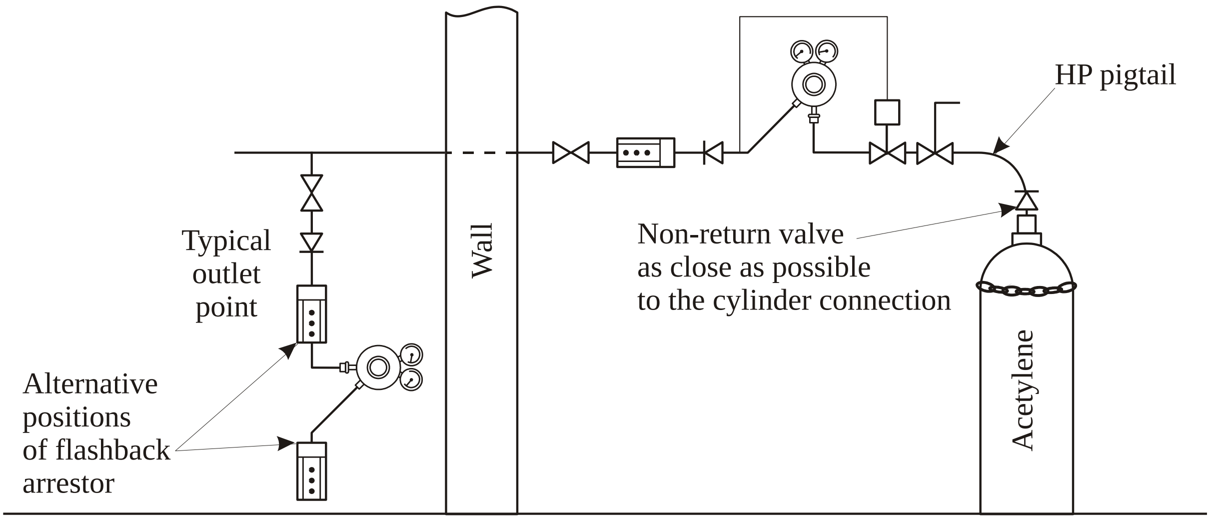
 Pressure sensitive shut-off valve or relief device

 Flashback arrestor and cut-off valve
(temperature or pressure sensitive)

 Manual quick acting shut-off valve
or automatic quick acting shut-off device

 Pressure regulator

PERMANENT SINGLE CYLINDER SUPPLY INSTALLATION



KEY

Isolation valve

Non-return valve

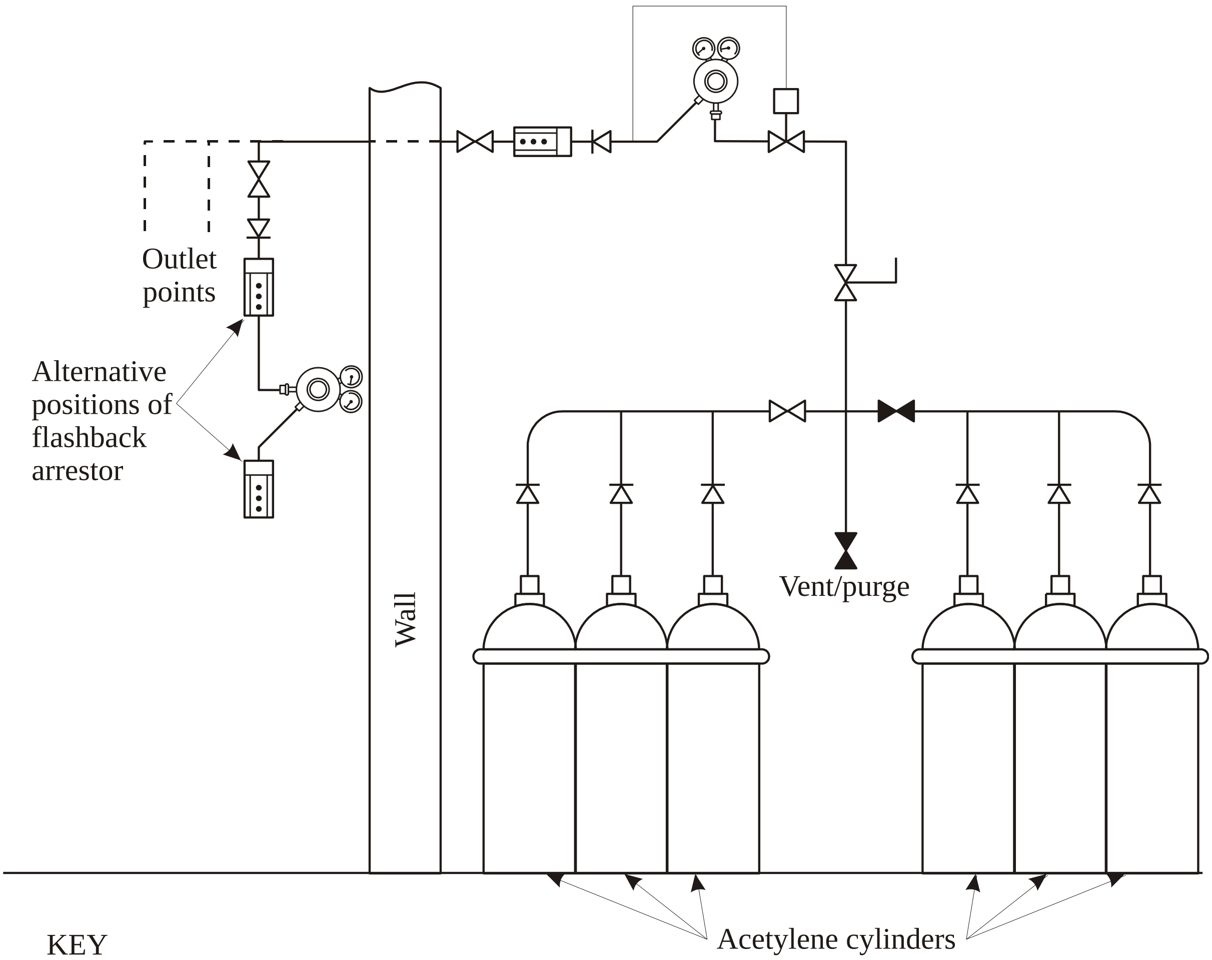
Pressure sensitive shut-off valve or relief device

Flashback arrestor and cut-off valve (temperature or pressure sensitive)

Manual quick acting shut-off valve or automatic quick acting shut-off device

Pressure regulator

PERMANENT INSTALLATION CYLINDER MANIFOLD SUPPLY



KEY

Isolation valve

Isolation valve in closed position

Non-return valve

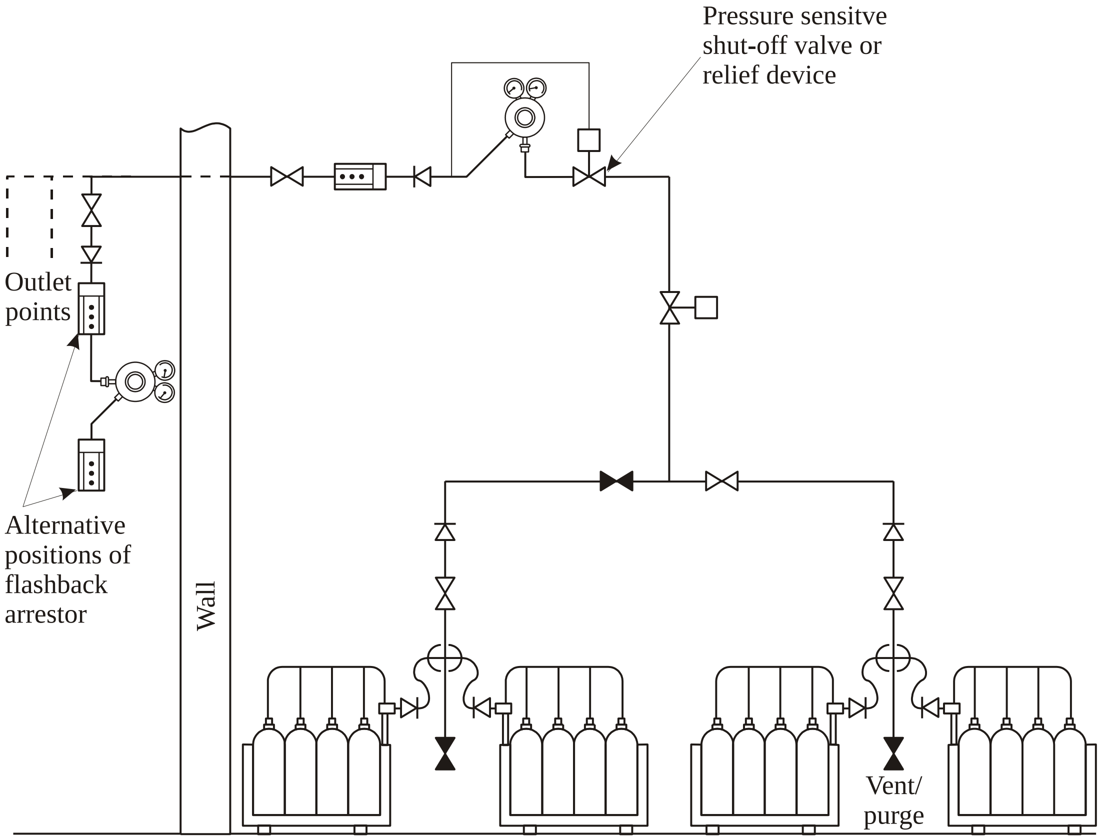
Pressure sensitive shut-off valve or relief device

Manual quick acting shut-off valve
or automatic quick acting shut-off device

Flashback arrestor and cut-off valve
(temperature or pressure sensitive)

Pressure regulator

PERMANENT INSTALLATION: BUNDLE MANIFOLD – TYPICAL ARRANGEMENT



KEY

Isolation valve

Isolation valve in closed position

Non-return valve

Pressure senstive shut-off valve or relief device

Pressure regulator

Flashback arrestor and cut-off valve (temperature or pressure sensitive)

Automatic quick acting shut-off device

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