CODE OF PRACTICE
ACETYLENE

AIGA 022/13

Revision of AIGA 022/05

Asia Industrial Gases Association

3 HarbourFront Place, #09-04 HarbourFront Tower 2, Singapore 099254

Tel: +65 62760160 Fax: +65 62749379

Internet:http://www.asiaiga.org

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ASIA INDUSTRIAL GASES ASSOCIATION

3 HarbourFront Place, #09-04 HarbourFront Tower 2, Singapore 099254
Tel: +65 62760160 Fax: +65 62749379
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Note: Technical changes from the previous edition are underlined

1 Introduction

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

2 Scope

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

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

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

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

3 Definitions

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

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

Acetylene gasholder. Device for storing the acetylene produced before cylinder filling.

Acetylene heat exchanger or cooler: Equipment where the temperature of the passing acetylene is intentionally decreased or increased.

Acetylene dryer. Equipment for decreasing the water vapour content of acetylene

Acetylene purifier. Equipment for reducing impurities of acetylene

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

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

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

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

Deflagration. Explosion propagating at subsonic velocity.

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

*Explosion. A*brupt 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 acetylene decomposition.

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

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: including gloves, goggles, safety shoes and other protective equipment.

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

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

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

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 to saturate the solvent at atmospheric pressure and 15 °C (refer to EN 1800 [1]).

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

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

Tare S. Tare A plus the weight of the saturation gas.

Tare F. Tare A minus the weight of the solvent.

Tare BA_{max}. is the sum of the Tare A weights of all cylinders manifolded together in a bundle containing the maximum weight of solvent including the amount of positive solvent operating range plus the weight of the rigid frame and the weight of all equipment.

Tare BS_{max}. is the sum of the Tare S weights of all cylinders manifolded together in a bundle containing the maximum weight of solvent including the amount of positive solvent operating range plus the weight of the rigid frame and the weight of all equipment.

Tare BA_{min}. is the sum of the Tare A weights of all cylinders manifolded together in a bundle containing the maximum weight of solvent including the amount of negative solvent operating range plus the weight of the rigid frame and the weight of all equipment.

Tare BS_{min}. is the sum of the Tare S weights of all cylinders manifolded together in a bundle containing the maximum weight of solvent including the amount of negative solvent operating range plus the weight of the rigid frame and the weight of all equipment.

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

For this document the following applies:

- **Shall** is used only when procedure is mandatory. Used wherever criterion for conformance to specific recommendation allows no deviation.
- **Should** is used only when a procedure is recommended.
- **May** and **Need Not** are used only when procedure is optional.
- **Will** is used only to indicate the future, not a degree of requirement.
- **Can:** Indicates a possibility or ability.

4 General

4.1 Training of personnel

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

- The general requirements of this Code of Practice.
- Properties of all gases, chemicals and impurities involved in the production of acetylene.
- Operation of the relevant part of the acetylene process.
- Emergency procedures and equipment.
- PPE requirements.
- Acetylene cylinder properties and characteristics.

Persons undergoing training shall be supervised by a competent person(s) when working in an acetylene plant. Further details can be found in AIGA 009.[2]

4.2 Management of change

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

Any changes to the plant or the operational procedures shall be approved and validated by a competent person using formal change management procedures. Such procedures shall include validation of any changes to the plant or process using techniques such as HAZOP (Hazard and Operability Study), Risk Assessment, FMEA (Failure Mode Effects Analysis) as appropriate. Further details can be found in AIGA 010 [3].

5 Acetylene properties

5.1 Physical and chemical properties

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

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

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

5.2 Physiobiological

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

5.3 Tables of acetylene properties

Table 1: Physical properties of acetylene

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

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

Note 2: Physical data from Air Liquide gas encyclopaedia

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

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

Table 3: Solubility of acetylene in acetone in g/kg (reference: Miller [4])

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

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

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

5.4 Acetylene decomposition

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

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

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

5.5 Polymerisation

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

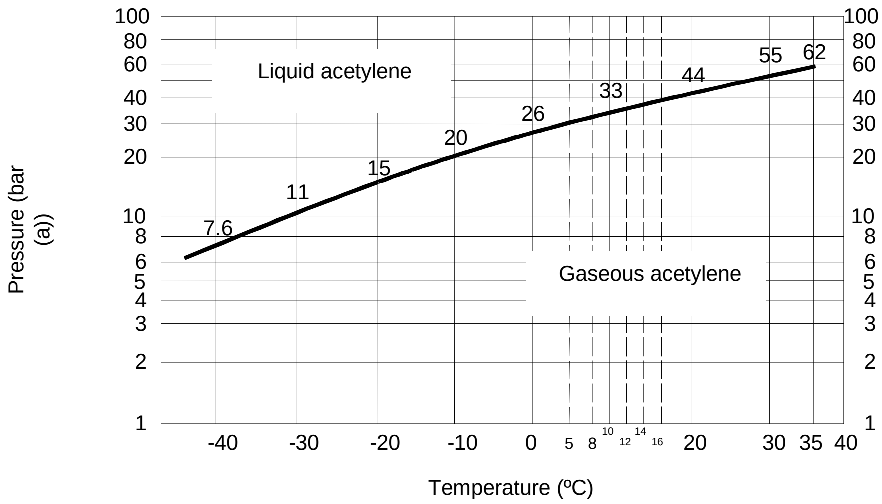
Once the process is started, heat is liberated and the reaction becomes self-sustaining above atmospheric pressure; this can lead to an explosive decomposition of acetylene into its elements, carbon and hydrogen.

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

5.6 Liquid acetylene

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

Figure 1: Liquid acetylene formation

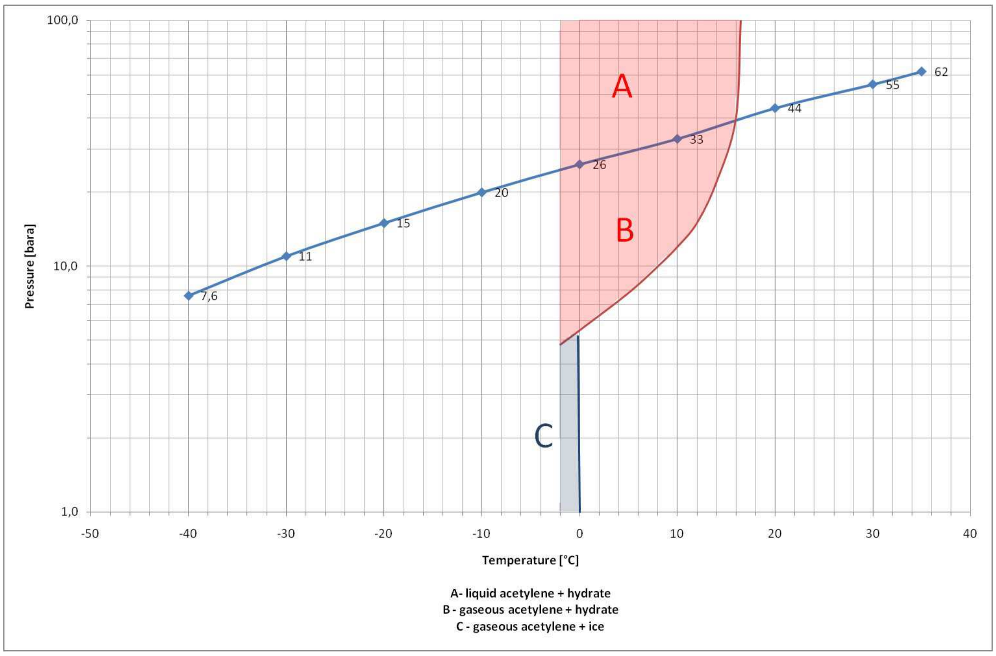


5.7 Acetylene hydrate

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

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

Figure 2: Acetylene hydrate formation



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

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

5.8 Acetylides

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

See 6.2 regarding materials of construction for further details.

5.9 Adiabatic compression

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

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

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

Based on the above, the following shall be considered:

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

6 Acetylene system components

6.1 Design consideration

Acetylene production and filling plants shall be designed, constructed and operated to standards and procedures to ensure the maximum integrity of the equipment and safety for personnel. Design and construction of plant and equipment shall be in accordance with all applicable European Directives, including the Machinery Directive 2006/42/EC [5], the Pressure Equipment Directive (PED) 97/23/EC, [6] and the Equipment for explosive atmospheres (ATEX) Directive 94/9/EC, [7].

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

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

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

6.2 Materials of construction

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

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

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

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

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

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

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

Material	Conditions for use
Copper and copper alloys containing more than 70% copper *	Not allowed.
Alloys containing up to 70% Copper*	Permitted. Consideration should be given to the use of copper alloys for filters, sieves etc. that have a large surface area in contact with acetylene and also for parts in contact with moist unpurified acetylene. Any heat process which produces copper enrichment on the surface of the copper alloy shall be avoided.

Silver and mercury	Not allowed.
Silver alloys*	Suitable for brazing, provided that the silver content does not exceed 43%, the copper content does not exceed 21% and the gap between the two parts to be brazed does not exceed 0,3 mm. Care shall be taken to minimise the area of filler metal exposed to acetylene and to remove as far as is practicable all traces of flux.
Aluminium, Zinc, Magnesium, and their alloys	Not recommended for components, which come in contact with wet acetylene contaminated with lime or ammonia (un-purified generator gas).
Zinc	Suitable as external anti-corrosion protective coating.
Glass	Should be used only for sight glasses such as U-tube manometers and similar devices. This type of device should either be protected against external damage or be designed to withstand breakage or alternatively, the system designed so that breakage will not cause a hazard.
Organic materials	May be used if they are resistant against acetylene, solvents and impurities.

Note: Where brazing alloys containing silver and copper are not in compliance with the above Refer to EN ISO 9539 [8]

6.3 Cleaning

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

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

6.4 Valves, fittings, regulators, hoses and safety devices

6.4.1 Regulators

Regulators shall comply with EN ISO 7291, [9].

6.4.2 High pressure hoses

Hoses shall comply with EN ISO 14113, [10].

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

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

Where hoses are used in an installation the resistance between the two end-couplings should not exceed 10^6 ohm to reduce the risk of electrostatic charging. Further details can be found in EN 12115 [10a].

6.4.3 Pressure relief devices

Acetylene vented from pressure relief devices should be discharged outside the building to an area specifically classified for acetylene where there is no risk of ignition. <u>All discharge pipes or orifices to</u>

the open air shall be designed and made in such a way as to avoid choking, obstruction or frictional pressure drop. Pressure relief device discharge pipes should be separate and connection to a manifold should be avoided.

6.4.4 Flame arrestors and flashback arrestors

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

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

See also 10.5

6.4.5 Pressure sensors and indicators

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

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

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

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

Pressure indicators shall be in compliance with EN 837-1 [11]

6.4.6 Valves and pipework fittings

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

High pressure valves should comply with the requirements of EN ISO 15615 [12].

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

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

6.5 Operating procedures, periodic inspection and maintenance

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

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

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

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

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

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

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

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

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

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

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

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

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

6.5.1 General

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

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

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

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

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

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

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

6.5.2 Pressure relief devices (PRDs)

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

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

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

6.5.3 Process safety equipment

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

6.5.4 Modifications and changes

Refer to 4.2.

6.5.5 Training and protection of personnel

The appropriate personal protective equipment (PPE), see AIGA 066, [13] shall be used for the task being carried out. For example, safety shoes, gloves, goggles and flame-retardant clothing. Do not wear PPE clothing that is made from synthetic fibres as these can cause a static discharge and also they can burn and melt when exposed to fire.

6.5.5.1 Work permit

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

Refer to AIGA 011 "Work Permit Systems", [14].

6.5.5.2 Entry into vessels

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

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

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

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

6.5.6 Return to service

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

These can include:

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

7 Facility safety requirements

7.1 Site and buildings

7.1.1 Location of plant

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

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

7.1.2 Layout and design of plant and buildings

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

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

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

Buildings or rooms housing acetylene operations shall be constructed of lightweight non-combustible materials or panels designed to relieve at a maximum internal pressure of 0.012 bar (NFPA 51A), [15]. The design shall be of a construction to limit damage in the event of an explosion. An explosion venting area, including windows, of at least 0.05 m^2 per m^3 of room volume is required. A lightweight blow-off roof is preferred.

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

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

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

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

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

All acetylene plants shall be provided with lightning protection.

All plant and building components shall be protected from electrostatic charges by maintaining an electrical conductivity with a maximum resistance of 10^6 ohm. (NFPA 77), [16] PD CLC/TR 50404:2003, [17]

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

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

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

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

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

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

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

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

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

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

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

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

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

7.1.3 Separation distances

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

EIGA Doc 75, [18] shows methodologies for calculating separation distances according to risk.

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

Table 6: Separation distances for acetylene plants

From	To	Distance in metres
Acetylene plants	Public Buildings where large numbers of people may congregate such as schools, hospitals, passenger railway stations etc.	200
Acetylene plants	Site boundary or public access route Buildings on adjacent properties Office buildings on site	15
Acetylene plants	Other buildings containing cylinder filling operations	6
Openings in acetylene plant buildings (windows doors and ventilation openings)	Gas bulk storage vessels (flammable, toxic, and oxidising) Gas cylinder storage areas	6
Acetylene cylinder storage	Bulk pressure vessels Cryogenic gas storage vessels Flammable liquid storage tanks	6
Calcium Carbide Storage	Site boundary Buildings on adjacent properties Office buildings on site	3

7.2 Explosion prevention

7.2.1 Ventilation and gas detection requirements

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

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

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

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

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

7.2.2 Equipment requirements

Electrical equipment and wiring in rooms housing acetylene operations shall conform to the requirements of the European Directive 94/9/EC (ATEX Directive), [7].

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

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

All equipment shall be protected from electrostatic charges by maintaining an electrical conductivity with a maximum resistance of 10^6 ohm, (NFPA 77), [16] PD CLC/TR 50404:2003, [17].

New equipment including mechanical and protective systems intended for use in potentially explosive areas shall comply with European Directive 94/9/EC (ATEX Directive), [7].

7.2.3 Use of forklift trucks

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

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

The movements of FLTs may include:

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

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

If any FLT is required to enter a classified zone then it should be a truck suitable for the zoned area according to the ATEX Directive, [7]. Manual operated as well as self-propelled fork lift trucks used in potentially explosive areas shall comply with EN 1755 [19] and its referenced standards.

7.3 Fire protection systems

7.3.1 Fire extinguishers

Carbon dioxide fire extinguishers are not recommended for flammable gas fires due to the risk of static electricity generation, for further information see EIGA SAC NL 76 [20].

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

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

7.3.2 Deluge systems

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

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

- BS 5306 [21]
- NFPA 51A [15]
- NFPA 15 [22]
- EN 12845 [23]

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

The basic requirements should include:

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

Deluge systems shall not be installed in the following:

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

The requirements for the deluge system performance are:

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

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

- From a fire water main.
- Pumped from a storage tank (topping up of the water in the tank by the emergency services is permitted though a minimum of one hours capacity is recommended).
- Pumped from a river or storage tank, with the ability to re-cycle the water back to the storage tank (not a reliable source according to EN 12845, [23]).

The system may be operated by:

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

The design should be of the dry riser type.

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

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

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

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

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

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

All activation points and valves shall be identified.

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

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

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

7.4 Storage – General requirements

Storage requirements, including quantities and capacities shall be in accordance with local and national regulations.

Calcium carbide is usually delivered in drums or bulk containers, (referred to as turn bins). Drums shall be stored under cover, but weatherproof containers may be stored outside.

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. Also maximum allowed storage capacity should be shown on a notice.

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 removal of any leaking or damaged containers/drums.

Drums shall not be stacked to an excessive height that could lead to the crushing of drums under the weight of those.

The store shall be organised such that rotation of the stock is possible, to ensure the oldest carbide is used first.

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

7.4.1 Internal 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 constructed of non-combustible or limited combustible materials, and the buildings are separated by walls with a fire resistance of at least one hour.

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;
- be high enough to prevent water exposure during flooding;
- have a holding area, where any surface water or snow on the containers/drums can be removed prior to entering the store;
- be 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.

7.4.2 External storage of calcium carbide

Outside storage of carbide containers is permissible if the containers are fully gas-tight and waterproof. Weather protection is recommended in areas of high rainfall and persistent snowfall.

7.4.3 Storage of solvents

The main requirements for the storage of solvents are the following:

- Outside storage separated from buildings is preferred, segregated from incompatible materials and gas cylinders.
- Storage tanks and drums shall be protected from extremes of temperature.

- Tanks and drums shall be designed to avoid ground water and sub-soil pollution from spills and leaks and have secondary containment capable of holding 110% of the largest tank or drum volume spillage kits shall be available to contain and dispose of any spilled solvent
- Receptacles shall be kept sealed when not in use.
- The storage installation shall be protected against physical damage.
- The storage installation shall be protected against electrostatic charges by earthing.
- Non-sparking type tools and equipment shall be used, including ATEX, [7] certified electrical equipment.
- Signs shall be posted indicating the identity and hazardous properties of the solvent.
- Safety Data Sheets shall be available.
- Storage and use areas shall be signed “No Smoking and no naked flames”.
- Ventilation shall be maintained at all times.
- Containers of solvents can be hazardous when empty as they can retain product residues (vapours, liquid). Observe all warnings and precautions listed for the product.
- PPE shall be worn when handling solvents, e.g. use a respiratory protective device for DMF handling. (See AIGA 066, [13]).

7.4.3.1 Acetone

Drums /Intermediate Bulk Container (IBC)

Acetone should be stored in metallic containers made of carbon steel, stainless steel or aluminium. Plastic materials may also be used, if they are compatible with acetone.

When in use containers shall be earthed and should be placed within a bund which is able to contain 110% of the full contents of a single vessel in the event of a leaking, damaged vessel.

Bulk transfer (to storage)

Road tanker unloading points shall be protected from impacts from vehicles and be separated from passing traffic during unloading operations.

Anti-tow-away systems/procedures shall be in place. See EIGA SAC NL 89/10/E , [24] on anti-tow-away)

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 to prevent electrostatic build-up during transfer (see 7.1.2).

<u>If using single membrane pumps a risk assessment shall be carried out considering the consequences of a defective membrane and a release of the utilities used, typically compressed air or compressed nitrogen, into the process, (e.g. air ingress) or into the environment, for example a nitrogen release into a confined space..</u>

Bulk storage

For new installations, tanks should be installed above ground and shall be located outdoors within a bund wall to contain 110 % of its storage capacity.

Tanks that are buried shall be of double walled construction with systems in place to detect any leakage of acetone between the double walls.

Tanks installed in a sealed underground pit shall not be covered with sand, soil or other materials as it is very difficult to detect leaks or inspect for corrosion of a tank covered in this way.

Low and high level alarms should be installed.

Storage tanks may be either atmospherically vented or a nitrogen gas atmosphere maintained in the tank above the solvent. Where applicable, national codes for the storage of flammable liquids in bulk shall apply.

Atmospherically vented tanks shall be fitted with a device to prevent any external fire of acetone vapour from burning back into the tank. These devices are normally flame arrestors and should be installed on all return lines back into the tank.

An emergency plant shut down shall stop acetone pumps immediately.

7.4.3.2 Dimethylformamide, DMF

Drums /Intermediate Bulk Container (IBC)

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

The properties of DMF require additional PPE for handling. Refer to the safety data sheet requirements for PPE.

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 storage tanks.

If there is bulk storage of DMF, the recommendations for the bulk storage of acetone shall apply.

7.4.4 Storage of cylinders

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

7.4.4.1 Storing acetylene cylinders

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

Acetylene cylinders should not be stored in the following locations:

- in rooms below ground level unless in use;
- in stairwells, corridors, enclosed yards;
- in passages and thoroughfares or in their immediate proximity;
- on steps;
- along specially marked escape routes;
- in garages where vehicles are parked; and
- in workrooms (workrooms do not include storage rooms, even if people are working there).

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

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

- ventilation requirements for indoor storage;
- requirements for emergency water supplies for fire fighting and cylinder cooling;
- the required number of fire extinguishers;
- zoning requirements according to Directive 94/9/EC (ATEX Directive), [7];
- control of ignition sources;
- potential off-site risks to neighbouring properties and populations;
- potential risks from off-site exposures;
- the security of the store;
- the maximum number of acetylene cylinders permitted;
- the layout of the store and segregation requirements from other gas cylinders;
- access and emergency escape routes.

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

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

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

To reduce the risk of a cascading fire spreading from one storage area to another the minimum distance between the edge of acetylene storage areas is recommended to be at least 3 metres (NFPA 55), [25]. This may be reduced (to nil) by provision of a one hour fire resistant partition of sufficient height and width to prevent the spread of fire.

7.4.4.2 Indoor storage

Acetylene cylinders should be stored outdoors.

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

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

7.4.4.3 Outdoor storage

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

- The floor area shall be flat and level such that the acetylene cylinders are stable.

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

7.4.5 Storage of chemicals

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

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

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

7.5 Environmental requirements

See EIGA Doc 109 - Environmental Impacts of acetylene plants, [26], and

Directive 2010/75/EU Industrial Emissions Directive on industrial emissions (integrated pollution prevention and control), [27]

8 Production

8.1 Acetylene Generators

8.1.1 Manufacturing method

Acetylene is either generated in chemical process plants or by the reaction of calcium carbide with water. This reaction is expressed by the formula:

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

Pure calcium carbide would liberate 2028 kJ per kg at 18º C and 1 bar. Commercial calcium carbide (typically about 80 % purity) would generate 1793 kJ of heat per kg of calcium carbide.

The stoichiometric reaction would, in the absence of cooling, heat the acetylene, which would undergo exothermic decomposition reactions to produce hydrogen and carbon. There shall be sufficient cooling to ensure that the reaction does not generate heat which could lead to decomposition of the acetylene.

The heat of reaction is controlled in a number of ways. Carbide to water generators ("wet" generators) use a large excess of water so that the heat can be dissipated, but water to carbide generators ("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 Calcium carbide properties

Calcium carbide is a grey rock-like solid that comes in irregular sized pieces, typically ranging from 5 mm–80 mm depending on customer specifications. The colour can differ depending on the impurities, e.g. if there is a high content of ferrous oxide the colour can be a deeper brown.

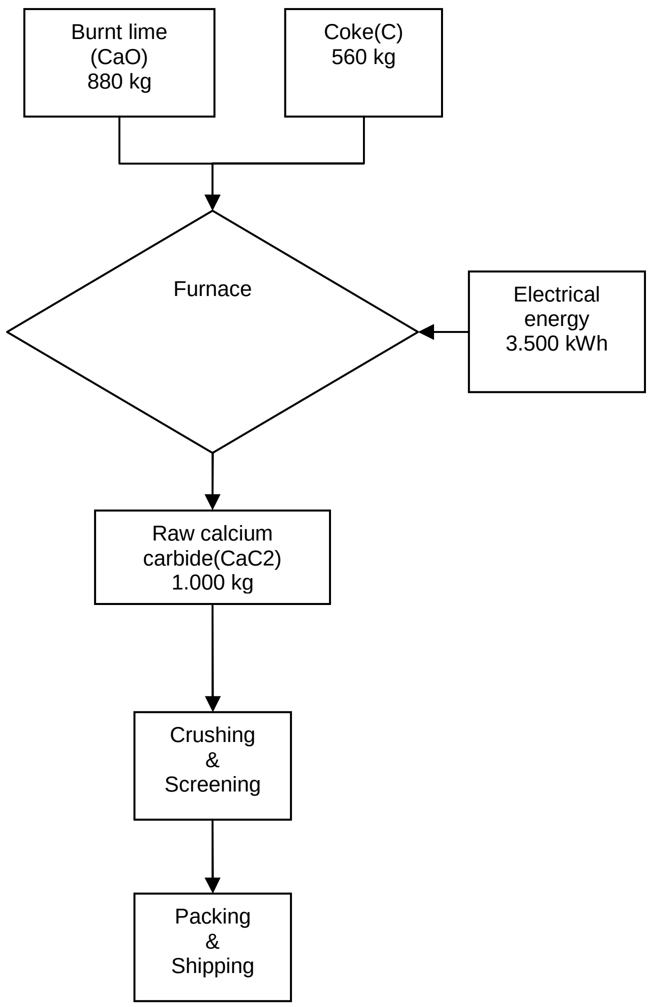
Calcium carbide is used:

- to produce acetylene gas,
- in the steel industry for de-sulphurising iron,
- in the production of other chemicals.

Calcium carbide is produced by a reaction between coke and burnt lime in an electric furnace at a temperature of between 2000°C and 2400°C (3600°F and 4400°F). Molten carbide is tapped from the furnace and run into moulds where it is left to solidify. When it cools it is crushed and screened by size.

The manufacturing process requires large amounts of electricity.

Figure 3: production process for 1 tonne of calcium carbide



Due to this production process the calcium carbide typically contains between 15 to 20% impurities. The main impurities are un-reacted lime (7-14%) and coke (0,4 - 3,0%). Additionally there are a minor amount of chemical compounds containing iron, silicon, aluminium and magnesium. The impurities present also depend on the source and quality of the raw materials used.

Calcium carbide reacts rapidly with water or even moisture in the atmosphere to generate acetylene and a carbide lime residue. This reaction creates considerable heat (exothermic reaction).

Calcium carbide shall be kept dry, to avoid unwanted reactions generating uncontrolled acetylene. The yield from the acetylene production process is expressed in terms of the volume of acetylene gas recovered from the weight of calcium carbide used. The maximum yield is maintained by ensuring the generator water reaction temperature is kept between 70°C and 80°C.

The yield also depends on the grade size of the calcium carbide, in general the greater the size the higher the yield. Typical yields are between 265–300 litres of gaseous acetylene per kilogram of solid carbide.

Calcium carbide is an irritant to the eyes, skin and respiratory system.

Always wash thoroughly with water any skin that could have come in contact with calcium carbide granules or dust. Calcium carbide dust in contact with the skin can react with moisture, creating heat and caustic carbide lime, which could cause severe burns.

8.1.3 Generator classification

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

Operating Pressure

Generators operate in 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. The maximum operating pressure is 0.2 barg
- *Medium Pressure (MP):* generators of this type may have a separate buffer to balance the generation rate with the capacity of the compressors. The maximum operating pressure range is between 0,2 -1,5 barg
- High Pressure generators operating above 1,5 barg, are not permitted.

Operating method

- *Batch*: these generators are shut down, drained and refilled with water at the end of each charge of calcium carbide.
- *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 of calcium carbide. However, a short shutdown is required at the end of each charge to refill the calcium carbide hopper.
- *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 usually has 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.

8.1.4 Requirements and recommendations

Clean and/or recycled water shall be supplied to a generator through a device to prevent backflow of acetylene from the generator.

The design of the water supply system shall prevent overfilling of the generator. This is to prevent water from coming in contact with unreacted carbide in the feeder which would result in acetylene generation in the feeder and excessive heat. Additionally it could lead to water carryover into the compressors in medium pressure generators.

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

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

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.

Loss and or disconnection of the instrument air shall cause the generator controls to move to a fail-safe position.

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

High temperature controls shall be installed to ensure that the acetylene gas does not reach 110°C. Depending upon the design, this can be achieved by monitoring the gas temperature or the water temperature or both. The generator water temperature shall not exceed 90°C. A high temperature alarm shall stop the carbide feed of the generator. Alarms that indicate the approach of shutdown conditions may be added as appropriate for operational reasons.

High and low water levels shall be controlled. A low water pressure shutdown switch shall be installed in the inlet water line close to the generator. Alternative systems may be employed to prevent the backflow of acetylene into the water system.

Water flow indicators may be installed.

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

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

Generators with motorised agitators should have an agitator function alarm installed.

There shall be no connections between the acetylene generator and the public sewers or drains.

Generators shall be fitted with nitrogen systems for purging during routine operations such as charging using an open skip or purging enclosed type hoppers used with containers. A nitrogen purge system may also be used in emergency situations.

Nitrogen purging shall be monitored by flow and/or by time to ensure an adequate purge has been achieved.

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

Multiple low-pressure generators shall be fitted with a system to prevent unwanted back flow of gas from the gasholder to the generator and also a secondary isolation device to be used in the event of an emergency.

8.2 Gasholder

8.2.1 General

Acetylene gasholders comprise a water 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

The gasholder shall be equipped with inlet and outlet shut off valves.

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.

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

The gasholder shall be equipped with visual means of detecting the water level and an overflow device to drain water that exceeds the maximum water level of the gasholder.

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.

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 a fixed 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 buffer shall be fitted with the following devices:

- inlet and outlet isolation valves;
- pressure gauge and a separate low pressure switch that shall stop the compressor(s) to prevent air ingress into the plant;
- pressure relief valve.

The seal shall be equipped with a water level control.

8.4 Purification and drying

The purity of acetylene compressed into cylinders is normally 99,5 % or better. Contaminants that could 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 which could contaminate the porous material.

8.4.1 Source of impurities

Air

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

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

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

Failure to maintain a positive suction pressure on the compressor can cause air to be drawn in, for example, at the shaft or rod packing.

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

New cylinders which have been evacuated and filled with solvent can draw in air if the valve leaks or if the valve is inadvertently opened before the cylinder is connected to the charging rack.

Air can enter the generator entrained in fresh mains water.

Air can enter the system if sample or drain valves are not closed after use or if such valves are leaking.

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

Water

Acetylene generated from calcium carbide is saturated with water vapour at the temperature and pressure conditions existing in the system upstream of the drier. The amount of water that will enter the cylinder with the gas depends on the performance of the drier system.

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.

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 can damage the porous material.
- It can cause corrosion of the internal cylinder walls.

Phosphine

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.

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

Hydrogen Sulphide

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.

The hydrogen sulphide content of purified acetylene will typically be below 10 ppm.

Ammonia

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.

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

Oil

Removal of excess compressor oil is normally accomplished at the compressor discharge moisture trap or dryer. At locations where dryers have been installed, the carryover 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 a decomposition occurring.

Oil contamination of cylinders normally occurs only when the moisture traps and drip legs are not drained on a routine basis. At such times a mixture of oil and water can be carried into the cylinders.

Nitrogen

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

8.4.2 Impurity removal equipment

Scrubbers

Scrubbers are used on most medium and low pressure acetylene generators to scrub and cool the exiting gas. They reduce the ammonia and hydrogen sulphide content of the gas. The scrubbers also prevent lime carryover.

Some low-pressure generators have 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 phosphine and hydrogen sulphide. The need for purification is based on the calcium carbide quality, the process and required acetylene specification.

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

- *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 could be dissolved in the acid in the scrubber sump and possibly be released and ignite spontaneously on contact with air.

If the lime treatment facilities are used to neutralize used acid, there could be, even with, small quantities of acid, unpleasant odours generated.

- *Dry purification*: Dry purification is no longer the preferred method of purification due to environmental reasons when disposing of the purification medium. In the dry purification method acetylene is passed through a vessel containing several layers of purifying compound, which removes 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 could result in the release of free mercury which can accumulate in dangerous quantities. This is why it is necessary to monitor the purifier's 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, e.g. alumina or 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 barg) 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 moisture content of about 70 ppm can be achieved.

Typical drying methods use:

- Calcium chloride (refer to HP drier).
- Silica gel.
- Coalescing filter (Knitmesh).
- 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 by cooling. The carryover of the water remaining after 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. The effect of high pressure drying will be a residual moisture content that will depend upon a number of factors such as condition of the drying agent, but results of less than 10 ppm can be achieved. 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 typically between 10 and 14 bars and achieve more efficient drying.

Typical drying agents used are:

- Calcium chloride
- Alumina
- Silica gel
- Molecular sieve

8.4.3 Requirements

Cleaning and drying agents shall be disposed in accordance with environmental requirements.

After use, liquid drying agents (alkali or acid) may contain dissolved acetylene. This should be considered when disposing of these substances.

After maintenance activities, purity checks shall be carried out to ensure the drier is functioning according to the design requirements of moisture level.

When using calcium chloride dryers there shall be periodic checks of the level of calcium chloride to ensure that there are no excessive cavities within the drying material.

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 between 10-12 %. As this is too dilute for economical shipment, the solids content may be increased by any of the following methods:

Decanting

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

Lime Ponds

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

Filtration

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

Mechanical Thickeners

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

Drying

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

8.5.3 Transport

Semi-solid

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

Slurry

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

8.5.4 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.

Calcium carbide lime pits should be fenced and sign-posted "NO SMOKING OR OPEN FLAMES", and Ex-sign as required by EU directive 99/92, [28]. A risk assessment should be carried regarding the presence of acetylene and the requirement for compliance with the ATEX directives for surrounding equipment, refer to EIGA Doc 134, [29].

For potential uses of carbide lime refer to EIGA Doc 143, [30].

Calcium carbide lime no longer needed 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 $Ca(OH)_2$.

Safety shower(s)/eye wash should be located within reach of lime handling areas and PPE shall be used.

In the event that somebody falls into a lime pond, settlement tank or a cleared water basin, emergency ladders shall be readily available. Ladders shall not be permanently installed.

Carbide lime contains residues of acetylene dissolved in it that can 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. Similar effects happen at high ambient temperatures in closed lime vessel trucks.

8.6 Blowing Down Acetylene Cylinders

Introduction

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

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

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

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

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

When to blow down

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

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

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

Blocked or broken valves

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

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

- only by competent personnel experienced and trained in the procedure.

Blow down manifold design considerations

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

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

Specific design considerations for atmospheric blow down manifolds

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

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

Blow down rate

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

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

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

Blow down period

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

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

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

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

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

Temperature effects

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

9 Cylinders and fittings

Requirements for acetylene cylinders are laid down in the European Agreement on the Carriage of Dangerous goods. Cylinders for free movement within the European Union need to comply additionally with Council Directive 2010/35/EU (Transportable Pressure Equipment Directive), [31].

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

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

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

9.1 Acetylene cylinder design

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

For seamless steel shells see EN 1964-1, [32] or ISO 9809-1, [33].

For welded steel shells see EN 13322-1, [34] or ISO 4706, [35].

Some acetylene cylinders are equipped with fusible plugs. This could be required by their national legislation. The fusible plugs melt to relieve the cylinder contents if the cylinder becomes exposed to temperatures, typically above 107 °C (ISO 3807Annex G, [36])

9.2 Acetylene cylinder bundle design

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

For design, manufacture, identification and testing of cylinder bundles see EN 13769, [37] and ISO 10961, [38].

9.3 Acetylene cylinder trailer design

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

For design information refer to EN 13807, [39].

For additional information see also CGA G- 1.6, [40].

9.4 Porous material and solvent

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

The porous materials have porosity of up to 92 %.

Porous materials for acetylene cylinders and their filling parameters shall be tested and approved by a competent body. Test requirements and conditions are laid down in EN 1800, [1] and ISO 3807, [36].

Technical data for the porous material shall be provided by the acetylene cylinder manufacturer. A non-exhaustive list of porous materials can be found in CR 14473, [41] (CEN/TC 23).

The filling parameters for the solvent charge in kg/l water capacity and the acetylene charge in kg/l water capacity ensures the safe use of the cylinder (a hydraulic pressure does not result from overfilling conditions) at a temperature of 65 °C, and protects against decomposition caused by a backfire (see ISO 3807, [36], EN 1800, [1], EN 1801, [42]).

9.5 Filling conditions

For general information refer to AIGA 37, [43].

For filling conditions of:

- single acetylene cylinders see EN 1801, [42] and ISO 11372 [44]
- acetylene cylinder bundles see EN 12755 [45] and ISO 13088 [46]
- acetylene battery trailers see EN 13720 [47].

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

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

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

9.6 Maintenance and inspection

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

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

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

The cylinder shall be periodically inspected in accordance with the requirements specified in P200 of the ADR, see 4.1.4.1 and 6.2.11.6 of ADR.

For requirements for the periodic inspection and maintenance of dissolved acetylene cylinders refer to EN 12863 [48] and ISO 10462 [49].

For inspection and maintenance of cylinder valves refer to EN 14189 [50] and ISO 22434 [51]

For dealing with blocked or inoperable valves refer to AIGA 025 [52]

(See also CGA C-13 “Guidelines for periodic visual inspection and requalification of acetylene cylinders.) [53]

9.7 Disposal of acetylene cylinders

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

For guidelines for disposal of acetylene cylinders refer to EIGA Doc 05 [54].

9.8 Acetylene cylinder valves

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

For specification, type testing and marking of acetylene cylinder valves refer to EN ISO 10297 [55].

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

Manufacturing, test and examination of valves refer to EN ISO 14246.[56]

Some cylinders may be equipped with residual pressure valves with non-return function (ISO 15996) [57] or with a valve incorporating a pressure regulator (ISO 22435) [58]. These valves shall only be repaired and refurbished by competent personnel trained in the repair of this type of valve.

9.9 Acetylene cylinder accessories

Acetylene cylinders valves shall be protected against impact damage. This can be achieved by valve design strength or by a valve protection cap or protection guard. For details see EN 962 [59] and ISO 11117 [60].

9.10 Acetylene cylinder identification

Requirements for cylinder identification are laid down in ADR including:

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

For colour coding refer to EN 1089-3, [61].

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 filling pressure. Acetylene compressors shall be specifically designed and constructed for acetylene service.

10.1.1 Design

General requirements and recommendations

Acetylene compressors shall be designed and constructed specifically for acetylene service and all their components shall be designed to withstand stresses that can arise during service.

Acetylene compressors shall be designed and constructed such that:

- acetylene/air mixtures can be purged;
- air cannot enter during normal operation; and
- the gas temperature within the compressor does not exceed 140 °C

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 outlet gas temperature does not exceed 70 °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.

Materials shall withstand all mechanical, chemical and thermal stresses that can arise and shall be designed in such a way as not to react dangerously with acetylene and with carbide residues as far as they can be exposed to them (for details refer to 6.2). If belts are used to drive the acetylene compressors, they shall not create electrostatic charges.

Condensate separators and other reservoirs in acetylene compressors shall be fitted with drain valve devices at their lowest points.

Inlet and outlet piping of each compressor shall be provided with readily accessible shut-off valves.

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

Pressure limiting devices

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 5 mbarg,
- the maximum discharge pressure is exceeded (25 barg).

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 5.6).

Each compression stage shall be equipped with a suitable safety valve that cannot be isolated. Safety valves shall be designed and adjusted to prevent the maximum operating pressure to be exceeded by more than 10 % and its nominal capacity shall be at least as high as the nominal capacity of the corresponding compression stage.

The safety valve vent pipes shall not cause a pressure and flow restriction to their discharge points and the discharge points shall be located outside the compressor room.

Each compression stage shall be equipped with a pressure measuring/indicating device with the maximum operating pressure marked.

Compressor identification markings

Acetylene compressors should be permanently marked with the following information

- type;
- manufacturer and manufacturer's 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 in all parts of the high pressure system, 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 pressures and temperatures shown in 5.6 are derived under theoretical static conditions and should not be used for operational conditions.

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 recommended 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 (barg)
+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

Acetylene Heat Exchangers (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 can arise during operation.

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 minimum compatible with the systems operation;
- acetylene/air mixtures can be purged;
- air cannot enter during operation;
- pressures and temperatures arising during operation cannot cause decomposition of acetylene.

Drying and purifying agents shall not react dangerously with acetylene and its impurities.

Materials shall withstand all mechanical, chemical and thermal stresses that can arise and shall be designed in such a way as not to react dangerously with acetylene and its impurities as far as they could be exposed to them (for details see 6.2). This includes the AHE cooling units (chillers) in case acetylene enters the cooling medium under fault conditions.

AHE, AD, AP shall be protected against corrosion internally and externally.

Air regeneration systems (purifiers) shall be segregated from the process and interlocked.

10.2.2 Accessories

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 permissible operating pressure of the equipment is not exceeded or they shall be able to withstand decomposition pressure.

Pressure/temperature measuring/indicating

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

Identification data

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

- manufacturer;
- type description;
- manufacturer’s number and year of manufacture;
- flow capacity;
- maximum operating pressure; and
- type approval data if applicable.

10.2.3 Dimensioning and Testing

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.

AHE, AD and AP operating at low pressure shall be designed for a minimum test pressure of 1 bar.

AHE, AD and AP operating at medium pressure and equipped with a bursting disc shall be designed for a minimum test pressure of 5 bars. The effective area of the bursting disc 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 AHE, AD and AP operating at medium pressure are not equipped with bursting discs the equipment shall be designed to a minimum test pressure of 24 bar.

AHE, AD and AP operating at high pressure shall be designed for a test pressure of 300 bar.

For dimensioning of piping see Chapter 11.

10.2.4 Operation and maintenance

General requirements

Observe the relevant requirements described in Chapter 6.5.

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 shall be detected in due time. A void of 10 % of the internal volume of the drier (with a maximum of 3 litres) is the maximum acceptable level.

The liquid trapped by the dryers (water and residue of calcium chloride) shall 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

Regeneration by the pressure swing (molecular sieve) method is preferably carried out using acetylene at a pressure and temperature not exceeding 0.5 barg and 200 °C.

Regeneration by the temperature swing method is preferably carried out using nitrogen or nitrogen and air.

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.

After regeneration of the adsorbent, it shall be cooled to ambient temperature before recompression begins 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.

The use of nitrogen for regenerating the dryers requires 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 inspected prior to replenishing with solvent and filling with acetylene. (Refer to EN 12754 [62]).

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

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

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

- which cannot be clearly identified as being dissolved acetylene cylinders;
- with external defects (including arc strike, large dents or signs of fire on the shell, significant corrosion,);
- with an excessive loss of solvent (more than 10 % of the nominal acetone quantity);
- with valves in inoperable condition (for example valve blocked, threads damaged,). In this case, the valve shall be replaced;
- returned from customers with open valves;
- 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 [48]);
- with missing or illegible regulatory identity or service markings (e.g. porous material name, solvent, tare, etc.);

- where filling is no longer authorised (withdrawn cylinders);
- with accessories that are in poor condition (cap, guard, foot ring, fusible plug,);
- which are unknown to the filling plant.

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

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

It shall be verified that the bundle and battery-vehicle is permitted to be filled in the country of the filling station, that the bundle does not have an expired test date and, if applicable, the number of refills has not exceed the prescribed value. Further requirements are given in EN 12755 [45] and EN 13720 [47].

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

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

10.3.2 Why is replenishing necessary?

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

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

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

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

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

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

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

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

10.3.3 Loss of solvent

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

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

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

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

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

10.3.4 Replenishing principles

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

The formulae in EN 1801 [42] 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 6 barg because the formula is not accurate above this pressure.

Cylinders with residual gas

Two possibilities exist:

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

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

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

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

Cylinders without residual gas

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

Consequently, the cylinder should not be replenished immediately if:

- It is returned to the plant with its valve open or
- The residual gas pressure is very low - less than about 0.1 barg – and the amount of missing solvent is more than 250 g/kg of acetylene. For example, 1.5 kg of acetone missing from a cylinder containing 6 kg of acetylene.

In both of these cases, cylinders should undergo:

- Pre-fill with acetylene to 4 to 5 barg.
- Vented to atmosphere to remove possible contaminants.
- Pre-fill check including solvent check and then filling with acetylene on normal fill process.

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

Special cases

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

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

Possible solutions include:

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

10.3.5 Replenishing procedure

Individual cylinders

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

- It is normally assumed that the cylinder's temperature is the same as the ambient temperature. However, if cylinders have been stored at high or very low temperatures, it is recommended that they be kept in the area where they will be replenished for sufficient time for the temperature of the cylinder and ambient area to equalise.
- Determine the amount of residual gas remaining in the cylinder taking into account the pressure and temperature of the gas. (see EN 1801 [42])
- Subtract the weight of acetylene remaining in the cylinder from the measured total weight of the cylinder.

- The result shall be subtracted from the stamped tare weight and the difference will be either:
    - Zero: the cylinder contains the correct amount of solvent
    - Positive (tare weight greater than result): it lacks solvent.
    - Negative (tare weight less than result): this means that there is either excess solvent, or there is another liquid in the cylinder.

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

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

Bundles and battery vehicles

The replenishing of cylinders mounted in bundles or battery vehicles requires a procedure different to that described for individual cylinders. It is not possible to ensure the correct replenishment of the solvent for each cylinder; therefore the bundles and battery vehicles shall not be collectively replenished but shall be dismantled prior to replenishing the individual cylinders with solvent. In order to avoid too frequent dismantling, a solvent tolerance is applied by reducing the acetylene charge. Further information is given in EN 12755 [45] and EN 13720, [47].

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

Solvent is added to each individual acetylene cylinder (refer to EN 1801 [42]) up to the upper limit determined for the collective filling in the bundle (refer to EN 12755 [45]) or the battery vehicle (refer to EN 13720 [47]).

10.3.6 Equipment and raw materials

Scales

Scales shall be selected with a range suitable for the type of cylinder to be replenished (maximum load and accuracy) and to maintain safe filling conditions (Permissible Charge/Filling Conditions for Acetylene Cylinders - AIGA 37 [43])

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

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

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

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

Solvents - General recommendations

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 always wear 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 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. In the case of accidental mixing, the cylinder should be either scrapped or returned to the cylinder manufacturer for reconditioning.

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 %	0.03 %
Refractive index at 25 °C		N = 1.427
Molecular weight	58.08	73.09
Boiling point at 1 013 hPa	56.1 °C	153 °C
Freezing point	- 94.6 °C	- 61 °C
Specific gravity at 15 °C	0.790 - 0.795	0.954
Specific gravity at 20 °C	0.791	0.959
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 is a potential fire hazard. Exposure to acetone can result in the following conditions:

- 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 can 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 can 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 (refer to national standards for actual exposure levels).
- 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 can 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 measurement uncertainties, which can occur due to the various accuracies of the filling equipment (for example, scales, pressure gauges, temperature measurement and replenishing method).

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

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

During and after filling, acetylene cylinders, cylinder bundles or battery vehicles shall be checked for leaks. The connections and the cylinder valves shall be tested, for example, by applying leak detection fluid, refer to AIGA 070 [63].

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

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

10.4.2 Cylinders cooling

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

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

10.4.3 Other recommendations

Cylinders

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

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

Bundles

The maximum number of fills before replenishment of solvent will depend on the type of solvent (acetone or DMF) and shall be determined for a bundle in accordance with EN 12755 [44]. Refer to 10.3.5.

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

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

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

Battery-vehicles

The maximum number of fills before replenishment of solvent will depend on the type of solvent (acetone or DMF) and shall be determined for a battery-vehicle in accordance with EN 13720 [47], also refer to 10.3.5.

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

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

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

10.4.4 Inspection after filling

For inspection after filling, the requirements of EN 12754 [62] 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 can be selected for weighing. The maximum permissible charge of acetylene shall not be exceeded. This requirement is valid for the total weight of bundles and battery-vehicles.

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

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

After filling the cylinder, including its valve, shall be leak tested. The valve protection cap if applicable shall be fitted. To allow sufficient time for the uniform distribution of acetylene across the entire cylinder, cylinders/bundles should not be placed in service until at least 12 hours after the end of filling; this is to ensure that the cylinder is within the safe working limits of the safe operating diagram. Refer to AIGA 37 [43].

10.5 Manifold and piping system – Design code

10.5.1 General

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

The filling manifolds and their ancillary equipment including valves, flexible hoses, and connections, shall be designed for safe operation in working range III (detonation resistance).

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

10.5.2 Flame arrestors and flashback arrestors

General

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

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

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

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

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

- In quenching the initial decomposition, the arrestor quenching medium absorbs the heat from the flame front and a hot area is produced in the quenching medium.

- Continued flow of acetylene over the hot area produces further decomposition and heating. This can lead to subsequent decompositions, which can be on the opposite side of the flame arrestor to that of the initial decomposition.
- Stopping the acetylene flow immediately after the initial decomposition can best prevent re-ignition.

Consequently:

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

Flame arrestors and flow cut-off devices may need to be tested under static conditions to prove their effectiveness (refer to EN ISO 15615 [11]). Several types of flame arrestor design exist, (aluminium packing, etc.). The device's two functions (flame arrestor and flow cut-off) may be incorporated in the same unit.

Requirements

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

A flame arrestor device shall meet the following requirements:

- Prevent decomposition in a high pressure pipe or pipe component passing through to the other parts of the pipework system.
- Pass the acetylene decomposition tests (at 6 bar and 25 bar) according to the procedure described in EN ISO 15615 [12].

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

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

10.5.3 Flame arrestors and flashback arrestors installation and use

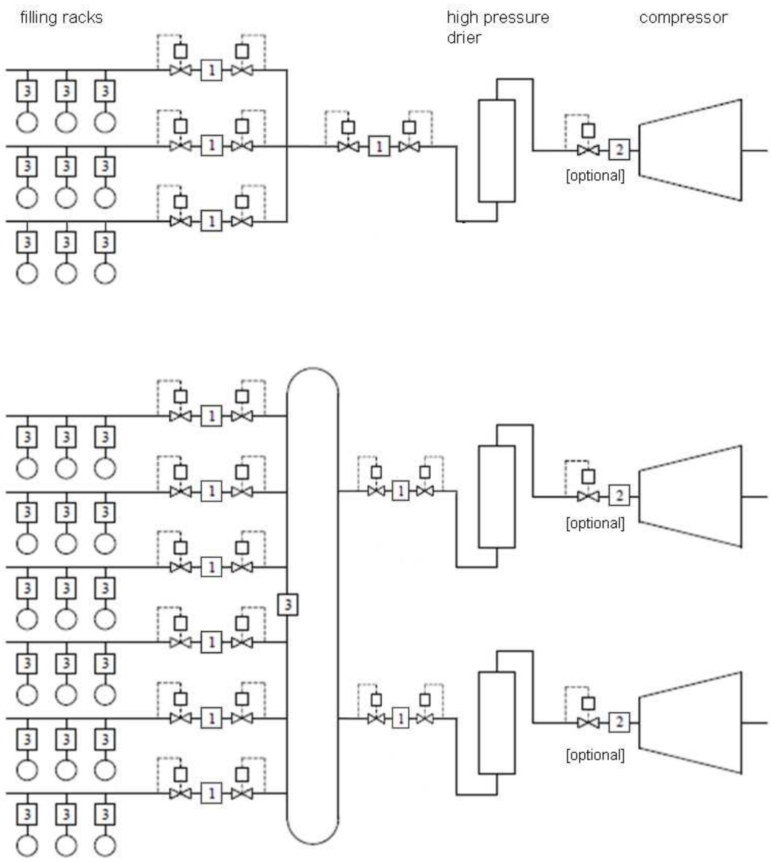
Flame arrestors and flashback arrestors shall be positioned at the following locations (see Figure 4).

- A flashback arrestor between individual compressors and any system distribution valve manifold shall be installed in the downstream-pipework of the compressors taking into account the possibility of oil residues plugging the flashback arrestor.
- A flashback arrestor providing protection against decomposition from either side is installed at the inlet to each charging rack immediately before or after the isolation valve for any individual filling manifold distribution pipe (cylinders, bundles or battery-vehicles) and also on the main lines.
- A flame arrestor on the manifolds at each connection point for filling cylinders. In this case, it is not necessary to have a cut-off device system. There should also be a non-return valve fitted

at each cylinder connection, to prevent reverse flow from one cylinder to another and also to minimise the leakage of gas in the event of a hose rupture or a major fire.

- It is recommended that flame arrestors or flashback arrestor be installed at charging rack outlets and in ring mains. When designing a cylinder filling installation the designer shall determine the number and location of additional flame arrestors with or without cut-off devices required to protect the plant.
- A flashback arrestor shall be fitted at each location where the acetylene pressure is dropped from high to low pressure, such as filling rack blowback points returning gas to the process. Flame arrestors shall not be installed in emergency vent pipes because gas should be vented freely without restriction under emergency situations.

Figure 4: Location of flame arrestors and flashback arrestors



1 – Flashback arrestor with cut-off devices providing protection against decomposition from either side.
2 – Flashback arrestors with cut-off device actuated from one side only providing protection against decomposition from that side.
3 – Flame arrestor (may be combined with a non-return valve).

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

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

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

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

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

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

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

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

Nominal pipe diameter (mm)	Max. operating pressure (barg)
90	0,7
80	0,8
70	0,9
60	1,1
50	1,5
40	1,7
30	2,1
25	2,5
20	2,9
15	3,6
10	4,7

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

10.5.5 Pressure gauges

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

10.5.6 Flexible hoses

All types of flexible hoses for high pressure acetylene shall withstand a decomposition test at 25 bar with acetylene and their bursting pressure shall be 1000 bar minimum. For all the other requirements, refer to EN ISO 14113 [10] and EN 12115 [10a].

10.5.7 Non return valves

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

11 Pipework

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

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

11.1 Working ranges

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

11.1.1 Deflagration limit pressure and detonation limit pressure

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

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

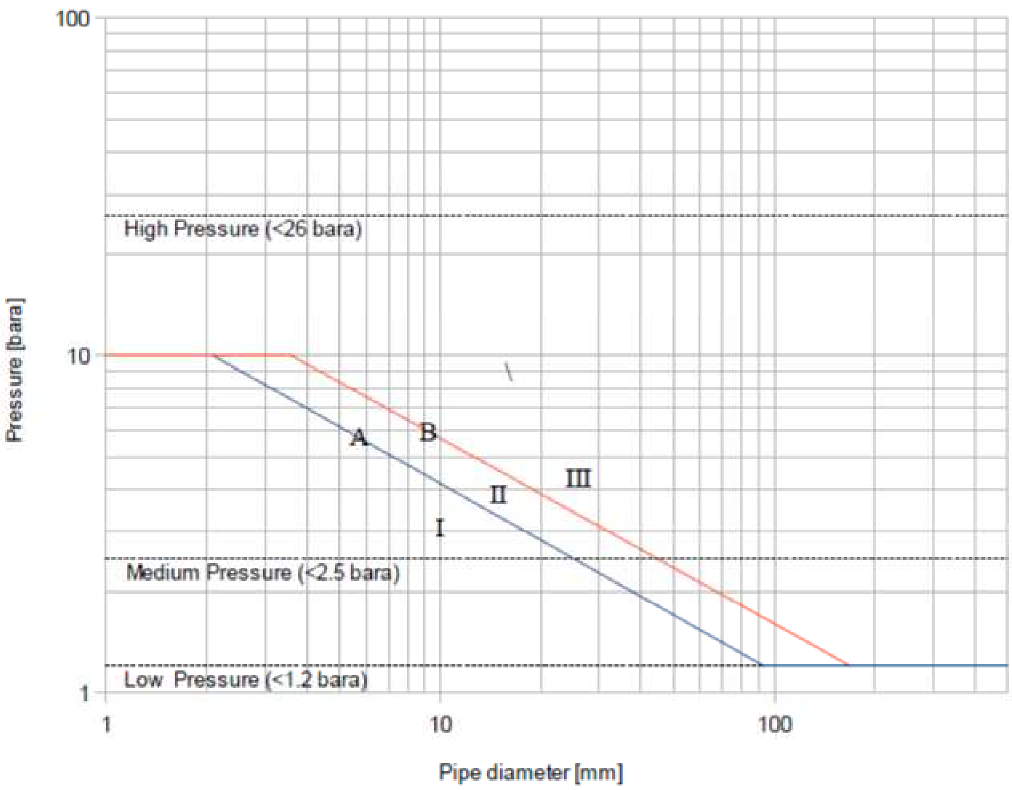
If the operating conditions in an acetylene line are located on the line A, or between line A and line B, the action of even moderate ignition energy upon the gas can lead to acetylene decomposition which is propagated along the pipeline in the form of a deflagration. Line A, marks the pressure limit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

11.1.2 Definition of working ranges

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

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

Figure 5: Working Ranges according to Sargent



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

11.1.3 Methods of determining the working ranges

Determination by means of diagram

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

Determination by means of experimental data or practical experience

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

11.1.4 Classification into working ranges

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

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

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

11.2 Materials

11.2.1 Recommended material

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

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

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

Table 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 11.4.1	
II and III	$R_m \geq 320$	$A_5 \geq 8400/R_m$ but not less than 17

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

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

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

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

11.2.2 Materials not allowed or recommended only under certain conditions

Restrictions and conditions stated in 6.2 shall be followed.

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

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

Table 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 Pipe specification

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

11.4 Wall thickness

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

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

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

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

11.4.1 Pipelines in Working Range I

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

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

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) = 2 x *Pw*

P_w = “maximum allowed working pressure (bar)”

D_e = external diameter of pipe (mm)

$f = f_y / 1{,}3$

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

The wall thickness of acetylene pipelines in Working Range I should be selected in accordance with recommended standards.

11.4.2 Pipelines in Working Range II

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

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

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

where:

e = minimum wall thickness (mm)

P = "dimensioning pressure" (bar)

D_e = external diameter of pipe (mm)

P_W = maximum allowed working pressure (bar)

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

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

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

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

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

11.4.3 Pipelines for Working Range III

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

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

Calculation of wall thickness

An acetylene detonation travels along the pipeline as a shock wave. Particularly high stresses are caused at or near those places of the pipeline, where the shock wave will be reflected.

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

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

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

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

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 = maximum allowed working pressure (bar)

f_y = stress at yield point of the material (N/mm2)

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

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

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

Design by means of decomposition tests

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

A suitable test facility is described in EN ISO14113 [10].

Worked example for minimum wall thickness to withstand detonation and reflection occurring at any point:

Working Conditions

Maximum working pressure	P_w	=	19 bar
Internal diameter of pipe	d	=	18 mm
Stress at yield point of pipe material (EN 10216 [64])	S_y	=	235 N/mm²

Calculations

Allowable stress

$$S = \frac{S_y}{1.1} = \frac{235}{1.1} = 214 \text{ N/mm}^2$$

"Design pressure"

$$P = 35 (P_w + 1) - 1 = 35 (19 + 1) - 1 = 699 \text{ bar}$$

Minimum wall thickness

$$t = \frac{Pd}{20S - P} = \frac{699 \times 18}{(20 \times 214) - 699} = 3.51 \text{ mm}$$

Worked example for minimum wall thickness to withstand undisturbed detonation with reinforcements at reflection points:

Working Conditions

Maximum working pressure	P_w	=	19 bar
Internal diameter of pipe	d	=	18 mm
Stress at yield point of pipe material	S_y	=	235 N/mm²

Calculations

Allowable stress S

$$S = \frac{S_y}{1.1} = \frac{235}{1.1} = 214 \text{ N/mm}^2$$

"Design pressure" P

$$P = 20\,(P_w + 1) - 1 = 20\,(19 + 1) - 1 = 399 \text{ bar}$$

Minimum wall thickness t

$$t = \frac{Pd}{20S - P} = \frac{399 \times 18}{(20 \times 214) - 439} = 1.85 \text{ mm}$$

Note: These examples do not include allowances for corrosion, reduction in wall thickness due to bending of the pipe, external loads or manufacturing tolerances.

11.5 Connections

Fully butt-welded connections are preferred.

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

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

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

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

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

11.6 Valves and seals

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

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

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

where:

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

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

Valve suitability for working ranges II and III may also be verified by performing detonation testing according to the requirements of EN ISO 15615 [12].

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

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

Seals or packing shall comply with 6.2.

11.7 Pressure Testing

11.7.1 General

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

Components that have been verified as appropriate for the working ranges, for example valves, flash back arrestors, pressure gauges by detonation testing according to the requirements of EN ISO 15615 which contain soft seals that may be damaged by the pipework pressure test should be removed for the pressure test and replaced by spool pieces. Specific parts may require separate testing or test methods. If parts are tested separately, it shall be ensured that all connecting elements are included in the tests.
Strength test of high pressure pipework should be carried out hydraulically. Where a pneumatic test is carried out precautions shall be taken to prevent injury to personnel or property damage in the event of a failure. A certificate shall be issued to document the results of the tests.

11.7.2 Test pressures

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

Table 11:Test pressure vs. Working range

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

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

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

11.7.3 Leak test

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

Leakage can be detected using a commercial leak test solution, see AIGA 070 [63]. Avoid detergent solutions that contain ammonia or other components that can initiate stress corrosion cracking. Leak tightness can also be checked by observing if there is decay in the pressure.

11.8 Dimensions and design

11.8.1 Manufacture

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

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

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

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

Butt-welding is preferred for all joints.

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

All sealing material shall be resistant against acetone and DMF.

Pipes shall be protected against external corrosion.

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

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

11.9 General guidelines for underground pipes

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

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

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

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

11.9.1 Equipment

Drainage

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

Pressure monitoring

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

Pressure limiting equipment

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

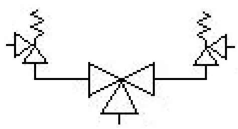
Isolation valves

Isolation valves shall be fitted to all gas withdrawal points.

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

Isolation valves shall be readily accessible and easy to operate.

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



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

Closing ends of pipes without connected equipment

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

11.10 Installation

General requirements

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

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

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

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

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

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

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

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

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

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

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

Pipelines installed above ground

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

Pipelines in accessible ducts

Pipelines should only be installed in ducts if:

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

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

Pipelines in non-accessible ducts

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

Non-accessible ducts shall be filled with sand.

Buried pipelines in the ground

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

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

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

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

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

Vent pipes

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

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

Vent pipes should not emerge below openings into buildings (for example windows). There shall be no sources of ignition within an area defined in the site hazardous area drawings and/or ATEX study (reference EIGA Doc 134 [29])

11.11 Operation

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

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

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

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

Pipelines shall be periodically checked for leaks (e.g. by using a suitable ammonia free leak detection fluid or by use of a gas detection unit, refer to AIGA 070 [63]) and for mechanical integrity according to the specific requirements for each type of installation.

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

Maintenance tasks on pipelines shall be carried out by competent persons only, following a risk assessment for the task and applying procedures such as work permit, logout/tagout, hot work and hand back procedures and documentation where applicable, refer to AIGA 011 [14] Work Permit Systems.

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

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

12 Acetylene supply systems at customer premises

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

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.

Note: the above items above can be integrated in one single device (integrated valve cylinders) except the safety devices.

12.1.1 General

Personnel handling acetylene systems shall have been trained and competent regarding:

- the specific hazards involved in handling acetylene and individual cylinder systems (Refer to EIGA doc SL 04 [65])
- actions that shall be taken in the event of incidents and faults.

12.1.2 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 [66].

Note: Integrated valves are designed with a pressure regulator integrated in the valve. See EN ISO 22435 [58]

Low pressure hoses up to 20 bar

Only welding hoses conforming to EN ISO 3821 [67], designed and approved for acetylene shall be used.

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 [68] and hose assemblies shall conform to EN 1256 [69]

Safety devices

Single cylinder systems shall be equipped with a flashback arrestor with a non-return valve (refer to EIGA SI 05 [70]). They shall conform to EN 730 [71].

12.1.3 Installation of single cylinder supply system

Individual cylinder systems shall not be located in confined spaces or areas of restricted access such as stairwells, corridors, passageways and thoroughfares. Only under controlled conditions should it be permissible to work in areas of restricted access (for example, 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 including cordoning off, securing an escape route and having 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 may be sufficient.

The number of individual cylinder systems in working rooms shall be minimised. Consideration should be given to use manifolded systems when multiple individual cylinder systems are in place.

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

Acetylene cylinders should not be used in the horizontal position. Free-standing acetylene cylinders shall be 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.

12.1.4 Operation

Acetylene single cylinder systems shall be operated so that no hazardous heating 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 open 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. Before the burner is ignited, any acetylene/air mixture in the hose shall be purged out with acetylene.

No pressure greater than 1.5 barg 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, for example 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, where applicable.

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 (for example from 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.

12.1.5 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.

When maintenance work is completed, a certificate should be issued by a competent person to document the approval before commissioning (see 11.11)

The supplier, or their authorised competent person, shall only perform repair work on acetylene cylinders.

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 Introduction

Battery and manifold systems are acetylene supply systems with two or more acetylene cylinders, also combined into cylinder bundles or acetylene battery vehicles (refer to EN ISO 14114 [72]).

Battery systems consist of:

- two or more acetylene cylinders,
- a high-pressure section,
- one or more main pressure regulator,
- a medium or low-pressure section downstream of the main pressure regulator,
- safety devices (as required in EN ISO 14114 [72]),
- installation rooms and installation locations (see ”Requirements for installation rooms” in chapter 12.2.4).

12.2.2 General

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

- operating battery systems;
- specific 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 14113 [10] and EN 12115 [10a] standards shall be used.

Acetylene cylinders with different porous material may be connected together in a battery system for collective withdrawal if they contain the same type of solvent and have the same acetylene content.

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 [10] and EN 12115 [10a] (Hoses)
- EN ISO 14114 [72] (cutting and welding equipment basic requirements)
- EN ISO 7291 [9] (Pressure regulators)
- EN ISO 15615 [12] (Safety requirement for high pressure equipment)
- EN 730 [71] (Safety Devices)

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 from both acetone and DMF. Hoses assemblies shall conform to EN ISO 14113 [10] and EN 12115 [10a].

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 [66] for battery systems with up to 6 acetylene cylinders and for larger battery systems shall conform to EN ISO 7291 [9].

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 to 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 room specifically designed for acetylene installations or outdoors as outlined in “Requirements for acetylene specific 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 should not be stored at the installation location of battery systems but at a dedicated storage location.

Unlimited amounts of inert gases may be stored near the battery supply system.

Oxygen may be stored and used in the battery supply, up to the same number of acetylene cylinders if there is a physical barrier (un-pierced wall) between the two gases or if the separation distance is at least 3 metres subject to local regulations.

If backup cylinders or bundles are used within the battery system they shall be connected to the high pressure collective line with their valves closed; in case of bundle the main valve closed but individual cylinders valves open.

If automatic change over switches are used all connected cylinders or bundles shall have open valves.

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):

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 can be achieved by means of a physical barrier, a fence and signs as outlined in *General requirements*.

Valves and safety fixtures shall be protected against the effects of the weather using non-flammable materials.

Requirements for acetylene specific installation sites and rooms

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 [7] in particular:

- they shall be constantly ventilated, either artificially or naturally: See 7.2.1.
- 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. in accordance with ATEX requirements.

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. Where other gas cylinders are to be stored in an acetylene battery room, this shall only be in compliance with any local regulations and following a risk assessment.

In the event of an emergency, it shall be possible to leave the installation rooms safely and without delay. 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 there 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 installation rooms shall be made of non-flammable materials.

Roofs of installation rooms

Refer to 7.1.2.

Heating equipment in installation rooms is only permissible if it is in compliance with the requirements of the Directive 94/9/EC [7] and does not exceed 225 °C surface temperature.

Sufficient water supplies shall be available to cool the cylinders in the event of a fire. Deluge systems shall be considered for large installations (refer to 7.3.2).

Fire extinguishers shall be provided at suitable locations.

12.2.5 Operation

General requirements

Acetylene battery systems shall be located so that the cylinders are not exposed to heating which can lead to acetylene decomposition. Cylinders should always be at least 0.5 m from heating 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 [7] and 99/92 EC [28] shall apply.

Acetylene battery systems, apart from portable battery systems, shall have a separation distance in accordance with national legislation depending on the amount of acetylene in the battery system. (refer to 12.2)

These distances may be reduced by structural measures (e.g. walls without openings) in accordance with national legislation.

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:

- 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;

  - o regulators for correct operation and outlet pressure.

- 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 (refer to table 11.7.2 for test pressures).

  It is preferred that pressure tests are carried out hydraulically for reasons of safety. However, pneumatic testing may be carried out if safety precautions are taken to protect personnel from an energy release if there was a failure during the test. For medium and low-pressure sections, pressure tests should be carried out using inert gas or air if safety precautions are taken. If air is used for pneumatic testing this shall be purged from the system prior to use with an inert gas, e.g. nitrogen.

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

- 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.

  It is recommended that all the tests carried out during commissioning of a system are recorded and retained in the system information file.

  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 thoroughly purged to remove the air.

  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 could be present in the system. Prior to commissioning, the system shall be checked by a person suitable knowledgeable and assessed for competency on such systems.

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 main shut off 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, in accordance with the type-approval of the bundle.

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 maintained to be sufficient. They shall be cleaned at least annually and shall be inspected for security against returning gas. Where required they shall be protected against freezing.

12.2.6 Maintenance

Regular inspection/maintenance shall ensure that:

- the equipment is in working order, is being correctly used, all the required components are in place and that there have been no unauthorised modifications have been made;
- all equipment such as regulators, piping, pigtails and flexible hoses are in a serviceable condition, e.g. not corroded or damaged;
- valves operate correctly;
- the system is operating in accordance with the design conditions, (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).

An annual inspection shall check to ensure that:

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

Leaking or damaged parts shall only be replaced or repaired by competent persons. Only spare parts equivalent to the original manufacturing specification shall be used for valves and fittings.

Maintenance of cylinders and cylinder valves shall only be performed by the cylinder supplier.

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

Refer to 7.4.4

12.3.2 Handling of acetylene cylinders

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

Acetylene cylinders should be transported in the supplier's vehicle. If using private transport, it is strongly recommended that an open or well ventilated vehicle is used, refer to EIGA Campaign for transporting gas cylinders in non-dedicated vehicles. [73]

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

Always follow no smoking requirements.

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

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

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

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

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

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

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

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

13 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 can 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. Ensure that the area where the emergency is occurring is cordoned off.

The container should not be moved until the reaction has ceased and the surface is cool. If possible any further contact with water should be eliminated.

(Refer to CGA pamphlet G-1.7, Standard for storage and handling of calcium carbide in containers) [74].

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 (typically <100 mbarg), through a small bore tubular probe, which may be inserted in to a pierced hole in the drum if the inlets not available.

Before starting to purge: Before a drum is purged, allow the drum to cool naturally by ambient air until cold to the touch then move it 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.

Procedure only to be followed by competent and trained personnel.

Hold a spark resistant tool against the drum and 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. Ensure that the purge gas is vented to a safe location.

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 25% LEL (acetylene in nitrogen). The container may then be used in the normal manner.

13.1.4 Carbide spillage

Equipment

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

- spark resistant shovel (full shovel with long handle),
- spark resistant bucket,
- natural bristle broom (not nylon which could generate static electricity),
- steel drum without a lid,
- drum containing dry sand (in the event of a fire),
- Personal Protective Equipment (refer to AIGA 066) [13].

Use and maintenance of equipment

Equipment to clean up calcium carbide spills should be maintained at a designated spot in the acetylene plant and used for that sole purpose only.

Plastics or other potential spark generating equipment shall not be used.

Cleaning up a calcium carbide spill

Wear the following personal protective equipment:

- flame retardant gauntlets (long sleeve gloves),
- chemical resistant eye protection
- flame retardant clothing,
- dust mask.

If the spillage is a major loss of containment then evacuate personnel from the area to a location upwind and prevent vehicle access to the incident area in accordance with site emergency procedures

Keep water away from spilled calcium carbide. If carbide has become wet in the vicinity of the acetylene generator, immediately stop all acetylene production operations and ensure that the area is well ventilated in the vicinity of the spillage 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 spark-resistant 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 could cause an explosion.

If the PPE has become impregnated with calcium carbide, ensure that it is removed and laundered before re-use. Personnel should ensure that they have a shower immediately after the clean-up operation to remove residual calcium carbide products.

If spilled calcium carbide has come in contact with water and become wet, 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 the calcium carbide has not become contaminated, e.g. with sand, it may be kept covered and be used in the first available generator charge.

13.1.5 Carbide fires

13.1.5.1 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 could result in an explosion.

13.1.5.2 Procedure

Wear the following fire retardant personal protective equipment:

- leather gauntlets (long sleeve gloves),
- leather boots,
- chemical resistant eye protection,
- flame retardant clothing,

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

Isolate all sources of ignition in the area.

Re-ignition of generated acetylene could be a secondary risk, following extinguishing of the fire.

If water is present 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. This operation should only be carried out by the authorised emergency services trained to deal with this action for example the fire brigade.

Allow the building to ventilate freely by opening the doors and waiting for at least 30 minutes or until the atmosphere is safe.

Immediately place the spilt carbide into 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 could still be generated.

13.1.6 Carbide lime spillage

Wear the following personal protective equipment:

- flame retardant gauntlets (long sleeve gloves);
- chemical resistant eye protection;
- flame retardant clothing and cotton overalls; and
- rubber boots,

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 other devices designed for this purpose.

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.

13.2 Fire fighting in acetylene plants

13.2.1 General requirements

All national and local authority fire regulations shall be followed.

Fire and emergency drills shall be held on a regular basis, at least once per year.

Fire protection equipment shall be maintained and tested regularly in accordance with the manufacturer's instructions or local regulations.

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.

13.2.2 Fire fighting equipment

Dry powder fire extinguishers are preferred. Carbon dioxide fire 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 and motor rooms (Carbon dioxide 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. (Refer to 7.3.2)

13.2.3 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 could 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. Refer to 7.1.2.

Fires from the high-pressure system are potentially extremely hazardous. These fires can only be extinguished by stopping the flow of escaping acetylene where safe to do so. 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 shall 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 where fitted.

Fire can also spread rapidly through the filling plant if escaping gas from a cylinder valve or a burst hose ignites. The recommended protective option is to install water deluge systems, refer to 7.3.2.

13.2.4 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 pipework causing decomposition of the acetylene in the cylinder.
- Internal decomposition due to high pressure and or temperature in the cylinder, Hot cylinders can be difficult to detect, some indications could be:
    - A sudden sharp noise when closing the valve;
    - Feeling a rise in temperature in the neck area of the cylinder shell when disconnecting from the cylinder manifold;
    - Steam rising from the cylinder surface;
    - Unusual smell from burning paint or valve seals;
    - Blistering of paintwork on the cylinder shell; and
    - Cylinder shell becoming red or white hot

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

1. The following actions shall 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 shall depend upon the circumstances of the particular emergency, for example the layout of the area).

    - Do not move any hot cylinder.
    - If cylinder cooling water is used at the site, leave it running 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 stoop filling and instigate the site emergency procedure.
    - Operate the emergency alarm system to evacuate all personnel to designate assembly areas. All personnel shall be evacuated immediately.
    - 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.

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.

    Activating deluge or monitors 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 person of the incident, who shall assume control of the emergency.

4. After 1 hour a competent and trained person (acting with the authority of the responsible person shall examine the condition of the cylinder to see if it is still steaming. This shall be performed from the furthest possible distance (using visual aids such as binoculars, thermal camera 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 before the cylinder is inspected for signs of residual heat.

   Cylinders, which have gas escaping from fusible plugs or bursting discs, shall 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 turned off, wait to see if the water on the surface of the cylinder evaporates rapidly. This indicates that the cylinder is still warm.

   Turn on the water and continue cooling for an additional hour before re-checking as above.

   Continue this cycle until the cylinder remains wet when the water is turned off Only after this occurs proceed to the next step.

6. Remove the cylinder from the building and gently place it in a 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 shall be regularly checked to ensure it is not leaking or evaporating, and the water level shall be maintained as required

   It may not be possible to use a water bath for an acetylene bundle because of its size and therefore it shall be cooled by spraying with water for 12 hours, instead of immersing in a water bath.

   It may not be possible to check that the cylinders within the centre of the bundle have been sufficiently cooled and therefore .t is not recommended to dismantle the cylinders from the bundle framework.

   Do not dismantle the bundle until all cylinders have been verified as cool.

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

7. After 12 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 (see 8.6).

   Note 1: It is safer to blow the cylinder down under water because the cylinder can contain quantities of hydrogen as a result of the decomposition of acetylene.

Note 2: To ensure that remaining cylinders have not been affected by the ignition, leave them on the rack for 12 hours before being released.

Inspect the filling hoses and pipework for damage and internal contamination with soot. Any suspect equipment shall be replaced.

For additional information refer to EIGA Safety Information 02, [75]

Note 3: Another method to deal with hot acetylene cylinders is shooting with a rifle to relieve the pressure. This is only allowed in some countries where it is always managed by the emergency services and the method shall refer to their National procedures.

13.2.5 Nitrogen purge emergency systems

In situations where a fire or decomposition occurs inside the equipment or piping, an effective way to remove the flammable gas from the plant is by means of introducing in an automated or remote manner a large quantity of inert gas which is vented to the atmosphere via the controlled vent points

An emergency nitrogen purge system may be designed to remove all acetylene from the plant and to leave it in a safe condition. It is to be activated when an emergency situation is observed by an operator e.g. a major problem with a cylinder on the fill manifold or a fire anywhere in the production buildings.

The function is:

- shutdown the plant;
- stop machinery (for example compressors, carbide feed, acetone supply), and
- open automatic nitrogen inlet valves and open vent valves to atmosphere.

13.3 Plant shutdown and evacuation

The situations described in this chapter may involve a Plant Emergency Shutdown with the objective to protect personnel, eliminate main sources of ignition (for example electrical equipment) and leave the plant safe.

In 7.1.2 the design of the subsystems is specified.

In all the cases is recommended to have the appropriate activators (for example emergency stops) easy to activate from local or remote locations and an evacuation alarm with a different sound from the process alarms.

14 Standards and Legislation

14.1 References

[1] EN 1800 Acetylene cylinders – Basic requirements and definitions

[2] AIGA 009 Safety Training of Employees

[3] AIGA 010 Management of change

[4] S A Miller Properties of Acetylene Volume 2

[5] Directive 2006/42/EC of the European Parliament and of the Council of 17th May 2006 on the approximation of the laws of the Member States relating to machinery

[6] 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

[7] Directive 94/9/EC of the European Parliament and of 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,(ATEX)

[8] EN ISO 9539 Materials for equipment used in gas welding, cutting and allied processes

[9] EN ISO 7291: Gas welding equipment – Pressure regulators for manifold systems used in welding, cutting and allied processes up to 300 bar

[10] EN ISO 14113 Gas welding equipment – Rubber and plastic hoses assembled for compressed or liquefied gases up to a maximum design pressure of 450 bar.

[10a] EN 12115 Rubber and thermoplastics hoses and hose assemblies for liquid or gaseous chemicals. Specification

[11] EN 837 Pressure gauges

[12] EN ISO 15615 Gas welding equipment – Acetylene manifold systems for welding, cutting and allied processes, and safety requirements in high-pressure devices

[13] AIGA 066 Selection of personal protective equipment

[14] AIGA 011 Work permit systems

[15] NFPA 51A Standard for acetylene cylinder charging plants

[16] NFPA 77 Recommended practices on static electricity

[17] PD CLC/TR 50404 2003 Electrostatics, code of Practice for the avoidance of hazards due to static electricity.

[18] EIGA Doc 75 Determination of safety distances

[19] EN 1755 Safety of industrial trucks – Operation in potentially explosive atmospheres – Use in flammable gas, vapour, mist and dust

[20] EIGA SAC NL 76 Risk of generating static electricity when using CO2 as an inerting agent

[21] BS 5306 Code of practice for fire extinguishing installations and equipment

[22] NFPA 15 Standard for water spray fixed systems for fire protection

[23] EN 12845 Fixed fire fighting installations: Automatic sprinkler systems, Design installation and maintenance

[24] EIGA SAC NL 89 Typical cylinder bundle/pallet tow away incidents

[25] NFPA 55 Compressed gases and cryogenics fluids code

[26] EIGA Doc 109; Environmental impacts of acetylene plants

[27] Directive 2010/75/EU Industrial Emissions Directive on industrial emissions (integrated pollution prevention and control),

[28] Directive 1999/92/EC Council Directive on minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres

[29] EIGA Doc 134 Potentially explosive atmospheres

[30] EIGA Doc 143 Guide to lime applications

[31] *Directive 2010/10/EC:* Directive 2010/35/EC of the European Parliament of 16 June 2010 on transportable pressure equipment

[32] EN 1964-1 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

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

[34] EN 13322-1 transportable Gas cylinders Refillable welded steel gas cylinders – Design and construction

[35] ISO 4706 Gas cylinders – Refillable welded steel cylinders – Test pressures 60 bar and below

[36] ISO 3807-1 Cylinders for acetylene – Basic requirements

Part 1: Cylinders without fusible plugs

[37] EN 13769 Cylinder bundles - Design, manufacture, identification and testing

[38] ISO 10961 Gas cylinders -- Cylinder bundles -- Design, manufacture, testing and inspection

[39] EN 13807 Design of battery vehicles

[40] CGA G-1.6 Standard for Mobile Acetylene Trailer Systems

[41] CR 14473 Transportable gas cylinders - Porous masses for acetylene cylinders

[42] EN 1801 Filling conditions for single acetylene cylinders

[43] AIGA 037 Permissible charge/filling conditions for acetylene cylinders

[44] ISO 11372 Gas Cylinders Acetylene Cylinders Filling conditions and filling inspection

[45] EN 12755 Transportable gas cylinders - Filling conditions for acetylene bundles

[46] ISO 13088 Gas cylinders Acetylene cylinder bundles Filling conditions and filling inspection

[47] EN 13720 Battery vehicles – Design, manufacture, identification and testing

[48] EN 12863 Periodic inspection and maintenance of dissolved acetylene cylinders

[49] ISO 10462 Gas cylinders –Transportable cylinders for dissolved acetylene – Periodic inspection and maintenance

[50] EN 14189 Inspection and maintenance of cylinder valves at time of periodic inspection of gas cylinders

[51] ISO 22434 Transportable gas cylinders – Inspection and maintenance of cylinder valves

[52] AIGA 025 Pressure receptacles with blocked or inoperable valves

[53] CGA C-13 Guidelines for periodic visual inspection and requalification of acetylene cylinders.

[54] EIGA Doc 05 Guidelines for the management of waste acetylene cylinders

[55] EN ISO 10297 Transportable gas cylinders - Cylinder valves - Specification and type testing

[56] EN ISO 14246 Transportable gas cylinders - Gas cylinder valves - Manufacturing tests and inspections

[57] ISO 15996 Gas cylinders – Residual pressure valves – General requirements and type testing

[58] ISO 22435 Gas cylinders – Cylinder valves with integrated pressure regulators – Specification and type testing

[59] EN 962 Valve protection caps and valve guards for industrial and medical gas cylinders – Design construction and tests

[60] ISO 11117 Gas cylinders Valve protection caps and vale guards for industrial and medical gas cylinders – Design, construction and tests

[61] EN 1089-3 Transportable gas cylinders – cylinder identification – colour coding Part 3

[62] EN 12754 Cylinders for dissolved acetylene – Inspection at time of filling

[63] AIGA 070 Leak detection fluids

[64] EN 10216 Seamless steel tubes for pressure purposes

[65] EIGA SL 04 The safe transport, use and storage of acetylene cylinders for users

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

[67] EN ISO 3821 Gas welding equipment. Rubber hoses for welding, cutting and allied processes

[68] EN 560 Gas welding equipment – Hose connections for welding, cutting and allied processes

[69] EN1256 Gas welding equipment – Specification for hose assemblies for equipment for welding cutting and allied processes

[70] EIGA SI 05 Flashback and flame arrestors

[71] EN 730 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

[72] EN ISO 14114 Gas welding equipment – Acetylene manifold systems for welding cutting and allied processes – General requirements

[73] EIGA Campaign for transporting gas cylinders in non-dedicated vehicles

[74] G-1.7 Standard For Storage And Handling of Calcium Carbide In Containers

[75] EIGA Safety Information 02 Handling of Gas Cylinders at and after Fire/Heat Exposure

[76] Council Directive 2012/18/EU of the European parliament and of the Council of 4th July 2012 on the control of major-accident hazards involving dangerous substances, amending and subsequently repealing Council Directive 96/82/EC

[77] EIGA Doc 60 Prevention of Major Accidents

14.2 Seveso Directive

It shall be noted that the storage of acetylene above 5 tonnes in Europe requires that the establishment is subject to the provisions of the Seveso Directive [76] (lower tier) with in particular the obligation to notify the competent authority and to establish a Major Accident Prevention Policy. If the storage of acetylene is above 50 tonnes (upper tier) there are additional requirements and in particular to produce a Safety Report. Also the storage of calcium carbide and solvents (acetone and DMF) is subject to limitations. In addition, if in an establishment there are other dangerous substances in one or more installations (for example oxygen storage), it shall be checked by the application of the addition rule of Annex I of the Seveso Directive: it is possible that an establishment where the storage of acetylene is under the limits of 5 or 50 tons but other dangerous substances are present, may be promoted to be subjected to the application of the Seveso directive or to switch from the lower tier to the upper tier. Reference shall be made to the EIGA doc 60 Prevention of Major Accidents, [77].