AIGA

PERMISSIBLE CHARGE / FILLING CONDITIONS FOR ACETYLENE CYLINDERS

AIGA 037/06

Asia Industrial Gases Association

3 HarbourFront Place, #09-04 HarbourFront Tower 2, Singapore 099254
Tel : +65 6276 0160 • Fax : +65 6274 9379
Internet : http://www.asiaiga.org

AIGA 037/06

PERMISSIBLE CHARGE / FILLING CONDITIONS FOR ACETYLENE CYLINDERS

KEYWORDS

- ACETYLENE
- BUNDLE
- CYLINDER

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

Acknowledgement

This document is adopted from the European Industrial Gases Association document IGC 26/04 ' Permissible charge/filling conditions for acetylene cylinders'. Acknowledgement and thanks are hereby given to EIGA for permission granted for the use of their document.

Table of Contents

1 Scope

This document has been produced to guide and advise engineers who are competent in acetylene systems to assist them in setting up and maintaining safe filling of acetylene cylinders.

The permissible charge for acetylene cylinders was specified in different ways by various national regulations although in the course of generating an international and European standard, experts have internationally agreed upon a simple and appropriate safety concept. This safety concept supersedes the arbitrary free space and/or maximum pressure requirements in some older national regulations.

In addition to the prime objective of producing an easy method of determining the permissible charge conditions for acetylene cylinders this document is intended to demonstrate the effects of the essential parameters such as

- Maximum acetylene content
- Necessary solvent content
- Acetylene/solvent ratio
- Acetylene filling tolerance
- Solvent filling tolerance
- Free volume in the cylinder
- Porosity of filler mass

Furthermore this document is intended to supplement the following standards

EN 1800	Transportable gas cylinders – Acetylene cylinders – Basic requirements and definitions
EN 1801	Transportable gas cylinders – Filling conditions for single acetylene cylinders
ISO 3807-1	Cylinders for acetylene – Basic requirements
EN 12755	Transportable gas cylinders – Filling conditions for acetylene bundles
EN 13720	Transportable gas cylinders – Filling conditions for acetylene battery vehicles

2 Introduction

Cylinders for dissolved acetylene contain a porous mass, solvent and acetylene. Therefore the acetylene cylinder is a complex system with interdependent parameters.

For the safe operation of individual acetylene cylinders containing a certain porous mass two basic criteria are internationally acknowledged.

The acetylene content and the solvent content of individual dissolved acetylene cylinders have to be selected in such a way that for a cylinder with the specified solvent content and with 105 % of the maximum approved acetylene content*:

- hydraulic pressure does not develop at a uniform temperature of 65 °C and that
- the porous mass is able to prevent the spread of an acetylene decomposition in the cylinder.

Tests must be carried out to confirm that the above requirements are met.

* *The maximum approved acetylene content is the maximum acetylene content specified by the approving authority or cylinder porous mass manufacturer. It may be equal to or less than the maximum acetylene content.*

3 Definitions and symbols

Acetylene cylinder

Pressure vessel, manufactured and suitable for transport of acetylene, containing a porous mass and solvent for acetylene (or solvent-free where applicable) with valve and other accessories fixed to the cylinder

Porous mass

Monolithic porous material introduced or formed in the cylinder shell filling the entire cylinder volume and that, due to its porosity, allows the absorption of the solvent/acetylene solution

Saturation gas

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

Solvent replenishment

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

a_1

Specific increase in volume of solvent due to dissolving acetylene in l/kg

a_2

Specific volume of the pure solvent in l/kg

L **– Solvent loss**

Solvent loss of an acetylene cylinder per filling and emptying cycle in kg/l

m_{A0} – Maximum acetylene content

Maximum permissible mass of acetylene including saturation gas in the cylinder in kg

m_A – Acetylene content

Actual mass of acetylene including saturation gas in the cylinder in kg

m'_A – Acetylene filling ratio

Acetylene content per litre of cylinder water capacity in kg/l

m_{S0} – Specified solvent content

Specified mass of solvent in the cylinder necessary for the specified maximum acetylene content in kg

m_S – Solvent content

Actual mass of solvent in the cylinder in kg

m'_S – Solvent filling ratio

Solvent content per litre of cylinder water capacity in kg/l

N – Number of bundle fillings

Maximum number of consecutive fillings of an acetylene cylinder bundle without disassembly

P – Porosity

Porosity of the porous mass determined according to EN 1800 or ISO 3807-1 in %

S_{min} – Minimum solvent filling ratio

Minimum solvent filling ratio in an acetylene cylinder within a bundle in kg/l

S_{max} – Maximum solvent filling ratio

Maximum solvent content in an acetylene cylinder within a bundle in kg/l

t **– Solvent safety margin**
Solvent safety margin for bundle filling conditions in kg/l

V_a – Available volume
Volume in the cylinder which is not occupied by porous mass and can hold solvent and acetylene in l

V_A – Volume increase
Increase of the volume of the solvent due to dissolving acetylene in l

V_F – Free volume
Volume of free space in the cylinder in l

V_S – Volume of the solvent
Volume of the solvent in the cylinder in l

V_w – Water capacity
Water capacity of the empty cylinder shell in l

4 Basic considerations

4.1 Available volume

The internal space of acetylene cylinders is completely filled with a porous mass (normally except for a core hole under the cylinder valve). The task of the porous mass is to distribute the solvent evenly within the cylinder and to stop the propagation of an acetylene decomposition which may enter the cylinder. Modern monolithic porous masses have a porosity of about 90 % which means that the solid substance of the porous mass excluding the pores takes up about 10 % of the water capacity V_w of the cylinder shell.

The remaining volume can hold solvent and acetylene and is commonly known as the available volume V_a consisting of the sum of all pores and can be expressed as:

$$V_a = V_w \cdot P / 100 \quad (1)$$

The available volume V_a (see schematic depiction in figure 1) is the sum of

- the volume of the solvent V_S
- the volume increase V_A of the solvent due to dissolving acetylene
- the volume of free space V_F

$$V_a = V_S + V_A + V_F \quad (2)$$

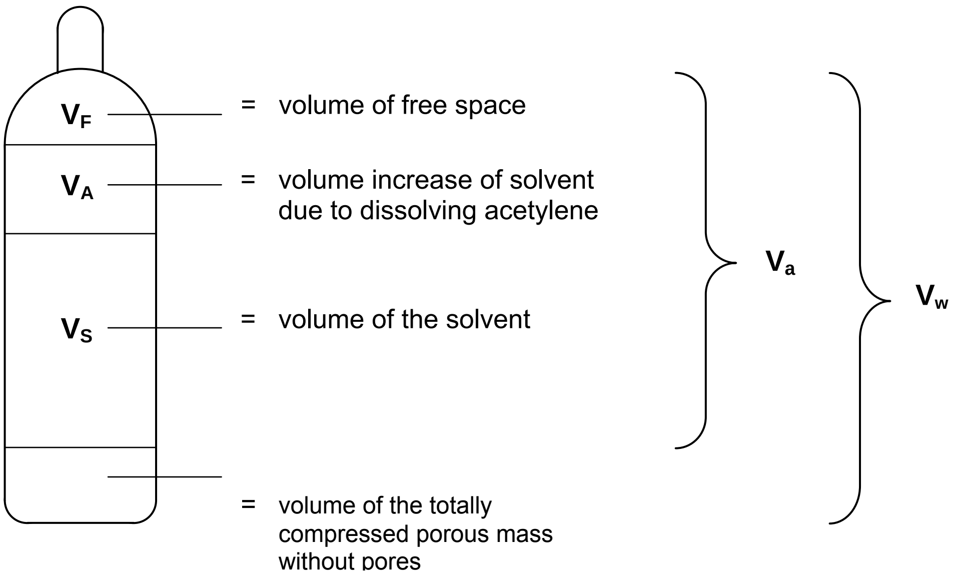

Figure 1 Schematic description of the available volume of an acetylene cylinder

The volume of an acetylene/solvent solution $V_A + V_S$ shall not exceed the available volume V_a.

The volume of the solvent V_S can be expressed by the term $a_2 \cdot m_S$, a_2 therefore is the reciprocal value of the density of the solvent.

The volume increase V_A of the before mentioned volume V_S due to dissolving acetylene can be expressed by the term $a_1 \cdot m_A$.

The volume of an acetylene/solvent solution $V_A + V_S$ is therefore given by:

$$V_A + V_S = V = a_1 \cdot m_A + a_2 \cdot m_S \quad (3)$$

The values of a_1 were experimentally determined for acetone and dimethyl-formamide (DMF) and their values are given in table 1 (values are taken from EN 12755).

Table 1 Values for a_1 and a_2 at 15 °C

	a_1 in l/kg	a_2 in l/kg
Acetone	1.91	1.25
DMF	1.75	1.05

4.2 Hydraulic filling

Hydraulic filling of acetylene cylinders results from all pairs of mass of acetylene m_A and mass of solvent m_S which take up the entire available volume V_a of the cylinder without leaving any free space. At a uniform temperature of 65 °C this line is called the f_{65} = 0 line (see figure 2). The f_{65} = 0 line is different for each solvent but the same for all cylinders containing the same solvent.

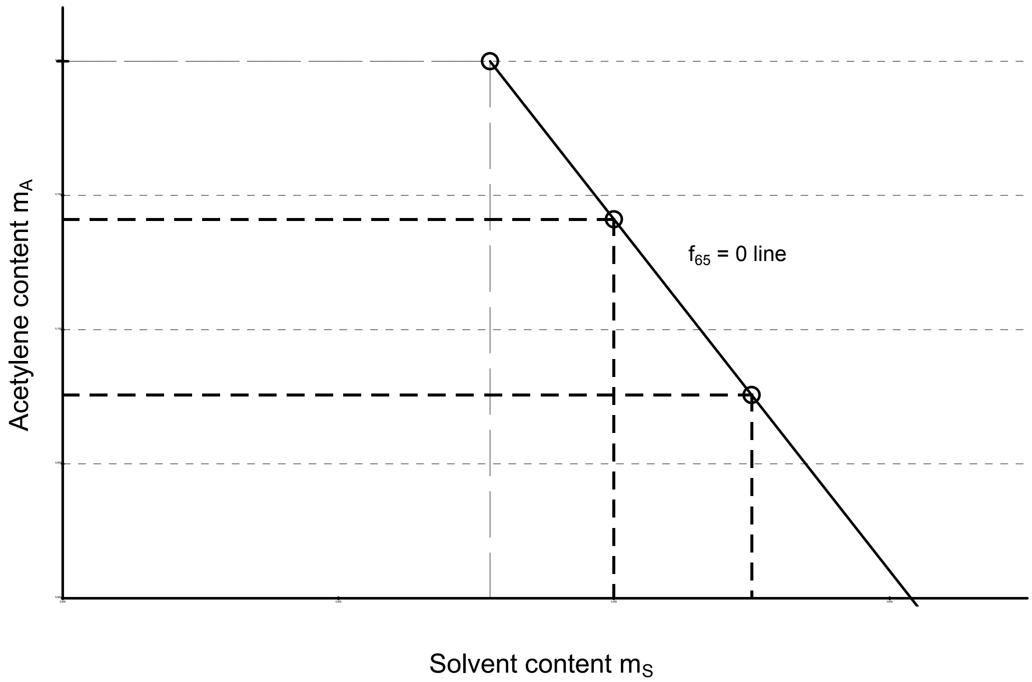

Figure 2 Diagram showing hydraulic filling at the f_{65} = 0 line

All acetylene/solvent ratios to the right and above of the f_{65} = 0 line are not permitted because hydraulic filling can occur already at temperatures below 65 °C.

4.3 Resistance against propagation of an acetylene decomposition

Since it is the objective to accommodate as much acetylene as possible under safe conditions in a cylinder we are looking for safe filling conditions as far as possible to the upper left side of the f_{65} = 0 line and thus at highest possible values for m_A. This means that the solvent content decreases as the acetylene content increases, since there is only a given available volume in the cylinder. On the other hand the resistance of acetylene cylinders against the propagation of an acetylene decomposition (often called backfire resistance) decreases with increasing acetylene content and decreasing solvent content.

The limit of the resistance against the propagation of an acetylene decomposition of a cylinder can be determined by a series of backfire tests as shown in figure 3.

A test series 1 is carried out with a certain acetylene content $(m_A)_1$ and varying solvent contents. The solvent content $(m_S)_{1,min.}$ is the minimum solvent content necessary to pass the backfire test with the acetylene content $(m_A)_1$.

For a test series 2 the procedure is repeated by selecting an acetylene content $(m_A)_2$ and conducting tests with varying solvent contents as described above to establish $(m_S)_{2,min}$.

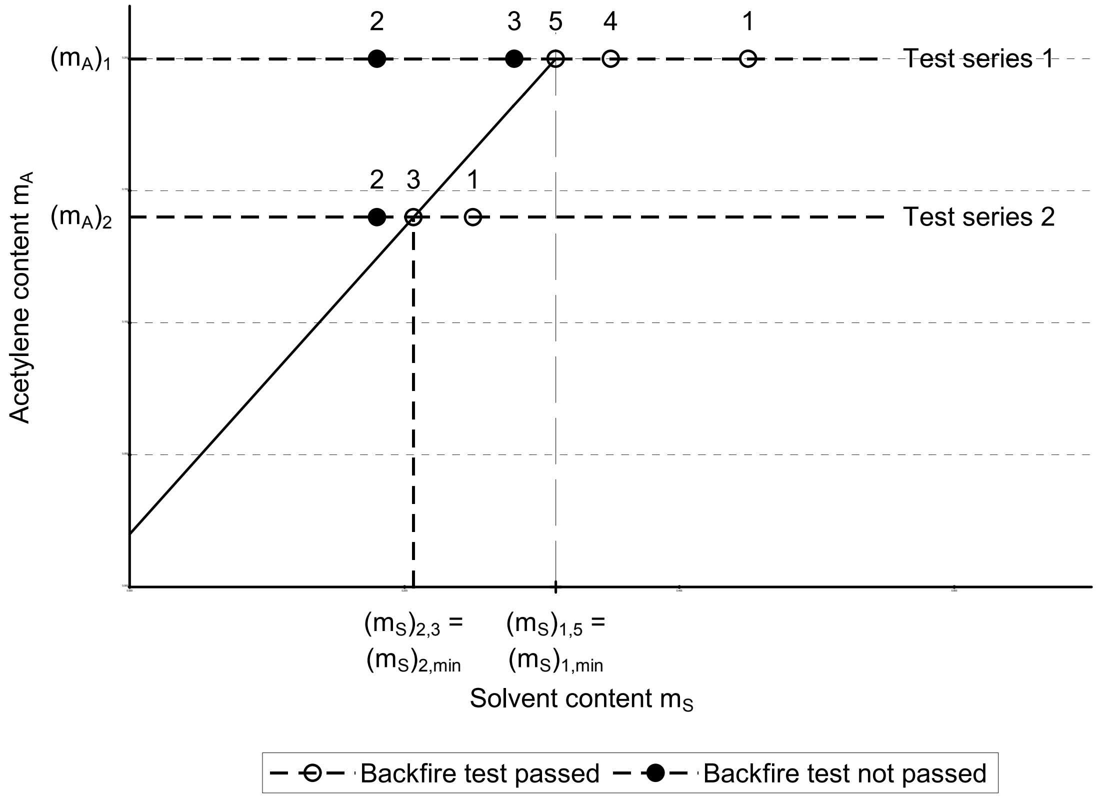

Figure 3 Determination of the resistance against propagation of an acetylene decomposition

All acetylene/solvent ratios to the left and above the line connecting $(m_S)_{2,min}$ and $(m_S)_{1,min}$ are not permitted because they are not backfire resistant.

5 Filling conditions for individual acetylene cylinders

Based on the manufacturers experience and the attempt to align the filling conditions for acetylene cylinders, it is normally not necessary to carry out the complete test programme as described in chapter 4.2 and 4.3 for the determination of the line for hydraulic filling and the backfire resistance. Instead the manufacturer specifies the intended solvent content and the intended maximum acetylene content for individual cylinders. Then acetylene cylinders containing the specified solvent content and 105 % of the intended maximum acetylene content are subjected to

- elevated temperature tests in order to prove that hydraulic pressure does not develop at a uniform temperature ≤ 65 °C and
- backfire tests in order to prove that the porous mass is able to stop the propagation of an acetylene decomposition within the cylinder.

If the tests are passed the specified filling conditions reflect the permissible filling conditions for individual acetylene cylinders (see figure 4).

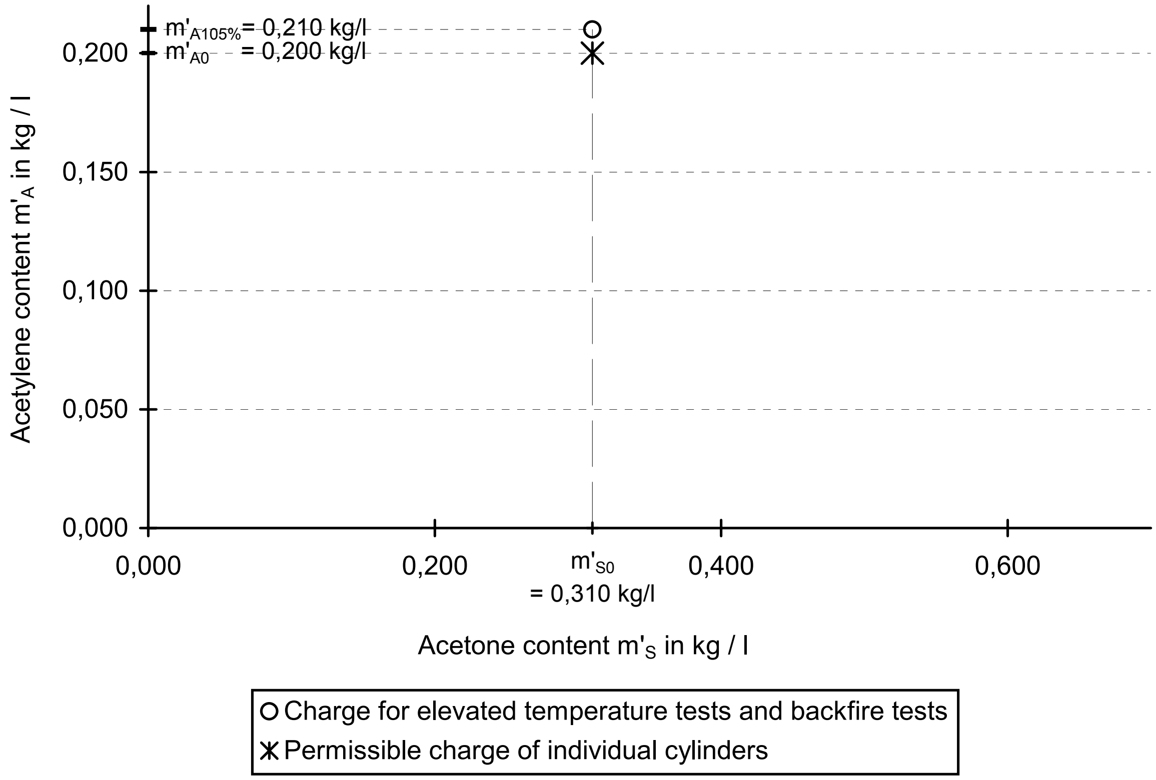

Figure 4 Permissible filling conditions for individual acetylene cylinders as determined by elevated temperature tests and backfire tests.

Example with a maximum acetylene filling ratio of 0,200 kg / l and a specified acetone filling ratio of 0,310 kg / l.

6 Filling conditions for acetylene cylinder bundles

Cylinders in bundles are supposed to be filled and emptied together for a certain number of times during which the solvent is not intended to be replenished. Therefore the filling conditions have to be selected in such a way that they allow for a tolerance of the solvent content. These filling conditions are derived from the permissible filling conditions for individual cylinders based on some considerations with regard to safe filling conditions.

6.1 Constant volume line

The volume of an acetylene/solvent solution at a given temperature is given by (see also chapter 4.1):

$$V = a_1 \cdot m_A + a_2 \cdot m_S \qquad (3)$$

The volume V_0 as given by the permissible filling conditions is known to be safe as it passes the elevated temperature test. It is given by:

$$V_0 = a_1 \cdot m_{A0} + a_2 \cdot m_{S0} \qquad (4)$$

The volume V of an acetylene/solvent solution shall not exceed V_0. Filling conditions with the same volume but a lower acetylene/solvent ratio are given by a line for constant volume through the permissible filling conditions. This line is obtained by equating of equation (3) and (4) and then solving for m_A leads to:

$$\begin{aligned} m_A &= \frac{a_1 \cdot m_{A0} + a_2 \cdot m_{S0} - a_2 \cdot m_S}{a_1} \\ &= m_{A0} + \frac{a_2}{a_1} \cdot m_{S0} - \frac{a_2}{a_1} \cdot m_S \\ &= m_{A0} + \frac{a_2}{a_1} \cdot (m_{S0} - m_S) \end{aligned} \tag{5}$$

Equation (5) is called the constant volume line. Filling conditions on this line have the same volume but a lower acetylene/solvent ratio than the permissible filling conditions for individual cylinders (see figure 5). Therefore the filling conditions on and below this line must be considered as safe as well.

The constant volume line is different from the f_{65} = 0 line as described in chapter 4.2, but using the constant volume line has the advantage that no additional tests have to be carried out once the permissible filling conditions for individual acetylene cylinders were determined.

6.2 Backfire line

The acetylene/solvent ratio m_{A0} / m_{S0} as given by the permissible filling conditions for individual cylinders is known to be safe as it passes the backfire test. Filling conditions with the same acetylene/solvent ratio are given by the line connecting the permissible filling conditions for individual cylinders and the zero point (see figure 5). Therefore the filling conditions on and below this line must be considered as safe as well. This gradient is called the backfire line and is described by:

$$m_A = \frac{m_{A0}}{m_{S0}} \cdot m_S \tag{6}$$

The backfire line is slightly different from the line of backfire resistance as described in chapter 4.3, but using the backfire line as well has the advantage that no additional tests have to be carried out once the permissible filling conditions for individual acetylene cylinders were determined.

6.3 Safe filling conditions

Safe filling conditions are reflected by all filling conditions on and below the backfire line and the constant volume line as shown in figure 5.

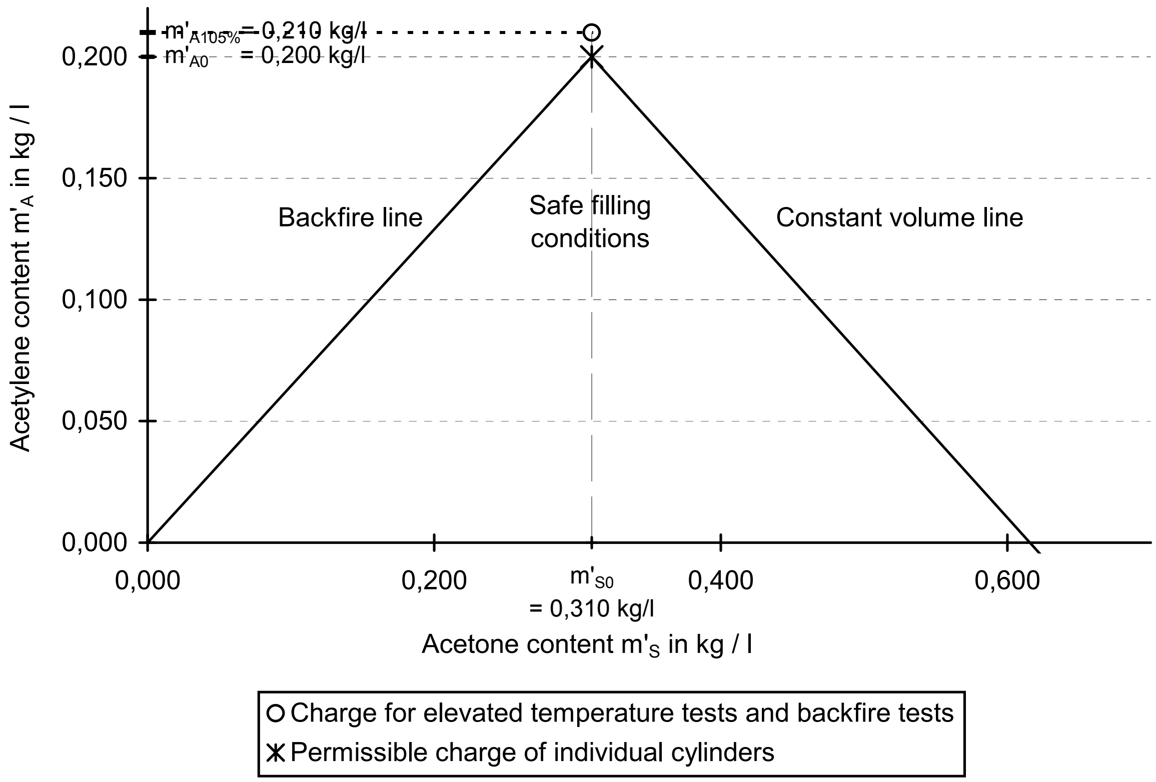

Figure 5 Safe filling conditions for acetylene cylinders as given by the backfire line and the constant volume line.

Example with a maximum specified acetylene filling ratio of 0,200 kg / l and a specified acetone filling ratio of 0,310 kg / l.

6.4 Tolerance for solvent content

In order to keep acetylene cylinders within the "triangle" of safe filling conditions as given in figure 5 and to allow for a tolerance of the solvent content, the acetylene content must be lower than the maximum permissible acetylene content. According to EN 12755 the acetylene content should be decreased to 90 % of the maximum permissible acetylene content m_{A0}. This allows for a tolerance of the solvent content until reaching either the backfire line or the constant volume line.

In addition, the different filling behaviour of the individual cylinders within the bundle has to be considered. Therefore the solvent tolerance also has to take into account an additional safety margin *t* to the backfire line and the constant volume line. This safety margin is given by EN 12755 and amounts to:

t = 0,010 kg / l for acetone

and t = 0,025 kg / l for DMF

Using these safety margins the minimum solvent content $S_{\min}$ and the maximum solvent content $S_{\max}$ can be calculated for a given acetylene content as follows:

$$S_{\min} = m_{A90\%} \cdot \frac{m_{S0}}{m_{A0}} + t \tag{7}$$

$$S_{\max} = \left(m_{A0} - m_{A90\%} + \frac{a_2}{a_1} \cdot m_{S0} \right) \cdot \frac{a_1}{a_2} - t \tag{8}$$

6.5 Number of consecutive fillings

The loss of solvent during a number of consecutive fillings before disassembly of a bundle for solvent replenishment shall not exceed the solvent tolerance. The average loss of solvent per cycle is given by EN 12755 and amounts to:

L = 0,00750 kg / l for acetone

and L = 0,00025 kg / l for DMF

The maximum number of consecutive fillings N is determined by dividing the solvent tolerance by the average loss of solvent per cycle:

$$N \leq \frac{S_{\max} - S_{\min}}{L} + 1 \tag{9}$$

6.6 Filling conditions for bundles according to EN 12755

Filling conditions for acetylene cylinder bundles determined as described in the previous chapters are in accordance with EN 12755 if the individual cylinders are approved according to EN 1800. An example is shown in figure 6.

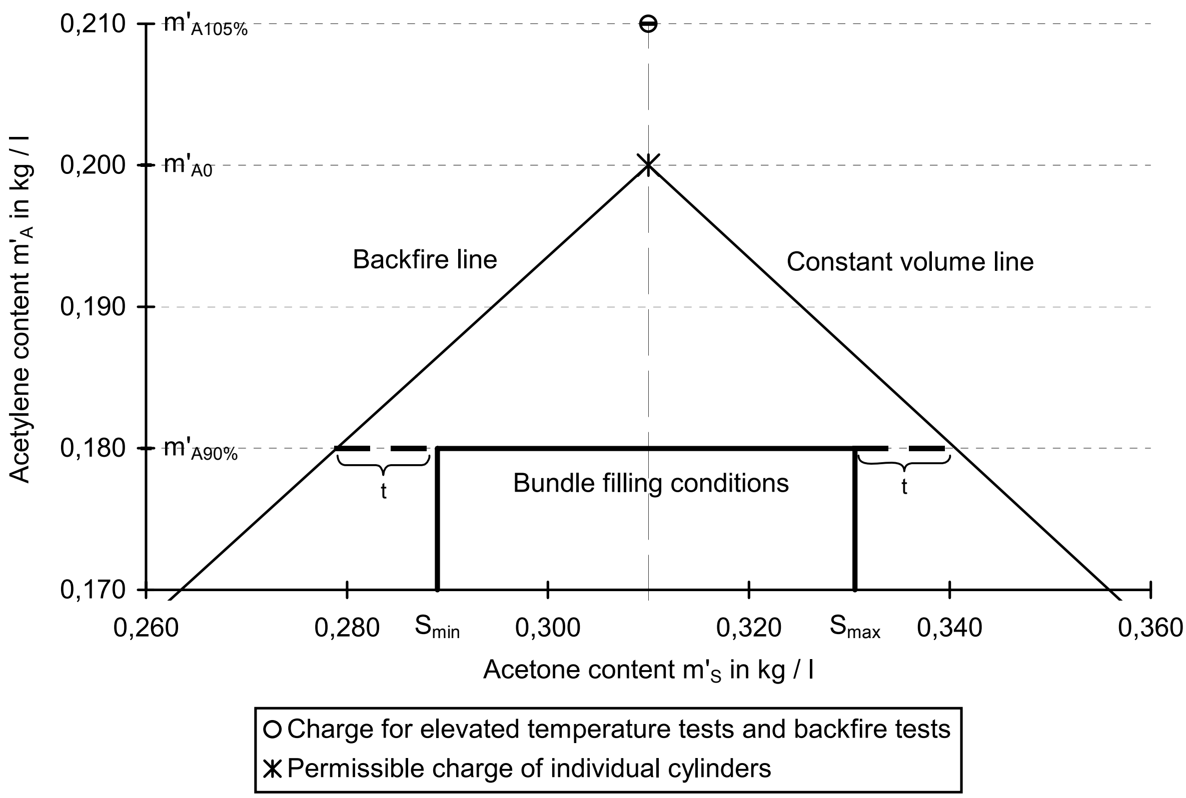

Figure 6 Example for filling conditions for acetylene cylinder bundles according to EN 12755:
(Note: The scale of the axes is changed compared to figure 5)

Individual cylinders:

Maximum acetylene filling ratio:	*0,200 kg / l*	
Specified acetone filling ratio:	*0,310 kg / l*	

Cylinders in bundles:

Maximum acetylene filling ratio:	*0,180 kg / l*	
Minimum acetone filling ratio:	*0,289 kg / l*	
Maximum acetone filling ratio:	*0,331 kg / l*	*(rounded up from 0.33056 kg / l)*
Maximum number of consecutive fillings:	*6*	

Information on approved porous masses for acetylene cylinders and their filling conditions can be found in

CR 14473 Report of CEN/TC 23
Transportable gas cylinders - High porous masses for acetylene cylinders

List of porous masses pdf- file to be downloaded from the BAM Server

http://www.bam.de/english/expertise/areas_of_expertise/department_2/division_21/laboratory_211.htm
and then hyperlink "Porous masses for acetylene cylinders"