EIGA

CODE OF PRACTICE ACETYLENE

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Revision of Doc 123/21

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Amendments to 123/21

The previous publication had become very large and for the review of it, it will be split in separate publications on different topics. Step by step parts will be taken out, reviewed and published separately. The final review of this document will be done once all other sub publications are finalised.

Section	Change
8 and 10	Parts of the former content have been removed from this publication and moved to new documents: EIGA Doc 237 *Safe Operation of Acetylene Generator Systems* EIGA Doc 239 *Mechanical Integrity of Acetylene Generator Systems in Acetylene Plants* EIGA Doc 240 *Commodity Specification Acetylene* EIGA Doc 241 *Purification, Compression and Drying of Acetylene*
10	Parts of the former content have been removed from this publication and moved to new documents: EIGA Doc 241 *Purification, Compression and Drying of Acetylene*
11.4	Update of the calculation formulas; examples of calculation are moved to new design documents
13	Change of title

1 Introduction

This document has been prepared by the European Industrial Gases Association (EIGA) to give guidance for the safety requirements in acetylene production, operations filling and handling.

The previous publication had become very large and for the review of it, it will be split in separate publications on different topics. Step by step parts will be taken out, reviewed and published separately. The final review of this document will be done once all other sub publications are finalised.

2 Scope

The document covers the basic requirements for the safe and correct design and maintenance of an acetylene plant as well as customer installations.

The document also includes recommendations for the safe supply, storage, transport and use of acetylene cylinders, bundles and trailers.

The document does not relate to any particular design or construction of an acetylene plant. The document is not intended to replace manufacturers and company instructions but should be used in conjunction with such instructions.

An existing plant that is not in strict compliance with the provisions of this Code of Practice may continue to operate provided that it does not constitute an unacceptable risk to life, health or adjoining property.

3 Definitions

3.1 Publications terminology

3.1.1 Shall

Indicates that the procedure is mandatory. It is used wherever the criterion for conformance to specific recommendations allows no deviation.

3.1.2 Should

Indicates that a procedure is recommended.

3.1.3 May and Need not

Indicate that the procedure is optional.

3.1.4 Will

Is used only to indicate the future, not a degree of requirement.

3.1.5 Can

Indicates a possibility or ability.

3.2 Technical definitions

3.2.1 Acetylene compressor

comprises all components of the installation, from the suction tubes of the first compression stage to the backflow tubes placed behind the last stage of the compressor including the safety equipment and other accessories required for the operation of the compressor.

3.2.2 Acetylene cylinder bundle

Transportable unit consisting of two cylinders up to usually not more than 16 cylinders permanently manifolded together and contained within a rigid frame equipped with all necessary equipment for filling and use.

3.2.3 Acetylene dryer

Equipment for decreasing the water vapour content of acetylene

3.2.4 Acetylene filling plant

Plant in which acetylene is filled into acetylene cylinders, bundles or trailers, (battery vehicle).

3.2.5 Acetylene gasholder

Device for storing the acetylene produced before cylinder filling.

3.2.6 Acetylene generator

Equipment in which acetylene is generated from the reaction of calcium carbide with water.

3.2.7 Acetylene heat exchanger or cooler

Equipment where the temperature of the passing acetylene is intentionally decreased or increased.

3.2.8 Acetylene purifier

Equipment for reducing impurities of acetylene

3.2.9 Acetylene system

Any equipment instrument, device from the cylinder valve or bundle outlet connection to the use point.

3.2.10 Automatic quick acting shutoff device

Self-acting device which closes quickly, for example when triggered by acetylene decomposition.

3.2.11 Battery system

System of two or more cylinders connected on the high-pressure side for collective withdrawal.

3.2.12 Battery vehicle

Assembly of cylinders or bundles connected to a manifold and securely attached to a vehicle chassis such that the assembly is transported and emptied as a single unit and can be filled as a single unit.

3.2.13 Calcium carbide briquette

Compressed block of calcium carbide dust.

3.2.14 Calcium carbide containers

Vessels normally made of sheet steel with a rectangular or cylindrical shape. They are watertight and are handled either by fork lift or crane. The containers can be classified into:

- intermediate bulk container (IBC) with a capacity up to 3 m^3 or 2,5 t
- other containers up to 22m^3 or 20 t

3.2.15 Calcium carbide drums

Vessels manufactured from sheet steel with a capacity up to 400 kg but usually not exceeding 110 kg. They are water-tight and, depending on the design, drums can be used for one or multiple trips. Larger drums are sometimes referred to as barrels.

3.2.16 Calcium carbide dust

Calcium carbide that passes through a test sieve having a mesh width of 1 mm.

3.2.17 Calcium carbide flow bin

Bulk container (approximately 1.5 t) which is filled from the top and emptied from the bottom.

3.2.18 Calcium carbide (oversize)

Calcium carbide retained on coarser sieves.

3.2.19 Calcium carbide (undersize)

Calcium carbide that passes through the finer sieves. Any needle like pieces remaining after the sieving operation are to be counted as part of the next finer size provided that they can be pushed through the holes by hand.

3.2.20 Calcium carbide transport containers (capacity 20 t)

Containers that are used only for the transport of calcium carbide.

NOTE The calcium carbide is transferred to a charging skip or charging container. The 20 t containers have ventilation systems with drying absorbents and connections for purge and analysis or are under a light pressurization with nitrogen (e.g. 50 mbarg)

3.2.21 Calcium carbide turn bin

Bulk container (approximately 1.5 t) that has only one opening at the base that is used for filling and emptying. The bin is turned at the carbide manufacturers to enable it to be filled.

3.2.22 Deflagration

Explosion propagating at subsonic velocity.

3.2.23 Detonation

Explosion propagating at supersonic velocity and characterised by a shock wave.

3.2.24 Distributed system

Acetylene system with fixed or permanent piping.

3.2.25 Explosion

Abrupt oxidation or decomposition reaction producing an increase in temperature, pressure, or in both simultaneously.

3.2.26 Flame arrestor

Device that quenches a flame front.

3.2.27 Flashback arrestor

Device to stop a flame front and the flow of gas in the case of acetylene decomposition. This device can be activated either by a pressure shock wave or by a temperature sensing device. This is also known as decomposition blocker, see EN ISO 14114, *Gas welding equipment – Acetylene manifold systems for welding, cutting and allied processes – General requirements* [1] [1] .

3.2.28 Grain size

Defines the dimension of the calcium carbide pieces. The specification for the grain size of calcium carbide will depend upon the requirements of the generator system. Example: "25/40" means the size of carbide which passes the 40mm sieve (but not the 25mm sieve) in the carbide packaging.

3.2.29 Hot spots

Locally overheated (glowing) areas of calcium carbide. These can be identified by hot sur-faces on the calcium carbide vessels and generator system

3.2.30 Lime

Carbide lime or 'carbide lime slurry' is a suspension of calcium hydroxide in water produced when water is added to calcium carbide to make acetylene. Carbide lime is also referred to as carbide slurry, carbide sludge generator slurry, lime slurry, lime sludge, lime hydrate, lime water, or activated lime

3.2.31 Localized system

Acetylene system without fixed or permanent piping, normally being just a flexible hose, for example a torch.

3.2.32 Manifold system

System of two or more cylinders connected on the high-pressure side for collective withdrawal (see also battery system).

3.2.33 Pressure range

Acetylene plants are divided into one of the following pressure ranges:

- Low pressure. Pressure not exceeding 0.2 bar
- Medium pressure. Pressure greater than 0.2 bar but not exceeding1.5 bar
- High Pressure. Pressure greater than 1.5 bar but not exceeding 25 bar

3.2.34 Pressure units

This document uses "bar" as the unit of pressure, and if not stated otherwise, the pressure is stated as bar gauge.

3.2.35 Residual gas

- For Tare A or Tare F: The total amount of acetylene in a cylinder returned

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[1] References are shown by bracketed numbers and are listed in order of appearance in the reference section.

- For Tare S: The total amount of acetylene in a cylinder returned minus the saturation gas

3.2.36 Saturation gas

The amount of acetylene required to saturate the solvent at atmospheric pressure and 15 °C (refer to EN ISO 3807, *Cylinders for acetylene — Basic requirements and type testing* [2]).

3.2.37 Solvent replenishment.

Procedure for filling solvent into an acetylene cylinder up to the specified solvent content.

3.2.38 Tare A

Sum of the empty weight of the cylinder shell, the weight of the porous mass, the specified weight of the solvent content, the weight of the valve and the weight of all other parts that are permanently attached (e.g. clamps, guards, or nut bolt fixing) to the cylinder before it is filled.

3.2.39 Tare BA_{max}

Sum of the Tare A weights of all cylinders manifolded together in a bundle containing the maximum weight of solvent including the amount of positive solvent operating range plus the weight of the rigid frame and the weight of all equipment.

3.2.40 Tare BA_{min}

Sum of the Tare A weights of all cylinders manifolded together in a bundle containing the maximum weight of solvent including the amount of negative solvent operating range plus the weight of the rigid frame and the weight of all equipment.

3.2.41 Tare BS_{max}

Sum of the Tare S weights of all cylinders manifolded together in a bundle containing the maximum weight of solvent including the amount of positive solvent operating range plus the weight of the rigid frame and the weight of all equipment.

3.2.42 Tare BS_{min}

Sum of the Tare S weights of all cylinders manifolded together in a bundle containing the maximum weight of solvent including the amount of negative solvent operating range plus the weight of the rigid frame and the weight of all equipment.

3.2.43 Tare BF

Sum of the Tare F weights of all cylinders manifolded in a bundle, plus the weight of the rigid frame and the weight of all the equipment.

3.2.44 Tare F

Tare A minus the weight of the solvent.

3.2.45 Tare S

Tare A plus the weight of the saturation gas.

3.2.46 Yield

Number of litres of crude acetylene obtained from a 1 kg sample. The yield is determined in l/kg and is corrected to 15°C and 1013 mbar moist, that is saturated at 15°C with water vapour.

4 General

4.1 Training of personnel

All personnel involved in acetylene operations shall be fully trained in both the theory and practice of acetylene and also assessed for competency in the following as required:

- The general requirements of this Code of Practice.
- Properties of all gases, chemicals and impurities involved in the production of acetylene.
- Operation of the relevant part of the acetylene process.
- Emergency procedures and equipment.
- Personal Protective Equipment (PPE) requirements, including gloves, goggles, safety shoes and other protective equipment.
- Acetylene cylinder properties and characteristics.

Persons undergoing training shall be supervised by a competent person(s) when working in an acetylene plant. Further details can be found in EIGA Doc 23, *Safety Training of Employees* [3].

4.2 Management of change

Acetylene plants shall be designed and constructed to the appropriate acetylene plant engineering standards. Changes to the plant or process can introduce serious hazards if not carried out in a controlled manner.

Any changes to the plant or the operational procedures shall be approved and validated by a competent person using formal change management procedures. Such procedures shall include validation of any changes to the plant or process using techniques such as HAZOP (Hazard and Operability Study), Risk Assessment, FMEA (Failure Mode Effects Analysis) as appropriate. Further details can be found in EIGA Doc 51, *Management of change* [4].

5 Acetylene properties

5.1 Physical and chemical properties

Acetylene is a compound of the elements carbon and hydrogen, its composition being expressed by the chemical symbol, C_2H_2. On a weight basis, the proportion of the elements in acetylene is about twelve parts of carbon to one part of hydrogen, or 92,3 % to 7,7 %, respectively. At atmospheric temperatures and pressures, acetylene is a colourless gas, which is slightly lighter than air. Pure acetylene is odourless, but acetylene of ordinary commercial purity has a distinctive, garlic-like smell. Some physical constants of acetylene are given in Table 1.

Acetylene burns in air with an intensely hot, luminous and smoky flame. The ignition temperatures of acetylene, mixtures of acetylene and air, and mixtures of acetylene with oxygen will vary according to composition, pressure, water vapour content and initial temperature. As a typical example, mixtures containing 30 % acetylene by volume with air at atmospheric pressure can auto ignite at about 305 ºC. The flammable limits of mixtures of acetylene with air and acetylene with oxygen will depend on the initial pressure, temperature and water vapour content. In air at atmospheric pressure, the upper limit of flammability is about 82 % acetylene and the lower limit is about 2.3 % acetylene.

Acetylene can be liquefied and solidified with relative ease and both phases are unstable. Mixtures of gaseous acetylene with air or oxygen in certain proportions can explode if ignited. Gaseous acetylene under pressure without the presence of air or oxygen can decompose with explosive force. This can also occur at low pressure under certain conditions.

5.2 Physiobiological

Pure acetylene is classified as non-toxic but is an asphyxiant gas with slight anaesthetic properties. Pure acetylene has been shown in experiments to have no chronic harmful effects even in high concentrations. Unpurified acetylene generated from calcium carbide contains phosphine in concentrations of typically 300-500 ppm, which is toxic. Poor quality calcium carbide can generate phosphine concentrations in excess of 1000 ppm. Therefore, exposure to personnel shall be monitored and controlled. Acetylene is a simple asphyxiant if present in such high concentrations that the lungs are deprived of their required supply of oxygen. In such cases, asphyxiation will result. It should be noted however, that the lower flammable limit of acetylene in air will be reached well before asphyxiation occurs, and that the danger of fire or explosion is reached before any other health hazard is present.

5.3 Tables of acetylene properties

Table 1: Physical properties of acetylene

Chemical formula	C_2H_2	
Molecular weight	26,04	g/mol
Specific mass (0 °C, 1,013 bar)	1,172	kg/m^3
Relative mass (air = 1)	0,908	
Critical temperature	35,2	°C
Critical pressure	61,9	bar(a)
Critical density	231	kg/m^3
Temperature at triple point	-80,6	°C
Pressure at triple point	1,282	bar(a)
Sublimation point (1,013 bar)	-83,8	°C
Vapour pressure of the liquid (0 °C)	26,7	bar(a)
Viscosity (0°C)	95	µPa*s
Specific heat at constant pressure (0 °C, 1,013 bar)	1637	J/(kg*K)
Specific heat at constant volume (0 °C, 1,013 bar)	1309	J/(kg*K)
Thermal conductivity (0 °C, 1,013 bar)	18,4	kJ/(s*m*K)
Heat of formation $\Delta H_f°$ (25 °C, 1,013 bar)	227,4	kJ/mol
Heat of combustion $\Delta H_c°$ (25 °C, 1,013 bar)	1301,1	kJ/mol
Flammability limits (in air) (see note 1)	2,3 –82*	% by volume
Flammability limits (in oxygen) (see note 1)	1,5 - 93*	% by volume
Minimum ignition energy in air	0,019	MJ
Auto ignition temperature in air	305	°C
Auto ignition temperature in oxygen	296	°C
Stability pressure	0,8	bar

NOTE 1 These figures are theoretical as they only refer to the reaction of acetylene with oxygen. The upper explosive limit for acetylene is effectively 100% due to its inherent instability.

NOTE 2 Physical data from Air Liquide gas encyclopaedia

Table 2: Solubility of acetylene in water in g/kg

Temp. in °C	Acetylene partial pressure in bar(a)						
	1,013	5,065	10,13	15,195	20,26	25,325	30,39
1	1,97	9,43	Acetylene hydrate tends to form				
10	1,56	7,40	14,2	20,3	Acetylene hydrate tends to form		
20	1,23	5,82	11,4	16,6	21,2	25,0	28,7
30	1,01	4,70	9,5	14,0	17,9	21,5	25,0

Table 3: Solubility of acetylene in acetone in g/kg (reference: Miller [5])

Temp. in °C	Acetylene partial pressure in bar(a)								
	1,013	2,026	3,039	5,065	10,13	15,195	20,26	25,325	30,39
0	58,0	109,5	158	241	526	912			
5	48,7	95,3	137	208	447	754	1157		
10	41,1	83,0	122	182	384	636	958		
15	34,0	72,0	107,2	161	335	546	811	1146	
20	27,9	62,4	94,2	142,3	293	472	689	960	1297
25	22,4	53,5	82,2	126,6	259	413	597	822	1099
30	17,9	45,7	72,1	113,0	230	364	521	710	940
40	10,4	33,0	54,0	92,5	185	289	408	546	709
50		22,7	41,2	75,2	150,5	234	327	432	554

Table 4: Solubility of acetylene in DMF (dimethylformamide) in g/kg (Reference: Miller [5])

Temp. in °C	Acetylene partial pressure in bar(a)						
	1,013	5,065	10,13	15,195	20,26	25,325	30,39
0	77,3	258	521	736			
5	66,6	224	447	649			
10	57,3	196	391	582	728		
15	49,5	173	341	509	653	742	
20	42,7	154	301	452	593	702	
25	37,2	138	269	404	536	654	739
30	32,3	125	241	362	485	602	701
40	24,4	103	197	295	398	504	607
50	18,8	86	164	245	331	421	514

5.4 Acetylene decomposition

Acetylene decomposition is the spontaneous reaction to elemental carbon and hydrogen. This can occur at low or medium pressure as either a deflagration at a relatively slow reaction rate, or as a detonation at supersonic velocity.

Deflagration produces final reaction pressures ten to eleven times initial pressure from the energy released by the reaction. Detonation of high-pressure acetylene can produce pressure peaks up to fifty times the original pressure. Detonation pressure peaks are short lived but shall be considered in designing a safe high-pressure acetylene system. Conventional pressure relief devices offer no protection as detonations proceed at supersonic velocity and they cannot react with sufficient speed.

NOTE Decomposition temperature depends on different conditions and operating parameters. For example, temperature and moisture content of the gas, internal pipe surface corrosion, contaminants, and flow rate.

5.5 Polymerisation

Acetylene is capable of reacting with other acetylene molecules to form larger hydrocarbon molecules, for example benzene. This process is known as polymerisation and heat is required to initiate the reaction.

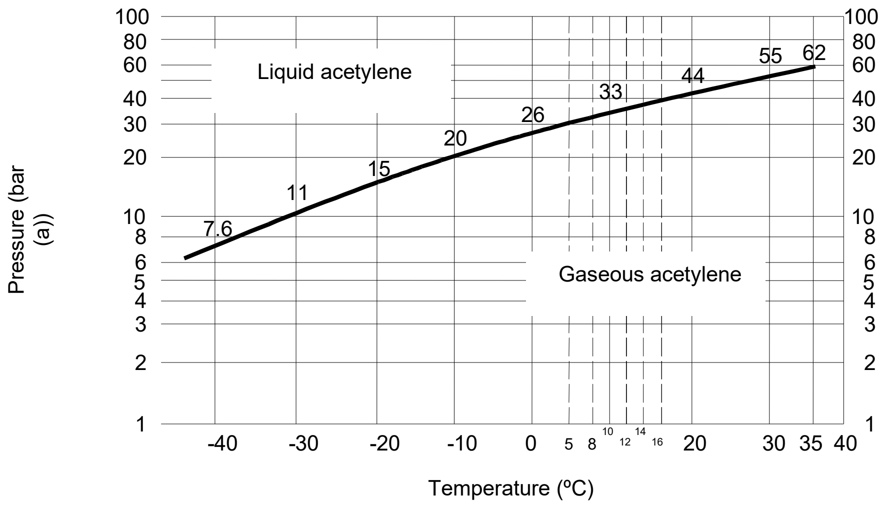
Once the process is started, heat is liberated and the reaction becomes self-sustaining above atmospheric pressure; this can lead to an explosive decomposition of acetylene into its elements, carbon and hydrogen.

Polymerisation readily commences at 400˚C and at atmospheric pressure and can occur at lower temperatures in the presence of catalysts such as pipe scale, rust, silica gel, diatomite (kieselguhr), charcoal.

5.6 Liquid acetylene

Liquefied acetylene has a high explosive potential and has higher shock sensitivity and energy density than compressed gaseous acetylene. Thus, the liquefaction of acetylene shall be absolutely avoided in acetylene charging operations. Figure 1 presents the vapour pressure curve for acetylene. Note that at low temperature operations, acetylene could liquefy.

Figure 1: Liquid acetylene formation

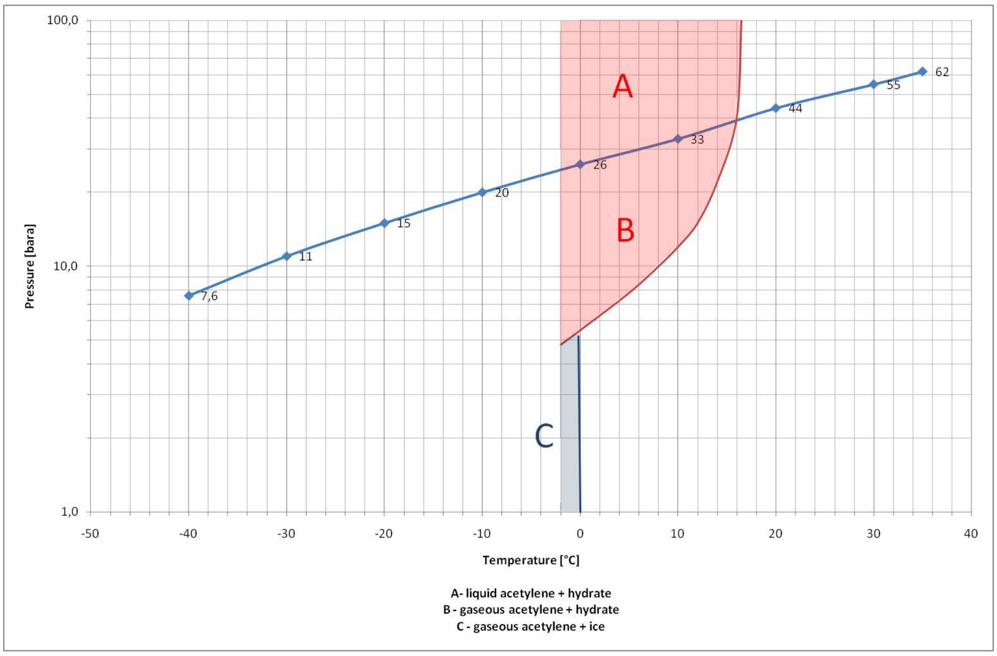


5.7 Acetylene hydrate

The formation of acetylene hydrates $C_2H_2*5,75\ H_2O$ as an acetylene compound shall be considered in the acetylene process. Acetylene hydrate is not as dangerous as liquid acetylene, but it may decompose. Solid acetylene hydrate can cause blockages in acetylene piping, valves, flashback arrestors and other components.

When wet acetylene cools under increasing pressure, acetylene hydrate can be formed. Acetylene hydrate formation conditions are shown in Figure 2.

Figure 2: Acetylene hydrate formation



To minimise the risk of hydrate formation, the following precautions shall be taken

- Avoiding working with wet acetylene at high pressure.
- Keeping the acetylene pressure and temperature conditions to the right and out of cross-hatched areas in the graph above.
- Minimising rough surfaces that can encourage formation of hydrates and create blockages in restricted passages.

5.8 Acetylides

When acetylene comes into contact with copper, silver, mercury or salts of these metals, explosive acetylides can form. These acetylides are highly sensitive to shock or friction.

See 6.2 regarding materials of construction for further details.

5.9 Adiabatic compression

Adiabatic compression of gases results in a temperature rise that could be sufficient to initiate acetylene decomposition.

Decomposition in acetylene pipework and hoses arising from adiabatic compression of acetylene shall be considered during the design of an acetylene installation. There have been a number of incidents where adiabatic compression has caused decomposition in acetylene pipework and hoses.

The presence of nitrogen or air in acetylene pipework and hoses will increase the risk of a decomposition occurring under adiabatic compression conditions. This is due to the higher adiabatic compression temperature of nitrogen.

Based on the above, the following shall be considered:

- Prevent the ingress of air into pipework and hoses carrying high-pressure acetylene for example, when connecting cylinders to a manifold. The use of non-return valves on filling hoses and by purging will reduce the possibility of air ingress and consequently reduce the possibility of adiabatic ignition.
- Use safety devices such as a flashback arrestor with a cut-off device to prevent the transmission of decomposition through the system.

6 Acetylene system components

6.1 Design consideration

Acetylene production and filling plants shall be designed, constructed and operated to standards and procedures to ensure the maximum integrity of the equipment and safety for personnel. Design and construction of plant and equipment shall be in accordance with all applicable European Directives, including the *Machinery Directive* 2006/42/EC, *the Pressure Equipment Directive* (PED) 2014/68/EU and the *Equipment for explosive atmospheres (ATEX) Directive* 2014/34/EU [6, 7, 8].

Safety devices shall be provided on the system to ensure that parameters such as pressures, temperatures, and flow levels are kept within safe limits at all times.

The equipment shall be designed, equipped, operated and maintained to ensure that during normal conditions of operation:

- Air or oxygen cannot enter the system and shall never exceed 50% of the lower flammability limit in acetylene containing parts.
- Air or acetylene can be eliminated from the system by purging with an inert gas such as nitrogen for maintenance tasks.
- An excessive rise of pressure and temperature can be prevented.

6.2 Materials of construction

Materials of construction shall withstand the mechanical and thermal conditions that can occur during normal operation and under anticipated upset conditions. Materials of constructions shall be chemically compatible with the processes involved in acetylene production. The materials should not cause adverse reactions with acetylene, solvents, carbide and other products generated from carbide.

Because acetylene can form explosive compounds with copper, silver and mercury, these metals are prohibited in the construction and maintenance of acetylene systems. Some alloys containing restricted amounts of these metals may be used.

Steel is the preferred material for the construction of acetylene system components.

Plastic materials and man-made fibres shall not be used in an acetylene plant for tools or equipment unless it has been demonstrated that the risk for electrostatic charging is eliminated, for example brooms and buckets.

Materials used in packing, sealing and membranes shall be resistant against acetone or other solvents used. For additional information refer to EIGA Doc 225, *Solvents for Acetylene Filling* [9]

Table 5 provides information on prohibited or restricted compatibility materials for acetylene applications:

Table 5: Materials not allowed or recommended only under certain conditions

Material	Conditions for use
Copper and copper alloys containing more than 70% copper *	Not allowed.
Alloys containing up to 70% Copper*	Permitted. Consideration should be given to the use of copper alloys for filters, sieves etc. that have a large surface area in contact with acetylene and also for parts in contact with moist unpurified acetylene. Any heat process which produces copper enrichment on the surface of the copper alloy shall be avoided. NOTE ADR and EN ISO 11114-1 Gas cylinders – Compatibility of cylinder and valve materials with gas contents – Part 1: Metallic materials, use a figure of 65% copper for **transportable** equipment [10,11]
Silver and mercury	Not allowed.
Silver alloys*	Suitable for brazing, provided that the silver content does not exceed 43%, the copper content does not exceed 21% and the gap between the two parts to be brazed does not exceed 0,3 mm. Care shall be taken to minimise the area of filler metal exposed to acetylene and to remove as far as is practicable all traces of flux.
Aluminium, Zinc, Magnesium, and their alloys	Not recommended for components, which come in contact with wet acetylene contaminated with lime or ammonia (un-purified generator gas).
Zinc	Suitable as external anti-corrosion protective coating.
Glass	Should be used only for sight glasses such as U-tube manometers and similar devices. This type of device should either be protected against external damage or be designed to withstand breakage or alternatively, the system designed so that breakage will not cause a hazard.
Organic materials	May be used if they are resistant against acetylene, solvents and impurities.

NOTE Where brazing alloys containing silver and copper are not in compliance with the above Refer to EN ISO 9539, *Materials for equipment used in gas welding, cutting and allied processes* [12]

6.3 Cleaning

Degreasing is normally not required for acetylene plants. After construction works acetylene systems, particularly for high pressure shall be cleaned internally to remove any loose matter, e.g. by blowing through with compressed air.

Before initial start-up and after maintenance and service work, the system should be purged with an inert gas, usually nitrogen. The use of carbon dioxide for purging is not recommended due to the risk of static electricity generated from droplets and dry ice particles.

6.4 Valves, fittings, regulators, hoses and safety devices

6.4.1 Regulators

Regulators shall comply with EN ISO 7291, *Gas welding equipment – Pressure regulators for manifold systems used in welding, cutting and allied processes up to 300 bar* [13].

6.4.2 High pressure hoses

Hoses shall comply with EN ISO 14113, *Gas welding equipment – Rubber and plastic hoses assembled for compressed or liquefied gases up to a maximum design pressure of 450 bar* [14].

Hoses should only be used where rigid pipes are not able to be used. The length and the diameter of the hose should not be larger than necessary.

Consideration should be given to the design of the end fittings, particularly to the avoidance of sudden changes in internal diameter. Where there is a change in diameter a gradual taper should be made.

Where hoses are used in an installation the resistance between the two end-couplings should not exceed 10^6 ohms to reduce the risk of electrostatic charging. Further details can be found in EN 12115*, Rubber and thermoplastics hoses and hose assemblies for liquid or gaseous chemicals. Specification* [15].

6.4.3 Pressure relief devices

Acetylene vented from pressure relief devices should be discharged outside the building to an 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. Pressure relief device discharge pipes should be separate and connection to a manifold should be avoided.

6.4.4 Flame arrestors and flashback arrestors

The location of flame arrestors and flashback arrestors depends on the type, size and operating pressure of the installation. Flame arrestors and flashback arrestors may be necessary to separate sections, which fall under different operating pressures.

All components of the flame arrestor shall resist the expected mechanical, thermal and chemical loads for their intended use.

See also 10.5

6.4.5 Pressure sensors and indicators

Pressure sensors and indicators shall be constructed with a sensing element of steel, or alloys containing less than 70 % of copper.

Pressure sensors and indicators shall be constructed with a solid bulkhead and a blow-out back or safety vent, the dial of the gauge should be marked ACETYLENE and be suitable for the maximum working pressure

Pressure sensors and indicators for medium and high working pressure shall comply with one of the following:

- be fitted with an impulse line restrictor of 0.5 mm diameter to limit the escape of gas should the pressure gauge fail and to protect the mechanism from damage due to pressure surges; or
- protected by a flame arrestor.

Pressure indicators shall be in compliance with EN 837-1, *Pressure gauges* [16].

6.4.6 Valves and pipework fittings

Cast steel flanged fittings or forged steel welding fittings are recommended for use in all pipe sizes. Screwed fittings may be used if they have been verified as being suitable for the appropriate working range.

High pressure valves should comply with the requirements of EN ISO 15615, *Gas welding equipment – Acetylene manifold systems for welding, cutting and allied processes, and safety requirements in high-pressure devices* [17].

The design of valves or the method of installation shall be such as to minimise the risk of ignition due to friction. Filters may be used to eliminate the possibility of dirt getting onto the valve seat.

Any type of seal or packing may be used provided it complies with 6.2.

6.5 Operating procedures, periodic inspection and maintenance

The appropriate tools and equipment shall be used. For example, the use of spark proof tools. The work should comply with maintenance schedules from the equipment suppliers.

The operation of a plant for the production and filling of acetylene shall only be carried out by competent persons trained and assessed in the hazards, handling and maintenance of the products and equipment. For example, when maintaining ATEX certified equipment.

Equipment shall not be taken out of service for repair until all pressure has been released and the system purged with nitrogen whenever necessary. Using carbon dioxide is not recommended due to the risk of static electricity.

When purging by dilution, the procedure used shall be validated (including, but not limited to gas flow, duration, number of cycles).

Precautions should be taken to prevent ignition and ventilation should be provided during purging operations for as long as there is a possibility of an air-acetylene mixture existing, for example, by opening windows and doors.

The atmosphere inside the equipment shall be controlled to prevent an explosive atmosphere. The atmosphere shall be tested with a gas detector suitable for measuring combustible gases (Explosimeter). Explosimeters shall be suitable for measuring acetylene in nitrogen as well as acetylene in air. E.g. pellistor type explosimeters are not able to measure acetylene in nitrogen.

Personnel shall be trained and assessed in the correct operation of such equipment.

It is recommended to continuously monitor the atmosphere while work is being undertaken.

Attempts to test for a combustible gas in an atmosphere low in oxygen can give unreliable readings.

Verify with an oxygen meter that the level of oxygen inside the equipment to be entered is within safe limits for breathing before entry.

All the equipment used to measure the atmosphere (explosimeter and oxygen detector) shall be operated, maintained and kept in working condition in accordance with the manufacturers' recommendations and requirements. Periodic inspection of this equipment shall be carried out.

The purge gases shall be vented to outside of the local working area to a safe location.

When emptying the water in acetylene carrying equipment (including the gasholder or generator) the water shall be discharged to a location (lime pit) where the dissolved acetylene can disperse rather than it being directed into a sewer or drain whilst still saturated with acetylene. This water shall not be discharged into the sewer or town drainage system.

6.5.1 General

Periodic inspection and maintenance is required to ensure that the installation remains within the specified design parameters.

Routine inspection and maintenance of equipment shall be carried out on a planned basis and be recorded.

The production site shall be inspected to ensure that it is within the specified design parameters and that safety distances originally specified are still maintained.

An installation dossier shall be held on site; this dossier should include:

- process and instrumentation diagrams;
- pressure vessel and tank dossiers;
- operating and maintenance instructions.

Check the plant and equipment at appropriate intervals (for example daily, weekly, and annually) to verify:

- The condition of the main plant components, for example, the generator, gasholder, dryers, compressor, tanks, pressure vessels and piping and accessories.
- The operation and settings of all control loops and systems.
- All safety related operations and non-return valves for safety against backflow of gas and safety valves.
- Operation of the deluge system.
- Minor repairs, e.g. changing of seals.
- The pigtails and flexible hoses are not damaged.
- The valves open and close correctly and the system is operating within normal parameters (for example, if system is using more gas than normal, an unusual drop in pressure or smell of gas which could indicate a malfunction or leak).
- The regulators are not damaged, and they operate within their specified operating parameters.
- Piping and fittings are not corroded.

6.5.2 Pressure relief devices (PRDs)

Routine visual inspections of the PRDs shall be carried out during operation of the plant.

Pressure relief valves shall be tested to a defined schedule based on the manufacturers' recommendations, national requirements or Process Hazard Analysis whichever is the more stringent.

Whilst bursting discs are not commonly used on acetylene plants, bursting disc elements can deteriorate with time resulting in their relief pressure rating being reduced. Therefore it can be necessary to replace bursting disc elements periodically.

6.5.3 Process safety equipment

Process safety equipment, such as critical trips and alarms shall be maintained and tested to a defined schedule based on the original equipment manufacturers' recommendations, national codes or Process Hazard Analysis whichever is the more stringent.

6.5.4 Modifications and changes

Refer to 4.2.

6.5.5 Training and protection of personnel

The appropriate personal protective equipment (PPE), see EIGA Doc 136, *Selection of personal protective equipment,* shall be used for the task being carried out [18]. For example, safety shoes, gloves, goggles and flame-retardant clothing. Do not wear PPE clothing that is made from synthetic fibres as these can cause a static discharge and they can burn and melt when exposed to fire.

6.5.5.1 Work permit

There are many good engineering practices that shall be applied during maintenance activities on acetylene generators e.g. management of change, isolation practices, lockout/tagout, safety work permit, confined space entry, working in flammable hazardous areas, working with electrical equipment etc.. Companies shall have suitable systems in place to ensure these are applied. Refer to EIGA SL 06 *Life Saving Rules Brochure* & SL 07 *Life Saving Rules Poster* [19, 20]

Maintenance and repair work shall be carried out under a work permit system. This will normally require a risk assessment and method statement. The permit shall be issued by a person authorized for the activity and accepted by trained to the individual(s) carrying out the work.

Refer to EIGA Doc 40, *Work Permit Systems* [21].

6.5.5.2 Entry into vessels

The following precautions, which are not necessarily all those required, shall be observed before entering any tank or vessel:

- A documented confined space entry procedure;
- Complete emptying and purging of the tank contents.
- Ensure the tank is at ambient temperature.
- Complete isolation of the process lines from other equipment which could still be in service, by blanking discs or physical disconnection.
- Analysis of the atmosphere in the vessel at several selected points with a suitable gas detector (probes may be necessary) It may be necessary to measure this regularly or continuously and to install forced ventilation while work is in progress.
- Presence of standby person (s) outside or adjacent to the access manhole.
- Use of safety equipment such as harnesses, protective clothing, fire extinguishers.
- Availability of rescue equipment (including, but not limited to harnesses, self-contained breathing apparatus, winches, radio links)

Attempts to rescue affected persons from confined spaces or where an oxygen-deficient atmosphere could be present should be made only by persons who are wearing and trained in the use of breathing apparatus and who are familiar with confined space entry procedures.

The victim may not be aware of the asphyxia. If any of the following symptoms appear; rapid and gasping breath, rapid fatigue, nausea, vomiting, collapse or incapacity to move, unusual behaviour, in situations where asphyxia is possible and breathing apparatus is not in use, move the affected person immediately to the open air, if necessary following up with artificial respiration: rapid and gasping breath, rapid fatigue, nausea, vomiting, collapse or incapacity to move, unusual behaviour.

6.5.6 Return to service

After maintenance, cleaning, and repair operations and before returning to service, procedures shall be followed to ensure that the installation is safe to start up.

These can include:

- Verification that there are no contaminants inside the equipment: solid particles (metal, plastics) which can lead to friction and a risk of ignition within the piping system.
- Verification that the instrument air/nitrogen supply is functioning.
- Verification that the building ventilation system is operating correctly.
- Performing pressure tests for new equipment (for example pipes,).
- Performing leak tests at the maximum operating pressure. Vent all pressure prior to repairing any leaks found as it is not recommended repairing leaks in equipment that are still under pressure.
- Purge any remaining air with nitrogen (do not use carbon dioxide) and analyse the atmosphere inside the equipment.
- Pressurising the equipment or the installation to normal working pressure with nitrogen.
- Remove locks/tags and activate the power.
- Cancel the Work Permit.
- Follow all operational purge requirements specified by the equipment manufacturers.

7 Facility safety requirements

7.1 Site and buildings

7.1.1 Location of plant

Acetylene plant and buildings shall be located at a distance from public rights-of-way and from lines of adjoining property that can be built upon. These distances shall be determined by a risk assessment that considers both the on and off-site hazards. Distances are specified in table 7.1.3. Acetylene plants shall be separated from other gas production and cylinder filling operations according to the relative risk assessed.

NOTE Where an acetylene plant is located on a site with an Air Separation Unit there shall be a requirement for the Air Separation Unit to have monitoring equipment in place to detect unacceptably high levels of acetylene in the atmosphere for the ASU process.

7.1.2 Layout and design of plant and buildings

The property where the plant is located shall be securely fenced and guarded to prevent access by unauthorised persons.

Buildings housing acetylene operations shall not be used for any other type of product storage filling or handling.

Acetylene generating or cylinder filling plant shall not have floors above or basements below the plant. This shall also include maintenance and cylinder storage areas.

Buildings or rooms housing acetylene operations shall be constructed of lightweight non-combustible materials or panels designed to relieve at a maximum internal pressure of 0.012 bar (see NFPA 51A, *Standard for acetylene cylinder charging plants* [22]). The design shall be of a construction to limit damage in the event of an explosion. An explosion venting area, including windows, of at least 0.05 m^2 per m^3 of room volume is required. A lightweight blow-off roof is preferred.

Where windows are required, they should be installed with anti-shatter blast protection film. Window frames should be made of steel; aluminium may be used instead. Doors and door frames should be made of steel.

Gasholders may be located outside or inside the plant buildings. Where located inside the building, ventilation shall be able to handle anticipated releases of acetylene. Provided that extreme weather conditions are taken into account (such as anti-freeze precautions and/or the provision of shade) there are safety advantages in locating gasholders outdoors.

For buildings or rooms housing carbide storage or transfilling areas see 7.4.

Buildings or rooms housing acetylene operations shall have accessible exit doors opening outwards. There shall be at least two escape exit routes from a building. Exits should be located so that it shall not be necessary to travel more than 25m from any point to reach the nearest exit. Such exits shall not be permanently locked and it shall always be possible to exit at all times in an emergency using for example, emergency push-bars on the doors Where there are multilevel buildings there shall be at least one escape route provided on one of the levels above ground level.

Each level of a multilevel building for example a generator house shall be provided with emergency exits.

All acetylene plants shall be provided with lightning protection.

All plant and building components shall be protected from electrostatic charges by maintaining an electrical conductivity with a maximum resistance of 10^6 ohm. (see NFPA 77, *Recommended practices on static electricity* and IEC60079-32-1, *Explosive Atmospheres – Part 32-1: Electrostatic hazards, Guidance* [23, 24].

It is good practice to separate the various operations such as carbide store, generating and purification, compression and drying, filling operations, cylinder inspection and maintenance facilities by solid walls. Separation walls shall be constructed of non-combustible or limited combustible materials and have a fire resistance of at least 1 hour. If possible, avoid the installation of doors in separation walls.

Where there are pipes or cables passing through rooms which do not contain any acetylene operations for example electrical rooms, instrument air compressor room, storage rooms, these shall be sealed to prevent the passage of gas.

All supporting structures in the plant shall have a fire resistance of at least 1 hour.

Buildings or rooms devoted to acetylene operations shall be maintained at a temperature sufficient to prevent the formation of liquid acetylene or solid acetylene hydrate in the high-pressure pipework during operation and to prevent the water used in the low-pressure parts in the plant or drains from freezing. Alternatively, suitable controls shall be in place to prevent operation of the plant under climatic conditions likely to create acetylene hydrate formation.

Heating equipment should be ducted hot air, steam or hot water. The maximum surface temperature of all heating equipment shall be limited to 225 °C.

All equipment related to acetylene operations that have separators or drains shall not be discharged directly into site internal or public sewage systems to avoid spreading acetylene gas in an uncontrolled manner.

Readily accessible and identifiable emergency electrical or pneumatic shutdown switches shall be provided adjacent to, and outside the main emergency exits from the plant to shut down the acetylene plant and non-essential electrical equipment.

Consideration should be given to installing a remote emergency shutdown switch at the entrance of the office building or the plant main entrance. The emergency stop shall shut down all:

- compressors
- generator drives (carbide feed)
- pumps
- nominated remotely actuated valves on the acetylene system to a safe position.

The emergency stop shall ***not*** isolate:

- fire pumps
- lighting required for emergency escape purposes
- water pumps for cooling the cylinders on the filling racks
- alarms and essential safety instrumentation

The high-pressure systems shall be depressurised in the event of an emergency.

All vent pipes should be located according to the recommendations in 11.10. Vent pipes should not be connected together in a single manifold to prevent a potential ignition propagating back into the plant through other vent pipes. If vent pipes are connected together in a single manifold, then a risk assessment shall be conducted to ensure adiabatic compression effects do not occur within the manifold and that the manifold is sized accordingly to minimise pressure drop.

7.1.3 Separation distances

The separation distance between acetylene plant and other operations shall be determined according to a risk assessment process.

EIGA Doc 75, *Determination of safety distances* shows methodologies for calculating separation distances according to risk [25].

The following table gives guidance on separation distances that need to be considered. The values given are indicative and subject to a risk assessment of the particular plant. These distances may not be reduced unless a process of quantified risk assessment is applied and appropriate risk control measures are put in place. Distances specified by local legislation shall take precedence.

Table 6: Separation distances for acetylene plants

From	To	Distance in metres
Acetylene plants	Public Buildings where large numbers of people may congregate such as schools, hospitals, passenger railway stations etc.	200
Acetylene plants	Site boundary or public access route Buildings on adjacent properties Office buildings on site	15
Acetylene plants	Other buildings containing cylinder filling operations	6
Openings in acetylene plant buildings (windows doors and ventilation openings)	Gas bulk storage vessels (flammable, toxic, and oxidising) Gas cylinder storage areas	6

Acetylene cylinder storage	Bulk pressure vessels Cryogenic gas storage vessels Flammable liquid storage tanks	6
Calcium Carbide Storage	Site boundary Buildings on adjacent properties Office buildings on site	3

7.2 Explosion prevention

7.2.1 Ventilation and gas detection requirements

Acetylene gas is lighter than air. Acetylene and air mixtures are highly flammable and can ignite with a very low energy source.
Acetylene can accumulate in pockets inside a building, room, in confined spaces, or in lime pits. Ventilation openings and air circulation should be provided to ensure that the concentration of acetylene does not reach ignitable concentrations.

Rooms housing acetylene plant and operations shall be ventilated at a rate of not less than 0.3 $m^3/min/m^2$ of ceiling area.

Ventilation inlet openings shall be near the floor, and outlet openings shall be located at the highest point of the room.

NOTE Natural ventilation is heavily dependent upon local meteorological conditions and the size of the ventilation openings may have to be increased if still air conditions are predominant.

Analysis instruments (explosimeters) may be used to detect the escape of acetylene into the air.

If installed, sensors should be located at high levels and where leaks or accumulation at low levels are considered to be likely to occur. The alarm of the sensors should be set at maximum 25% of the lower explosive limit (LEL) and shut the plant down at maximum 50% LEL. Advice from the equipment manufacturer may be required to locate the sensors in the appropriate positions to achieve the desired coverage.

7.2.2 Equipment requirements

Electrical equipment and wiring in rooms housing acetylene operations shall conform to the requirements of the European Directive 2014/34/EU *(ATEX)* [8].

Non-certified portable electrical battery operated equipment such as mobile phones, pagers, laptop computers, calculators, torches (flashlights), radios, etc., are not permitted in acetylene plant zoned areas. Quartz wrist watches are permitted if they have no additional functionality such as calculators. Non-certified hearing aids (in-ear types) are permitted if they are not operated with a remote control.

All mechanical equipment and tools used in acetylene operations shall not be capable of generating sparks or a static charge.

All equipment shall be protected from electrostatic charges by maintaining an electrical conductivity with a maximum resistance of 10^6 ohm, see NFPA 77 and IEC60079-32-1 [23, 24].

New equipment including mechanical and protective systems intended for use in potentially explosive areas shall comply with European Directive 2014/34/EU (ATEX) [8].

For additional information refer to EIGA Doc 134, *Potentially explosive atmospheres* [26].

7.2.3 Use of forklift trucks

Standard forklift trucks (FLT) could ignite acetylene gas present in the atmosphere in the area that they are operating.

The use of forklift trucks in acetylene plant areas shall take account of the FLT electrical systems, the potential for equipment hot-spots and friction/sparks caused by mechanical impacts, for example fork blades.

The movements of FLTs may include:

- calcium carbide transfer from delivery vehicles to storage area;
- calcium carbide transfer to the generator area;
- cylinder/pallet movement to and from the cylinder storage area to the filling plant;
- cylinder/pallet movement within the plant.

If any of the above movements are outside of the classified zones, a standard FLT may be used.

If any FLT is required to enter a classified zone then it should be a truck suitable for the zoned area according to the ATEX Directive [8]. Manual operated as well as self-propelled fork lift trucks used in potentially explosive areas shall comply with EN 1755, *Safety of industrial trucks – Operation in potentially explosive atmospheres – Use in flammable gas, vapour, mist and dust* and its referenced standards [27].

7.3 Fire protection systems

7.3.1 Fire extinguishers

Carbon dioxide fire extinguishers are not recommended for flammable gas fires due to the risk of static electricity generation, for further information see EIGA SAC NL 76, *Risk of generating static electricity when using CO2 as an inerting agent* [28].

Dry powder fire extinguishers should be installed at the following locations:

- calcium carbide store exits;
- generator room exits;
- gas-holder and purifier room exits;
- compressor room exits;
- cylinder examination room exits;
- acetone (or Dimethylformamide (DMF)) pumps and acetone tank coupling points;
- acetone (or DMF) drum storage area exits;
- points of transfer of acetone (or DMF) from drums to the process;
- generator hopper level; usually on a mezzanine;
- cylinder filling and preparation area.

7.3.2 Deluge systems

Deluge systems for acetylene plants are designed to cool hot cylinders undergoing decomposition and are not specifically designed for extinguishing fires.

There are no specific national or international standards referring to deluge systems for acetylene plants. However, the following reference sources supply general information regarding the design of deluge systems.

- BS 5306, *Code of practice for fire extinguishing installations and equipment* [29]
- NFPA 51A [22]
- NFPA 15, *Standard for water spray fixed systems for fire protection* [30]
- EN 12845, *Fixed fire fighting installations: Automatic sprinkler systems, Design installation and maintenance* [31]

It is recommended that specialist advice be sought when designing a deluge system.

The basic requirements should include:

- provision of cooling water over a sustained period of time for (single) filling racks containing a hot cylinder(s) until the cylinder(s) is cool and safe for transfer to a water bath.
- provision of cooling water to all racks in the event of a major fire, to prevent cylinder explosions but not to extinguish the fire. The intention is to evenly wet the cylinder shells.

Deluge systems shall not be installed in the following:

- carbide storage areas;
- carbide skip loading areas;
- generator rooms; and
- acetylene compressor areas (to prevent oil contamination of the fire water run off)

The requirements for the deluge system performance are:

- To provide a water density of 10 l/m^2/minute on the floor area of the filling racks, based on the surrounding floor area occupied by the cylinders. The intention is to evenly wet the cylinder shells at this flow rate.
- To have sufficient water supply capacity to sustain the above flow rate for at least 90 minutes through the entire system over the filling racks. Allowance should be made for additional capacity requirements within the plant used for other purposes including for example fire monitors and fire hydrants.
- To sustain the above flow rate for 12 hours in the event of a hot cylinder incident. To optimise the water supply, this can be achieved by confining the water over the area of the hot cylinder by isolating the water supply to the unaffected cylinder charging racks

A reliable and secure water supply for the above shall be available, by any of the following means:

- From a fire water main.
- Pumped from a storage tank (topping up of the water in the tank by the emergency services is permitted though a minimum of one hour’s capacity is recommended).
- Pumped from a river or storage tank, with the ability to re-cycle the water back to the storage tank (not a reliable source according to EN 12845 [31]).

The system may be operated by:

- Automatic remote controlled valves which can be initiated by a remote switch, alarm system or fire detection system such as heat sensors, quartzoid bulbs, fusible links.
- Manually operated valves in a protected safe location outside the filling building and labelled.
- Additionally manual valves may be provided, in a safe location, to isolate individual filling racks and other parts of the deluge pipework system in order to conserve water and concentrate it in the area of the hazard. The valves shall be locked in the open position to ensure sufficient water is provided to all affected areas in an emergency.

The design should be of the dry riser type.

The nozzle design shall be able to provide the minimum constant rate of wetting and also apply the water in such a manner that it cascades down the surface of the acetylene cylinders and maximises the cooling effect.

Water spray shall be diverted away from oil sumps of compressors and other areas where oil could be present to prevent potential pollution with the water run-off.

The water run-off shall be diverted away from lime pits, compressors, oil storage, acetone storage, carbide storage and any environmentally sensitive areas.

Water run-off shall not create flooding or thermal pollution of rivers or streams.

Any parts of the system normally containing water (for example up to the main control valve) shall be protected against frost and freezing.

There shall be no isolation valves between the water supply and the main control valve.

All activation points and valves shall be identified.

Personnel escape routes in the filling building shall be identified as visibility is severely reduced when a deluge system operates.

The deluge system shall be periodically tested to ensure it is functioning correctly. It is recommended that the testing is carried out every three months or more frequently if required by national/local regulations.

Fire drills shall be performed at least once per year to ensure all personnel are familiar with the procedures for dealing with fires and hot cylinders.

7.4 Storage – General requirements

7.4.1 Storage of calcium carbide

For additional information refer to EIGA Doc 196 *Calcium Carbide Storage and Handling* [32].

7.4.2 Storage of solvents

For additional information refer to EIGA Doc 225 [9].

7.4.3 Storage of cylinders

Only gas cylinders containing acetylene shall be stored in the dissolved acetylene filling area.

7.4.3.1 Storing acetylene cylinders

Acetylene cylinders may be stored inside or outside. Outdoor storage facilities are defined as those that are open on at least two sides. Outdoor facilities may also be open on one side only if the distance between the open side and the back wall does not exceed its height. A side of a room is also considered as being open if it consists of a wire grill or has a similar free area.

Acetylene cylinders should not be stored in the following locations:

- in rooms below ground level unless in use;
- in stairwells, corridors, enclosed yards;
- in passages and thoroughfares or in their immediate proximity;

- on steps;
- along specially marked escape routes;
- in garages where vehicles are parked; and
- in workrooms (workrooms do not include storage rooms, even if people are working there).

Acetylene cylinder storage areas shall be used exclusively for acetylene cylinder storage and shall not be used for gas transfer operations or for the maintenance of cylinders.

A risk assessment shall be performed for all acetylene cylinder storage areas. This shall determine:

- ventilation requirements for indoor storage;
- requirements for emergency water supplies for fire fighting and cylinder cooling;
- the required number of fire extinguishers;
- zoning requirements according to Directive 2014/34/EU (ATEX) [8];
- control of ignition sources;
- potential off-site risks to neighbouring properties and populations;
- potential risks from off-site exposures;
- the security of the store;
- the maximum number of acetylene cylinders permitted;
- the layout of the store and segregation requirements from other gas cylinders;
- access and emergency escape routes.

The storage area shall not be accessible to general traffic and unauthorised persons. Signs shall indicate this exclusion. Warning notices shall indicate the zones and the respective hazard (risk of explosion).

Flammable materials (for example flammable liquids, wood, wood chips, paper and rubber) shall not be stored in acetylene cylinder storage areas.

Due to the potential for a cascading fire amongst acetylene cylinders the maximum number of cylinders (empty or full) to be stored in any storage area should be kept to a minimum.

To reduce the risk of a cascading fire spreading from one storage area to another the minimum distance between the edge of acetylene storage areas is recommended to be at least 3 metres (NFPA 55, *Compressed gases and cryogenic fluids code*) [33]. This may be reduced (to nil) by provision of a one hour fire resistant partition of sufficient height and width to prevent the spread of fire.

7.4.3.2 Indoor storage

Acetylene cylinders should be stored outdoors.

If indoor storage cannot be avoided, the following shall apply:

- The walls, partitions and roofs of storage rooms shall be constructed of non-combustible materials. Separation walls shall be impervious and have a fire resistance of at least one hour.
- The floor covering in storage rooms shall be non-flammable and shall be level to ensure cylinders remain stable.
- Storage rooms shall be sufficiently ventilated at both high and low level (see 7.2.1).
- Emergency escape routes to the outside of the building from the store shall be provided. Escape routes from neighbouring rooms shall not pass through the storage room.
- There shall be no access or other open connections to cellar rooms.
- Storage rooms for acetylene cylinders that border onto a public transport route shall have on the side directly adjacent to the transport route a wall without doors or openings to a height of at least 2 metres. This does not apply to doors that are self-closing and fire-retardant.

- Separation shall be maintained between acetylene cylinders and cylinders containing oxidising gases.

7.4.3.3 Outdoor storage

For outdoor storage the following shall apply (or national requirements if more stringent):

- The floor area shall be flat and level such that the acetylene cylinders are stable.
- There shall be drainage to ensure cylinders do not stand in water;
- When filled acetylene cylinders are stored in the open, a distance shall be maintained to nearby systems and equipment (see 7.1.3);
- Smoking and sources of ignition are not permitted within three metres of the storage area.
- Controlled access of vehicles and forklift trucks is permitted;
- Acetylene cylinders shall not be stored closer than three metres from the boundary fence. (This distance can depend on national requirements). Where not possible to achieve the required distance, a three metre high, 1 hour fire-resistant wall shall be provided or in accordance with national requirements.
- Cylinders shall be stored so that they are protected from vehicle impact.

7.4.4 Storage of chemicals

Chemical storage can include: purification chemicals (such as sulphuric acid and sodium hydroxide), lubrication oils, drying agents (for example. molecular sieve, calcium chloride or silica gel).

The storage of chemicals related to the acetylene production process requires the following:

- Segregation of storage from acetylene cylinders and potential sources of fire.
- Spillage containment of fluids to contain the loss of the largest container stored.
- Availability of safety data sheets.
- Appropriate PPE.
- Safety showers and eyewash facilities where applicable.

7.5 Environmental requirements

Further guidance on environmental topics is available in the following publications:

- EIGA Doc 84, *Calculation of Air Emissions fron an Acetylene Plant* [34]
- EIGA Doc 85, *Noise Management for the Industrial Gas Industry* [35]
- EIGA Doc 88, *Good Environmental Management Practices for the Industrial Gas Industry* [36]
- EIGA Doc 106, *Environmental Issues Guide* [37]
- EIGA Doc 108, *Environmental Legislation apllicable to Industrial Gases Operations within the EU* [38]
- EIGA Doc 109, *Environmental Impacts of acetylene plants* [39],

8 Production

8.1 Acetylene Generators

For additional information refer to EIGA Doc 237 *Safe Operation of Acetylene Generator Systems* and EIGA Doc 239 *Mechanical Integrity of Acetylene Generator Systems in Acetylene Plants* [40, 41].

8.2 Purification and drying

For additional information refer to EIGA Doc 241 *Purification, Compression and Drying of Acetylene* [42]

8.2.1 Source of impurities

For additional information refer to EIGA Doc 240 *Commodity Specification Acetylene* [43]

8.2.2 Impurity removal equipment

For additional information refer to EIGA Doc 241 [42]

8.3 Handling and storage of carbide lime

8.3.1 General

Carbide lime is a co-product obtained from the reaction of water and calcium carbide in the generation of acetylene. It is also referred to as carbide slurry, generator slurry, lime slurry, sludge or lime hydrate.

8.3.2 Carbide lime processing and handling

Lime slurry from a “wet” generating process has an approximate solids content of between 10-12 %. As this is too dilute for economical shipment, the solids content may be increased by any of the following methods:

Decanting

Decanting systems are normally a series of inter-connected tanks, which receive the slurry from the acetylene generators as 10-12 % solids. The tanks are used to settle the solids, permitting removal of the excess water. As the solids settle to the bottom of the tanks, the water will accumulate on the top, thus by using a pump to add heavy lime from the bottom of one tank to the bottom of another tank, the water on the top of the receiving tank can be decanted to a water holding tank or holding pond for reuse. A consistency of 30-40 % solids content can be achieved, depending on the time available for the settling process.

Lime Ponds

Lime ponds shall be constructed according to local and environmental regulations. As carbide lime slurry is pumped into a pond from the generating process, the solids begin to settle with the clear water rising to the top. After prolonged settling, a solids content of 50 % or more can be obtained. The water from this process can be reused in the acetylene generators or alternatively, disposed of in accordance with local legislation. Lime in ponds with a high content of solid particles can give the impression that it is solid and stepping on the surface is dangerous because carbide lime is thixotropic.

Filtration

Lime slurry can be concentrated by a filter press usually consisting of a filter system with cloths and plates that typically operates at pressures of 8–14 bar. The solids are concentrated between the plates in block form and the water removed is reused for acetylene generation or treated and discarded. The higher the temperature, the better the filtration process and the lower the water content in the block. Lime blocks can be formed with as little as 15 % moisture by weight.

Mechanical Thickeners

Commercial operations have demonstrated that the slurry can be concentrated to up to 60 % solids in a centrifuge. Mechanical thickeners can obtain a concentration of approximately 40 % solids.

Drying

Diluted or concentrated slurry can be dried effectively by mixing it with quicklime (CaO). The surplus water in the carbide lime slurry slakes the quicklime so that the percent solids of the resultant mixture are appreciably increased, even to the extent of achieving a commercially dry hydrate. This is accomplished in a slurry tank with a manually controlled discharge, a quicklime feeder and a mixing tank or hydrator. The quicklime hydration develops considerable heat, which vaporises some of the water and the volatile impurities of carbide lime.

8.3.3 Transport

Semi-solid

At about 50 % or higher solids, the consistency of the carbide lime is that of a fairly firm putty which can be handled by power shovels of the clam shell or dipper type, or by scrapers or scoops operated from draglines. This material can be transported in watertight hopper body trucks, river barges, and by rail in hopper cars of the bulk cement type.

Slurry

Carbide lime of 20-40 % solids can be further concentrated to a putty firm enough for shovelling by settling, or by additional filtration to remove excess water. In the case of settled carbide lime, addition of water and agitation are required to produce slurry of uniform density. Agitation can be accomplished with a submerged jet of compressed air, steam, or high-pressure water applied through pipes or nozzles, or by portable equipment such as circulating pumps. Manually operated tools and power-driven rotating paddles can also be used effectively. Slurries of carbide lime containing up to 40 % solids can be pumped satisfactorily with centrifugal pumps. Transport of the low solids content slurries has been demonstrated to be possible.

8.3.4 Requirements

Calcium carbide lime shall be discharged to outdoor storage or other well-ventilated areas, at a safe distance from ignition sources (according to zoning requirements) and the line of adjoining property.

Calcium carbide lime pits should be fenced and sign-posted "NO SMOKING OR OPEN FLAMES", and Ex-sign as required by EU directive 1999/92, *Minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres* [41]. A risk assessment should be carried out regarding the presence of acetylene and the requirement for compliance with the ATEX directives for surrounding equipment, refer to EIGA Doc 134 [26].

For potential uses of carbide lime refer to EIGA Doc 143, *Guide to Carbide Lime Applications* [44].

8.4 Blowing Down Acetylene Cylinders

Introduction

“Blowing down” an acetylene cylinder is the removal of acetylene to partially or completely reduce the pressure in the cylinder. "Blowing down" is sometimes referred to as, blowing back, venting, emptying, or de-gassing.

Acetylene cylinders shall be blown down using a manifold specifically designed and approved for that purpose.

Where possible, the “blow back” acetylene should be re-used to minimise the environmental impact of the gas emissions.

A blow down manifold directed to an atmospheric vent shall be used for:

- acetylene cylinders whose contents are of unknown quality that can affect the process and quality of the final product if the acetylene is re-used;
- normalising the pressure to atmospheric conditions in an acetylene cylinder before it is de-valved where otherwise the system blow-down manifold restrictors or exit pressure would prevent complete pressure reduction.

When to blow down

Acetylene gas shall be released from cylinders in the following situations:

- when they are overfilled;
- before they can be examined internally;
- when the cylinder is defective or requires repair, e.g. leaking cylinder valves;
- to reduce cylinder pressure to the required parameter prior to filling and replenishing with solvent.

Cylinders containing different types of solvent shall not be blown down on the same rack at the same time due to potential cross contamination.

Blocked or broken valves

Acetylene cylinders with blocked or broken valves shall be blown down:

- under a permit-to-work (PTW) control, approved by the responsible person (for example. a manager or supervisor; or
- using an approved and risk assessed method statement and procedure; or
- one cylinder at a time, if the procedure involves freely venting acetylene (e.g. gradual valve or fusible plug loosening without a gas capture system); and
- only by competent personnel experienced and trained in the procedure.

Blow down manifold design considerations

The manifold pipework shall be designed and manufactured in accordance with 10.5 and 11 of this document.

The blow down manifold comprises a rack to which cylinders are connected. The system shall be designed to inherently restrict the flow rate of acetylene venting from the cylinder into the manifold and to ensure that the cylinders do not blow down too quickly. In the case of an atmospheric blow down manifold, blowing down the gas over a long period of time limits concentration of acetylene and dispersal of the gas as it exits the vent outlet. Where a manifold blows back gas to the low pressure side of the system, for example, a gasholder, the system shall be designed such that over-pressurisation and backflow does not take place.

Specific design considerations for atmospheric blow down manifolds

When designing atmospheric blow down manifolds, the following precautions should be considered to minimise the risk of ignition:

- restrict the flow rate into the vent stack to reduce the exit velocity and pressure within the stack to minimise jet effects from the vent stack;
- incorporate flame arrestors at appropriate points in the system;
- carry out atmospheric dispersion modelling of the gas as it exits the vent stack;
- ensure no sources of ignition are present within the defined boundaries of the dispersion model;
- install lightning protection appropriate for the site location;
- incorporate automatic shut off valves in the vent line so that blow down can be stopped in the event of an emergency, for example plant evacuation.

Blow down rate

Cylinders containing acetylene should not be blown down too quickly. This is because:

- the solvent is carried over with the acetylene, especially acetone;
- rapid blow down cools the inside of the cylinder and reduces the cylinder pressure and can result in a false empty indication. There could still be considerable amounts of gas in the cylinder which is released when the cylinder warms up again.

The blow down rate is controlled, e.g. by a pressure regulator or other flow restriction, in order to ensure the gas is completely withdrawn at an appropriate rate and to mitigate any potential adiabatic compression effects within the manifold.

Blow down period

The blow down period typically is similar to how long it takes to fill the cylinder on a conventional filling system (i.e. not a fast-filling system).

Large full cylinders normally take between 8 and 10 hours to blow down, depending upon the ambient temperature.

The blow down period varies with cylinder size and amount of returned gas. For example, it may be shortened for smaller cylinders or for cylinders containing very little residual gas.

Blowing down back to the low pressure part of the system only reduces the cylinder pressure to the operating pressure of the generator/gasholder. If the pressure needs to be reduced completely the cylinders should then be vented to atmosphere through the blow down system.

After the pressure has decayed, leave all cylinders on the blow down rack with their valves open until they are warmed to ambient temperature. During this time, do not add or remove any cylinders from the rack.

Temperature effects

If the temperature of the cylinder after blow down is lower than the ambient temperature where the valve is to be removed, there is a possibility of the cylinder warming up with a consequent pressure build-up. This can result in a further discharge of acetylene when the valve is removed. Therefore, the cylinder should be normalised on the atmospheric blow down manifold prior to removal of the valve.

9 Cylinders and fittings

Requirements for acetylene cylinders are laid down in the European Agreement on the Carriage of Dangerous goods (ADR). Cylinders for free movement within the European Union need to comply additionally with Council Directive 2010/35/EU, *Transportable Pressure Equipment Directive* [10].

Acetylene cylinder shells may be fabricated from welded steel, seamless steel or sometimes seamless aluminium alloy. For seamless aluminium alloys shells, as indicated in ISO 7866, whenever any exposure to heat is necessary, e.g. during porous material manufacturing, the resulting modification of the characteristics of the aluminium alloy used shall be considered when designing the shell.

The cylinders are filled with either a granular material (usually only on older cylinders) or a monolithic material. The acetylene is dissolved in a solvent, normally acetone or DMF, and the cylinders are equipped with a valve and a valve protection device (cap, cage or shroud), unless the valve meets certain impact criteria.

For specific applications there are a small number of solvent free cylinders.

9.1 Acetylene cylinder design

Acetylene cylinders are typically between 3 and 60 l water capacity. They are manufactured as seamless or welded cylinders.

For seamless steel shells see

ISO 9809-1, *Refillable seamless steel gas cylinders -- Design, construction and testing -- Part 1: Quenched and tempered steel cylinders with tensile strength less than 1 100 MPa* [45].

For welded steel shells see
EN 13322-1 *Transportable Gas cylinders Refillable welded steel gas cylinders – Design and construction* [46] or
or ISO 4706, *Gas cylinders – Refillable welded steel cylinders – Test pressures 60 bar and below* [47].

Some acetylene cylinders are equipped with fusible plugs. This could be required by their national legislation. The fusible plugs melt to relieve the cylinder contents if the cylinder becomes exposed to temperatures, typically above 107 °C (EN ISO 3807 [2]).

9.2 Acetylene cylinder bundle design

Cylinder bundles comprise a number of single cylinders, which are interconnected for simultaneous filling and discharging and are enclosed in a rigid frame for handling by crane and/or forklift.

For design, manufacture, identification and testing of cylinder bundles see EN ISO 10961, *Gas cylinders - Cylinder bundles - Design, manufacture, testing and inspection* [48].

9.3 Acetylene cylinder trailer design

Cylinder battery trailers comprise a number of acetylene cylinder bundles interconnected for simultaneous operation mounted onto a trailer chassis or a battery of single cylinders manifolded together comprising the entire trailer.

For design information refer to EN 13807, *Design of battery vehicles* [49].

For additional information see also CGA G-1.6, *Standard for Mobile Acetylene Trailer Systems* [50].

9.4 Porous material and solvent

The porous material holds a solvent (acetone or DMF), in which acetylene is dissolved under pressure.

The porous materials have porosity of up to 92 %.

Porous materials for acetylene cylinders and their filling parameters shall be tested and approved by a competent body. Test requirements and conditions are laid down in EN ISO 3807 [2].

Technical data for the porous material shall be provided by the acetylene cylinder manufacturer. A non-exhaustive list of porous materials can be found in TR 14473, *Transportable gas cylinders - Porous masses for acetylene cylinders* [51].

The filling parameters for the solvent charge in kg/l water capacity and the acetylene charge in kg/l water capacity ensures the safe use of the cylinder (a hydraulic pressure does not result from overfilling conditions) at a temperature of 65 °C, and protects against decomposition caused by a backfire (see ISO 3807 and EN ISO 11372, *Gas cylinders. Acetylene cylinders. Filling conditions and filling inspection* [2, 52]).

9.5 Filling conditions

For general information refer to EIGA Doc 26, *Permissible charge/filling conditions for acetylene cylinders* [53].

For filling conditions of:

- single acetylene cylinders, see EN ISO 11372 [52]

- acetylene cylinder bundles see EN 12755, *Transportable gas cylinders - Filling conditions for acetylene bundles* and ISO 13088, *Gas cylinders - Acetylene cylinder bundles - Filling conditions and filling inspection* [54, 55]
- acetylene battery trailers see EN 13720, *Battery vehicles – Design, manufacture, identification and testing* [56].

As acetylene cylinders are subject to marginal losses of solvent depending upon conditions during discharging, the solvent level shall need to be checked and could need to be replenished prior to being refilled with acetylene.

Acetylene bundles and trailers are disassembled for solvent replenishment if they have reached either the maximum specified solvent loss, or a predetermined number of uses whichever is the sooner as laid down in the bundle or trailer approval.

Bundles with acetone are typically solvent replenished after 6 fillings or with DMF after 100 fillings. In practice it depends on the operating conditions.

9.6 Maintenance and inspection

Acetylene cylinders can be subjected to wear and tear resulting from improper use and handling. As a result damage can occur to:

- cylinder shell and/or cylinder fittings,
- the porous material,
- cylinder bundle frames and their interconnecting pipe-work,
- cylinder foot-ring – for example corrosion between the foot-ring and sidewall of the cylinder.

The cylinder including all attachments needs to be inspected for integrity prior to every refilling (see chapter 10.3.1 for inspection requirements).

The cylinder shall be periodically inspected in accordance with the requirements specified in P200 of the European Agreement on the Carriage of Dangerous Goods (ADR), see 4.1.4.1 and 6.2.11.6 [10].

For requirements for the periodic inspection and maintenance of dissolved acetylene cylinders refer to EN ISO 10462, *Gas cylinders. Acetylene cylinders. Periodic inspection and maintenance* [57].

For requirements for the periodic inspection and maintenance of dissolved acetylene cylinder bundles refer to EN ISO 20475, *Gas cylinders. Cylinder Bundles. Periodic inspection and testing* [58]

For inspection and maintenance of cylinder valves refer to EN ISO 22434, *Transportable gas cylinders. Inspection and maintenance of cylinder valves* [59]

For dealing with blocked or inoperable valves refer to EIGA Doc 129, *Pressure receptacles with blocked or inoperable valves* [60].

For fitting of valves to acetylene cylinders refer to EN ISO 13341, *Gas cylinders – Fitting of valves to gas cylinders* [61]

(See also CGA C-13, *Guidelines for periodic visual inspection and requalification of acetylene cylinders* [62]).

9.7 Disposal of acetylene cylinders

Cylinders, that need to be disposed of, shall be treated in accordance with relevant national environmental legislation as they are classified as hazardous waste (No. 15.01.11 of the European Waste Catalogue) for their solvent and in some cases for their asbestos containing porous material, typically less than 1% of the total cylinder volume.

For guidelines for disposal of acetylene cylinders refer to EIGA Doc 05, *Guidelines for the management of waste acetylene cylinders* [63].

9.8 Acetylene cylinder valves

Acetylene cylinders valves have various outlet configurations in accordance with national regulations.

For specification, type testing and marking of acetylene cylinder valves refer to EN ISO 10297, *Transportable gas cylinders - Cylinder valves - Specification and type testing* [64].

π-marked cylinders require a π- marked valve for unrestricted EU use.

Manufacturing, test and examination of valves refer to EN ISO 14246, *Transportable gas cylinders - Gas cylinder valves - Manufacturing tests and inspections* [65].

Some cylinders may be equipped with residual pressure valves with non-return function (ISO 15996, *Gas cylinders – Residual pressure valves – General requirements and type testing*) or with a valve incorporating a pressure regulator (ISO 22435, *Gas cylinders – Cylinder valves with integrated pressure regulators – Specification and type testing*) [66, 67]. These valves shall only be repaired and refurbished by competent personnel trained in the repair of this type of valve.

9.9 Acetylene cylinder accessories

Acetylene cylinders valves shall be protected against impact damage. This can be achieved by valve design strength or by a valve protection cap or protection guard. For details see EN ISO 11117, *Gas cylinders. Valve protection caps and valve guards. Design, construction and tests* [68].

9.10 Acetylene cylinder identification

Requirements for cylinder identification are laid down in ADR [10] including:

- the approval marks:
- the necessary markings, which shall be metal stamped on the cylinder shoulder or on a permanently attached metal plate, at the time of manufacture:
- the necessary identification data, which shall be permanently shown on the cylinder by use of paint or labelling: and
- the precautionary labels for transportation

For colour coding refer to EN 1089-3, *Transportable gas cylinders – cylinder identification – colour coding* [69].

10 Filling

10.1 Compression/Compressors

For additional information refer to EIGA Doc 241 [42]

10.2 Acetylene heat exchangers, dryers and purifiers

For additional information refer to EIGA Doc 241 [42]

10.3 Solvent replenishment

10.3.1 Pre-fill inspection

To assure safe handling of cylinders in the filling plant and delivery of a safe product to customers, it is essential that all cylinders be inspected prior to replenishing with solvent and filling with acetylene. (Refer to EN ISO 11372 [52]).

Acetylene cylinders may only be replenished with solvent and filled with acetylene if:

- they are marked with the Notified Body's test stamp;
- the cylinders have not passed their due date for re-test;
- they do not show any external defects in the shell, the valve the guard and other fittings;
- the required stamp marking, label and colour coding data are present.

Cylinders that are not fit for service shall not be replenished with solvent and filled with acetylene but quarantined for further investigation. The following are examples of cylinders that shall not be directly replenished with solvent or filled with acetylene. Those:

- which cannot be clearly identified as being dissolved acetylene cylinders;
- with external defects (including arc strike, large dents or signs of fire on the shell, significant corrosion);
- with a loss of solvent of more than 10% of the nominal solvent quantity
  Site operations may find that it is easier for operators to understand this rule (10%) if it is expressed as follows:
    a) a maximum kg of solvent by cylinder type.
    b) a maximum kg of solvent per liter volume of the cylinder
  In this case, check of the cylinder shell integrity, especially looking for leaks in the bottom part (pinhole corrosion), shall be performed.
- with valves in inoperable condition (for example valve blocked, threads damaged,). In this case, the valve shall be replaced;
- returned from customers with open valves or without residual pressure; In this case, see 10.3.4
- whose inspection date (or retesting date for certain countries) is missing, illegible or has been exceeded. In this case, periodic inspection shall be performed (see EN ISO 10462 [57]);
- with missing or illegible regulatory identity or service markings (e.g. porous material name, solvent, tare, etc.);
- where filling is no longer authorised (withdrawn cylinders);
- with accessories that are in poor condition (cap, guard, foot ring, fusible plug,);
- which are unknown to the filling plant.

The filling plant procedures shall specifically indicate all of the cases where cylinders shall not be replenished directly.

Before filling it shall be checked that acetylene bundles and battery vehicles (including frame, cylinders and connections) are in a safe condition and have no visible defects.

It shall be verified that the bundle and battery-vehicle is permitted to be filled in the country of the filling station, that the bundle does not have an expired test date and, if applicable, the number of refills has not exceed the prescribed value. Further requirements are given in EN 12755 and EN 13720 [54, 56].

The documentation records for the battery vehicle and bundles shall be available at the filling station.

If the test date of the bundles and battery-vehicles has expired, a periodic inspection shall be performed.

10.3.2 Why is replenishing necessary?

All acetylene cylinders are designed and approved for a specified charge of acetylene; the quantity of gas is determined in relation to a nominal quantity of solvent. Complying with the approved ratio for the quantity of gas/nominal quantity of solvent is one of the conditions for the safe operation of the cylinder.

Excess solvent can result in a hydraulically full cylinder that, when subjected to a temperature increase, can develop extremely high internal pressures. An insufficient quantity of solvent will result in the cylinder becoming less resistant against decomposition due to flashback.

Solvent replenishing of acetylene cylinders is essential. This operation shall therefore be systematically carried out with care, before refilling cylinders with gas.

Each type of cylinder has a stamped tare weight (refer to 3 for tare weight definitions).

Prior to filling cylinders with acetylene, checks shall be made to ensure that the amount of solvent is within specified parameters, by comparing the weight of the cylinder returned by the customer with the tare weight marked on the cylinder. There are two methods to achieve this:

- Either
  - Empty the gas in the cylinder to the gasholder. In this case the cylinder's weight should correspond with the tare since it contains no gas (apart from the saturation gas). If it is less than the tare, additional solvent shall be added up to the tare. This method is often used in small capacity plants.
- Or
  - Determine the residual gas contained in the cylinder. In this case, the amount of residual gas is subtracted from the cylinder's measured weight. This weight difference subtracted from the cylinder tare weight represents the solvent loss/excess. Additional solvent will be added to the cylinder if the result thus obtained is less than the tare. This is the most common method used.

The latter replenishing technique enables top filling, i.e. the filling of cylinders while preserving the gas already in the cylinder.

Cylinders still indicating an excess of solvent could be contaminated and shall not be filled. They shall be put aside for investigation.

10.3.3 Loss of solvent

During use, an acetylene cylinder will lose some of its solvent for the following reasons:

- *The solvent's volatility*. Some solvent loss is normal. For acetone, in a country with a temperate climate, the average loss rate is approximately 60 g/kg of acetylene used. In the warm climate, the loss rate can increase to 100 g/kg of acetylene used.

  The volatility of acetone is greater than that of Dimethylformamide (DMF). Acetone is generally used for individual cylinders and DMF is used for cylinders in bundles and battery-vehicles.

  However, in some cases, individual cylinders may also use DMF for certain applications and acetone may be used for bundles (either for specific applications or where National Regulations forbid the use of DMF).

- *The so-called "spitting" phenomena.* Spitting occurs when solvent is expelled in liquid form when gas is withdrawn from the cylinder during use. Solvent spitting is not a normal phenomenon. It can be caused by an excessive withdrawal rate during use, defects in the porous material or excess solvent in the cylinder.

10.3.4 Replenishing principles

Before filling an acetylene cylinder, the weight of the solvent and acetylene present in the cylinder shall be determined with weight, pressure and temperature checks. For this purpose, information shall be provided to determine the weight of the acetylene present in the cylinder in relation to the pressure and temperature. This information can be presented in several forms for each cylinder size and type such as tables, diagrams or computer programmes.

The formulae in EN ISO 11372 may be used to determine residual gas content in relation to temperature and pressure [52]. It should not be used for cylinders with residual pressures higher than 6 barg because the formula is not accurate above this pressure.

Cylinders with residual gas

Two possibilities exist:

- Emptying to the gasholder or low pressure system (refer to 8.6). This procedure is available when a low-pressure type generator is used. Cylinder weight and pressure are checked (pressure shall always be verified using a pressure gauge but never by opening the cylinder's valve directly to the air because the gas can ignite) and they are then connected to a dedicated blow-down or emptying manifold for discharging to the gasholder or low pressure system for recovery of the gas. When cylinders are completely empty of gas their pressure is once again checked using a pressure gauge and they are re-weighed.
- Without emptying the cylinder

  This is generally the case, since customers usually return cylinders with residual gas pressure. Before filling a cylinder the solvent content shall be determined by calculating the residual gas from pressure and temperature. This residual quantity of gas shall be used to calculate the solvent shortage. Various techniques and systems such as tables, graphs or computer software are used to indicate the pressure, temperature and quantity of gas remaining in the cylinder for the cylinder's type.

  Acetylene cylinders need time to reach the equilibrium temperature. Additional settling time should be allowed, in particular if the temperature is very low and the pressure is very high.

  NOTE A cylinder returned by a customer with a residual gas pressure of 6 barg or greater may either be filled directly (in this case it is assumed that no solvent was lost). However, it is recommended that the cylinder is partially emptied to reduce its pressure below 6 barg to accurately measure the residual gas and solvent loss. The solvent can then be replenished to the appropriate level before refilling the cylinder with acetylene.

Cylinders without residual gas

A cylinder returned by a customer without residual gas shall be treated with care. Unless the customer has used all of the gas, it is likely that such cylinders have had their valves left open. These cylinders can contain air, which shall be removed before final acetylene filling.

Consequently, the cylinder shall not be replenished immediately if:

- It is returned to the plant with its valve open or without residual pressure
- There is a loss of solvent of more than 10% of the nominal solvent quantity.

In both of these cases, cylinders should undergo:

- Pre-fill with acetylene to 4 to 5 barg.
- Vented to atmosphere to remove possible contaminants.

- Pre-fill check including solvent replenishment and then filling with acetylene on normal fill process.

Cylinders for emptying to atmosphere shall be connected to a specific manifold vented to a safe area.

Special cases

If there is an apparent excess of solvent in the cylinder, it shall not be filled with acetylene. This can be determined if its tare is more than 100 g per kg of gas capacity above the stamped tare weight.

This excess weight indicates either excess solvent in the cylinder, and/or the presence of another liquid (for example water, oil or another solvent such as DMF). This will require the reason for the excess weight of the cylinder to be investigated.

Possible solutions include:

- Removal of acetone by a controlled method, e.g. heating and recovery of solvent followed by a tare check against original manufacturing data to confirm no liquid contaminants remain and then replenishment with solvent to the original weight
- Scrapping of the cylinder

10.3.5 Replenishing procedure

Individual cylinders

After performing the pre-fill inspection, (see 10.3.1) prior to replenishing with solvent and segregating cylinders that shall not be directly replenished. The following procedure should be observed:

- It is normally assumed that the cylinder's temperature is the same as the ambient temperature. However, if cylinders have been stored at high or very low temperatures, it is recommended that they be kept in the area where they will be replenished for sufficient time for the temperature of the cylinder and ambient area to equalise.
- Determine the amount of residual gas remaining in the cylinder taking into account the pressure and temperature of the gas. (see EN ISO 11372 [52]).
- Subtract the weight of acetylene remaining in the cylinder from the measured total weight of the cylinder.
- The result shall be subtracted from the stamped tare weight and the difference will be either:

    - Zero: the cylinder contains the correct amount of solvent
    - Positive (tare weight greater than result): it lacks solvent.
    - Negative (tare weight less than result): this means that there is either excess solvent, or there is another liquid in the cylinder.

- Add solvent, if necessary. If the manufacturer of the porous mass has determined a maximum replenishing pressure, this shall be followed.
- Weigh the cylinder again to check that the tare was correctly re-established.

    NOTE for cylinders equipped with a fixed valve protection, e.g. guard or shroud, this shall not be removed before replenishing if it is considered part of the tare weight)

Bundles and battery vehicles

The replenishing of cylinders mounted in bundles or battery vehicles requires a procedure different to that described for individual cylinders. It is not possible to ensure the correct replenishment of the solvent for each cylinder; therefore the bundles and battery vehicles shall not be collectively replenished but shall be dismantled prior to replenishing the individual cylinders with solvent. In order to avoid too frequent dismantling, a solvent tolerance is applied by reducing the acetylene charge. Further information is given in EN 12755 and EN 13720 [54, 56].

If the weight of the cylinder bundle or the battery-vehicle is less than the minimum tare weight specified after the residual acetylene weight has been deducted, the bundle or the battery vehicle shall be disassembled for solvent replenishment before filling with acetylene.

Solvent is added to each individual acetylene cylinder (refer to EN ISO 11372) up to the upper limit determined for the collective filling in the bundle (refer to EN 12755) or the battery vehicle (refer to EN 13720) [52, 54, 56]).

10.3.6 Equipment and raw materials

Scales

Scales shall be selected with a range suitable for the type of cylinder to be replenished (maximum load and accuracy) and to maintain safe filling conditions (Permissible Charge/Filling Conditions for Acetylene Cylinders - EIGA Doc 26 [53]).

For example, a scale should not be the same for a small cylinder type (5 litres) as for a large one (50 litres).

Small Cylinder	Medium Cylinder	Large Cylinder
volume =< 6l	Volume >6=<20l	volume >20l
Scale tolerance ±20g	Scale tolerance ±50g	Scale tolerance ±100g

Scales shall be checked daily before use with standard calibration weights. This may be a cylinder whose weight is known. It is not mandatory, but good practice to record this daily check. Additionally the scales should be calibrated annually by a person qualified to check for accuracy.

If the scale of the appropriate tolerance is not available, then the filling ratio shall be reduced to compensate for the increase in scale tolerance.

Solvents - General recommendations

For additional information refer to EIGA Doc 225 [9].

10.4 Acetylene cylinders filling

10.4.1 General

A cylinder, bundle or battery-vehicle shall be filled only if it has successfully passed the pre-fill inspection as specified in 10.3.1

It is necessary to take into account all the measurement uncertainties, which can occur due to the various accuracies of the filling equipment (for example, scales, pressure gauges, temperature measurement and replenishing method).

When placing acetylene cylinders on the filling manifold, precautions are required to avoid cross contamination of DMF and acetone. This can occur if cylinders containing acetone are blown down too rapidly on a manifold connected to the compressor suction line, which also may be used for filling cylinders containing DMF.

Contamination can occur if cylinders containing different types of solvent are filled on the same manifold. Consequently it is recommended to fill cylinders containing different types of solvents separately.

During and after filling, acetylene cylinders, cylinder bundles or battery vehicles shall be checked for leaks. The connections and the cylinder valves shall be tested, for example, by applying leak detection fluid, refer to EIGA doc 78, *Leak detection fluids* [70].

If a leak cannot be stopped immediately or if other faults are found on the cylinder, which could create a hazard, the cylinder shall be depressurised on an appropriate blow down system.

Cylinder valves shall be opened before actuating the valves of the charging manifold. At the end of the filling the cylinder valves shall not be closed before the valves of the charging manifold have been closed.

10.4.2 Cylinders cooling

During the filling of acetylene cylinders, the heat of solution of the acetylene in the solvent warms the cylinder and the pressure rises until the maximum charging pressure is reached before the cylinder has taken its full acetylene charge. This phenomenon is more important during the warmer months of the year when cylinder initial temperatures are high enough to affect the charging rate.

To dissipate the heat of solution and cool the cylinders, each charging rack (individual cylinders, bundles and battery-vehicles) may be fitted with cooling sprays. For a uniform charge, it is important that the spray evenly covers the cylinders on the same manifold. Otherwise, the warmer cylinders not covered by water will not charge as fast as those cooler cylinders covered by the sprays.

10.4.3 Other recommendations

Cylinders

Care shall be taken with cylinders having different porous materials or high amounts of residual gas. Cylinders should be sorted and connected to the manifold in the following order:

- type of porous material;
- size (water capacity);
- quantity of residual gas (pressure).

Bundles

The maximum number of fills before replenishment of solvent will depend on the type of solvent (acetone or DMF) and shall be determined for a bundle in accordance with EN 12755 [54]. Refer to 10.3.5.

Before filling bundles, it is necessary to verify that *all* the cylinder valves are open.

Each of the cylinders within the bundle shall be fitted with a valve. If there is a main valve on the bundle, the cylinder valves shall be left open during storage and shipping. The main valve on the bundle shall be closed.

If National regulations require individual cylinder valves to be closed after filling, sufficient time shall be allowed for pressure equilibrium to be reached before the valves are closed.

Battery-vehicles

The maximum number of fills before replenishment of solvent will depend on the type of solvent (acetone or DMF) and shall be determined for a battery-vehicle in accordance with EN 13720, also refer to 10.3.5. [56].

Before filling, it is necessary to verify that *all* the cylinders valves are open.

After filling, time shall be allowed to reach pressure equilibrium before closing the cylinder valves. The same rules for bundles shall be applied for the battery-vehicles concerning the position of the valves (closed or open).

It is recommended that a deluge system is installed over the battery vehicle filling area.

10.4.4 Inspection after filling

For inspection after filling, the requirements of EN ISO 11372 shall apply [52].

After individual cylinders or bundles have been filled they shall be weighed to determine the amount of acetylene. For battery vehicles a representative sample of cylinders can be selected for weighing. The maximum permissible charge of acetylene shall not be exceeded. This requirement is valid for the total weight of bundles and battery-vehicles.

When the total measured weight does not correspond to the specified values the following alternative actions shall be taken:

- If the receptacles do not reach their specified total weight, they shall be segregated and investigated before proceeding to be refilled or sent for inspection.
- If the receptacles are over-filled, they shall be blown down either to the gasholder or to the suction side of the compressors until the correct weight is achieved.

After filling the cylinder, including its valve, shall be leak tested. The valve protection cap if applicable shall be fitted. To allow sufficient time for the uniform distribution of acetylene across the entire cylinder, cylinders/bundles should not be placed in service until at least 12 hours after the end of filling; this is to ensure that the cylinder is within the safe working limits of the safe operating diagram. Refer to EIGA Doc 26 [53].

10.5 Manifold and piping system – Design code

10.5.1 General

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

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).

For the design code concerning the piping system (pipes in the working ranges I to III) or equipment including valves, connections, pressure gauge, hoses, see 11.

10.5.2 Flame arrestors and flashback arrestors

General

Acetylene is particularly sensitive to decomposition especially when it is very dry, and it only requires a very low level of energy to ignite and decompose. For these reasons, it is necessary to avoid sudden changes of direction of the gas flow (such as excessively tight bends) or any disturbance in the flow rate (for example a sudden change in diameter or particle entrainment). These disturbances or shocks could result in initiating a decomposition and detonation. These areas can also reflect a shock wave from a detonation. If the shock wave is reflected back to meet the original detonation then the effect of the shock is drastically amplified.

To prevent the transmission of any acetylene decomposition or detonation throughout the high- pressure pipework in an acetylene cylinder filling plant, flame arrestors shall be installed.

Flame arrestors or flashback arrestors are safety devices protecting the high-pressure part of filling stations from the hazards of acetylene decomposition. It is essential that the flame is quenched and the acetylene flow is cut off when decomposition occurs.

The most widely used method for testing the effectiveness of high-pressure acetylene flame arrestors is by means of a detonation produced in static acetylene at a pressure greater than the maximum working pressure for which the arrestor is designed.

In practice however, decomposition can occur in either static or flowing acetylene and may be either a deflagration or a detonation. Consequently, flame arrestors and flashback arrestors shall be effective under all these conditions. It has been shown that in flame arrestors which have been subjected to a decomposition produced in flowing acetylene the following occurs:

- In quenching the initial decomposition, the arrestor quenching medium absorbs the heat from the flame front and a hot area is produced in the quenching medium.
- Continued flow of acetylene over the hot area produces further decomposition and heating. This can lead to subsequent decompositions, which can be on the opposite side of the flame arrestor to that of the initial decomposition.
- Stopping the acetylene flow immediately after the initial decomposition can best prevent re-ignition.

Consequently:

- A flame arrestor shall either itself cut-off the flow or shall be used with a suitably positioned cut-off device.
- The flow cut-off shall be triggered automatically by the initial decomposition because the time before re-ignition occurs could be too short to permit manual operation. It is also possible that the initial decomposition will not be heard or seen.

Flame arrestors and flow cut-off devices may need to be tested under static conditions to prove their effectiveness (refer to EN ISO 15615 [17]). Several types of flame arrestor design exist, (aluminium packing, etc.). The device's two functions (flame arrestor and flow cut-off) may be incorporated in the same unit.

Requirements

A flame arrestor device that acts only as a flame arrestor will arrest the flame front generated by high pressure acetylene decomposition. But because the flow of acetylene has not been arrested, there is still a risk, from the hot area of further decomposition being initiated on the side of the flame arrestor not subjected to the initial decomposition. For this reason, it is recommended to install devices, which arrest *both* ignition and the gas flow on high-pressure acetylene lines.

A flame arrestor device shall meet the following requirements:

- Prevent decomposition in a high pressure pipe or pipe component passing through to the other parts of the pipework system.
- Pass the acetylene decomposition tests (at 6 bar and 25 bar) according to the procedure described in EN ISO 15615 [17].

These two requirements apply for all types of flame arrestors (those in high pressure acetylene lines and those equipped in manifold hose couplings).

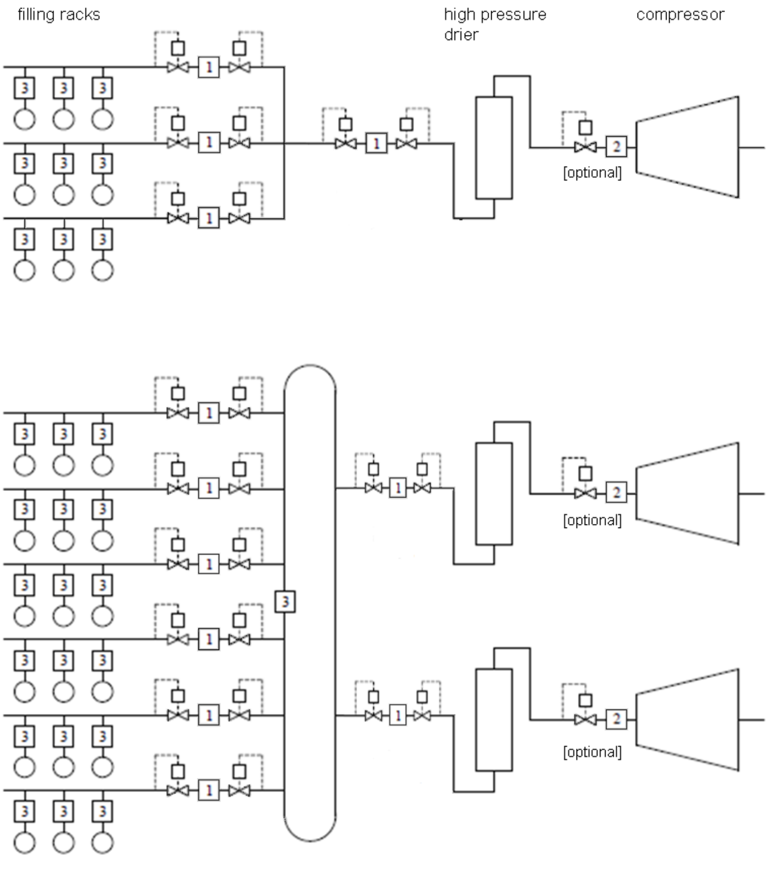
For the flame arrestor used to protect the main pipelines (or manifolds), the device shall also stop the gas flow (in both directions) in the event of a gas decomposition. The device shall be operated automatically by sensing the increase in the temperature, pressure or a combination of both.

10.5.3 Flame arrestors and flashback arrestors installation and use

Flame arrestors and flashback arrestors shall be positioned at the following locations (see Figure 4).

- A flashback arrestor between individual compressors and any system distribution valve manifold shall be installed in the downstream-pipework of the compressors taking into account the possibility of oil residues plugging the flashback arrestor.
- A flashback arrestor providing protection against decomposition from either side is installed at the inlet to each charging rack immediately before or after the isolation valve for any individual filling manifold distribution pipe (cylinders, bundles or battery-vehicles) and also on the main lines.
- A flame arrestor on the manifolds at each connection point for filling cylinders. In this case, it is not necessary to have a cut-off device system. There should also be a non-return valve fitted at each cylinder connection, to prevent reverse flow from one cylinder to another and also to minimise the leakage of gas in the event of a hose rupture or a major fire.
- It is recommended that flame arrestors or flashback arrestor be installed at charging rack outlets and in ring mains. When designing a cylinder filling installation the designer shall determine the number and location of additional flame arrestors with or without cut-off devices required to protect the plant.
- A flashback arrestor shall be fitted at each location where the acetylene pressure is dropped from high to low pressure, such as filling rack blowback points returning gas to the process. Flame arrestors shall not be installed in emergency vent pipes because gas should be vented freely without restriction under emergency situations.

Figure 3: Location of flame arrestors and flashback arrestors



1 – Flashback arrestor with cut-off devices providing protection against decomposition from either side.
2 – Flashback arrestors with cut-off device actuated from one side only providing protection against decomposition from that side.

3 – Flame arrestor (may be combined with a non-return valve).

For the correct positioning of flame arrestors and flashback arrestors in pipes, the manufacturers' recommendations shall be followed.

Specific requirements may exist for positioning the flame arrestors and flashback arrestors in pipes or on equipment, for example horizontally or vertically, downstream or upstream of the device.

10.5.4 Flashback arrestors for gasholders or customer supply pipelines using acetylene for further chemical treatment

For gasholders of greater than 100 m^3 capacity or customer supply pipelines using acetylene for further chemical treatment shall be equipped with flashback arrestors at the gas inlet and outlet point to stop any acetylene decomposition occurring.

The flashback arrestors shall be designed for the same test pressure as the associated pipework. Designated pipe sections or vessels could be used as a flashback arrestor if they contain a determined length of packing material. The length of packing depends on the operating pressure, the dimensions of the packing material and the operating conditions (dry or irrigated packing; NOTE: irrigated packing are considered more effective). The packing material shall be ring-shaped steel parts such as Raschig or Pall-rings.

Guidance for designing flashback arrestors with ring-shaped packings made from steel in acetylene pipelines which are operated for pipeline supply used for further chemical treatment of acetylene:

operating pressure [bar g]	maximum packing material size [mm](diameter × length)	minimum length of effective trip section [m]	
		dry	wet
<= 0,2	10 × 10	1,5	1,0
	15 × 15	2,0	1,5
	25 × 25	5,0	4,0
> 0,2 up to 0,4	10 × 10	1,5	1,0
	15 × 15	2,5	2,0
	25 × 25	7,0	5,0
> 0,4 up to 0,7	10 × 10	1,5	1,0
	15 × 15	3,5	2,5
> 0,7 up to 1,0	10 × 10	2,0	1,0
	15 × 15	4,5	3,0
> 1,0 up to 1,5	10 × 10	2,5	2,0
	15 × 15	(not allowed)	5,0

In pipelines with a nominal diameter >100 mm and an operating pressure >0,4 bar g the flashback arrestor shall be connected to the pipeline diagonally; the free ends of the pipeline shall be equipped with burst discs. The same design conditions shall be applied if the nominal diameter of the pipeline is less than 100 mm and the operating pressure exceeds the pressure figures shown in the following table:

Nominal pipe diameter (mm)	Max. operating pressure (barg)
90	0,7
80	0,8
70	0,9

60	1,1
50	1,5
40	1,7
30	2,1
25	2,5
20	2,9
15	3,6
10	4,7

If the operating pressure of any pipeline is higher than 0,4 barg the pipeline shall include remotely operated cut-off devices to interrupt the gas flow in case of decomposition.

10.5.5 Pressure gauges

The design of pressure gauges shall be in compliance with the requirements stated in chapter 6.

10.5.6 Flexible hoses

All types of flexible hoses for high pressure acetylene shall withstand a decomposition test at 25 bar with acetylene and their bursting pressure shall be 1000 bar minimum. For all the other requirements, refer to EN ISO 14113 and EN 12115 [14, 15].

10.5.7 Non return valves

At filling stations, a non-return valve shall be installed at the connection to each individual cylinder on the manifold, preferably at the cylinder end of the hose, to prevent back flow of gases from the acetylene cylinder.

11 Pipework

The design of acetylene pipelines described in this chapter is based upon the work of H.B. Sargent (Chemical Engineering, 1957/2 pp.250-254).

The design considerations apply to acetylene pipelines having a maximum working pressure not exceeding 25 bar gauge and are typically installed in acetylene cylinder filling plants and supply systems for welding, brazing, cutting and allied processes.

11.1 Working ranges

Working Ranges are defined in this Document (see 11.1.2) which are related to the type of hazard under certain conditions determined by pressure, internal pipe diameter and pre-detonation distance.

11.1.1 Deflagration limit pressure and detonation limit pressure

The publication by H.B. Sargent summarises the results of a large number of studies on ignition of acetylene and the progress of the decomposition as deflagration or detonation. One of the graphs published by H.B. Sargent has been used as the basis of the diagram for this Code of Practice. The two lines in the diagram indicate the *deflagration limit pressure (line A)* and the *detonation limit pressure (line B)* as a function of the inside diameter of the pipe.

In acetylene pipelines whose operating conditions lie in the area below line A it is possible for acetylene decomposition to be initiated, but this can occur only under conditions of unusually high ignition energy.

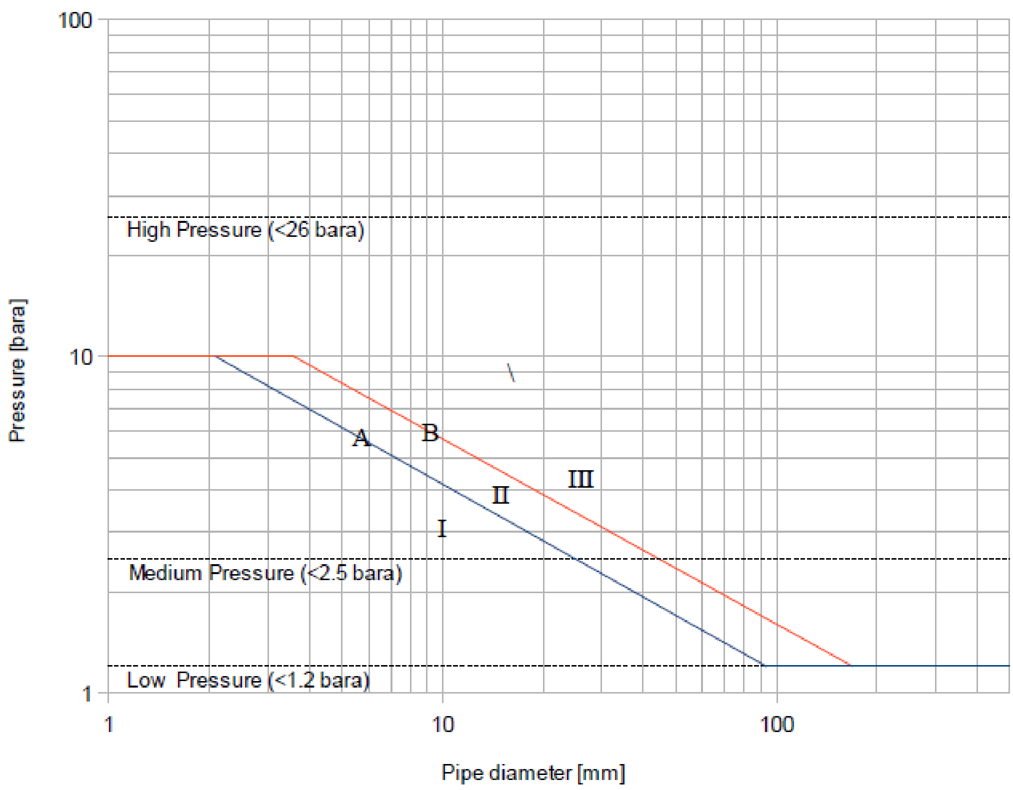
If the operating conditions in an acetylene line are located on the line A, or between line A and line B, the action of even moderate ignition energy upon the gas can lead to acetylene decomposition which is propagated along the pipeline in the form of a deflagration. Line A marks the pressure limit as a function of pipe diameter from which initiation of acetylene decomposition and its propagation in the form of deflagration shall be considered possible.

11.1.2 Definition of working ranges

The lines A and B on the diagram thus demarcate three ranges over the entire area of the diagram. The ranges are designated "Working Ranges" which correspond to the following stages with regard to hazard arising from acetylene decomposition:

- *Working Range I*: Below line A, $d_i < (15.1 / P_{abs})^{1.79212}$. Acetylene decomposition hazard is slight.
- *Working Range II:* On and above line A but below line B. On ignition, acetylene decomposition in the form of deflagration can occur.
- *Working Range III:* On and above line B, $d_i < (20.2 / P_{abs})^{1.8181}$. On ignition, acetylene decomposition will start as a deflagration; in sufficiently long pipelines transition to detonation may occur.

Figure 4: Working Ranges according to Sargent



On the basis of the maximum gas pressure and the maximum pipeline diameter occurring in a part of an installation, a particular "working point" on the diagram will correspond to the operating conditions occurring in that part. The position of this point on the diagram will place that part in one of the three Working Ranges.

11.1.3 Methods of determining the working ranges

Determination by means of diagram

According to 11.1.2 and the diagram the internal diameter of the pipe and the maximum gas pressure will place any pipeline into one of the three Working Ranges.

Determination by means of experimental data or practical experience

Where experimental data or practical experience – such as that gained with national regulations – are available, these may be used for determining the Working Ranges of a pipeline.

11.1.4 Classification into working ranges

Where the acetylene (battery system) installation consists of more than a single pipeline of uniform diameter throughout, the following rules apply:

- Equipment directly connected to the pipeline e.g. pressure regulators, shut-off valves, withdrawal points will normally be classified into the same Working Range as the pipeline. However, in some cases it is possible for the equipment to fall into a different Working Range because of its dimensions in relation to the working pressure.
- In Working Range III a minimum distance is required for an ignition to develop into a detonation, which is known as the pre-detonation distance. If the gas chamber is shorter than the pre-detonation distance, a decomposition will proceed as a deflagration not a detonation. In such cases, the pipeline can be classified as being in Working Range II. However, it is rare that a pipeline is shorter than the pre-detonation distance. This Code of Practice does not deal in detail with the pre-detonation distance.
- For a pipeline system comprising sections with different internal diameters working at the same maximum gas pressure, the Working Range derived for the part with the maximum internal diameter is valid for all sections, unless flame arrestors are fitted to separate it into sections with different Working Ranges.
- In the case of a system consisting of sections working at different maximum gas pressures, all of it shall be in the higher Working Range, unless the equipment causing the difference in pressure does itself prevent the transmission of an ignition, or alternatively a flame arrestor is fitted between the sections.

  If one of these conditions is met separate Working Ranges upstream and downstream of the equipment causing the difference in pressure are to be defined according to the rules given above.

11.2 Materials

11.2.1 Recommended material

Steel is recommended as the material for acetylene pipelines. Pipe materials other than steel, e.g. other metals, metal alloys, plastics, may only be used in the construction of acetylene pipelines if it has been proved that they are suitable for the operating conditions and compatible with acetylene and other relevant media, such as acid and lye in the purifier (see 6.2).

When selecting the material for a pipeline it shall withstand not only the stresses at maximum operating pressure but also, especially in the case of pipelines in Working Ranges II and III, the thermal and mechanical stresses occurring in case of acetylene decomposition.

If carbon steels are used, they shall conform to the specifications given in Table 9.

Table 7: Carbon Steels Recommended as Materials for Acetylene Pipelines

Working Range	Tensile Strength R_m (N/mm^2)	Elongation after Fracture A_5 (%)
I	see 11.4.1	

II and III	$R_m \geq 320$	$A_5 \geq 8400/R_m$ but not less than 17

Generally materials which are subject to ageing or brittle fracture are not suitable, particularly for Working Ranges II and III.

When austenitic stainless steel is used potential corrosion by chlorides is to be considered, normally applicable in case of calcium chloride drying.

Environmental conditions that can accelerate corrosion such as shipyard supplies in coastal areas with salty environmental air shall be taken into account.

For welded pipelines the materials chosen shall have suitable welding characteristics.

11.2.2 Materials not allowed or recommended only under certain conditions

Restrictions and conditions stated in 6.2 shall be followed.

For fittings, valve housings and similar components the ferrous materials marked “+” in Table 10 may be used. Where “0” is entered in the table the material is not suitable unless measures such as design, material quality, testing are taken to ensure its suitability.

These materials are of limited use in new acetylene plant designs and this information is included for historical reference only.

Table 8: Other ferrous materials

Material	For Use in Working Range		
	I	II	III
Grey cast iron	+	0	0
Malleable cast iron	+	0	0
Spheroidal graphite cast iron	+	+	0
Wrought iron	+	+	+

11.3 Pipe specification

Pipes for Working Ranges II and III made of steels according to 11.2.1 shall be seamless. The pipes shall be tested in accordance with the specifications or standard to which they are manufactured.

11.4 Wall thickness

In this section the calculation of the wall thickness of pipes made of metals and metal alloys as recommended in 11.2 will be described as necessary due to the classification of the pipeline or section of it into a Working Range. The classification into the Working Range is described in 11.1. The wall thickness calculations do not consider external loads such as fatigue, additional mechanical and/or thermal loads, allowance for corrosion factors.

The requirement for additional wall thickness for corrosion and external loading shall be considered taking into account factors such as environment and piping material and incorporated if required.

If welded pipes (as described in 11.3) with a weld factor (f_w) below 1 are used, the method of calculation of the wall thickness shall be modified to include the weld factor in the respective wall thickness formula. For example: $e_{corrected} = e / f_w$

For Working Range II and III the calculation will be based on a "Dimensioning Pressure" derived from the maximum operating pressure by taking into account the rise in pressure occurring in case of deflagration/detonation.

11.4.1 Pipelines in Working Range I

The dimensioning pressure *P* shall be defined as twice the maximum working gauge pressure P_w.

The required wall thickness may be calculated according to recognised (national) pipework design standards such as EN 13480-3, *Metallic industrial piping - Part 3: Design and calculation*, section 6.1 [71]

$$e = \frac{p_c * D_o}{2 * f * z + p_c}$$

where:

e = minimum wall thickness (mm)

p_c = “calculation pressure” (N/mm² or MPa)

D_o = outer diameter of pipe (mm)

f = min $\left\{\frac{R_{eH\,t}}{1,5} \; or \; \frac{R_{p0,2\,t}}{1,5}; \frac{R_m}{2,4}\right\}$, nominal design stress for non-austenitic steels“ (N/mm² or MPa); see EN 13480-3, section 5.2.1.1 [71]

z = joint coefficient (see EN 13480-3, section 4.5 [71])

11.4.2 Pipelines in Working Range II

The wall thickness of acetylene pipes used for installations in Working Range II shall be designed to enable the line to withstand an acetylene decomposition occurring as a deflagration.

To calculate the minimum wall thickness of the pipes use the formula as per Working Range I but with a calculation pressure of:

$$p_c = 11 * (p_w + 1) - 1$$

where:

$p_w = maximum\ allowed\ working\ pressure$

Alternatively pipelines in Working Range II may be designed by means of acetylene decomposition tests; see 11.4.3.

11.4.3 Pipelines for Working Range III

Pipelines or sections of pipelines for Working Range III shall be designed to withstand detonation.

Pipelines in Working Range III may be designed either by calculation of wall thickness or by means of decomposition tests.

Calculation of wall thickness

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 can be sharp bends, valves, and closed ends of pipes. There are two methods of designing a pipe system falling in Working Range III based upon calculated wall thickness of the pipe that may be used:

Designing the whole system to withstand reflection occurring at any point:

To calculate the minimum wall thicknesses of the pipes use the formula as per Working Range I but with a calculation pressure of:

$$p_c = 35 * (p_w + 1) - 1$$

where:

$p_w = maximum\ allowed\ working\ pressure$

Designing of straight parts of the line to withstand undisturbed detonation; increased wall thickness at places where reflection is to be expected:

The wall thickness of the pipes is calculated as per Working Range I but with a calculation pressure of:

$$p_c = 20 * (p_w + 1) - 1$$

where:

$p_w = maximum\ allowed\ working\ pressure$

Pipes in high-pressure systems (1,5 barg < p <= 25 bar) with wall thickness calculated in this way may be used only for straight parts of the line. Pipe bends with a bending radius of 5 times the internal diameter of the pipe or more may be considered as straight lines if the strength of the bent pipe is comparable to that of the straight pipe. Reduction in wall thickness will still occur on these bends and a thinning allowance should be included in the wall thickness calculations for good engineering practice. Examples of this are included in as recommended by ASME B31.1 Table1-2.4.5 when calculating pipe wall thickness.

Reinforcement of the wall thickness shall be employed at points of reflection for example blind ends, tees, valves and bends with bending radius of less than 5 times the internal diameter (sharp bends). The reinforcements shall increase the total wall thickness to at least twice the calculated wall thickness. In the case of blind ends and sharp bends the reinforcements shall cover a pipe length at least equal to 3 times the internal diameter of the pipe. Where a point of reflection is protected by a flame arrestor that is within the pre-detonation distance from the point of reflection, it is not necessary to apply reinforcements at that point.

There shall be no sudden change in the internal bore of the pipeline. Particular note of this shall be taken when designing the reinforcements.

Design by means of decomposition tests

In a part (or a model) of the pipeline to be built, acetylene decomposition is ignited at the maximum operating pressure of acetylene using a suitable ignition device. This method can only be used where the necessary facilities and experience with decomposition tests exist. The test set-up used shall be designed to reproduce the conditions which can be expected to occur in the actual pipeline on ignition, e.g. same pipe diameter, adequate length to allow deflagration/detonation to develop. The wall thickness of the pipe shall be proven to be adequate to withstand the stresses occurring in the tests without serious damage.

A suitable test facility is described in EN ISO 14113 [14].

11.5 Connections

Fully butt-welded connections are preferred.

Welds on pipelines should, if possible, be located at places where the minimum bending stresses occur. Welding of joints shall be carried out to a recognised welding standard.

For Working Ranges II and III the couplings shall be of the same calculated strength as the pipeline to which they are fitted.

Non-welded connections are permitted if they are able to withstand the requirements of the working range.

When pipes in Working Range III are connected together at two or more points so as to form one or more ring mains, each ring main shall be protected by a flame arrestor (ref. 10.5.2) unless the pipe is dimensioned in accordance with 11.4.

Standard engineering pipe couplings may be used for Working Range I.

11.6 Valves and seals

The strength of a valve assembly shall be at least equivalent to the calculated strength of the pipeline in which it is installed. If the manufacturer's test pressure of the valve is known, the following formula may be used to calculate the maximum permissible working pressure:

Working Range II: $$P_t = \frac{11(P_w + 1) - 1}{1{,}1}$$

Working Range III: $$P_t = \frac{20(P_w + 1) - 1}{1{,}1}$$

where:

P_t = minimum testing pressure (absolute) of the valve (bar)

P_W = maximum allowed working pressure (absolute) (bar)

Valve suitability for working ranges II and III may also be verified by performing detonation testing according to the requirements of EN ISO 15615 [17].

For Working Ranges II and III, the design of the valve or the method of installation shall be such as to minimise the risk of ignition due to friction.

Filters may be used to eliminate the possibility of dirt getting into the valve seat.

Seals or packing shall comply with 6.2.

11.7 Pressure Testing

11.7.1 General

Testing shall be carried out to the appropriate test pressure given in 11.7.2. The system may be tested as a complete assembly or alternatively each section may be tested separately.

Components that have been verified as appropriate for the working ranges, for example valves, flash back arrestors, pressure gauges by detonation testing according to the requirements of EN ISO 15615 which contain soft seals that may be damaged by the pipework pressure test should be removed for the pressure test and replaced by spool pieces [17]. Specific parts may require separate testing or test methods. If parts are tested separately, it shall be ensured that all connecting elements are included in the tests.

Strength test of high pressure pipework should be carried out hydraulically. Where a pneumatic test is carried out precautions shall be taken to prevent injury to personnel or property damage in the event of a failure. A certificate shall be issued to document the results of the tests.

11.7.2 Test pressures

The following test pressures apply to those parts designed in accordance with 11.4:

Table 9:Test pressure vs. Working range

Working range	Test pressure
I	P_{test} = 1.5 P_w, bar, min 3,75 bar
II	P_{test} = 10 P_w, bar, min 20 bar
III	P_{test} = 20 P_w, bar, min 30 bar, max 300 bar

NOTE For DN50 pipes P_{test} is 24bar if used below 1.5 bar (medium pressure)

P_{test} = test pressure and P_w = max. working pressure

11.7.3 Leak test

Leak testing following final assembly shall be carried out with an inert gas or air at a pressure not less than the maximum working pressure.

Leakage can be detected using a commercial leak test solution, see EIGA Doc 78 [70]. Avoid detergent solutions that contain ammonia or other components that can initiate stress corrosion cracking. Leak tightness can also be checked by observing if there is decay in the pressure.

11.8 Dimensions and design

11.8.1 Manufacture

Where breakable connections are used to join pipes, (for example to remove equipment for maintenance), these shall be suitable for the working ranges. Where gaskets are used, they shall be compatible with acetylene and any solvents. All breakable connections shall be gas tight.

Where pipes are welded, this shall be in accordance with a recognised piping design code. All materials used in the welding process shall follow the welding procedure. The installation shall minimise piping stresses.

Welding work shall be carried out by competent welders who have valid certification for the type of welding work concerned.

Piping (pipe to pipe or pipe to fitting joints) shall be fully welded as far as is practicable; flanged, union or screwed connections shall only be used for accessories or to enable dismantling of the system for maintenance purposes.

Butt-welding is preferred for all joints.

In the case of pipes that are installed above ground screwed assemblies can be used that have an O-ring seal or screw bushings or screw bushings with adhesive and filling materials based on cyanoacrylate, silicone and PTFE as sealants. Pipe elbows in detonation-resistant high-pressure lines shall have an average radius of at least five times the inside diameter of the pipe.

All sealing material shall be resistant against acetone and DMF.

Pipes shall be protected against external corrosion.

A suitable protective paint is generally sufficient for pipes installed above ground or in accessible ducts. Sites where the pipes touch or are supported shall be protected against corrosion.

Pipes that pass-through walls or ceilings should be installed in a suitable protective metallic or plastic pipe.

11.9 General guidelines for underground pipes

Joints in underground pipes shall be fully welded (avoiding thread connections or flanges). Buried piping shall be sufficiently protected against corrosion, either by cathodic protection or passively by a high-quality pipe sheath with a high insulating resistance and appropriate mechanical strength (e.g. polyethylene sheathing or wound sheathing).

The above also applies to pipes that are installed in non-accessible ducts embedded in sand.

If the use of cathodic corrosion protection is not feasible for technical reasons (for example in factories where other pipes or electrical cables are installed in the ground near to the pipe conveying acetylene) or if the section of the pipe installed underground is shorter than 50 m, the pipe sheathing should be periodically checked using an insulation test device (test voltage for polyethylene sheath is 20 kV). Ensure the pipeline earthing system is intact before the test, to avoid arcing.

NOTE The above is general guidance and a specialist in underground piping should be consulted for all installations involving underground acetylene pipes

11.9.1 Equipment

Drainage

Pipes for wet acetylene, which can be subject to condensation of water shall be fitted with drainage facilities at the lowest points to protect against freezing.

Pressure monitoring

Piping shall be fitted with pressure indicators to monitor the operating pressure of the system. The maximum permissible pressure shall be marked on the indicator.

Pressure limiting equipment

Piping systems in acetylene plants shall be fitted with a pressure-limiting device, e.g. a pressure relief valve. It can be part of a generator, gasholder, and compressor. Pressure regulators shall be equipped with a separate pressure relief valve sized to accommodate the full flow rate of the regulator under failure conditions.

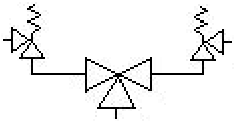
Isolation valves

Isolation valves shall be fitted to all gas withdrawal points.

Taper plug valves and ball valves should not be used in medium or high-pressure piping unless especially designed to prevent adiabatic compression leading to decomposition (e.g. slow opening device).

Isolation valves shall be readily accessible and easy to operate.

Pressure relief valves shall not be fitted with isolation valves. Three way change over valves are permitted on the inlets of duplex valve systems. (See example below)



Pressure relief valve discharge pipes (discharging to atmosphere) shall not be connected together in a manifold

Closing ends of pipes without connected equipment

Ends of pipes (including unused branch lines) without connected equipment shall be closed by means of threaded caps, threaded plugs or blind flanges. Isolation valves alone - except for sample points - are not sufficient.

11.10 Installation

General requirements

The design and installation of pipelines shall take into account the expected thermal expansion, for example, omega loops, expansion bellows (low pressure only).

If pipelines are installed near other pipelines the distance shall be such that any necessary maintenance and repair work is possible without risk to other pipelines.

Pipelines shall not be used as earthing conductors. The pipelines should be kept at a suitable distance (e.g. 50 mm in the case of 220 V power cables) from electrical installations.

Pipelines shall be protected against excessive external heating during operation, for example from steam pipes.

If possible, pipelines should be installed above ground and be accessible for inspection and maintenance.

Off-site pipelines should be installed above ground. If this is not possible such as for long distance pipelines, then they shall be installed underground in suitable ducts.

It is not permissible to install underground or buried pipelines inside buildings.

Pipelines inside buildings shall be installed above ground or in ducts.

Pipelines shall not pass-through inaccessible rooms (e.g. through ventilation ducts or lift shafts).

Penetrations through firewalls or fire-resistant ceilings and through walls and ceilings separating hazardous zones shall be sealed with a gas tight device.

Pipelines should not be installed in concrete or brickwork. However, if a pipeline has to be installed in concrete or brickwork due to existing building layout (for example to cross beneath a crane path) a sleeve shall protect the pipeline.

Pipelines installed above ground

Pipelines installed above ground shall be securely fixed to prevent uncontrolled movement and protection against impact damage and shall be identified by colour coding or labelling.

Pipelines in accessible ducts

Pipelines should only be installed in ducts if:

- the ducts have a headroom of at least 1.5 m;
- the ducts are constantly well ventilated;
- the pipelines can be installed so that they are easily accessible, and
- the pipelines are protected against water.

Pipelines in accessible ducts shall be identified by colour coding or labelling.

Pipelines in non-accessible ducts

Pipelines shall only be installed in non-accessible ducts if the pipes are fully welded. Any necessary cut-off devices or other fittings shall be installed in access pits.

Non-accessible ducts shall be filled with sand.

Buried pipelines in the ground

Buried pipelines shall be supported along their entire length and shall be protected against possible external damage. This requirement is generally fulfilled when the infill covering is at least 0.60 m. The infill covering should not be less than 1 m for long distance pipelines.

In areas where construction work is to be expected, a warning tape made of a durable material, e.g. plastic, shall be installed. The tape should be installed at a distance of approx. 0.30 m above the pipeline.

Buried pipelines shall be installed so that the insulation is not damaged and there is a distance of at least 0.50 m from public supply lines or the safety of the supply lines is guaranteed by some other means.

To prepare the base and fill the trenches, sand or other such filler material shall be used that does not contain any sharp objects (e.g. stones, or slag), foreign matter or aggressive substances. Supports used as installation aids shall be removed.

The route of the buried pipelines shall be documented on the site drawings and shall be marked at the site.

Vent pipes

Vent pipes shall be installed and secured so that they are capable of withstanding all anticipated vent and wind loadings.

Vent pipes shall be protected so that rain and foreign matter cannot enter.

All acetylene vents should be piped to a safe location away from ignition sources. Areas around acetylene vents should be kept unobstructed and a safe distance from ignition sources. Reference EIGA Doc 134 [26].

Vent pipes should not emerge below openings into buildings (for example windows).

11.11 Operation

Before start-up, the pipelines shall be checked to ensure that they comply with the requirements of this Code of Practice. These checks shall ensure compliance to the installation specification including all strength and leak tests. A hydraulic pressure test is required for pipelines intended for a maximum working pressure of more than 0.5 barg.

In acetylene pipelines the pressure up to the withdrawal point should not fall below the value of 5 mbar gauge. There shall be instructions and/or instruments to ensure that all consumers connected to the network stop operation if gas pressure falls below 5 mbarg.

Refer to 10.1.3 for the operation of high-pressure pipelines that are supplied from compressors at ambient temperatures of less than 10 °C.

When several gas pipelines are supplying a common line, protection should be applied to avoid backflow because of different source pressures.

Pipelines shall be periodically checked for leaks (e.g. by using a suitable ammonia free leak detection fluid or by use of a gas detection unit, refer to EIGA Doc 78) and for mechanical integrity according to the specific requirements for each type of installation [70].

There shall be a specific mechanical integrity program for buried or inaccessible piping.

Maintenance tasks on pipelines shall be carried out by competent persons only, following a risk assessment for the task and applying procedures such as work permit, logout/tagout, hot work and hand back procedures and documentation where applicable, refer to EIGA Document 40 [21].

Maintenance tasks can require the pipeline to be vented and purged with an inert gas. The minimum requirements in case of hot work are:

- Isolation of acetylene source;
- Depressurization and purge with an inert gas, and
- Flammable gas atmosphere monitoring with an acetylene gas detector, for example acetylene in nitrogen gas detector.

12 Acetylene supply systems at customer premises

For additional information refer to EIGA Doc 212, *Acetylene installations at customer site* [72].

12.1 Storage and handling

12.1.1 Storing acetylene cylinders

Refer to 7.4.2

12.1.2 Handling of acetylene cylinders

Depending on the quantity of product, the transportation of acetylene cylinders could be subject to the Carriage of Dangerous Goods Regulations (ADR), which the supplier can advise upon [10].

Acetylene cylinders should be transported in the supplier's vehicle. If using private transport, it is strongly recommended that an open or well-ventilated vehicle is used, refer to EIGA SL 08, Safe transport of Gases [73].

Do not transport acetylene cylinders in an unventilated vehicle or unventilated compartment within the vehicle, because small leaks can create explosive atmospheres.

Always follow no smoking requirements.

Always close cylinder valves during transport: acetylene cylinders are never completely empty because acetylene is dissolved in the solvent and residual acetylene remains, even if there is no more flow/pressure when the valve is open.

Ensure that any valve protection is in place and that regulators and other equipment are disconnected from the cylinder before transport.

Cylinders shall not be lifted by the valve protection device or valve, unless they are specifically designed for that purpose.

Only lifting equipment that does not cause damage to the acetylene cylinder and prevents the acetylene cylinder falling or dropping shall be used.

Always ensure that gas cylinders are fixed and secured for transport, preferably in the vertical position and separated from the driver's compartment.

Acetylene cylinders shall not be subjected to violent impacts to prevent damage to the cylinder and its valve.

Acetylene cylinders shall not be transported together with other flammable loads such as wood chips or paper.

When the destination is reached, remove any cylinder(s) from the vehicle. Do not store cylinder(s) inside any vehicle.

13 Operational response

For additional information refer to EIGA Doc 231, *Response to Operational issues in Acetylene Plants* [74].

14 Standards and Legislation

14.1 Seveso Directive

It shall be noted that the storage of acetylene above 5 tonnes in Europe requires that the establishment is subject to the provisions of the Seveso Directive 2012/18/EU (lower tier) with in particular the obligation to notify the competent authority and to establish a Major Accident Prevention Policy [75]. If the storage of acetylene is above 50 tonnes (upper tier) there are additional requirements and in particular to produce a Safety Report. Also the storage of calcium carbide and solvents (acetone and DMF) is subject to limitations. In addition, if in an establishment there are other dangerous substances in one or more installations (for example oxygen storage), it shall be checked by the application of the addition rule of Annex I of the Seveso Directive: it is possible that an establishment where the storage of acetylene is under the limits of 5 or 50 tons but other dangerous substances are present, may be promoted to be subjected to the application of the Seveso directive or to switch from the lower tier to the upper tier. Reference shall be made to the EIGA doc 60, *Prevention of Major Accidents* [76].

15 References

Unless otherwise specified, the latest edition shall apply

[1]	EN ISO 14114, *Gas welding equipment – Acetylene manifold systems for welding, cutting and allied processes – General requirements,* www.iso.org
[2]	EN ISO 3807, *Cylinders for acetylene — Basic requirements and type testing*, www.iso.org
[3]	EIGA Doc 23, *Safety Training of Employees*, www.eiga.eu
[4]	EIGA Doc 51, *Management of change*, www.eiga.eu
[5]	S A Miller, Properties of Acetylene, Volume 2
[6]	Directive 2006/42/EC of the European Parliament and of the Council of 17th May 2006 on the approximation of the laws of the Member States relating to machinery, eur-lex.europa.eu
[7]	Directive 2014/68/EU of the European Parliament and of the Council of 15 May 2014 on the harmonisation of the laws of the Member States relating to the making available on the market of pressure equipment, eur-lex.europa.eu
[8]	Directive 2014/34/EU of the European Parliament and of the Council of 26 February 2014 on the harmonisation of the laws of the Member States relating to equipment and protective systems intended for use in potentially explosive atmospheres (ATEX), eur-lex.europa.eu
[9]	EIGA Doc 225*, Solvents for Acetylene Filling*, www.eiga.eu
[10]	Directive 2010/35/EC of the European Parliament of 16 June 2010 on transportable pressure equipment, eur-lex.europa.eu
[11]	ISO 11114-1 *Gas cylinders – Compatibility of cylinder and valve materials with gas contents – Part 1: Metallic materials,* www.iso.org
[12]	EN ISO 9539, *Materials for equipment used in gas welding, cutting and allied processes,* www.iso.org
[13]	EN ISO 7291, *Gas welding equipment – Pressure regulators for manifold systems used in welding, cutting and allied processes up to 300 bar,* www.iso.org

[14]	EN ISO 14113, *Gas welding equipment – Rubber and plastic hoses assembled for compressed or liquefied gases up to a maximum design pressure of 450 bar,* www.iso.org
[15]	EN 12115*, Rubber and thermoplastics hoses and hose assemblies for liquid or gaseous chemicals. Specification*, www.cen.eu
[16]	EN 837-1, *Pressure gauges,* www.cen.eu
[17]	EN ISO 15615, *Gas welding equipment – Acetylene manifold systems for welding, cutting and allied processes, and safety requirements in high-pressure devices*, www.iso.org
[18]	EIGA Doc 136, *Selection of personal protective equipment,* www.eiga.eu
[19]	EIGA SL 06, *Life Saving Rules Brochure,* www.eiga.eu
[20]	EIGA SL 07, *Life Saving Rules Poster,* www.eiga.eu
[21]	EIGA Doc 40, *Work permit systems*, www.eiga.eu
[22]	NFPA 51A, *Standard for acetylene cylinder charging plants,* www.nfpa.org
[23]	NFPA 77, *Recommended practices on static electricity,* www.nfpa.org
[24]	IEC60079-32-1 *Explosive Atmospheres – Part 32-1: Electrostatic hazards, Guidance,* www.iecex.com
[25]	EIGA Doc 75, *Determination of safety distances,* www.eiga.eu
[26]	EIGA Doc 134, *Potentially explosive atmospheres*, www.eiga.eu
[27]	EN 1755, *Safety of industrial trucks – Operation in potentially explosive atmospheres – Use in flammable gas, vapour, mist and dust,* www.cen.eu
[28]	EIGA SAC NL 76, *Risk of generating static electricity when using CO2 as an inerting agent,* www.eiga.eu
[29]	BS 5306, *Code of practice for fire extinguishing installations and equipment,* www.bsigroup.com
[30]	NFPA 15, *Standard for water spray fixed systems for fire protection,* www.nfpa.org
[31]	EN 12845, *Fixed fire fighting installations: Automatic sprinkler systems, Design installation and maintenance,* www.cen.eu
[32]	EIGA Doc 196*, Calcium Carbide Storage and Handling,* www.eiga.eu
[33]	NFPA 55, *Compressed gases and cryogenics fluids code,* www.nfpa.org
[34]	EIGA Doc 84*, Calculation of air emmissions from an acetylene plant,* www.eiga.eu
[35]	EIGA Doc 85, *Noise Management for the Industrial Gas Industry,* www.eiga.eu
[36]	EIGA Doc 88*, Good Environmental Management Practices for the Industrial Gas Industry,* www.eiga.eu
[37]	EIGA Doc 106, *Environmental Issues Guide,* www.eiga.eu
[38]	EIGA Doc 108*, Environmental Legislation apllicable to Industrail Gases Operations within the EU,* www.eiga.eu
[39]	EIGA Doc 109, *Environmental impacts of acetylene plants,* www.eiga.eu
[40]	EIGA Doc 237 *Safe Operation of Acetylene Generator Systems*
[41]	EIGA Doc 239 *Mechanical Integrity of Acetylene Generator Systems in Acetylene Plants*
[42]	EIGA Doc 241 *Purification, Compression and Drying of Acetylene*
[43]	EIGA Doc 240 *Commodity Specification Acetylene*
[44]	EIGA Doc 143, *Guide to Carbide Lime Applications,* www.eiga.eu

[45]	ISO 9809-1, *Refillable seamless steel gas cylinders -- Design, construction and testing -- Part 1: Quenched and tempered steel cylinders with tensile strength less than 1 100 MPa*, www.iso.org
[46]	EN 13322-1, *Transportable Gas cylinders Refillable welded steel gas cylinders – Design and construction*, www.cen.eu
[47]	ISO 4706, *Gas cylinders – Refillable welded steel cylinders – Test pressures 60 bar and below*, www.iso.org
[48]	EN ISO 10961, *Gas cylinders. Cylinder bundles. Design, manufacture, testing and inspection*, www.iso.org
[49]	EN 13807, *Design of battery vehicles*, www.cen.eu
[50]	CGA G-1.6, *Standard for Mobile Acetylene Trailer Systems,* www.cganet.com
[51]	TR 14473, *Transportable gas cylinders - Porous masses for acetylene cylinders,* www.cen.eu
[52]	EN ISO 11372, *Gas cylinders. Acetylene cylinders. Filling conditions and filling inspection*, www.iso.org
[53]	EIGA Doc 26, *Permissible charge/filling conditions for acetylene cylinders,* www.eiga.eu
[54]	EN 12755, *Transportable gas cylinders - Filling conditions for acetylene bundles,* www.cen.eu
[55]	ISO 13088, *Gas cylinders - Acetylene cylinder bundles - Filling conditions and filling inspection*, www.iso.org
[56]	EN 13720,*Battery vehicles – Design, manufacture, identification and testing,* www.cen.eu
[57]	EN ISO 10462, *Gas cylinders. Acetylene cylinders. Periodic inspection and maintenance,* www.iso.org
[58]	EN ISO 20475, *Gas cylinders. Cylinder Bundles. Periodic inspection and testing,* www.iso.org
[59]	EN ISO 22434, *Transportable gas cylinders. Inspection and maintenance of cylinder valves*, www.iso.org
[60]	EIGA Doc 129, *Pressure receptacles with blocked or inoperable valves,* www.eiga.eu
[61]	EN ISO 13341, *Gas cylinders – Fitting of valves to gas cylinders*, www.iso.org
[62]	CGA C-13, *Guidelines for periodic visual inspection and requalification of acetylene cylinders*, https://www.cganet.com/
[63]	EIGA Doc 05, *Guidelines for the management of waste acetylene cylinders*, www.eiga.eu
[64]	EN ISO 10297, *Transportable gas cylinders - Cylinder valves - Specification and type testing*, www.iso.org
[65]	EN ISO 14246, *Transportable gas cylinders - Gas cylinder valves - Manufacturing tests and inspections*, www.iso.org
[66]	ISO 15996, *Gas cylinders – Residual pressure valves – General requirements and type testing*, www.iso.org
[67]	ISO 22435, *Gas cylinders – Cylinder valves with integrated pressure regulators – Specification and type testing*, www.iso.org
[68]	EN ISO 11117, *Gas cylinders. Valve protection caps and valve guards. Design, construction and tests*, www.iso.org
[69]	EN 1089-3, *Transportable gas cylinders – cylinder identification – colour coding,* www.cen.eu
[70]	EIGA Doc 78, *Leak detection fluids*, www.eiga.eu

[71]	EN 13480-3, *Metallic industrial piping - Part 3: Design and calculation,* www.cen.eu
[72]	EIGA Doc 212, *Acetylene installations at customer site*, www.eiga.eu
[73]	EIGA SL 08, *Safe transport of Gases*, www.eiga.eu
[74]	EIGA Doc 231, *Response to Operational issues in Acetylene Plants,* www.eiga.eu
[75]	Council Directive 2012/18/EU of the European parliament and of the Council of 4th July 2012 on the control of major-accident hazards involving dangerous substances, amending and subsequently repealing Council Directive 96/82/EC – Seveso, eur-lex.europa.eu
[76]	EIGA Doc 60*, Prevention of Major Accidents,* www.eiga.eu