AIGA

CODE OF PRACTICE
ACETYLENE

AIGA 022/05

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KEYWORDS

- ACETYLENE
- CALCIUM CARBIDE
- PIPING SYSTEM
- SAFETY
- STORAGE

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1 Introduction

This publication was originally compiled by the European Industrial Gases Association (EIGA) to meet the knowledge and harmonisation requirements for safety in acetylene production, operations filling and handling. The document has been reviewed by an Asian Industrial Gases Association (AIGA) work group and has been amended only to aid understanding

The document incorporates the combined knowledge of the acetylene experts within the European and Asian industrial gas industry.

Many of the references within the document refer to European Union legislation and IGC codes. These references have been left in, as there are currently no equivalent pan Asian references.

Most of these documents can be found on Internet and provide additional explanation in their respective areas

Legal requirements in country may vary from this code so operators must ensure these legal requirements are met.

2 Scope

The document covers the basic requirements for the safe and correct design and maintenance of an acetylene plant. The document does not relate to any particular design or construction of an acetylene plant. The contents are not intended to replace existing manufacturers and company instructions but they should be used in conjunction with such instructions.

This standard shall apply to plants that are engaged in the generation of acetylene from calcium carbide and/or the compression of acetylene and in the charging of acetylene cylinders.

An existing plant that is not in strict compliance with the provisions of this standard shall be permitted to continue operations provided that it does not constitute an unacceptable risk to life or health or adjoining property.

3 Definitions and regulations

3.1 General definitions

shall

Verbal form to indicate a requirement strictly to be followed

shall not

Verbal form to indicate a prohibition

should

Verbal form to indicate a preferred course of action

should not

Verbal form to indicate a deprecated course of action

may

Verbal form to indicate a permissible course of action

need not

Verbal form to indicate that a course of action is not required

can

Verbal form to indicate a possible course of action

cannot

Verbal form to indicate an impossible course of action

3.2 Specific definitions

Acetylene cylinder bundle

System of normally not more than 16 cylinders attached to each other and inter-connected by pipes on their high-pressure side and which can be transported as an inseparable unit.

Acetylene plant

Plant in which acetylene is generated from calcium carbide and/or compressed into acetylene cylinders

-**Acetylene generator**

Plant in which acetylene is generated from calcium carbide

-**Acetylene gasholder**

Device for storing the acetylene produced before cylinder filling.

-Acetylene heat exchangers or coolers

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

-**Acetylene dryer**

Device for decreasing the water vapour content of acetylene flowing through it

-**Acetylene purifier**

Device for reducing impurities of acetylene flowing through it

Acetylene filling plant

Plant in which acetylene is filled into acetylene cylinders

Acetylene compressor

An 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 compression including the safety equipment and other accessories required for the operation of the compressor.

Battery system

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

Battery vehicle

System of several cylinders or cylinder bundles connected on the high-pressure side for collective withdrawal, which is permanently fixed to a vehicle.

Deflagration

Explosion propagating at subsonic velocity

Detonation

Explosion propagating at supersonic velocity and characterised by a shock wave

Explosion

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

Flame arrestor

Device to stop a flame front in case of an acetylene decomposition

Flame arrestor with cut-off devices

Device to stop a flame front and the flow of gas in the case of an acetylene decomposition. This device may be activated either by a pressure shock wave or by a temperature sensing device.

Manifold system

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

PPE

Personal Protective Equipment: gloves, goggles, safety shoes, specific equipment (for acid, as example, etc.).

Pressure units

For clarity this document will use bar as the unit of pressure. If not stated otherwise, the pressure is given as overpressure or gauge pressure (in bar gauge). A bar is approximately 14.5 p.s.i. (pounds force per square inch).

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 exceeding 1.5 bar

-**High Pressure**

Pressure greater than 1.5 bar but not exceeding 25 bar

Residual gas

For Tare A or Tare F: the total amount of acetylene in a cylinder returned
For Tare S: the total amount of acetylene in a cylinder returned minus the saturation gas

Saturation gas

The amount of acetylene required saturating the solvent at atmospheric pressure and 15 °C

Solvent replenishment

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

Tare A

Sum of the weights of the empty cylinder shell, the porous mass, the specified solvent content, the valve and of all other parts permanently attached to the cylinder (e.g. clamps, guards, or nut bolt fixing)

Tare S

Tare A plus the weight of the saturation gas

Tare F

Tare A minus the weight of the solvent

Tare BA_{max}

Sum of the weights of Tare A of the acetylene cylinders in a bundle containing the specified maximum solvent content, the rigid frame and associated equipment

Tare BS_{max}

Sum of the weights of Tare S of the acetylene cylinders in a bundle containing the specified maximum solvent content, the rigid frame and associated equipment

Tare BA_{min}

Sum of the weights of Tare A of the acetylene cylinders in a bundle containing the specified minimum solvent content, the rigid frame and associated equipment

Tare BS_{min}

Sum of the weights of Tare S of the acetylene cylinders in a bundle containing the specified minimum solvent content, the rigid frame and associated equipment

Tare BF

Sum of the weights of Tare F of the acetylene cylinders in a bundle, the rigid frame and associated equipment

3.3 European and International regulations

Directive 2001/2/EC

Commission Directive 2001/2/EC of 4 January 2001 adapting to technical progress Council Directive 1999/36/EC on transportable pressure equipment

Directive 1999/92/EC

Directive 1999/92/EC of the European Parliament and of the Council of 16 December 1999 on minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres

Directive 1999/36/EC (TPED)

Council Directive 1999/36/EC of 29 April 1999 on transportable pressure equipment

Directive 98/37/EC

Directive 98/37/EC of the European Parliament and of the Council of 22 June 1998 on the approximation of the laws of the Member States relating to machinery

Directive 97/23/EC (PED)

Directive 97/23/EC of the European Parliament and of the Council of 29 May 1997 on the approximation of the laws of the Member States concerning pressure equipment

Directive 96/49/EC

Council Directive 96/49/EC of 23 July 1996 on the approximation of the laws of the Member States with regard to the transport of dangerous goods by rail

Directive 94/55/EC

Council Directive 94/55/EC of 21 November 1994 on the approximation of the laws of the Member States with regard to the transport of dangerous goods by road

Directive 94/9/EC (ATEX)

Directive 94/9/EC of the European Parliament and the Council of 23 March 1994 on the approximation of the laws of the Member States concerning equipment and protective systems intended for use in potentially explosive atmospheres

ADR

European Agreement concerning the International Carriage of Dangerous Goods by Road

RID

Regulations concerning the International Carriage of Dangerous Goods by Rail

UN Orange Book

Recommendations for the Transport of Dangerous Goods

4 General

4.1 Training of personnel

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

- 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
- PPE requirements
- Acetylene cylinder requirements and properties

Persons undergoing training shall be supervised by a competent person(s) when working in the acetylene plant. Further details can be found in IGC Doc/23/00.

4.2 Management of change

Acetylene plants are designed and constructed to very strict engineering standards. Changes to the plant or process can introduce serious hazards.

Any changes to the plant or the operational procedures shall be properly approved and validated by a competent person using formal Engineering Change Management procedures. Such procedures shall include validation of any changes to the plant or process using for example, techniques such as HAZOP (Hazard and Operability Study), Risk Assessment, FMEA (Failure Mode Effects Analysis) as appropriate. Further details can be found in IGC Doc 51/02.

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 38 % 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. The lower limit is 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 may decompose with explosive force. This may also occur at low pressure under certain conditions.

5.2 Physio-biological

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. Like most other gases, 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 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
Critical density	231	kg/m^3
Temperature at triple point	-80,6	°C
Pressure at triple point	1,282	Bar
Sublimation point (1,013 bar)	-83,8	°C
Vapour pressure of the liquid (0 °C)	26,7	Bar
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)	2.5 - 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.

Table 2: Solubility of acetylene in water in g/kg (reference: S A Miller: ACETYLENE Its properties Manufacture and Uses)

Temp. in °C	Acetylene partial pressure in bar						
	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: S.A Miller)

Temp. in °C	Acetylene partial pressure in bar								
	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: S.A. Miller)

Temp. in °C	Acetylene partial pressure in bar						
	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, the spontaneous reaction to elemental carbon and hydrogen, may 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 10 to 11 times initial pressure from the energy released by the reaction. Detonation of high-pressure acetylene may produce pressure peaks up to 50 times 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.

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.

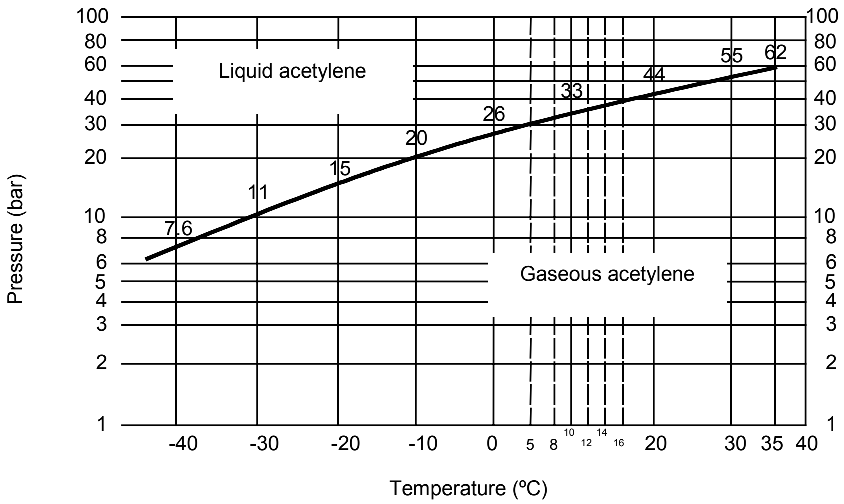
Once the process is started, heat is liberated and the reaction becomes self-sustaining above atmospheric pressure. This may lead to an explosive decomposition of acetylene into its elements, carbon and hydrogen.

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

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 1h below presents the vapour pressure curve for acetylene. Note that at low temperature operations, acetylene could liquefy.

Figure 1: Liquid acetylene formation

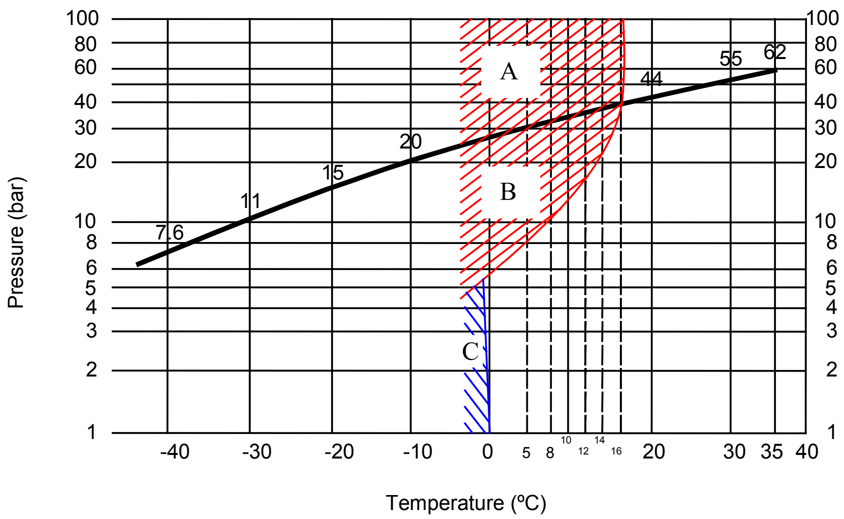


5.7 Acetylene hydrate

The acetylene hydrate $C_2H_2*5,75H_2O$ as an acetylene compound shall be considered in the acetylene condensation process. This 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 may be formed. Acetylene hydrate formation conditions are shown in figure 2.

Figure 2: Acetylene hydrate formation



A - Liquid acetylene + hydrate
B - Gaseous acetylene + hydrate
C - Gaseous acetylene + ice

To minimise the risk of hydrate formation, the following shall be considered.

- Working with wet acetylene in high pressure.
- Keeping the acetylene within the temperature conditions shown in the graph above.
- Rough surfaces that may 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 may form. These acetylides are highly sensitive to shock or friction.

See chapter 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 an acetylene decomposition. Acetylene alone cannot reach the ignition temperature but when mixed with other gases such as nitrogen or air, decomposition has been known to occur.

Decomposition in acetylene pipework and hoses arising from adiabatic compression of acetylene shall be considered. There have been a number of accidents when adiabatic compression has caused decomposition in acetylene bundle pipe work and hoses.

The presence of nitrogen or air in acetylene piping/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 precautions shall be considered:

- Prevent ingress of air in pipework and hoses for high-pressure acetylene i.e. when connecting cylinders to a manifold. This could be achieved using non-return valves, correct purging technique, etc.
- Use safety devices such as a flame arrestor to prevent the transmission of a 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 the Machinery Directive 89/392/EC, the Pressure Equipment Directive (PED) 97/23/EC and the Explosion Protection Directive (ATEX) Directive 94/9/EC.

Safety devices shall be provided on the system to ensure that pressures, temperatures, flow levels, etc are kept within safe limits.

The equipment should be designed, equipped, operated and maintained in such a way that during normal conditions of operation:-

- Air or oxygen entering the equipment is prevented.
- Under-pressure shall be eliminated to prevent the above.
- The air content does not exceed 2 % by vol. in acetylene containing parts.
- Air or acetylene/air mixtures shall be safely eliminated by purging, both before and after maintenance.
- Excessive rise of pressure and temperature shall be prevented.

6.2 Materials of construction

Materials of construction shall withstand the mechanical, chemical and thermal constraints that may appear during normal operating conditions. Materials shall not react with the substances with which they come into contact.

The materials should not cause adverse reactions with acetylene, solvents, carbide and other products generated from carbide.

Because acetylene may 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 acetylene plant for tools or equipment unless it has been demonstrated that the risk for electrostatic charging is eliminated.

Materials used in packing, sealing and membranes shall be resistant against acetone or other solvents used.

The materials in table 5 are not permitted for equipment in direct contact with acetylene:

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. Special 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.
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. Special 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 anti-corrosion protective coating
Glass	Should generally 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 it has been proved that they are sufficiently resistant against acetylene, solvents and impurities.

6.3 Cleaning

A high degree of cleaning or degreasing is normally not necessary in an acetylene plant. After construction work 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. i.e. nitrogen. The use of carbon dioxide is not recommended due to the risk of static electricity generated from droplets and dry ice particles.

It is also strongly recommended to carefully eliminate all debris that may be present in the piping system (dust, elastomer or welding residues, etc.) to avoid friction with the gas.

6.4 Valves, fittings, regulators, hoses and safety devices

6.4.1 Regulators

Regulators used shall comply with EN ISO 7291.

6.4.2 High pressure hoses

Hoses used shall comply with EN ISO 14113.

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

Special 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 it shall be taken in account that for protection against electrostatic, charging the resistance between the two end-couplings should not exceed 10^6 ohm.

6.4.3 Pressure relief devices

Acetylene escaping from the pressure relief devices should be discharged outside the building into the open air in a place involving no risk using devices designed for this purpose. Such devices should be designed to ensure that there is no risk of them becoming accidentally choked and that their proper operation can be easily verified. All discharge pipes or orifices to the open air shall be designed and made in such a way as to avoid choking or obstruction that may affect the normal operation or safety or the apparatus they are protecting. Connecting pressure relief device discharge pipes to a manifold should be avoided.

6.4.4 Flame arrestors

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

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

See also Chapter 10.5.2.

6.4.5 Pressure sensors and indicators

Pressure sensors and indicators shall be constructed with a sensing element of steel, steel alloy or alloy 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:

- Fitted with a 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.
- Pressure sensors and indicators should be protected by a flame arrestor.

Pressure indicators shall be in compliance with EN 837-1

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 shall only be used in low and medium pressure applications up to and including 75 mm pipe size.

Flanged or welding-neck valves are generally recommended.

The strength of valves and pipework fittings shall be consistent with that of the other components in the system.

High pressure valves should comply with the requirements of EN ISO 15615.

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.

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

6.5 Operating procedures and maintenance

The operation of a plant for the production and filling of acetylene shall be entrusted to competent persons trained and assessed in the hazards, handling and maintenance of the products and equipment.

A planned preventative maintenance program shall be in place all equipment is kept in good working condition

Correct tools and equipment should be used (spark proof). The work should comply with maintenance schedules from the suppliers of equipment. Correct spare parts and approved material shall be used.

6.6 Cleaning, maintenance and repairs

During these operations, three phases exist: purging, repairing (or cleaning) and restarting of the installation. The responsible person shall be present during all major operations.

6.6.1 General

- All equipment shall be regularly maintained and kept in good working condition.
- The system shall not be modified and components shall not be removed or modified (electrical or mechanical equipment, flexible hoses, safety devices, lubricant, etc.), without proper risk assessment and authorisation. See IGC Doc 51/02.
- Refer to the Manufacturer's Manual and the Plant Acetylene System Process and Instrumentation Diagram (P&ID) where necessary.
- Wear appropriate personal protective equipment (PPE). For example, safety shoes, gloves, goggles, flame-retardant clothing, etc.
- The work should comply with maintenance schedules specified by the equipment manufacturers and the Pressure Equipment Directive (PED).
- Regularly check the plant and equipment at appropriate intervals (daily, weekly, annually, etc.). For example to verify that :
  - The safety devices are operating correctly (e.g. non-return valves for safety against backflow of gas, safety valves, etc.).
  - The plant is in good order, is being used correctly and all the required equipment is fitted,

  - The pigtails and flexible hoses are not damaged.
  - The valves open and close correctly and the system is operating within normal parameters (i.e. report 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.
  - Setting and operation of regulators are satisfactory.
  - External finish of pipes and their protection against corrosion is acceptable.
  - Etc.
- Strictly follow the procedures stated by the equipment manufacturer. For example:
  - Operate the generator until all carbide is consumed (carbide in the generator and hoppers).
  - Allow the compressor(s) to run until the low suction pressure switch stops it.
  - Stop the machinery and leave in a safe state.
  - turn off and lock-out all machine electrical power, protection barriers, physical disconnection etc.
  - Close any shut-off valves if fitted.
  - Cool down and purge the equipment (generator, for example).
  - Remove the lime sludge from the generator.
  - Replace the water in the gasholder with fresh water.
  - Etc.
- Only spare parts recommended by the manufacturer, approved materials and procedures shall be used.
- Whenever actions are to be taken beyond described working procedures, a working permit is required (see IGC Doc 40/02). This permit shall mention all the requirements necessary to perform the work in safe conditions (procedures, emergency response, protective personal equipment, fire fighting equipment, etc.). All the requirements given in the permit shall be followed. A work permit shall be prepared in the following instances for example:
  - Non-routine work: replacement or modification of the piping system, new design or equipment, welding or cutting, etc.
  - Maintenance/cleaning in a confined space
  - Removal and service of equipment (gasholder, compressor, generator, etc.).
  - Etc.
- When emptying the water in acetylene carrying equipment (gasholder or generator, etc.) the water shall be discharged to a safe place (lime pit) where the dissolved acetylene can disperse rather than it being run directly into a sewer while still saturated with acetylene. Do not discharge this water into the sewer or town drainage system.
- Before maintenance is started all equipment shall be depressurised and adequately 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 and strictly followed (gas flow, duration, number of cycles, etc.).
- Take all necessary precautions against ignition and provide good ventilation during purging operations for as long as there is a <u>possibility</u> of an air-acetylene mixture existing. Open windows and doors where available.
- The atmosphere inside the equipment shall be controlled to:

  - prevent an explosive atmosphere. Test the atmosphere with a combustible gas detector (explosimeter). It is recommended to continuously monitor the atmosphere while work is being undertaken. Explosimeters are intended to detect combustible gases in an air atmosphere and is the only service in which they should be used. Attempts to test for a combustible gas in an atmosphere low in oxygen may give unreliable readings;
  - verify with an oxygen meter that the level of oxygen inside equipment to be entered is within safe limits for breathing before entry.
- All the equipment used to measure the atmosphere (explosimeter and oxygenometer) shall be maintained and kept in good working condition. Periodic inspection of this equipment shall be carried out. Explosimeters shall be specifically calibrated for acetylene.
- The gas purge shall be directed outside of the local working area to a safe location.

6.6.2 Return to service

After maintenance, cleaning, and repair operations and before returning to service, precautions shall be taken to be sure that the installation is in good working condition.

For example:

- Verify that there are no residues inside the equipment: solid particles (metal, plastics) which can lead to friction and a risk of ignition within the piping system.
- Activate the instrument air/nitrogen supply.
- Open all doors and windows in the working area.
- Pressurise the equipment or the installation to normal working pressure with nitrogen.
- Perform hydraulic test for new equipment (pipes, etc.).
- Check leaks with products designed for that purpose. Perform leak tests at the maximum operating pressure. Vent all pressure prior to repairing any leaks found because it is not recommended to repair leaks still under pressure.
- Purge adequately with nitrogen (not use carbon dioxide) and then analyse the atmosphere inside the equipment.
- Remove locks/tags and activate the power.
- Cancel the Hazardous Work Permit.
- Follow all operational purge requirements specified by the equipment manufacturers.
- Restart the equipment

7 Facility safety requirements

7.1 Site and buildings

7.1.1 Location of plant

Acetylene plant and buildings shall be located at a safe distance from public rights-of-way and from lines of adjoining property that can be built upon. This distance shall be determined by a detailed risk assessment that considers both the on and off-site hazards. The minimum distance specified in chapter 7.1.3 shall not be tolerated unless validated by risk assessment.

Acetylene plants shall be separated from other gas production and cylinder filling operations according to the relative risk assessed. They should not be located on sites containing Air Separation Plants due to the high risk of escaping acetylene entering the air intake of such plants.

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.

Acetylene generating or cylinder filling plant shall not have floors above or basements below their areas. 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 0.12 bar. The design shall be of a construction to limit damage in the event of an explosion. An explosion venting area of at least 0.05 m^2 per m^3 of room volume is required. A lightweight blow-off roof is preferred, supported by walls able to resist an internal explosion.

Buildings or rooms housing acetylene operations shall have readily accessible exit doors opening outwards. There shall be at least two escape exit routes. Exits should be located so that it will 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.

All acetylene plants shall be provided with appropriate 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.

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 etc.

Heating equipment should be of ducted hot air, steam or hot water types.

The location of such rooms shall be in accordance with the zoning requirements as determined under the regulations (See Directive 1999/92/EC)

Rooms containing electrical equipment and wiring not conforming to the above shall be separated from acetylene operations by an un-pierced wall, sealed against the passage of gas. 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 pipework during operation. Alternatively, suitable controls shall be in place to prevent operation of the plant under climatic conditions likely to create acetylene hydrate formation.

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

The emergency stop shall shut down all:

- compressors
- generator drives (carbide feed)
- pumps
- remotely actuated valves on acetylene pipes to a fail 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

7.1.3 Separation distances

IGC Doc 75/01 gives methodologies for calculating separation distances according to risk. These methodologies require a specialist to apply but may be used to justify deviations from the norm.

Buildings housing acetylene operations shall not be used for any other type of product storage filling of handling. The separation distance between acetylene plant and other operations shall be determined according to a risk assessment process.

Portions of plants housing acetylene operations shall be separated by un-pierced walls (proofed against the penetration of gas) from other portions of the buildings that do not meet the provisions of this standard applicable to acetylene operation. Separation walls shall be constructed of non-combustible or limited combustible materials and have a fire resistance of at least 1 hour. All supporting structures in the plant shall have a fire resistance of at least 1 hour.

Gasholders may be located outside or inside the plant building. Where located inside the building, ventilation shall be able to safely handle the occasional release 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.

The following table gives guidance on separation distances that need to be considered. The values given are indicative and subject to a proper risk assessment of the plant. These distances may not be reduced unless a careful process of quantified risk assessment is applied and appropriate risk control measures are put in place.

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

7.2 Explosion prevention

7.2.1 Ventilation/gas detection requirements

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 (mechanical ventilation). Natural ventilation requires at least $1m^2$ roof and $1m^2$ lower wall ventilation for each 300 m^2 of floor area. When the roof is flat and un-peaked, the roof opening shall be at either the higher end of the roof or in the wall at the higher end of the roof. Natural ventilation is heavily dependent upon local meteorological conditions and the above figure for ventilation openings may have to be greatly 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 shall be located at high levels and set to alarm at 25 % of the lower explosive limit (LEL) and to shut the plant down at 50 % LEL.

Acetylene sensors should be installed in the cylinder filling rooms and examination areas.

The location of these sensors should be decided by assessing the most likely sources of release and then taking the advice of the instrument manufacturer 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 94/9/EC.

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 watches are permitted.

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

New mechanical equipment, protective systems, etc. intended for use in potentially explosive areas shall be Ex- and CE marked according to the European Directive 99/92. Equipment already on the market must be risk assessed by the operating company before 1 July 2006.

7.2.3 Use of forklift trucks

Standard forklift trucks (FLT) possess the potential to generate sparks which could ignite acetylene gas present in the atmosphere in which they are taken.

The use of forklift trucks in acetylene plant areas shall take account of the FLT electrical systems and the potential for equipment ,hot-spots.

The movements of FLT’s to be considered are:

- 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.

Some of the above movements are outside of the classified zones and in this case, a standard FLT may be used.

If any FLT is required to enter a classified zone then it should be a flameproof truck suitable for the zonal requirements according to the ATEX Directive. Manual as well as self-propelled fork lift trucks used in potentially explosive areas shall comply with EN 1755 and corresponding sub-standards.

7.3 Fire protection systems

7.3.1 Fire extinguishers

CO_2 extinguishers are not recommended for flammable gas fires due to the risk of static electricity generation, for further information see EIGA SAG NL 76/02.

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

- calcium carbide store exits;
- generator room exits;
- inside gas-holder and purifier room exits;
- compressor room exits;
- cylinder examination room exits;
- acetone (or 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 including filter press areas;
- cylinder filling and preparation area for small fires (e.g. ignition occurring when a cylinder valve is slightly open).

7.3.2 Deluge systems

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 such systems.

- BS 5306 (UK)
- NFPA 51A (USA)
- NFPA 15 (USA)

It is recommended that specialist advice be sought when specifying a design. However, the contents of this code will provide the basic requirements for a specialist fire equipment manufacturer to provide a quotation to supply and install the equipment.

Basic requirements:

- Provide cooling water over a sustained period of time for a single rack containing a hot cylinder(s) until the cylinder(s) is cool and safe for transfer to a water bath.
- Provide cooling water to all racks in the event of a major fire, to prevent cylinder explosions but not to extinguish the fire.
- Minimise fire damage to other plant equipment and company assets.

Do not fit deluge systems in:

- Carbide storage areas
- Carbide skip loading areas
- Generator rooms

- Acetylene compressor areas (to prevent oil contamination of the fire water run off)

The requirements for the deluge system performance are:

- To provide water density of 10 $l/m^2/min$ upon the floor area of the filling racks, based upon the general surrounding floor area occupied by the cylinders. The intention is to evenly wet the cylinder shells at this flow rate.
- To sustain the above flow rate for at least 2 hours through the entire system over the filling racks in the event of a major fire.
- To sustain the above flow rate for 12 hours over a single isolatable section of the deluge system in the event of a hot cylinder incident.

A reliable, 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 service is permitted after the first hour of operation)
- Pumped from a river or storage pond, with the ability to re-cycle the water back to the pond
- From the local emergency services pumping water in to breach connections on the fixed deluge system inlet (only with their agreement of the emergency services and if an attendance time less than 5 minutes is possible.

The system may be operated by:

- Automatic remote controlled valves which may be initiated by a remote switch, alarm system or fire detection system such as heat sensors, quartzoid bulbs, fusible links etc.
- Manually operated valves in a protected safe location outside the filling building and clearly labelled
- Additionally, manual valves may be provided, in a safe location, to isolate individual filling racks and other parts of the deluge pipe work system in order to conserve water and concentrate it in the area of the hazard. The position of the valves shall be normally open to ensure sufficient water is provided to all affected areas under all emergency situations.
- The pipe work should preferably be in the form of a dry riser system.
- The nozzle design shall be able to provide the correct 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 not get on to oil sumps of compressors etc. and cause potential pollution with the 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.
- Water run-off shall not create thermal pollution of rivers or streams (water temperature and consistency shall not kill fish etc.).
- Any parts of the system normally containing water (e.g. up to the main control valve) shall be protected against frost and freezing in cold weather in temperate climates.
- There shall be no shut-off valves between the water supply and the main control valve.
- All activation points and valves should be clearly identified.

- Escape routes for personnel in the filling building shall be considered (visibility is severely reduced when a deluge system operates)

The system shall be periodically operated to ensure it is in good order. Monthly testing is recommended.

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

7.4 Storage – general requirements

7.4.1 Storage of calcium carbide

Storage areas should be isolated from other buildings and congested areas.

The storage area may adjoin other single storey buildings if it is constructed of non-combustible or limited combustible materials, and the buildings are separated by walls with a fire resistance of at least one hour.

When designing calcium carbide storage areas, consideration shall be given to precautions to avoid calcium carbide exposure to water. The storage area shall be:

- dry, prevent pooling of water on floors and have a waterproof roof
- high enough to prevent water exposure during flooding
- complete with a holding area, where any surface water or snow on the containers/drums can be removed prior to entering the store
- designed to prevent water and/or snow coming in contact with calcium carbide

All exits to carbide storage buildings shall be kept clear at all times to allow entry and exit in the event of an emergency.

External storage of carbide containers is permissible if the containers are fully waterproof. Weather protection is highly recommended.

Calcium carbide storage shall be located at least 3 m from any line of adjoining property that can be built upon.

Each area of the plant where calcium carbide is handled, stored or used shall be posted with notices reading:

> "CALCIUM CARBIDE - DANGEROUS WHEN WET – IN THE EVENT OF A FIRE DO NOT SPRAY WITH WATER" or using equivalent wording.

Calcium carbide storage areas shall be provided with an adequate supply of dry sand or dry powder extinguishers or both.

Water, lime, condensate or steam pipes shall not pass through the storage area.

Calcium carbide areas shall not be used for the storage of flammable materials or cylinders of compressed or liquefied gases.

When storing calcium carbide vessels, ensure enough room is left to allow forklift trucks to manoeuvre safely and without causing damage.

Carbide drums and containers shall be stored in a manner to prevent damage and to enable visual inspection and easy removal of any leaking or damaged containers/drums.

Drums shall not be stacked excessively high, crushing of drums under the weight of those above shall be avoided.

The store shall be organised such that rotation of the stock is possible, to ensure the oldest carbide is used first (First in, First out rules).

The store shall be regularly cleaned to prevent the accumulation of carbide dust.

See also IGC Doc 03/92

7.4.2 Storage of solvents

General

The main requirements are the following:

- Outside storage separated from the building is preferred, segregated from incompatible materials and compressed gas cylinders.
- Store drums in a cool place (preferably not above about 25 °C and not in direct sunlight)
- Tanks and drums shall be placed in a retention pit (bund wall) to avoid ground water and sub soil pollution from spills and leaks. This shall be sized to contain 110 % the leakage of the contents of one full container.
- Keep receptacles tightly sealed when not in use.
- Protect the installation against electrostatic charges.
- Containers should be bonded and grounded for transfers to avoid static electricity sparks.
- Protect the containers (tanks or drums) against physical damage.
- Signs shall be clearly posted indicating the identity and hazardous properties of the solvent.
- Use non-sparking type tools and equipment, including flameproof electrical equipment.
- Ensure good ventilation/exhaustion is maintained at all times.
- Storage and use areas should be signed “No Smoking and no naked flames”.
- Keep a respiratory protective device available for DMF handling and maintenance.
- Wear face shields or chemical proof goggles when handling this material.
- Prevent formation of aerosols.
- Safety Data Sheets shall be available to give information about solvent properties and about health hazards.
- Containers of solvents may be hazardous when empty since they retain product residues (vapours, liquid). Observe all warnings and precautions listed for the product.
- Spillage kits shall be available to contain and dispose of any spilled solvent.

7.4.3 Acetone

Acetone may be stored in metallic vessels made of carbon steel, stainless steel or aluminium. Certain plastic materials may also be used, but it is necessary to check the compatibility with the acetone.

Bulk storage

Normally the storage of acetone is either in underground buried vessels or underground vessels placed in a pit made of concrete.

In order to check the condition of the tanks, new tanks shall not be buried (unless they are of double walled construction). They shall be placed either outdoors above ground in a bund wall to contain 110 % of the storage capacity or in a sealed underground pit. In the latter case, they shall not be covered with sand or soil, as it is very difficult to detect leaks or inspect for corrosion of a tank covered in this way.

Systems shall be in place to detect any interstitial leakage of acetone.

Vessels may be either atmospherically vented (as for petrol storage vessels) or pressure vessels which contain the solvent under a blanket of nitrogen gas. National codes for the storage of flammable liquids in bulk shall apply.

Atmospherically vented tanks must be fitted with a device to prevent any external fire of acetone vapour from burning back in to the tank. These devices are normally flame arrestors and must be specifically designed for acetone vapour.

Remotely operated emergency shut off valves to isolate the supply of acetone to the filling plant shall be fitted for emergency shut down in the event of fire or spillage.

Low and high level alarms should be fitted.

Road tanker unloading points shall be protected from vehicle impact and be separated from passing traffic during unloading operations.

Anti tow-away systems/procedures shall be in place.

The surrounding ground should be such that any spillage drains to a safe containment area away from the tanker and cannot enter surface water drains. Temporary cover plates may be fitted to the drains to meet this requirement.

Earthing connections shall be provided for the road tanker.

7.4.4 Dimethylformamide, DMF

DMF is normally stored in drums and requires similar precautions to acetone drum storage.

The additional toxic properties of DMF require additional PPE for emergency use. See PPE requirements for DMF.

Bulk storage

The quantity of DMF used in an acetylene filling plant is usually small and this is why it is not normally stored in bulk vessels.

Nevertheless, if it’s necessary to use bulk storage, recommendations made for bulk storage of acetone shall apply (see here above).

7.4.5 Storage of cylinders

Other compressed and liquefied gas cylinders shall not be stored in the dissolved acetylene filling area.

It is recommended that large stocks full acetylene cylinders are stored in a segregated area with no more than 200 cylinders in each block of cylinders and a separation distance of 1.5 m between the blocks.

For further details see 12.3

7.4.6 Storage of chemicals

Chemical storage may include: purification chemicals – acid and sodium hydroxide, lubrication oils, drying agents – molecular sieve, calcium chloride or silica gel.

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

- Segregation of storage from acetylene cylinders and potential sources of fire is required
- Spillage containment of fluids is required to contain the loss of the largest container stored
- Safety Data Sheets shall be readily available

Appropriate PPE shall be available

7.5 Environmental requirements

See, IGC Doc 109/03 - Environmental Impacts of acetylene plants

8 Production

8.1 Acetylene generators

8.1.1 Manufacturing method

Acetylene is produced by the reaction of calcium carbide with water. This reaction is expressed by the formula:

$$CaC_2 + 2H_2O \rightarrow C_2H_2 + Ca(OH)_2 \quad \Delta H= 129.9\ kJ$$

Pure calcium carbide would therefore liberate 2028 kJ per kg at 18º C and 1 bar. Commercial carbide (typically about 80 % pure) would have an approximately yield of 300 l of gas and generate 1793 kJ of heat per kg of carbide. The stoichiometric reaction would, in absence of cooling heat the acetylene, which would undergo exothermic decomposition reactions. Explosive conditions could be reached when carbide and water are mixed with inadequate cooling, especially if air is also present.

The heat of reaction is controlled in a number of ways. Various types of water to carbide generators control the reaction rate so that the heat can be dissipated. Carbide to water generators use a large excess of water, but “dry” generators use a comparatively small excess of water where all (or nearly all) of this excess water is vaporised.

The generation of acetylene for compression into dissolved acetylene cylinders is normally carried out in “wet” generators in which carbide is added to an excess of water.

8.1.2 Generator classification

Operating pressure

Acetylene generators shall be designed, constructed and operated to standards and procedures, so as to ensure the maximum integrity of the equipment and safety for personnel. Safety devices should be provided on the system to ensure that pressures, temperatures, flows levels, etc, are kept within safe limits.

Generators operate under either Low Pressure or Medium Pressure ranges:

- **Low Pressure (LP)**. Generators of this type require the use of a gasholder to balance the generation rate with the capacity of the compressors. Maximum operating over-pressure is 0.2 bar
- **Medium Pressure (MP).** Maximum operating over-pressure is 0.2 – 1.5 bar
- High Pressure generators, above 1.5 bar, are not permitted.

Operating method

a) **Batch.** These generators are shut down, drained and refilled with water at the end of each carbide charge.

b) **Semi-continuous**. These types of generators have automatic water addition and drain controls making it unnecessary to drain and refill the generator with water at the end of each charge. However, a short shutdown is required at the end of each charge to refill the carbide hopper.

c) **Continuous**. These types of generators have automatic water addition and drain controls and the charging container is connected to the feed hopper via a connecting chamber and usually a gastight seal. The feed hopper has usually an isolation valve at the top. Other continuous type generators are equipped with a double carbide hopper arrangement to permit continuous carbide feed.

The operating and safety controls depend on the manufacturer and generator type.

8.1.3 Requirements and recommendations

1) Clean and/or recycled water is supplied to a generator through a device to prevent backflow of acetylene from the generator. *(NFPA 51A 4-2.3)*

2) The design of the water supply system shall prevent overfilling of the generator. This is to prevent water from coming in to undesired contact with unreacted carbide.

3) The design of the water feed system shall eliminate the presence of entrained air in the fresh water supply system.

4) The water feed system shall be designed to prevent a back flow of recycled water or lime in to the fresh water supply system.

5) Instrument air supplies to the generator system controls should be equipped with physical isolation devices to allow deactivation of the controls for maintenance lockout/tagout and extended periods when not in use.

6) Loss/disconnection of the instrument air shall cause the generator controls to move to a fail-safe mode (Applicable generator manufacturer design standards)

7) The generator shall be equipped with devices to prevent over pressurisation. Additional pressure controls may be installed as required to safely interrupt or shut down normal generator operations. Alarms that signal the approach of shutdown conditions may be added as appropriate for efficient operation.

8) High temperature controls shall be installed to ensure that the acetylene gas does not reach 110 °C. Depending upon the design and the manufacture, this can be achieved by monitoring the gas temperature or the water temperature or both. A high temperature alarm shall shut down the generator. Alarms that signal the approach of shutdown conditions may be added as appropriate for efficient operation.

9) High and low water levels shall be controlled. Alarms that signal the approach of shutdown conditions may be added as appropriate for efficient operation. A low water pressure shutdown switch shall be installed in the inlet water line.

10) Additionally, water flow indicators may be installed to help control the water level.

11) Water level controls and an inlet water pressure shutdown switch are not required on generators that batch control water addition.

12) Where used, acetylene generator sight glasses shall be provided with external protection (such as a screen or protective mesh).

13) Generators with agitators should have an agitator function alarm installed.

14) There shall be no connections between the acetylene generator and the sewer.

15) Generators shall be fitted with nitrogen systems to extinguish accidental hopper fires when charging using an open skip, or to purge enclosed type hoppers used with containers and for generator emergencies.

16) Nitrogen purging shall be monitored by flow/time to ensure an adequate purge.

17) Sludge drain valves should have a secondary means of closure in the event of a leak or failure to close.

18) Multiple low-pressure generators shall be fitted with a system to prevent unwanted back flow of gas from the gasholder to the generator.

8.2 Gasholder

8.2.1 General

Acetylene gasholders comprise a water/oil filled vessel fitted with an internal floating bell, which rises and falls with varying gas content to maintain a constant system pressure. The gasholder level position is used to control the generator carbide feed rate.

The gasholder(s) are installed in low-pressure acetylene generation plants to balance the generation rate with the compression rate.

8.2.2 Requirements

Controls

a) The gasholder shall be equipped with inlet/outlet shut-off valves.

b) The gasholder shall be equipped with an emergency high-level alarm that trips to stop the carbide feed to the generator. Some gasholders may be equipped with a high-level cut out switch to stop the generator carbide feed before the gasholder reaches the high alarm level and to re-start the feed when the gasholder falls.

c) The gasholder shall be equipped with an emergency low-level cut out switch, which will stop the compressors.

d) The gasholder shall be equipped with visual means of detecting the water level.

The gasholder(s) shall have sufficient capacity to contain any over-run after stopping the generator carbide feed drive during normal operation or in an emergency.

Low ambient temperature conditions

Gasholders located outside where freezing temperatures are encountered shall be provided with means to prevent the water in the gasholder from freezing. During extremely cold weather, the gasholder should be inspected frequently to make sure that any ice formation is not holding the bell in the raised position.

8.3 Buffer

Buffers are installed in some types of medium pressure acetylene generators to balance the generation rate to compression rate. The buffer is a vessel with an integrated water seal - the function of the water seal is as a safety device not a pressure relief device. A pressure regulator is installed at the top of the vessel with high and low pressure limits to regulate the calcium carbide feed to the generator.

The following requirements shall be observed:

a) The buffer shall be equipped with inlet/outlet isolation valves.

b) Supplementary to contact manometer for calcium carbide feeding control a separate manometer shall be installed, equipped with emergency low level cut out switch, which will stop the compressor.

c) The buffer shall be equipped with a pressure relief valve.

d) The seal shall be equipped with a water level control.

8.4 Purification and drying

The purity of acetylene compressed into cylinders is normally 99,6 % or better. Contaminants, that may be present include air, water vapour, phosphine, hydrogen sulphide, ammonia, oil, and nitrogen. If not controlled, these contaminants can contribute to reduce cylinder capacity, high settled pressures, solvent “spitting”, and the formation of undesirable compounds within the acetylene cylinder.

8.4.1 Source of impurities

Air

a) Some air may enter the system with the carbide each time the generator is charged. Purging of the carbide container and/or the generator hopper can reduce this.

b) Failure to adequately purge equipment being returned to service can increase level of air or purge gas contamination.

c) If the generator vacuum relief system does not function properly, air can be drawn in when the generator cools.

d) Failure to maintain a positive suction pressure on the compressor can cause air to be drawn in. For example, at the shaft packing.

e) Air can be drawn directly into a cylinder if the valve is left open or when it is removed for repairs.

f) New cylinders which have been evacuated and replenished can draw in air if the valve leaks or if it is inadvertently opened before been connected to the charging rack.

g) Air may enter the generator entrained in fresh mains water.

h) It has been determined that each 0,1 % increase in the level of air contamination will increase settled pressure of acetylene cylinder by 0,4 bar.

Water

a) Carbide generated acetylene is saturated with water vapour at the temperature and pressure conditions existing in the system up to the dryers. The amount of water that will enter the cylinder with the gas, depends on the performance of the drier system.

b) Water can also enter the cylinder if it is allowed to stand with the valve open. This is particularly true of cylinders with concave heads since water can build up above the level of the valve inlet.

c) The water should be prevented from entering the acetylene cylinders for the following reasons:

- It will mix with the solvent and reduce its ability to dissolve acetylene.
- It may damage the porous mass.

- It may cause corrosion of the internal cylinder walls.

Phosphine

a) Phosphorous compounds in the calcium carbide react to form phosphine gas during generation of the acetylene. The amount of phosphine present in the acetylene depends on the purity of the raw materials used for the manufacture of calcium carbide (see section 5.2)

b) Purification may be required to satisfy some special customer requirements. The phosphine content of purified acetylene will typically be below 15 ppmV.

c) Phosphine is a highly toxic gas and personnel exposure to high levels of unpurified acetylene gas must be strictly controlled and monitored.

Hydrogen sulphide

a) Sulphur compounds in the calcium carbide react to form hydrogen sulphide gas during generation of acetylene. The amount of hydrogen sulphide generated depends on the purity of the raw materials used in the manufacture of calcium carbide, but the generator scrubber and water sprays or the ammonia scrubber removes some of this contaminant.

b) The hydrogen sulphide content of purified acetylene will be below 10 ppmV

Ammonia

a) The ammonia content of generated acetylene results from the reaction of calcium cyanamide with water. The calcium cyanamide is formed by the reaction of atmospheric nitrogen with the hot surface of the freshly poured carbide.

b) Ammonia promotes the formations of undesirable polymers in the acetylene cylinders and should be controlled by water scrubbers or spray towers.

Oil

a) Removal of excess compressor oil is normally accomplished at the compressor discharge moisture trap or dryer. At locations where dryers have been installed the carry over of compressor oil is normally less than is required to maintain a satisfactory oil film in the high-pressure lines and manifolds. Oiling of the high-pressure pipework is thought to reduce the risk of decompositions occurring.

b) Oil contamination of cylinders normally occurs only when the moisture traps and drip legs are not drained on a proper schedule. At such times a mixture of oil and water can be carried in to the cylinders.

Nitrogen

a) Nitrogen enters the acetylene mainly through purging operations or leaking valves in the nitrogen purging equipment.

8.4.2 Impurity removal equipment

Scrubbers

a) Scrubbers, provided on most medium and low pressure acetylene generators to scrub and cool the exiting gas, will reduce the ammonia and hydrogen sulphide content of the gas to acceptable levels. The scrubbers also prevent lime carryover.

b) Some low-pressure generators have hydraulic mains (bubble through water baths). The main purpose of these is to prevent back flow of acetylene from the gasholders or other generators but in addition they remove the lime and some of the ammonia and hydrogen sulphide. This method of scrubbing the gas is not as effective as scrubbers and may not reduce the ammonia content of the gas to acceptable levels in all cases. Separate ammonia scrubbers may be used at low pressure generating plants.

Purifiers

Acetylene is purified mainly to remove the toxic substances, phosphine and hydrogen sulphide. The need of purification is to be determined based on carbide quality, the process and acetylene specification.

Two purifying methods are in use - dry purification and wet purification

a) **Wet purification.** In the wet purification process acetylene is passed through a tower filled with a packing material such as “Raschig” rings. Concentrated sulphuric acid is pumped into the top of the tower and flows downwards against the acetylene flow. Phosphine and hydrogen sulphide are removed by contact of sulphuric acid with acetylene. Any acidic substances carried over with the acetylene are neutralised in a subsequent alkaline scrubbing tower. It is important that the system is kept cool as the reaction is exothermic.

   Maintaining a high purity of the sulphuric acid is critical, small quantities of mercury or iron impurities will catalyse polymerisation of the acetylene itself. The products of the polymerisation process resemble tar and clog the filter interstices. The final result could be a blocking of the gas flow or a deflagration of the acetylene. This problem is more likely to occur at elevated temperatures.

   The maintenance of the correct acid concentration is important otherwise phosphine may be dissolved in the acid in the scrubber sump and may be released and ignite spontaneously on contact with air.

(b) **Dry purification.** Dry purification is no longer the preferred method of purification for environmental reasons when disposing of the purification medium. In the dry purification acetylene is passed through a vessel containing several layers of purifying compound, which remove the acetylene impurities. All purifying compounds are acidic and have a corrosive effect on human tissue. When the raw acetylene passes through the purifier material, the phosphine and the remaining traces of hydrogen sulphide and ammonia are oxidized or absorbed and removed from the gas stream. The purifier material becomes less efficient after a finite lifetime and eventually has to be regenerated or re-oxidized by exposure to air. Then it may be reused. The material can be regenerated several times before it has to be discarded. Some of these dry purification compounds contain mercuric chloride which may result in the release of free mercury which can accumulate in dangerous quantities. This is why it is necessary to monitor the purifiers performance and change the compound when it starts to deteriorate in performance.

Dryers

The basic principle for acetylene drying processes is the passing of the gas through a vessel containing drying material. This drying agent may be a dissolving, moisture absorbing material i.e. calcium chloride or adsorbent materials which can be regenerated, i.e. alumina, molecular sieves.

There are low-pressure (LP) dryers and high-pressure (HP) dryers in use. HP drying is more efficient but LP drying helps eliminate acetylene hydrate formation at higher pressures.

Drying at low pressure (up to a maximum pressure of 0,2 bar) requires large vessels for containing the drying agent. In case of an emergency, vessels and lines have to withstand no more than the pressure of decomposition. A final moisture content of about 70 ppm can be achieved in low pressure drying.

Typical drying methods use:

- Calcium chloride (refer to HP drier)
- Silica gel
- Coalescing filter (Knitmesh or Ceramic Rings)
- Cooler condenser

Drying at high pressure (up to a pressure of 25 bar) Acetylene is fed directly from the compressor where most of the water is removed by lowering the dew point. The turnover of the water remaining for the dryers is small and thus the vessels for containing the dehydrating agent can also be small. All vessels and lines should be designed to withstand detonation pressure. This calls for higher investment costs than are usual with the low-pressure process, however, because of the lower operational costs the investment costs will be recovered within a short period of time. The effect of high pressure drying will be a residual moisture content of 2 ppm. In the high-pressure system, it is convenient to install a separator before the vessel containing the dehydrating agent to remove condensate and oil from the gas. A back pressure valve after the dryers can be used to maintain the pressure in the system at a minimum level of 14 bar and achieve more efficient drying. See 10.2 for further information.

Typical drying agents used are:

- Calcium chloride
- Alumina
- Silica gel
- Molecular sieve

8.5 Handling and storage of carbide lime

8.5.1 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.

8.5.2 Carbide lime processing and handling

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

a. 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.

b. 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 excess 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 a proper manner.

c. Filtration

Lime slurry can be concentrated by a filter press - a filter system with cloths and plates - that 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 suitably treated and discarded. The higher the temperature, the better the filtration process and the lower the water content in the block. Lime blocks may be formed with as little as 15 % moisture by weight.

d. 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.

e. 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 is 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. The resultant hydrated lime is completely free from sulphide and other objectionable odours.

8.5.3 Transport

a. 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.

b. 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 mounted on barques. Manually operated hoes 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. Tank truck or car haulage of the low solids content slurries has been demonstrated satisfactorily.

8.5.4 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, which may be built upon.
- Calcium carbide lime pits shall be fenced and sign-posted "NO SMOKING OR OPEN FLAMES", and Ex-sign as required by EU directive 99/92.

- If not further used calcium carbide lime shall be disposed of in an environmentally acceptable manner. Under waste legislation carbide lime is classified as hazardous (irritant) and is shipped under European Waste Catalogue code 06 02 01 for $Ca(OH)_2$.
- A safety shower(s)/eye wash should be located within easy reach of lime handling areas and PPE shall be used.
- Carbide lime contains residues of acetylene dissolved in it that may present a hazard when confined in road tankers for transport. Such tankers use a vacuum to draw the slurry and the reduction in pressure results on the release of free acetylene.

9 Receptacles and fittings

Requirements for transportable acetylene receptacles are laid down in the ADR. Pi-marked cylinders for unlimited European use need to comply additionally with Council Directive 1999/36/ EC (TPED).

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

The receptacles are filled entirely with a granular mass (older cylinders) or a monolithic mass (modern cylinders). A solvent is used to dissolve the acetylene, normally acetone or DMF, and the receptacles are equipped with a valve and sometimes a valve protection device.

For special purposes there are a small number of solvent-free cylinders in existence.

9.1 Acetylene cylinder design

Acetylene cylinders are common in sizes between 3 and 60 l water capacity.

They are manufactured as seamless or welded cylinders.

For seamless steel shells see EN 1964-1 or ISO 9809-1.

For welded steel shells see EN 13322-1 or ISO 4706.

For seamless aluminium shells see EN 1975 or ISO 7866.

Some acetylene cylinders are equipped with fusible plugs according to their national legislation.

The fusible plugs melt to relieve the cylinder contents if the cylinder becomes exposed to an extensive fire.

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 easy crane and/or forklift handling.

Cylinder bundles are not considered to be *Multi Element Gas Containers (MEGC)* as defined in ADR.

For design, manufacture, identification and testing of cylinder bundles see EN 13769.

Cylinder bundles equipped with a central or main isolation valve shall be transported with open cylinder valves.

9.3 Acetylene cylinder trailer design

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

For design information see EN 13807.

For additional information see also CGA G – 1.6.

9.4 Porous masses and solvent

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

The porous masses have porosity of up to 92 %.

Porous masses 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 1800 or ISO 3807 (Part 1 or Part 2).

For a partial list of porous masses see BAM (Bundesanstalt für Materialforschung und –prüfung, www.bam.de.) More porous masses can be found in CR 14473 (CEN/TC 23).

The filling parameters for the solvent charge in kg/l water capacity and the acetylene charge in kg/l water capacity shall ensure that a charged cylinder does not develop hydraulic fill up to a uniform temperature of 65 °C (ISO 3807, EN 1800, EN 1801, IGC Doc (new no.)).

9.5 Filling conditions

For general information see IGC Doc (new no.)

For filling conditions of:

- single acetylene cylinders see EN 1801
- acetylene cylinder bundles see EN 12755
- acetylene battery trailers see EN 13720.

As acetylene cylinders are subject to marginal losses of solvent depending from conditions during discharging, they need to be solvent-replenished prior to being refilled.

Acetylene bundles and trailers are not solvent-replenished prior to every refilling. They are disassembled for solvent replenishment if either they have reached the maximum specified solvent loss or a predetermined number of uses whichever the sooner as laid down in the bundle or trailer approval.

Bundles with acetone shall normally be solvent-replenished after a maximum of 6 fillings or with DMF after 100 fillings maximum. In practice its depends on the operating conditions.

9.6 Maintenance and re-testing

Acetylene cylinders may 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 mass and/or
- cylinder bundle frames and their interconnecting pipe-work

The cylinder including all attachments needs therefore to be inspected for general integrity prior to every refilling (see chapter 10.3).

The entire cylinder shall latest be inspected after elapsing of its retest period laid down in ADR 6.2.1.6 and 4.1.4.1 – P 200.

For requirements for the periodic inspection and maintenance of dissolved acetylene cylinders see EN 12863 and ISO/DIS 10462.

For inspection and maintenance of cylinder valves see EN ISO 14189.

For attendance to blocked or inoperable valves see IGC Doc TN 505/86.

9.7 Disposal of acetylene cylinders

Cylinders, that need to be disposed, shall be treated in accordance with relevant national environmental legislation as they are classified as hazardous waste (No. 150 111 of the European Waste Catalogue) for their solvent and in some cases for their asbestos containing mass fraction

For guidelines for disposal of acetylene cylinders see IGC Doc 05/00.

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 see EN 849.

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

For test and inspection of valves see EN ISO 14246.

Some cylinders may be equipped with NR/RPV (residual pressure valves with non-return function) or with an integrated valve-pressure regulator device.

9.9 Acetylene cylinder accessories

Acetylene cylinders valves shall be protected against impact damage. This may be achieved by design strength or by a valve protection cap or protection guard. For details see EN 962 and ISO 11117.

9.10 Acetylene cylinder identification

- Requirements for cylinder identification are laid down in ADR 6.2.1.7.
- ADR 6.2.1.7.1 lists the necessary markings, which shall be metal stamped on the cylinder shoulder or on a permanently attached metal plate, at the time of manufacture.
- ADR 5.2.1.6 lists the necessary identification data, which shall be permanently shown on the cylinder by use of paint or labelling.
- ADR 5.2.2.2.1.2 specifies the precautionary labels for transportation (see also ISO 7225):
- For metal stamped identification data arrangements see relevant EIGA Position Paper (05/02), which consolidates the requirements of ADR 6.2.1.7, EN 1089-1, ISO13769 and TPED (Council Directive 1999/36/EC).
- For identification data, which may be permanently shown on the cylinder other than, metal stamped see EN 1089-2,
- For colour coding see EN 1089-3.

10 Filling

10.1 Compression/Compressors

Acetylene compressors are normally slow running multi stage machines, with water or air cooling systems, that compress the acetylene from the generator pressure to the final pressure. Acetylene compressors shall be specifically designed and constructed for acetylene service. (see definitions)

10.1.1 Design

General requirements and recommendations

1) Acetylene compressors shall be designed and constructed specifically for acetylene service and all their components shall be designed to withstand stresses that may arise during service.
2) Acetylene compressors shall be constructed and equipped such that:
   - Acetylene/air mixtures can be properly purged.
   - Air cannot enter during normal operation.
3) Acetylene compressors shall be equipped with a cooling system after each compression stage. The cooling systems shall ensure that:
   - during normal operation temperatures cannot occur that are likely to cause decomposition of acetylene (for compressors lubricated with oil this is achieved if the temperature does not exceed 140 °C)
   - the acetylene temperature does not impair safe operation of the equipment installed downstream
   - a temperature indicator is installed after the cooling system of the last compression stage
4) Materials shall safely withstand all mechanical, chemical and thermal stresses that may arise and shall be designed in such a way as not to react dangerously with acetylene and with carbide residues as far as they may be exposed to them (for details see 6.2). If belts are used to drive the acetylene compressors, they shall not create electrostatic charges.
5) Condensate separators and other reservoirs in acetylene compressors shall be fitted with purge devices at their lowest points.
6) Inlet and outlet piping of each compressor shall be provided with readily accessible shut-off valves.
7) Drain lines from oil separators, condensate traps, and dryers shall be piped to a safe location away from any source of ignition and combustible material

10.1.2 Accessories

A. Pressure limiting devices

1) Acetylene compressors shall be equipped with pressure limiting devices to shut-off the compressor and actuate an alarm signal if:
   - the suction pressure falls below 1 mbar,
   - the maximum operating pressure is exceeded (25 bar).
2) The maximum operating pressure shall be adjustable at the pressure limiting device of the high-pressure compression stage to avoid formation of liquid acetylene (see 10.1.3).
3) Each compression stage shall be equipped with a suitable safety valve that cannot be blocked.

4) Safety valves shall be designed and adjusted to prevent the maximum operating pressure to be exceeded by more than 10 %
5) The nominal capacity of the safety valves shall at least as high as the nominal capacity of the corresponding compression stage.
6) The safety valve vent pipes shall not cause a pressure and flow restriction to their exit points and the exit points shall be located outside the compressor room
7) Each compression stage shall be equipped with a pressure measuring/indicating device with the maximum operating pressure marked.

B. Compressor identification markings

Acetylene compressors should be permanently marked with the following information

- type
- manufacturer
- manufacturers serial number
- year of manufacture
- flow capacity
- maximum operating pressure
- suction pressure
- power consumption
- type approval data.

10.1.3 Operation

To prevent liquefaction (condensation) of acetylene, care shall be taken to ensure that the operating pressure, for a given acetylene temperature, does not exceed the values given in table 7. These values have been determined empirically to take in to account the cooling effect of gas expansion and the heat transfer to adjacent pipework resulting in progressive lowering of the gas temperature. The use of re-cycle valves to return gas from the delivery pipework to the suction side and to control the maximum flow rate of the compressor is not advisable due to the risk of liquefying the acetylene. This has been known to cause explosions in the first stage of the compressor.

Table 7 – Maximum operating pressure vs. gas temperature

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

10.2 Acetylene Heat Exchanges, Dryers and High Pressure Purifiers

10.2.1 Design

General requirements

1) Acetylene Heat Exchanges (AHE), Acetylene Dryers (AD), Acetylene Purifiers (AP) shall be specifically designed and constructed for acetylene service and all their components shall be designed to withstand stresses that may arise during operation see 10.2.3.
2) AHE, AD and AP shall be constructed, equipped and operated in such a way that:
    - any empty voids within the systems, containing compressed acetylene are reduced to the strict minimum compatible with the systems operation,
    - acetylene/air mixtures can be properly purged,
    - air cannot enter during operation,
    - pressures and temperatures arising during operation cannot cause decomposition of acetylene.
3) Drying and purifying agents shall not react dangerously with acetylene and its impurities.
4) Materials shall safely withstand all mechanical, chemical and thermal stresses that may arise and shall be designed in such a way as not to react dangerously with acetylene and its impurities as far as they may be exposed to them (for details see 6.1).
5) AHE, AD, AP shall be protected against corrosion internally and externally.

10.2.2 Accessories

A. Pressure limiting devices

AHE, AD, AP are generally not equipped with pressure limiting devices. Therefore they either need to be operated in systems where devices are installed so that the maximum operating pressure of the equipment is not exceeded or they shall be able to withstand decomposition pressure.

B. Pressure/Temperature measuring/indicating

AHE, AD, AP must be equipped with pressure indicator and temperature indicator devices if considered necessary for the judgement of their correct operation.

C. Identification data

Every AHE, AD, AP shall be permanently marked with the following information

- manufacturer
- type description
- manufacturers number
- year of manufacturing
- flow capacity
- maximum operating pressure
- type approval data if applicable

10.2.3 Dimensioning and Testing

1) All acetylene exposed parts of AHE, AD, AP shall be designed to withstand test pressures with a safety factor of 1,1 against their yield strength.
2) AHE, AD and AP operating at low pressure shall be designed for a test pressure of 1 bar.
3) AHE, AD and AP operating at medium pressure shall be designed for a test pressure of 5 bar. If they are equipped with a bursting disc, its effective area shall be at least:

   $F \geq 300 * V^{2/3}$ (cm^2)
   where V = free gas volume in m^3.

   The burst activation pressure shall not exceed 4,5 bar. If not equipped with bursting discs the equipment shall be designed to a test pressure of 24 bar.
4) AHE, AD and AP operating at high pressure shall be designed for a test pressure of 300 bar.
5) For dimensioning of piping see chapter 11.

10.2.4 Operation and maintenance

A. General requirements

Observe the requirements described in section 6.5.

B. Additional requirements

Drying by adsorbent materials

Prior to HP drying, it is recommended to have effective purification and condensate separation of the gas, particularly when using silica gel or activated alumina in order to avoid deterioration of these products by impurities in the acetylene.

A filter should be used to absorb any oil vapours upstream from the dryers.

A dust filter should be installed downstream from the dryers.

Temperature indicators should be installed downstream from the dryers to check the temperature of the regeneration gas and upstream from the dryers to check the temperature of the acetylene gas.

It is recommended that moisture measurement be carried out to monitor the effectiveness of the dryers.

Drying by calcium chloride

The specification of the material used as a drying agent provided by the equipment manufacturer shall be controlled. Avoid using a grain size that can block the drainage pipes.

In high-pressure dryers the level of calcium chloride in the equipment shall be checked frequently so that a void will be detected in due time. A void of 10 % of the internal volume of the drier (with a maximum of 5 litres) is the maximum acceptable level.

The liquid trapped by the dryers (water and residue of calcium chloride) must be drained regularly at periods determined by the operating conditions.

High-pressure drying can be appreciably improved by installing back pressure regulators downstream of the high pressure dryer.

10.2.5 Regeneration of drying agents

1) Regeneration by the pressure swing method is preferably carried out using acetylene at a pressure and temperature not exceeding 0.5 bar and 200 °C
2) Regeneration by the temperature swing method is preferably carried out using nitrogen or nitrogen and air
3) If adsorbents are regenerated by air, purging with air and heating of the absorbent shall not start before the acetylene concentration in the exhaust gas falls below its lower explosion limit.
4) After regeneration of the adsorbent, it shall be cooled to ambient temperature before recompression begins. For this, complete the regeneration by purging with low pressure and dry acetylene at ambient temperature. The acetylene purge gas should be returned to the suction side of the acetylene compressor
5) The use of nitrogen for regeneration of dryers requires special precautions to be taken as the adiabatic heat of compression of the acetylene and nitrogen mixture can reach the acetylene decomposition temperature. In addition the heat of adsorption generated will add to this generation of heat. Therefore acetylene shall be passed through the system to remove the nitrogen before the dryer is re-pressurised

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 properly inspected prior to replenishing with solvent and filling with acetylene. (Refer to EN 12754).

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

a) They are marked with the Notified Body's test stamp.
b) The year of the next periodic inspection stamped on the cylinder has not yet elapsed.
c) They do not show any external defects in the shell, the valve the guard and other fittings.
d) 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 (arc strike, large dents or signs of fire on the shell, significant corrosion, etc.).
- with an excessive loss of solvent (more than 5 % of the nominal acetone quantity).
- with valves in inoperable condition (valve blocked, threads damaged, etc.). In this case, the valve shall be replaced.
- returned from customers with open valves
- 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 12863).

- with missing or illegible regulatory identity or service markings (e.g. porous mass 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, etc.).

- which are unknown to the filling plant.

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

–Bundles and Battery-vehicles

Before filling it shall be checked that acetylene bundles and battery vehicles (frame, cylinders, connections, etc.) 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 information is given in EN 12755 and EN13720

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 may result in a hydraulically full cylinder that, when subjected to a temperature increase, can develop extremely high internal pressures. A shortage 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 (see section 3 for 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 shall 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 may be contaminated and shall not be filled. They shall be put aside for investigation. (see section 10.3.4c)

10.3.3 Loss of solvent

During use, an acetylene cylinder will lose 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 on 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 may be caused by; an excessive withdrawal rate during use, defects in the porous mass 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 and 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 1801 may be used to determine residual gas content in relation to temperature and pressure. It should not be used for cylinders with residual pressures higher than 7 bar.

A - Cylinders with residual gas

Two possibilities exist:

- **Emptying to the gasholder**

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 may ignite) and they are then connected to a dedicated blow-down or emptying manifold for discharging to the gasholder. When cylinders are completely empty of gas their pressure is once again checked using a pressure gauge and they are re-weighed.

- **Without emptying**

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 7 bar or greater may either be filled directly (in this case we assume that no solvent was lost) or partially emptied to the gasholder (or other acetylene supply system in the case of medium pressure generation) then replenished if necessary.

After determining the amount of gas remaining in the cylinder, it is necessary to weigh the cylinder and subtract the amount of the residual acetylene from this weight read and compare this value with the tare value stamped on the cylinder.

B - Cylinders without residual gas

Any cylinder returned by a customer with the valve open, must be treated with caution. It is possible that such cylinders have been contaminated with rain water and will also contain a small amount of air.

Such cylinders shall be treated as follows

- Check the weight to see if they are severely "over tare" indicating either gross contamination with water or over acetoning. .
- If above is the case these cylinders must be sent to a specialist centre to have acetone and water completely removed in a distillation oven and then re acetoned or scrapped..
- If no apparent overweight is detected then the cylinders may be filled in the normal manner taking care to ensure that they take up the correct amount of acetylene. If at the end of the fill, the cylinder is under weight then water contamination must be suspected. In this case, the cylinder must be blown down slowly to avoid acetone loss (on a blow down manifold) and an attempt made to fill again. If the cylinder still does not reach the correct target weight then it should be emptied and sent for distillation treatment or scrapped.

C - Special cases

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

This excess weight generally indicates either excess solvent in the cylinder, or the presence of another liquid (generally water or oil). The cylinder will require the solvent to be removed in a distillation oven, to remove the contamination. Alternatively the cylinder may be scrapped.

10.3.5 Replenishing procedure

A - Individual cylinders

After performing all the checks prior to replenishing, and segregating cylinders that shall not be directly replenished, the following procedure should be observed:

a) 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 room where they will be replenished for sufficient time to acclimatise.

b) Determine the amount of residual gas remaining in the cylinder.

c) Subtract the weight of acetylene remaining in the cylinder from the measured total weight of the cylinder.

d) 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.

e) Add solvent, if necessary. If the manufacturer of the porous mass has determined a maximum replenishing pressure, this shall be followed.

f) Weigh the cylinder again to check that the tare was correctly re-established.

Note: for cylinders equipped with a fixed cap, the cap shall not be removed before replenishing.

B - 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 receptacles 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 (bundles) and EN 13720 (battery-vehicles).

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 (see EN 1801) up to the upper limit determined for the collective filling in the bundle (see EN 12755) or the battery-vehicle (see EN 13720).

10.3.6 Equipment and raw materials

A - Scales

Scales shall be selected with a range suitable for the type of cylinder to be replenished (maximum load and accuracy). For example, a scale should not be the same for a small cylinder type (5 Litres) as for a large one (50 litres).

Scales shall be checked daily before use with standard calibration weights.

B – Solvents - General recommendations

When handling or using solvents precautions shall be taken as stipulated on the Safety Data Sheets (SDS). These products are flammable (in particular the acetone) and have harmful properties. Operators shall therefore always wear appropriate personal protection equipment (e.g. goggles, gloves, etc.) when handling these products.

Solvent quality is very important with respect to cylinder filling (see Table 8). It is important to preserve the quality of the solvent to ensure good dissolution of the acetylene. Both solvents are hygroscopic and will therefore absorb water upon exposure to the atmosphere.

Acetone and DMF shall never be mixed as it will be impossible to determine residual gas content or the solvent loss.

Table 8 - Acetone and Dimethylformamide (DMF) characteristics and quality

	Acetone	Dimethylformamide (DMF)
Minimum concentration (by weight)	99.5 %	99.7 %
Maximum water content	0.3 %	0.3 %
Refractive index at 25 °C		N = 1.427
Molecular weight	58.08	73.09
Boiling point at 101.3 kPa	56.1 °C	153 °C
Freezing point	- 94.6 °C	- 61 °C
Specific gravity at 15 °C	0.790 - 0.795	
Specific gravity at 20 °C		0.954
Relative density of vapour (air = 1)	2	2.5
Flash point (closed cup)	- 18 °C	58 °C
Auto-ignition temperature	538 °C	410 °C
Lower explosive limits (% by volume in air)	2.15	2.2
Upper explosive limits (% by volume in air)	13	16
Vapour pressure at 20 °C	0.247 bar	0.0035 bar

- **Acetone**

It shall be colourless and clear. Acetone is highly flammable and volatile and therefore is a potential fire hazard. It is necessary to take precautions with this material:

- Prolonged breathing of acetone vapours could result in irritation of the respiratory system, headaches, coughing and slight fainting spells.

- Contact with the skin can result in de-fatting and may lead to dermatitis. To prevent any contact, wear impervious protective clothing such as neoprene or butyl rubber gloves, apron, boots or whole bodysuit, as appropriate.

Contact with the eyes can lead to severe irritation and discomfort. Reversible and/or irreversible corneal damage may occur.

- **Dimethylformamide (DMF)**

DMF is a clear, colourless and virtually odourless liquid. It is completely miscible with water and most common solvents.

It has a number of properties, which require extreme care when handling. In particular:

- DMF has a low occupational exposure level value of 10 ppm (compared to 1000 ppm for acetone).

- DMF is readily absorbed by the skin with deleterious effects. Irritant to skin and mucous membranes and irritating effect on the eye.

- DMF is a very powerful solvent particularly relative to resins, plastics and rubbers. Therefore great care shall be taken when selecting materials for both plant and customers.

- DMF will burn and form explosive mixtures with air or oxygen but it is not highly flammable.

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 uncertainties, which can occur due to the various accuracies of the equipment (scale, replenishing method and accuracy equipment, etc.).

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 excessively quickly on a manifold connected to the compressor suction line, which also may be used for filling cylinders containing DMF.

Contamination may also occur if cylinders containing different solvent are filled on the same manifold and it is recommended to fill cylinders containing different solvents separately.

During and after filling, the 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.

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 safely depressurised on an approved blow down system.

Pressure receptacle valves shall be opened before actuating the valves of the charging manifold. At the end of the filling the pressure receptacle shall not be closed before the valves of the charging manifold has 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

A – Cylinders

Special care shall be taken with cylinders having different porous masses or high amounts of residual gas. Cylinders should be sorted and put on the manifold in the following order:

- By type of porous mass.
- Then by size (water capacity).
- Then by quantity of residual gas (pressure).

B – 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 standard. (See 10.3.5)

Before filling bundles, it's necessary to verify that <u>all</u> the cylinder valves are open.

After filling, time shall be allowed to reach pressure equilibrium before closing the cylinder valves. Take note that 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 may be left open during storage and shipping. The main valve on the bundle shall be closed.

C – 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 standard. (See 10.3.5)

Before filling, it's 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, but as a battery-vehicle consists of bundles the same rules for bundles shall be applied for the battery-vehicles concerning the position of the valves (closed or open).

10.4.4 Inspection after filling

For inspection after filling, the requirements of EN 12754 shall apply.

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 shall 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 exist:

- If the receptacles do not reach their specified total weight, they shall be rejected, and 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.

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.

As a general rule, filling manifolds and their main equipment (valves, flexible hoses, 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 (valves, connections, pressure gauge, hoses, etc.) see Chapter 11.

10.5.2 Flame arrestors

A - General

Acetylene is particularly sensitive, especially when it is very dry, and it needs 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 pipe work in an acetylene cylinder filling plant, flame arrestors shall be installed.

Flame arrestors or flame arrestors with cut-off devices 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 has 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 may occur in either static or flowing acetylene and may be either a deflagration or a detonation. Therefore flame arrestors should 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 may 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 may 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 (see EN ISO 15615). Several types of flame arrestor design can exist, (aluminium packing, etc.). The device's two functions (flame arrestor and flow cut-off) may be incorporated in the same unit.

B - Requirements

A flame arrestor device, that acts only as a flame arrestor, will arrest the flame front generated by HP 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’s recommended to install devices, which arrest <u>both</u> ignition and the gas flow on high-pressure acetylene lines.

A flame arrestor device shall meet the following requirements:

- Prevent decomposition in a HP pipe or pipe component passing through to the other parts of the pipe work system.

- Pass the acetylene decomposition tests (at 6 bar and 25 bar) according to the procedure described in EN ISO 15615.

These two requirements apply for all types of flame arrestors (those in HP 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.

C – Installation and use

Flame arrestors and flame arrestors with cut-off device(s) shall be suitably positioned at the following locations (see Figure 3).

- A flame arrestor and shut off device between individual compressors (including oil separators) and any system of dryers or distribution valve manifold.

- A flame arrestor and cut-off device(s) providing protection against decomposition from either side, is installed at the inlet to each charging rack immediately before the isolation valve for any individual filling manifold distribution pipe (cylinders, bundles or battery-vehicles) and also on the main lines.

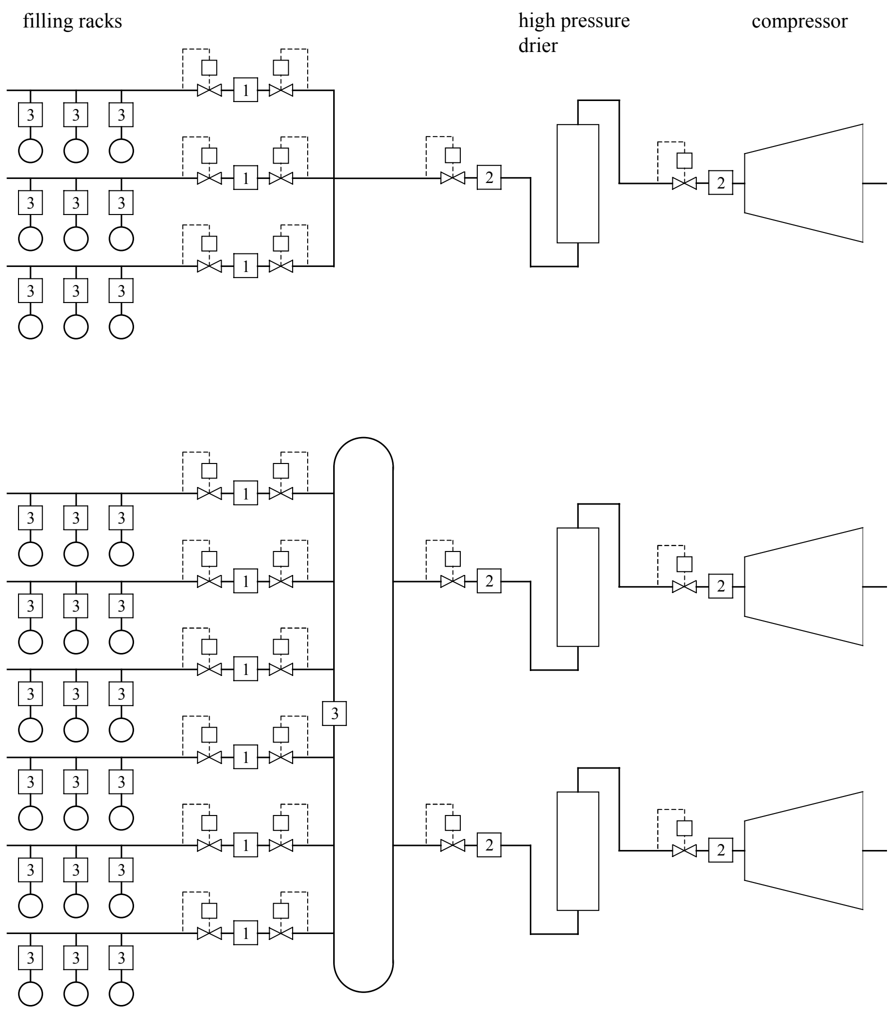
- A flame arrestor on the manifolds, at each connection point for filling cylinders. In this case, it's not necessary to have a cut-off device system. There should also be a non-return valve fitted at each cylinder connection, to prevent reverse flow from one cylinder to another and also to minimise the leakage of gas in the event of a hose rupture or a major fire.

- It is recommended that flame arrestors or flame arrestors with cut-off device(s) 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. For example high-pressure dryer inlet or outlets and in HP acetylene lines when they are very long. (e.g. between two parts of a factory.)

- A flame arrestor shall be fitted at each location where the acetylene pressure is dropped from high to low pressure, such as filling rack blowback points.

- Flame arrestors located directly after oil lubricated compressors and just before the oil separator are not necessary because there is a risk of pollution and blockage with oil or acetylene hydrate. Compressors that do not have a lubrication system on the gas feed may require a flame arrestor at the outlet.

Figure 3 – Location of flame arrestors



1 – Flame arrestor with cut-off devices providing protection against decomposition from either side.

2 – Flame 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 positioning flame arrestors in pipes, it is recommended to strictly follow the requirements established by the manufacturer of the equipment. Specific requirements may exist for positioning the flame arrestors in pipes or on equipment. For example horizontally or vertically, downstream or upstream of the device, etc. Flame arrestors shall be installed in accordance with the manufacturer's recommendations

10.5.3 Pressure gauge

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

10.5.4 Flexible hoses

All types of flexible hoses for HP acetylene shall withstand a decomposition test at 25 bar with acetylene and their bursting pressure shall be 1 000 bar minimum. For all the other requirements, see EN ISO 14113.

10.5.5 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 30 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 of this Code of Practice (see appendix). 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.

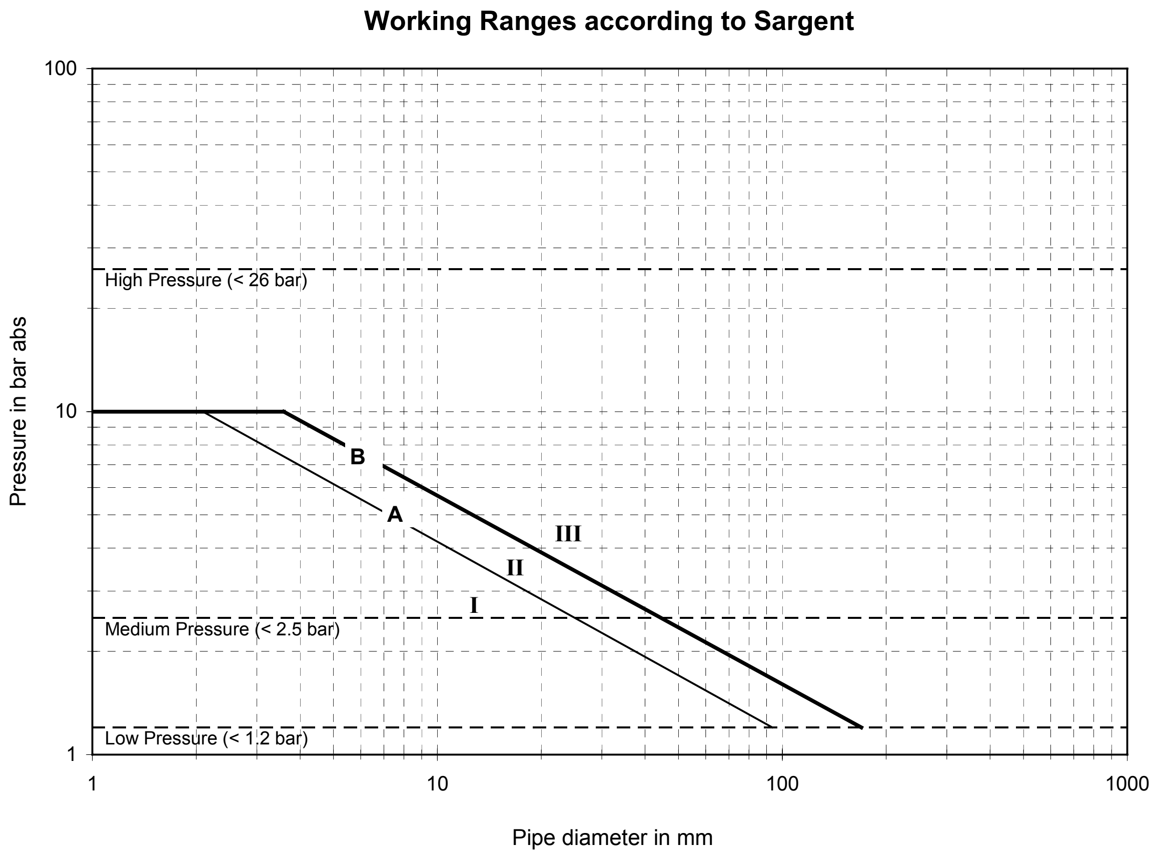
In acetylene pipelines whose operating conditions lie in the area below line A it is possible for acetylene decomposition to be initiated, but this may occur only under conditions of unusually high ignition energy.

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 may 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 may 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.



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.

11.2 Classification into working ranges

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

- Equipment directly connected to the pipeline 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.

11.3 Materials

11.3.1 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 (section 6.2).

When selecting the material for a pipeline it must 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 9: Carbon steels recommended as materials for acetylene pipelines

Working Range	Tensile Strength R_m (N/mm^2)	Elongation after Fracture A_5 (%)
I	see 11.4.2	
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 chloride is to be considered.

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

11.3.2 Materials not allowed or recommended only under certain conditions

Restrictions and conditions stated in 6.2 shall be observed.

For fittings, valve housings and similar components the ferrous materials marked "+" in Table 10 may be used. Where the Mark "0" is entered in Table 10 the material is not suitable unless special measures (e.g. 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 10: 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	+	+	+

11.3.3 Pipe specification

Pipes for Working Ranges II and III made of steels according to 11.3.1 shall be seamless or continuously machine-welded with a guaranteed weld factor. The pipes shall be tested in accordance with the specifications or standard to which they are manufactured.

11.4 Wall thickness

11.4.1 General

In this section the calculation of the wall thickness of pipes made of metals and metal alloys as recommended in 11.3.1 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 and in 11.2.

The wall thickness calculations do not consider external loads such as fatigue, mechanical, thermal, etc.

If welded pipes (as described in 11.3.3) with a weld factor below 1 are used, the method of calculation of the wall thickness must be modified to include the weld factor in the respective wall thickness formula.

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.

11.4.2 Pipelines in Working Range I

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

The required wall thickness may be calculated according to recognised national pipework design standards.

Alternatively, the required wall thickness as a function of the dimensioning pressure shall be calculated according to the formula.

$$e = \frac{PD_e}{20f + P}$$

Where:

e = minimum wall thickness (mm)

P = "dimensioning pressure" (bar)

D_e = external diameter of pipe (mm)

$$f = f_y / 1{,}3$$

f_y = stress at yield point (lower) of the material, (N/mm^2)

The wall thickness of acetylene pipelines in Working Range I should be selected in accordance with recommended standards, corrosion allowance must be added to the calculated wall thickness. External mechanical loading upon the pipework shall be considered.

11.4.3 Pipelines in Working Range II

The wall thickness of acetylene pipes used for installations in Working Range II must 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:

$$e = \frac{PD_e}{20f + P}$$

Where:

e = minimum wall thickness (mm)

P = "dimensioning pressure" (bar)

D_e = external diameter of pipe (mm)

The values of P and f are to be calculated as follows:

$$P = 11(P_w + 1) - 1$$

$$f = f_y / 1{,}1$$

Where:

P_W = max. working pressure (bar)

f_y = stress at yield point (lower) of the material, (N/mm^2)

Alternatively pipelines in Working Range II may be designed by means of acetylene decomposition tests; see 11.4.4.

11.4.4 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 may 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 may be used:

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

To calculate the minimum wall thickness of the pipes use the formula:

$$e = \frac{PD_e}{20f + P}$$

Where:

e = minimum wall thickness (mm)

P = "dimensioning pressure" (bar)

D_e = external diameter of pipe (mm)

f = allowable stress of the material (N/mm^2)

The dimensioning pressure P and the allowable stress f are calculated as follows:

$$P = 35(P_w + 1) - 1$$

$$f = f_y / 1{,}1$$

Where:

P_W = max. working pressure (bar)

f_y = stress at yield point (lower) of the material (N/mm^2)

B. 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 by the method described above, but the dimensioning pressure P is calculated as:

$$P = 20(P_w + 1) - 1$$

Pipes 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.

Reinforcement of the wall thickness must be employed at points of reflection e.g. blind ends, tees, valves and bends with bending radius of less than 5 times the internal diameter (sharp bends). The reinforcements must increase the total wall thickness to at least twice the calculated wall thickness. In the case of blind ends and sharp bends the reinforcements must 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 must 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 must 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 ISO14113.

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 done to a recognised standard.

For Working Ranges II and III the couplings must be of the same calculated strength as the pipeline to which they are fitted. Taper threaded connections are not recommended for Working Range III.

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 must be protected by a flame arrestor (ref. 10.5.2) unless the pipe is dimensioned in accordance with 11.4.4.

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 (gauge) of the valve (bar)

P_W = maximum working pressure (gauge) (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.

For Working Ranges II and III, the design of the valve or the method of installation must 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 11.7.4. The system may be tested as a complete assembly or alternatively each section may be tested separately.

Special parts may require separate testing or test methods. If parts are tested separately, ensure that all connecting elements are included in the tests.

Hydraulic testing shall be the preferred method.

Pneumatic testing may be carried out with an inert gas or air, provided sufficient precautions are taken to minimise all risks associated with the test.

11.7.2 Test pressures

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

Working range	Test pressure
I	P_{test} = 1.5 P_w, bar, min 4 bar

II	P_{test} = 10 P_w, bar, min 20 bar
III	P_{test} = 20 P_w, bar, min 30 bar, max 300 bar

P_{test} = test pressure

P_w = max. working pressure

11.7.3 Leak test

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

Leak-tightness can be checked by observing if there is a pressure decay. Leakage can also be detected using an appropriate commercial leak test solution. Avoid detergent solutions that contain ammonia or other ingredients that can initiate stress corrosion cracking.

11.8 Dimensions and design

11.8.1 Manufacture

Joints between pipes and the materials required to produce them shall be sufficient to ensure that a good connection is made and that the pipeline is gas tight.

Welds on pipes shall be made using suitable materials and fillers and produced carefully so that perfect welds are ensured and internal stresses are kept to a minimum.

Welding work shall be carried out, under proper supervision, by competent welders who have valid certification for the 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 may only be used for accessories or to enable dismantling of the system for maintenance purposes.

Butt-welding is preferred for all joints.

Joints in underground pipes shall be fully welded.

In the case of pipes that are installed above ground screwed assemblies can be used that have an O-ring seal or screw bushings with hemp or screw bushings with adhesive and filling materials based on cyanoacrylate, silicone and PTFE as sealants. If hemp is used, a lubricant and bonding agent shall be used.

Pipe elbows in detonation-resistant high-pressure lines shall have an average radius of at least five times the inside diameter of the pipe.

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 specially protected against corrosion.

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

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 great mechanical strength (e.g. strong PE sheathing or wound sheathing).

The same 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 (e.g. 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 PE sheath is 20 kV). Ensure the pipeline earthing system is intact before the test, to avoid arcing.

11.8.2 Equipment

Drainage

Pipes for wet acetylene, which may be subject to condensation of water, shall be fitted with drainage facilities at the lowest points protected 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 shall not be used in medium or high-pressure piping.

Isolation valves shall be easily accessible and easy to operate.

Pressure relief valves shall not be fitted with isolation valves. 3-way change over valves are permitted on the inlets of duplex valve systems.

Pressure relief valve discharge pipes (discharging to atmosphere) shall not be manifolded together.

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.

11.8.3 Installation

General requirements

- The installation of pipelines shall take the expected thermal expansion into account. For example, omega loops, expansion bellows (low pressure only).
- If pipelines are installed near other pipelines and, in particular, if they run parallel to or across other pipelines, the distance shall be such that any necessary maintenance and repair work is possible without risk to other pipelines.
- Pipelines should 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.
- If possible, factory pipelines should be installed above ground and be easily accessible.

- Long-distance pipelines to customers (off-site) shall be installed underground in suitable ducts.
- It is only permissible to install underground pipelines outside of buildings.
- Inside buildings pipelines 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 generally be installed in concrete or brickwork. If a pipeline has to be installed in concrete due to factory circumstances (e.g. 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 undesired movement and protection against impact damage.

Pipelines installed above ground shall be clearly identified by colour coding or labelling.

Pipelines in accessible ducts

Pipelines should only be installed in ducts if:

1. the ducts have a headroom of at least 1.5 m
2. the ducts are constantly well ventilated
3. the pipelines can be installed so that they are easily accessible
4. the pipelines are protected against dripping water.

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

Pipelines in non-accessible ducts

Pipelines may 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.

Pipelines installed in the ground

Pipelines installed in the ground shall be supported along their entire length.

Pipelines installed in the ground shall be protected against possible damage from outside. This requirement is generally fulfilled when the earth covering is at least 0.60 m. The earth 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 durable material, e.g. plastic, shall be installed. The tape should be installed at a distance of approx. 0.30 m above the pipeline.

In the ground pipelines shall be installed so that

1. the insulation is not damaged and
2. 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 minimum distance stated in No.2 can be ignored if the persons responsible for the supply pipelines agree and if other measures, e.g. overhead pipelines, guarantee that risks to the supply pipelines do not exist.

The course of the pipelines installed in the ground shall be documented in plans. The course shall be marked at the site.

Vent pipes

Vent pipes shall be installed and fastened such that repulsion forces cannot impair their function.

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

Vent pipes should not emerge below openings into buildings (e.g. windows). There shall be no sources of ignition within an area of at least 5 m above and to the sides and at least 1 m below the pipe outlets.

11.8.4 Operation

Before start-up the pipelines should be tested to ensure that they comply with the requirements of this Code of Practice. Tests should cover in particular proper manufacture, installation and fittings as well as pneumatic leak test at maximum working pressure. A hydraulic pressure test is also required for pipelines intended for a maximum working pressure of more than 0.4 bar. A certificate should be issued to document the results of the tests.

In acetylene pipelines the pressure up to the withdrawal point should not fall below the value of 1 mbar. There shall be instructions to ensure that all consumers connected to the network stop operation if there is a lack of gas.

Code of practice chapter 10.5, apply in regard to the operation of high-pressure pipelines that are supplied from compressors at ambient temperatures of less than 10 °C.

Pipelines should only be supplied from various gas sources if the acetylene enters the pipelines with virtually the same pressure from each source.

Pipelines installed above ground shall be monitored for leaks (e.g. by using a suitable ammonia free leak detection fluid or by use of a gas detection unit) and good condition.

Pipelines that are installed in the ground or are not freely accessible shall be checked every five years to test strength and leak proofing. Test pressures are to be in accordance with 11.7.2. The tests should be documented.

In cases where it is not possible to stop operation of a pipeline that is installed in the ground or is not accessible, an alternative test shall be made at intervals of twelve months. This test involves drilling into the ground and sniffing the earth with the aid of a suitable gas detector. The test should be documented.

Repair work on pipelines should be carried out by competent persons only.

The supply of acetylene shall be isolated before any repair work commences.

If repair work is prolonged or if hot work is required, the pipeline should be depressurised and visibly (e.g. sealing washer with flag) isolated from the system.

Hot work on pipelines should only be carried out after the acetylene has been purged using nitrogen.

12 Supply

Acetylene supply systems shall be designed, equipped and operated so that they can withstand expected operational stresses and do not create a hazard to employees or third parties. They shall be operated so that hazardous external corrosion does not occur and so that they remain protected against impact stresses.

Particular occurrences, defects or damage to individual cylinder systems, and also triggering of their safety devices, shall be reported immediately to the person(s) responsible for operation.

12.1 Single cylinder supply systems

12.1.1 Definitions

Individual cylinders are acetylene supply systems with one acetylene cylinder.

The single cylinder system consists of:

- the acetylene cylinder,
- the cylinder pressure regulator (cylinder pressure reducer),
- the medium-pressure or low-pressure equipment connected downstream of the cylinder pressure regulator (e.g. hose line) and
- safety devices.

12.1.2 General

Before commencing work, personnel shall be given the necessary training and competency assessment for:

- operating single cylinder systems,
- the special hazards involved in handling individual cylinder systems
- actions that shall be taken in the event of accidents and faults.

12.1.3 Equipment

Cylinder pressure regulator (cylinder pressure reducer)

A cylinder pressure regulator that limits the operating pressure of the connected medium-pressure or low-pressure line to the maximum permissible value, shall be fitted to the acetylene cylinder valve. The cylinder pressure regulator shall conform to EN ISO 2503.

Hoses

Only hoses conforming to EN 559, designed and approved for acetylene shall be used.

Fuel gas hoses shall be secured to the connection points by means of hose clamps or similar fasteners. Hoses shall not be joined together to extend their length. Hose connections shall conform to EN 560 and hose assemblies shall conform to EN 1256.

Safety devices

Single cylinder systems shall be equipped with a flashback arrestor and a non-return valve. They shall conform to EN 730.

12.1.4 Installation

Individual cylinder systems shall not be located in confined spaces or areas of restricted access such as stairwells, corridors, passageways and thoroughfares. Only under special circumstances is it permissible to work in areas of restricted access. (e.g. for essential repair work to stair rails.) In these cases, the individual cylinder systems should be set-up and used for a brief period only, ensuring that the necessary safety measures have been taken. (e.g. cordoning off, securing an escape route, ventilation)

Acetylene cylinders of single cylinder systems shall be set up so that they are easily accessible.

In areas that are accessible to the public, acetylene single cylinder systems shall either be constantly monitored or access restricted. In the case of temporary work, a notice to this effect is sufficient.

The number of individual cylinder systems in working rooms shall be minimised.

Working rooms shall be sufficiently ventilated, if necessary by artificial means.

Acetylene cylinders should not be used in the horizontal position. Free-standing acetylene cylinders shall be adequately supported, e.g. with chains, clamps or stands.

Acetylene cylinders shall be set-up so that the hose connector of the cylinder pressure regulator is not directed towards another gas cylinder to prevent any potential flame impingement.

12.1.5 Operation

Acetylene single cylinder systems shall be operated so that no hazardous heating-up can occur. They should always be at least 0.5 m from radiators and other sources of heating. There is no need for protection against sunlight.

Ignition sources such as glowing objects, naked flames and smoking are not permitted within an area of at least 1 m around an acetylene single cylinder system. There shall be no easily flammable materials in the vicinity.

Before connecting the cylinder pressure regulator, the cylinder valve shall be checked for dirt and cleaned if necessary. The practice of opening the cylinder valve to blow out dirt is not recommended, as there is the risk of a spontaneous ignition occurring.

Before opening the cylinder valve, the adjustment screw of the cylinder pressure regulator shall be fully screwed back until the spring is relieved. When the cylinder valve is opened reaching over the cylinder pressure regulator’s safety valve vent shall be avoided.

Before the burner is ignited, any acetylene/air mixture in the hose shall be purged out with acetylene.

No pressure greater than 1.5 bar shall be set at the cylinder pressure regulators.

The cylinder valves shall be closed and the hose lines shall be depressurised when not in use for extended periods. (e.g. at the end of the working day)

Before cylinder pressure regulators are disconnected from acetylene cylinders, including empty cylinders, the cylinder valves shall be closed. Immediately after removing the cylinder pressure regulator, the cylinder valve shall be protected by fitting the protective cap.

Only suitable means of transport (e.g. cylinder trolleys) should be used to move individual cylinder systems. Closed means of transport shall be well ventilated. The cylinder valves shall be closed during transportation.

If an individual cylinder system is not in good condition, posing a risk to employees or third parties, the system shall not be operated.

Cylinder valves and cylinder pressure regulators shall be protected against contamination and kept in a good condition.

Hose lines shall be protected against damage (e.g. being driven over, bending, and burning) and shall be kept in good condition.

Hose lines shall not be attached directly to acetylene cylinder valves and fittings.

12.1.6 Maintenance

Regular inspection/maintenance shall ensure that:

- the equipment is in good order, is being correctly used and all the required components are fitted;
- flexible hoses are not damaged;
- valves open and close correctly;
- the system is operating normally (i.e. report if system is using more gas than normal, an unusual drop in pressure or smell of gas which could indicate a malfunction or leak).

Annual inspection shall check that:

- the cylinder system is not leaking (leak test at the maximum operating pressure);
- setting and operation of the regulator is satisfactory;
- safety devices are operating correctly (e.g. non-return valves for safety against backflow of gas).

Leaking or damaged parts shall be replaced or repaired by competent persons. Authorised spare parts shall be used for valves and fittings.

The supplier or their authorised agent shall only perform repair work on acetylene cylinders. It is permissible for the operator to tighten cylinder valve glands.

In the event of flashbacks or other faults, individual cylinder system may only continue to be operated if the fault has been rectified and the system has been confirmed to be in good condition.

12.2 Battery and manifold supply systems

12.2.1 Definitions

Battery or manifold systems are acetylene supply systems with two or more acetylene cylinders, also combined into cylinder bundles or acetylene battery vehicles (see EN ISO 14114).

Battery systems consist of:

- two or more acetylene cylinders,
- a high-pressure section,
- a main pressure regulator,
- a medium or low-pressure section downstream of the main pressure regulator
- safety devices (as required in EN ISO 14114)
- special installation rooms and installation locations (see ”Requirements for special installation rooms” in chapter 12.2.4).

Transportable battery systems are battery systems, intended for use at different locations for temporary work such as building or repair work. Small battery systems are battery systems with up to 6 acetylene cylinders.

12.2.2 General

Before commencing work, personnel shall be given the necessary training and instructions about:

- operating battery systems;
- special hazards involved in handling battery systems;
- actions that shall be taken in the event of accidents and faults.

All parts of battery systems carrying acetylene shall be designed so that air or acetylene/air mixtures can be purged.

The high-pressure lines of battery systems should be kept as short as possible.

Only high-pressure hoses conforming to EN standards shall be used.

Acetylene cylinders with different porous masses may only be connected together in a battery system for collective withdrawal if they contain the same type of solvent and have the same filling ratio (ratio of acetylene to solvent content).

Special installation rooms shall conform to the requirements of local building regulations, and this Code of Practice

12.2.3 Equipment

Battery systems shall be equipped as outlined in

- EN ISO 14113
- EN ISO 14114
- EN ISO 15615
- EN 730

The main requirements are as follows:

High-pressure section

The high-pressure section shall be equipped with:

- high pressure non-return valves directly downstream of the cylinders or the bundle outlet to prevent the backflow of gas into the cylinders;
- a quick acting shut-off device in the high pressure section (either manual or automatic depending on the type of battery system) to prevent the continued withdrawal of acetylene if an acetylene decomposition or flashback occurs.

High-pressure hoses shall only be used when rigid pipes are unsuitable. The length and diameter of the hose shall be kept to a minimum and the hose shall be protected against external damage. Hoses shall have a minimum burst pressure of 1000 bar and they shall resist an acetylene decomposition of high-pressure acetylene at an initial pressure of 25 bar. When hoses are installed, the resistance between the two end fittings shall not exceed 10^6 ohms to give protection against electrostatic charging. Hoses shall be resistant to solvent attack, both acetone and DMF. Hoses assemblies shall conform to EN ISO 14113.

Main pressure regulator

A main pressure regulator limiting the operating pressure in the downstream low- or medium-pressure section to the highest permissible value shall be located at the end of the high-pressure line. The main pressure regulator shall conform to EN ISO 2503 for battery systems with up to 6 acetylene cylinders and for larger battery systems shall conform to EN ISO 7291.

The main pressure regulator shall be equipped with a pressure gauge at the upstream side (pressure range from 0 to 40 bar) and at the downstream side (pressure range from 0 to 2.5 bar). The maximum operating pressure of the downstream side shall be marked on the pressure gauge.

Medium or low-pressure section

The low or medium-pressure section shall be equipped with:

- a non-return valve,
- a flame arrestor,
- a pressure or temperature sensitive cut-off valve,
- a pressure limiting device limiting the pressure to the maximum operating pressure (this device may be part of the main pressure regulator) and
- a main shut-off valve.

It shall not be possible disable pressure limiting devices during operation. They shall be protected against unauthorised changes to the setting pressure, e.g. by lead sealing.

Safety valves (if installed) shall be fitted with vent lines that discharge the gas to a safe location outside.

12.2.4 Installation

General requirements

Acetylene battery systems shall not be located in confined spaces or areas of restricted access such as stairwells, corridors, passageways and thoroughfares. Only under special circumstances is it permissible to work in areas of restricted access. (e.g. for essential repair work to stair rails.) In these cases, the individual cylinder systems should be set-up and used for a brief period only, ensuring that the necessary safety measures have been taken. (e.g. cordoning off, securing an escape route, ventilation) Public access to acetylene battery systems shall be prevented.

Acetylene cylinders and the high-pressure section of battery systems shall be housed in a special room or outdoors as outlined in “Requirements for special installation rooms” in this chapter. If the operating personnel during acetylene withdrawal monitor the systems, then this does not apply to small systems and portable battery systems.

Acetylene cylinders within battery systems shall be easily accessible and set up so that they are protected against the effects of heat.

Spare cylinders may also be kept at the installation location of battery systems, but no more than 6 in the case of small battery systems.

Spare cylinders shall be connected to the high-pressure collective line with their cylinder valves closed. Cylinder bundles shall be connected with their main valve closed.

Acetylene pipelines incorporated in battery systems shall not be part of an electrical earthing installation serving other purposes.

Signs stating the following or similar, shall be displayed at the access point to battery systems (except for small systems):

(A)

Acetylene system
No unauthorised access
No smoking
No naked flames or fire

Requirements for special installation sites and rooms

It is recommended that acetylene battery systems are installed externally but if low ambient temperatures cause operational difficulties special purpose rooms may be required.

Requirements for outdoor installation sites

- Outdoor installation sites for battery systems shall be protected against unauthorised access. Depending on local conditions this may be achieved by means of a barrier, a fence or signs as outlined in "General requirements (A).
- Valves and safety fixtures shall be protected against the effects of the weather using non-flammable materials.

Requirements for special installation sites and rooms

- Special installation rooms for acetylene cylinders and the high pressure section of battery systems shall not be below other rooms or below ground level
- Installation rooms shall comply with the requirements of the Directive 94/9/EC in particular:
  - they shall be constantly ventilated, either artificially or naturally,
  - the guidelines for avoiding ignition hazards arising from electrostatic charges shall be followed;
  - all electrical equipment shall be suitable for use in potentially explosive atmospheres.
- Adequate illumination shall be provided.
- Only the acetylene cylinders and the high-pressure section, including the main pressure regulator with the downstream safety devices, shall be kept in the installation rooms.
- The storage of other types of gas cylinders within acetylene battery rooms is not recommended.
- In the event of an emergency, it shall be possible to leave the installation rooms safely and quickly. There shall be at least one exit leading directly outdoors. Doors for emergency exit routes shall open outwards.
- If installation rooms are not free standing but are adjacent to other rooms, they shall be separated from these other rooms by gas-impermeable and 1 hour fire-resistant walls. Doors or other openings are not permissible within these walls.
- Partition walls to neighbouring rooms shall be gas-impermeable and fire-resistant if the neighbouring rooms are unmanned and if here is a low risk of fire (e.g. in rooms for storing non-flammable material). Doors within these partition walls shall be fire-retardant and self-closing.
- Outer walls and doors of special installation rooms shall be made of non-flammable materials.
- Roofs of installation rooms shall be of a lightweight blow-off construction to relieve any explosion occurring within. Ceilings between the roof and the installation room are not permissible. The support structure of the roof, the roof boarding and any insulating layers inside the installation rooms shall be made of non-flammable materials. The roof cover shall be resistant to flames and radiated heat.
- Heating equipment in installation rooms is only permissible if it is in compliance with the requirements of the Directive 94/9/EC
- Adequate water supplies shall be available to cool the cylinders in the event of a fire. Deluge systems may be considered for large installations.
- Fire extinguishers shall be provided at suitable locations.

12.2.5 Operation

General requirements

Acetylene battery systems shall be operated so that no hazardous heating-up can occur. They should always be at least 0.5 m from radiators. There is no need for protection against sunlight.

Ignition sources such as, naked flames and smoking are not permitted within an area of at least 3 m around an acetylene battery system. There shall be no easily flammable materials. Acetylene cylinders of outdoor battery systems shall be separated from sources of ignition and flammable materials by at least 3 m. The requirements of the Directive 94/9/EC and 99/92EC shall apply.

Acetylene battery systems, apart from portable battery systems, shall have a separation distance of

- at least 5 m from public transport routes,
- at least 10 m from railways and traffic ways used by vehicles which may emit sparks and
- at least 15 m from public railways.

These distances may be reduced by structural measures (e.g. walls without openings).

Initial inspection prior to operation

Before being operated for the first time, battery systems shall be inspected to determine whether they meet the requirements of this Code of Practice. The following tests shall be carried out:

1. Function tests that shall be carried out are:
   - non-return valves for operation, tightness and gland leakage;
   - cut-off devices for correct operation and set pressure;
   - regulators for correct operation and outlet pressure.

2. Pressure testing. Parts can be tested separately if connecting elements are included in the test. Measuring devices, pressure-limiting devices, pressure regulators and venting lines do not require testing

   The test pressure shall be
   - at least 300 bar in the high-pressure section,
   - at least 24 bar in the medium-pressure section,
   - at least 2.5 bar in the low-pressure section and in the medium-pressure section with an operating pressure of no more than 0.4 bar.

   Pressure tests shall be carried out using water. For medium and low-pressure sections, pressure tests may be carried out using nitrogen or air if the necessary safety precautions are taken.

   After hydraulic tests the system shall be thoroughly dried to eliminate problems associated with to trapped moisture.

3. Prior to initial operation, the complete battery system shall be leak tested at its maximum operating pressure. This test should be carried out after purging the system with nitrogen.

The results of these tests shall be documented.

Before a battery system is operated for the first time, the entire pipework from the connecting lines of the cylinders to the dispensing points shall be purged thoroughly with nitrogen.

If existing battery systems are extended or modified with newly installed parts, the inspection and purging shall be carried out.

Operation

Acetylene cylinders and bundles shall be connected ensuring all connections are gas tight. Before connecting a cylinder bundle, the bundle manifold shall be purged with acetylene to eliminate any air that may be present in the system.

Cylinder valves of all acetylene cylinders connected for collective gas withdrawal shall be open during gas withdrawal.

When not in use for extended periods (e.g. during night or at weekends), the main isolation valves upstream of the main pressure regulator shall be closed.

Before empty acetylene cylinders or bundles are removed from the battery system, the isolation and cylinder valves shall be closed.

Acetylene cylinder valves in a bundle shall remain open during storage and transport. The bundles shall be isolated by the main shut-off valve only.

Before individual acetylene cylinders are transported, protective caps (if required) shall be fitted.

Only suitable transport means shall be used to move acetylene cylinders and bundles. It is not permissible to use magnetic cranes.

If wet seals (water seals) are used they shall be checked at least once per shift and after flashbacks to ensure that the water level is sufficient. They shall be cleaned at least annually and shall be inspected for security against returning gas.

12.2.6 Maintenance

Regular inspection/maintenance shall ensure that:

- the equipment is in good order, is being correctly used and all the required components are fitted,
- pigtails and flexible hoses are not corroded or damaged,
- regulators are not damaged
- valves open and close correctly
- the system is operating normally (i.e. report if system is using more gas than normal, an unusual drop in pressure or smell of gas which could indicate a malfunction or leak).

Annual inspection shall check that:

- the battery system is not leaking (leak test at the maximum operating pressure),
- setting and operation of regulators are satisfactory,
- safety devices are operating correctly (e.g. non-return valves for safety against backflow of gas),
- the condition of the equipment and pipework and their protection against corrosion is acceptable.

Leaking or damaged parts shall be replaced or repaired by competent persons. Authorised spare parts shall be used for valves and fittings.

The supplier or their authorised agent shall only perform repair work on acetylene cylinders. It is permissible for the operator to tighten cylinder valve glands

In the event of a flashback other or other faults, battery systems may only continue to be operated if the fault has been remedied and the system has been confirmed to be in good operating condition.

12.3 Storage and Handling

12.3.1 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 depth of the open side does not exceed its height. A side of a room is also classed as being open if it consists of a wire grille or has a similar free area.

- Acetylene cylinders may not be stored in rooms below ground level unless in use,
- in stairwells, corridors, enclosed yards and in passages and thoroughfares or in their immediate proximity,

- on outdoor steps,
- along specially marked escape routes,
- in vehicle parking garages and
- in workrooms.

Workrooms do not include storage rooms, even if people are working there.

Acetylene cylinder storage areas shall exclusively be used for cylinder storage and shall not be used for gas transfer operations nor 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 94/9/EC
- control of ignition sources
- potential off-site risks to neighbouring properties and populations
- potential risks by 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 safety zones and the respective hazard (risk of explosion).

12.3.2 Indoor storage

It is strongly recommended that acetylene cylinders are 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 so that the acetylene cylinders stand up safely.
- Storage rooms shall be sufficiently ventilated at both high and low level. Natural ventilation is sufficient if ventilation openings leading directly outside are present with a total cross section of at least 1/300th of the floor area of the storage room.
- 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.
- In storage rooms, there shall be no cellar access or other open connections to cellar rooms.
- Flammable materials (e.g. flammable liquids, wood, wood chips, paper and rubber) shall not be stored in acetylene cylinder storage 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 m. This does not apply to doors that are self-closing and fire-retardant.

- Adequate separation shall be maintained between acetylene cylinders and other cylinders containing oxidising gases.

12.3.3 Outdoor storage

For outdoor storage the following shall apply:

- The floor area shall be flat and level such that the acetylene cylinders stand safely.
- When filled acetylene cylinders are stored in the open, a safe distance shall be maintained to nearby systems and equipment.
- There shall be no flammable materials in the storage area.
- Smoking and sources of ignition are not permitted within two metres the storage area. Controlled access of vehicles and forklift trucks is permitted.
- Acetylene cylinders shall not be stored closer than five metres to the boundary fence of the site unless a two-metre high fire wall is provided. It is not recommended that acetylene cylinders are stored close to a boundary fence where there may be hazards created by the public.
- The cylinder store shall be protected from vehicle impact.

12.3.4 Handling

When transporting acetylene cylinders, caps shall be fitted where supplied.

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

If acetylene cylinders are transported with consumer units connected, the shut-off valves shall be closed. This does not apply if consumer units are being operated and supplied with gas during the journey.

Acetylene cylinders shall not be subjected to violent impacts.

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

When being transported on vehicles, acetylene cylinders shall be secured so that they cannot move. If acetylene cylinders are transported in closed vehicles, including those with tarpaulin covers, sufficient ventilation shall be provided both at the top and bottom. e.g. via ventilation slots, so that no explosive or harmful atmospheres can arise. See IGC Doc 103/03.

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

When acetylene cylinders are being transported on public roads, traffic laws concerning the transport of hazardous goods shall be observed.

12.3.5 Inland transport

For inland transport of acetylene within the European Community, the requirements of Directive 1999/36/EC on transportable pressure equipment (TPED) shall apply. This directive refers to the relevant provisions of Directive 94/55/EC, on the approximation of the laws of the Member States with regard to the transport of dangerous goods by road, and Directive 96/49/EC, on the approximation of the laws of the Member States with regard to the transport of dangerous goods by rail. For the technical requirements these Directives refer to two international treaties that are valid beyond the European Community in all member countries recognising these treaties. These are ADR (European Agreement Concerning the International Carriage of Dangerous Goods by Road), Annexes A and B and RID (Regulations Concerning the International Carriage of Dangerous Goods by Rail) (see also figure 4).

Some of the main requirements are summarised in the following:

For acetylene cylinders, cylinder bundles and trailers refer to chapter 9."Acetylene receptacles and fittings".

Persons involved with the transport of acetylene shall be instructed with regard to the transport of dangerous goods in general and specifically with regard to the transport of acetylene.

The driver of a dangerous goods transport shall have special training for which a certificate of the competent authority is issued.

In addition to the marking and labelling of the acetylene cylinders and bundles, the vehicles shall be specifically labelled and correct transport documentation shall be made and kept available.

Acetylene cylinder valves shall be closed and protected against damage during transport by a valve protection cap or a suitable valve protection device.

Acetylene cylinder valves in a bundle shall be kept open during storage and transport and the bundle shall be isolated by the main shut-off valve only.

Acetylene cylinders and bundles shall be secured during transport so that they are protected against moving.

A vehicle transporting acetylene shall be equipped with a suitable fire extinguisher.

In addition to the above, if acetylene cylinders are transported in closed vehicles, including those with tarpaulin covers, sufficient natural ventilation shall be ensured both at the top and bottom, e.g. via ventilation slots, so that no explosive or harmful atmospheres can arise.

If acetylene cylinders are transported with connected pressure regulators (not recommended), the cylinder shut-off valves shall be closed and the regulator valve be depressurised to the low-pressure position. The hoses shall also be de-pressurised.

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

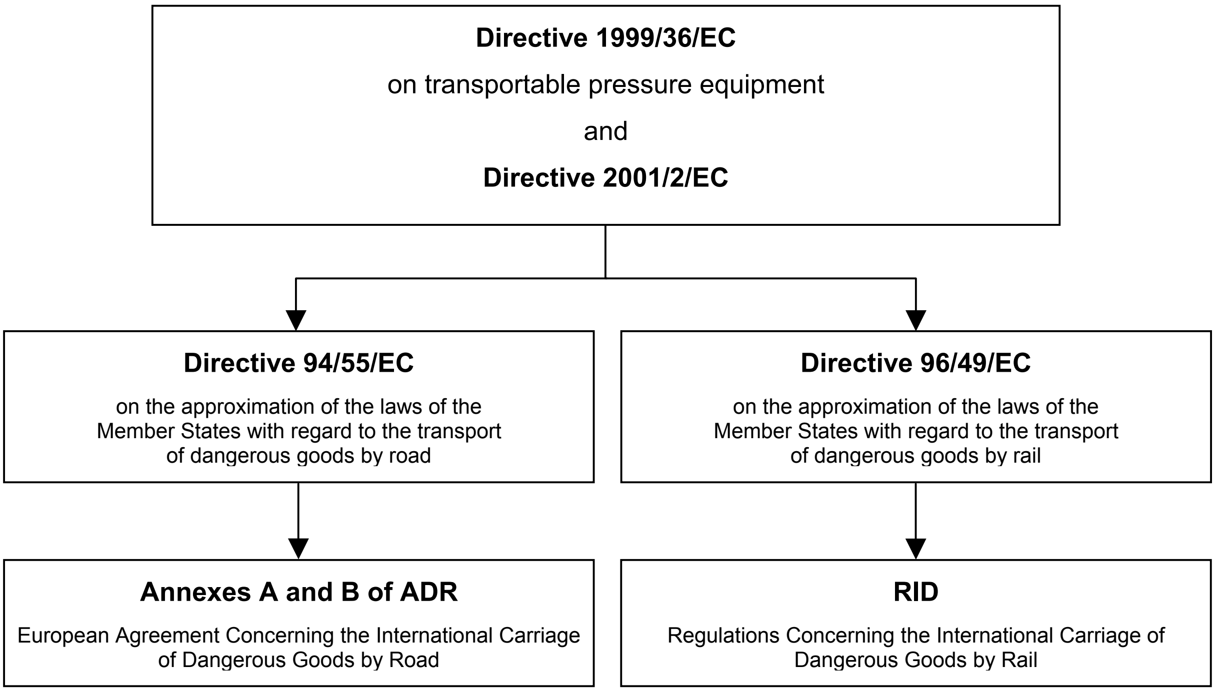


Figure 4: European regulations applying for the transport of acetylene

13 Emergency response

13.1 Emergency procedures for calcium carbide storage and transportation

13.1.1 Hot calcium carbide drums and containers

Calcium carbide drums or containers may become hot if they are damaged and there is any ingress of water. Emergency procedures and equipment shall be in place to safely deal with such situations.

13.1.2 Purging full calcium carbide drums

Follow this procedure when purging a full calcium carbide drum that is hot, under pressure or bulging.

Purging reduces or eliminates potentially flammable acetylene-air mixtures from calcium carbide drums. Nitrogen is passed through the drum to dilute and displace any potentially flammable acetylene-air mixtures. It also dries the carbide, stopping the generation of acetylene. Nitrogen is used because it is an inert, non-reactive gas.

The nitrogen purge equipment should be able to provide a controlled flow of nitrogen at low pressure, through a small bore tubular probe, which may be inserted in to a pierced hole in the drum.

a. Before starting to purge

   Before a drum is purged, it shall be taken to a designated safe location. This location shall be:

   - dry
   - well ventilated
   - at least 10 metres from gas cylinders, buildings, site boundary, sources of ignition, flammable materials
   - allow the drum to cool naturally by ambient air until cold to the touch

b. Procedure

   - Using a spark-free non-impacting tool, pierce one hole in the lid of the drum, and one near the drum base.
   - Only use a spark free tool to cut holes in the drum. Always ensure a competent second person is present and that a dry powder fire extinguisher and dry sand are available.
   - Insert a nitrogen purge line into the hole near the base.
   - Slowly turn the nitrogen on and purge the drum until cool.

   Continue purging, checking periodically that it is not re-heating, until the drum is opened for the next generator recharge.

13.1.3 Emergency procedures for hot carbide bulk containers

Bulk containers of calcium carbide are normally fitted with purging connection points. Any container showing signs of heat should be purged with nitrogen until the external surface of the container is cold and the gas venting off is less than 2% acetylene in nitrogen. The container may then be used in the normal manner.

13.1.4 Carbide spillage

a) Equipment

The following equipment is required for cleaning up calcium carbide spills:

- Aluminium or brass shovel (full shovel with long handle)
- aluminium or brass bucket
- natural bristle broom (not nylon which may generate static electricity)
- steel drum without a lid
- drum containing dry sand
- Personal Protective Equipment

b) Use and maintenance of equipment

Equipment to clean up calcium carbide spills should be:

- maintained at a designated spot in the acetylene plant
- used for that sole purpose only
- plastics or other potential spark generating equipment shall not be used

c) Cleaning up a calcium carbide spill

Wear the following personal protective equipment:

- rubber gauntlets (long sleeve gloves)
- chemical resistant goggles
- flame retardant cotton overalls
- dust mask

If the spillage is a major loss of containment then evacuate personnel from the area to a safe location upwind and barricade to prevent vehicle access.

Evacuation is not required for small spillages during normal transfer operations.

Keep water away from spilled calcium carbide. If carbide has landed in water in the vicinity of the acetylene generator, immediately stop all acetylene production and ventilate before beginning clean up.

Isolate all sources of ignition in the area.

Check for dust/fines (small granular carbide) in the spilled calcium carbide as these residues can:

- react rapidly with moisture in the air
- become hot enough to ignite the acetylene produced

If dust or fines are present:

Use appropriate spark-proof equipment to remove calcium carbide dust, fines and residues away from the acetylene plant.

Spread deposits thinly, on a designated disposal area, and hose with large quantities of water.

DO NOT throw agglomerated quantities of dust, fines and residues directly into water or carbide lime settling pits as this may cause an explosion. Dust must always be thinly distributed for disposal.

If spilled calcium carbide has come in contact with water, eliminate hot spots by covering it with sufficient dry sand so that no calcium carbide can be seen through the layer of sand. Wait until cool and then clean up calcium carbide using the recommended equipment and place it in a transfer cart or steel drum. Then:

- transfer to a safe area away from buildings and sources of ignition
- scatter calcium carbide and sand mixture in a thin layer on an designated disposal area and leave to react with the moisture in the air
- alternatively, after picking up the bulk of the spillage, water hoses may be used to wash the remaining spilt residues in to the carbide lime disposal system

If not contaminated with sand, the carbide may be kept covered and be used in the first available generator charge.

13.1.5 Carbide fires

a) Fighting a Calcium Carbide Fire

Calcium carbide is not flammable but generates acetylene gas when in contact with water.

Therefore never apply water or use foam extinguisher to a Calcium Carbide fire. The water will react with the Calcium carbide to produce more acetylene gas, feeding the fire.

It is preferable to let fires in carbide spills to burn out naturally. This consumes the escaping acetylene and avoids the formation of large unconfined gas clouds, which may result in an explosion.

b) Procedure

Wear the following personal protective equipment:

- leather gauntlets
- leather boots
- face shield
- flame retardant cotton overalls

Evacuate personnel from the area to a safe location upwind and barricade to prevent access.

Isolate all sources of ignition in the area.

Re-ignition of generated Acetylene may be a secondary risk, following extinguishing of the fire.

If a large amount of water is flowing, attempt to isolate the source of the water. It is best to leave the fire to burn out naturally until all of the generated acetylene has been consumed. The heat of the fire will dry out the carbide, thus stopping the generation of acetylene, which is the source of the fire.

In extreme circumstances, it is possible to extinguish the fire with a dry chemical powder but this is only necessary if the fire is creating an extreme hazard.

Allow the building to ventilate freely by opening the doors and waiting for 30 minutes.

Cover the spilt carbide with a fireproof blanket in order to minimise any exposure to atmospheric moisture, until it can be put in to air tight steel drums for storage until it can be used in the next generator charge.

Drums should be purged with nitrogen before sealing the lids tight as acetylene may still be generated.

13.2 Carbide lime spillage

Personal Protective Equipment

When using this procedure, the following personal protective equipment must be worn:

- Long sleeve protective gloves
- Rubber boots
- Chemical resistant goggles
- Flame retardant cotton overalls

Procedure for major spillage of carbide lime

- Isolate all sources of ignition in the area.
- Prevent spill from entering drains by using sandbags, absorbent pillows or a boom.
- Absorb the liquid waste in sand or other absorbent material, or sweep up solid material, and store in containers for disposal (preferably by returning it to the carbide lime treatment plant).
- Dispose of used sand via an approved disposal contractor.

Hose down all contaminated concrete surfaces with an excess of water, preferably draining the water back in to the lime treatment plant.

13.3 Fire fighting in acetylene plants

13.3.1 General requirements

All national and local authority fire regulations shall be followed.

Fire and emergency drills shall be held on a regular basis.

Fire protection equipment shall be maintained and tested regularly.

Systems and procedures shall be in place at all plants to prevent uncontrolled acetylene gas escaping into the atmosphere and to control a fire if ignition of acetylene gas occurs.

13.3.2 Fire fighting equipment

Dry powder extinguishers are preferred. CO_2 extinguishers can create static electricity and are preferred for electrical fires.

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

- Calcium carbide store exits
- Generator room exits
- Gas-holder and purifier room exits
- Compressor room exits
- Cylinder maintenance room exits
- Acetone pumps and acetone tank coupling points
- Acetone drum storage area exits
- Points of transfer of acetone from drums to the process
- Generator hopper level
- Cylinder filling and preparation area - for small fires (e.g. ignition occurring when a cylinder valve is briefly cracked open.)
- Lime pits
- Electrical switch rooms (CO_2 is preferred here)
- Motor rooms (CO_2 is preferred here)

In the acetylene plant there is the potential for many cylinders becoming hot due to an incident on the filling manifolds so it is essential to have a deluge system to cool the cylinders in such circumstances.

13.3.3 Fire fighting techniques

For fires, wherever possible (consistent with personnel safety) the source of acetylene feeding the fire should be isolated. Acetylene fires are not normally extinguished in any other way, except where the fire is very small in which case an extinguisher may be successful, allowing safe access to shut off the leak.

Emergency stop systems shall be provided to stop the plant in the event of a fire.

Large-scale fires from the high-pressure system are potentially extremely hazardous. These fires can only be extinguished by stopping the flow of escaping acetylene. Extinguishing a flame from a high-pressure acetylene leak could lead to a subsequent explosion if the gas is still escaping and re-ignites.

Copious quantities of water must be used to cool cylinders and equipment exposed to fire reducing the possibility of explosion or of more acetylene escaping through protective devices such as fusible plugs and bursting discs.

Fire can also spread rapidly through the filling plant if escaping gas from a cylinder valve or a burst hose ignites. The best protective option is to install water deluge systems which can be activated by acetylene sensors, by temperature or manually.

Water deluge systems must be installed to cover the cylinder filling area. Where cylinder storage areas are not physically separated from the above areas water deluge must be included. The deluge system shall be remotely operated. This may be automatic or manual.

13.3.4 Hot acetylene cylinders

Acetylene cylinders, which become hot, are potentially extremely hazardous.

They can become hot in several ways:

- Direct exposure to a fire or source of extreme heat

- Internal flashback from connected pipe work causing decomposition of the acetylene in the cylinder
- Internal decomposition due to high pressure and or temperature in the cylinder, sometimes initiated by the friction of closing the cylinder valve after filling

Hot cylinders may be difficult to detect, some indications may be:

- A sudden sharp noise when closing the valve
- Feeling a rise in temperature in the neck area of the cylinder shell when unloading the rack
- Steam rising from the cylinder
- Unusual smell from burning paint or valve seals
- Blistering of paintwork on the cylinder shell
- Cylinder shell becoming red or white hot

Procedures must be in place to deal with these heated cylinders safely:

1 The following actions must be taken when the hot cylinder is first identified. These actions can be performed in any order, as determined by the operator carrying out the procedure (the order will depend upon the circumstances of the particular emergency, layout of the area, etc.)

- Close the effected cylinder valve and the rack valve fully

  Note: if more than one cylinder is hot then do **not** attempt to close all of the valves

- Do not move any hot cylinder as this could lead to an explosion
- If cooling water is used at the site, leave it on to maximise the cooling of the cylinder. If the cooling water is not operating when the hot cylinder is detected, it should be turned back on.
- Operate the emergency stop system to stop filling and instigate the site emergency procedure
- Operate the emergency alarm system to evacuate all personnel to sheltered assembly areas
- Safe areas shall be at least 200 metres from direct line of sight of the cylinders. This distance may be reduced if there is suitable protection offered by solid objects such as brick or concrete walls or heavy plant items

DANGER It is imperative that all personnel are evacuated immediately.

2 If a deluge system or fixed monitors are available on the site, then they should also be turned on to direct additional cooling water in the direction of the hot cylinder

DANGER Activating deluge or monitor should not delay the evacuation of all personnel to sheltered area. A small hand held hose is not a safe option and should not be used.

3 Immediately inform the responsible Manager / Supervisor of the incident, who will assume control of the emergency.

4 After 2 hours an appropriately trained person (acting with the authority of the Manager / Supervisor) will examine the condition of the cylinder to see if it is still steaming. This must be performed from the furthest possible distance (using binoculars if necessary) and keeping behind a solid structure to avoid shrapnel in the event of an explosion.

If steam is still seen to come from the cylinder when the cooling water is temporarily interrupted then continue the cooling for a further hour before re-checking in the same manner.

Repeat this cycle until no steam is seen.

CAUTION

If it is not possible to view the cylinder, without exposing personnel to risk, then the water should be left running for a minimum of 24 hours before the cylinder is inspected for signs of residual heat.

Cylinders, which have gas escaping from fusible plugs or bursting discs, must not be approached under any circumstances, until all of the gas has safely vented. Leave the cooling water on.

5 If the cylinder is not steaming when the water is stopped then wait to see if it dries out quickly. This indicates it is still warm.

Continue cooling for a further hour before re-checking.

Continue this cycle until the cylinder remains wet when the water is stopped. Only after this occurs can you proceed to the next step.

6 Remove the cylinder from the building and gently place it in an approved cold water bath (or under sprays designed to supply copious amounts of water to the cylinder) for a further period of at least 12 hours.

The water level must be regularly checked to ensure it is not leaking or evaporating due to heat from the cylinder, and be topped up as needed.

DANGER

In plants that fill bundles in-situ, it is not possible to use a water bath for acetylene bundle.

It is not possible to check that the cylinders in the centre of the pack are adequately cool.

It is also not possible to dismantle the cylinders from the framework without causing shock impacts, which may result in an explosion.

These packs must be cooled additionally by spraying with water for 24 hours, instead of the water bath treatment.

If large numbers of cylinders are affected by heat then the above will also have to apply as it will not be practical to immerse them all in water.

7 After 24 hours, check the cylinder is completely cold. If not, then leave in the water bath until cold.

When the cylinder is completely cold, continue to the next step.

8 Blow down the cylinder. If possible, this should be done whilst the cylinder is under water. If not possible, remove the cylinder from the water bath and take it to a safe place to be blown down.

Note: It is safer to blow the cylinder down under water because the cylinder may contain quantities of hydrogen as a result of the decomposition of acetylene. This may catch fire spontaneously when venting.

9 Hold the remaining cylinders on the rack for 24 hours before being released. This is to ensure they have not been affected by the ignition.

10 Inspect the filling hoses and pipe work for damage and internal contamination with soot. Any suspect equipment must be replaced.

For additional information see EIGA Safety INFO 02/02.

14 Standards, referred to in the document

Recommended practices for mobile acetylene trailer systems	CGA G-1.6-1991
Safe charging systems for acetylene generators and other handling systems for calcium carbide	IGC 03/92
Guidelines for the management of waste acetylene cylinders	IGC 05/00
Safety training of employees	IGC 23/00
Permissible charge/ Filling conditions for individual acetylene cylinders	IGC (new no.)
Porous masses for dissolved acetylene cylinders. Presently manufactured	IGC 35/87
Work permit systems	IGC 40/02
Management of Change	IGC 51/02
Transporting gas cylinders or cryogenic receptacles in "enclosed vehicles"	IGC 103/03
Environmental Impacts of acetylene plants	IGC 109/03
Blocked or inoperable valves	EIGA TN 505/86
Gas welding equipment – Rubber hoses for welding, cutting and allied processes	EN 559
Gas welding equipment – Hose connections for welding, cutting and allied processes	EN 560
Gas welding equipment – Equipment used in gas welding, cutting and allied processes, safety devices for fuel gases and oxygen or compressed air – General specifications and tests	EN 730
Pressure gauges Part 1: Bourdon tube pressure gauges; dimensions, metrology, requirements and testing Part 2: Selection and installation, recommendations for pressure gauges	EN 837
Cylinder valves – Specification and type testing	EN 849 = ISO10297
Valve protection caps and valve guards for industrial and medical gas cylinders – Design construction and tests	EN 962 ISO 11117
Cylinder identification Part 1: Stamp marking Part 2: Precautionary labels Part 3: Colour coding	EN 1089
Gas welding equipment – Specification for hose assemblies for equipment for welding cutting and allied processes	EN 1256
Safety of industrial trucks – Operation in potentially explosive atmospheres – Use in flammable gas, vapour, mist and dust	EN 1755
Acetylene cylinders – Basic requirements and definitions	EN 1800
Filling conditions for single acetylene cylinders	EN 1801
Specification for the design and construction of refillable transportable seamless steel gas cylinders of water capacities from 0.5 litre up to and including 150 litres Part 1: Cylinders made of seamless steel with an Rm value of less than 1100 MPa	EN 1964-1
Refillable seamless steel gas cylinders -- Design, construction and testing -- Part 1: Quenched and tempered steel cylinders with tensile strength less than 1 100 MPa	ISO 9809-1
Specification for the design and construction of refillable transportable seamless aluminium and aluminium alloy gas cylinders of capacity from 0,5 litre up to 150 litres	EN 1975
Gas welding equipment – Pressure regulators for gas cylinders used in welding, cutting and allied processes up to 300 bar	EN ISO 2503
Cylinders for acetylene – Basic requirements Part 1: Cylinders without fusible plugs	ISO 3807-1
“Labels for transportation”	ISO 7225
Gas welding equipment – Pressure regulators for manifold systems used in welding, cutting and allied processes up to 300 bar	EN ISO 7291
Cylinders for dissolved acetylene – Inspection at time of filling	EN 12754
Filling conditions for acetylene bundles	EN 12755
Periodic inspection and maintenance of dissolved acetylene cylinders	EN 12863
Refillable welded steel gas cylinders - Design and construction Part 1:Carbon steel	prEN 13322-1

Battery vehicles – Design, manufacture, identification and testing	EN 13720
Cylinder bundles - Design, manufacture, identification and testing	prEN 13769
Design of battery vehicles	EN 13807
Gas welding equipment – Rubber and plastic hoses assembled for compressed or liquefied gases up to a maximum design pressure of 450 bar.	EN ISO 14113
Gas welding equipment – Acetylene manifold systems for welding cutting and allied processes – General requirements	EN ISO 14114
Inspection and maintenance of cylinder valves at time of periodic inspection of gas cylinders	EN ISO 14189
For test and inspection of valves	EN ISO 14246
Gas welding equipment – Acetylene manifold systems for welding, cutting and allied processes, and safety requirements in high-pressure devices	EN ISO 15615
Standard for acetylene cylinder charging plants	NFPA 51A-1996
Transportable Pressure Equipment Directive (TPED)	99/36/EC
Machinery Directive	89/392/EC
Pressure Equipment Directive	97/23/EC
Explosion Protection Directive (ATEX)	94/9/EC