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Gas cylinders — Acetylene cylinder bundles — Filling conditions and filling inspection

Bouteilles à gaz — Cadres de bouteilles d'acétylène — Conditions de remplissage et contrôle de remplissage

Reference number
ISO 13088:2011(E)

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Foreword

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The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 13088 was prepared by Technical Committee ISO/TC 58, *Gas cylinders*, Subcommittee SC 4, *Operational requirements for gas cylinders*.

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Introduction

This International Standard aims at the harmonization of the different operating and filling conditions of acetylene cylinder bundles and covers requirements that reflect current practice and experience regarding inspection at the time of filling.

Where there is any conflict between this International Standard and any applicable regulation, the regulation always takes precedence.

In International Standards, weight is equivalent to a force, expressed in newtons. However, in common parlance (as used in terms defined in this International Standard), the word “weight” continues to be used to mean “mass”, but this practice is deprecated (see ISO 80000-4).

In this International Standard the unit bar is used, due to its universal use in the field of technical gases. It should, however, be noted that bar is not an SI unit, and that the according SI unit for pressure is pascal (Pa).

Pressure values given in this International Standard are given as gauge pressure (pressure exceeding atmospheric pressure) unless noted otherwise.

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Gas cylinders — Acetylene cylinder bundles — Filling conditions and filling inspection

1 Scope

This International Standard specifies the minimum requirements for the filling conditions and filling inspection of acetylene cylinder bundles. It applies both to bundles which are filled while the cylinders are assembled in the bundle and to bundles of which the cylinders are filled as individual cylinders and are assembled into a bundle after filling. It does not apply to bundles containing solvent-free acetylene cylinders.

This International Standard is not applicable to individual acetylene cylinders that are not intended to be assembled into a bundle (see ISO 11372).

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 11372, *Gas cylinders — Acetylene cylinders — Filling conditions and filling inspection*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
acetylene cylinder
cylinder manufactured and suitable for the transport of acetylene, containing a porous material and solvent for acetylene, with a valve and other accessories affixed to the cylinder

NOTE When there is no risk of ambiguity, the word “cylinder” is used.

3.2
acetylene cylinder bundle
transportable unit comprising of at least 2 cylinders up to and usually not exceeding 16 cylinders that are permanently connected together by a manifold and contained within a rigid frame equipped with all necessary equipment for filling and use

3.3
cylinder shell
⟨acetylene cylinders⟩ empty cylinder manufactured and suitable for receiving and containing a porous material for use as part of an acetylene cylinder

3.4
filler
⟨gas cylinders⟩ trained person responsible for inspection prior to, during and immediately after filling

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3.5
maximum acetylene content
⟨acetylene cylinder bundles⟩ specified maximum weight of acetylene including saturation acetylene in the bundle cylinder

NOTE For the relationship of the maximum acetylene content of bundle cylinders and of individual cylinders, see 4.2.1.

3.6
maximum acetylene charge
⟨acetylene cylinder bundles⟩ maximum acetylene content minus the saturation gas

3.7
porous material
⟨acetylene cylinders⟩ single- or multiple-component material introduced to, or formed in, the cylinder shell, that, due to its porosity, allows the absorption of a solvent/acetylene solution

NOTE The porous material may be either:

— monolithic, consisting of a solid product obtained by reacting materials or by materials connected together with a binder, or

— non-monolithic, consisting of granular, fibrous or similar materials without the addition of a binder.

3.8
residual gas
⟨acetylene cylinder bundles⟩ weight of acetylene including the saturation acetylene contained in the cylinders of a bundle returned for filling

3.9
saturation gas
⟨acetylene cylinders⟩ acetylene that remains dissolved in the solvent in the cylinder at atmospheric pressure (1,013 bar) and at a temperature of 15 °C

3.10
solvent
⟨acetylene cylinders⟩ liquid that is absorbed by the porous material and is capable of dissolving and releasing acetylene

NOTE The following abbreviations are used:

— “A” for acetone;

— “DMF” for dimethylformamide.

3.11
solvent operating range
⟨acetylene cylinder bundles⟩ range from the minimum to the maximum solvent content permissible in a bundle which is filled while the cylinders are assembled

NOTE For the determination of the solvent operating range, see Annex A.

3.12
specified solvent content
⟨acetylene cylinders⟩ weight of solvent that the acetylene cylinder shall contain in accordance with the type approval

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3.13
tare
⟨acetylene cylinders⟩ reference weight of the acetylene cylinder including the specified solvent content

NOTE 1 The tare is further specified in accordance with definitions 3.13.1 to 3.13.2.

NOTE 2 For cylinders with solvent, the tare is expressed by indicating either tare S or both tare A and tare S.

3.13.1
tare A
⟨acetylene cylinders⟩ sum of the weights of the empty cylinder shell, the porous material, the specified solvent content, the valve, the coating, where applicable, and all other parts that are permanently attached (e.g. by clamping or bolting) to the cylinder when it is presented to be filled

3.13.2
tare S
⟨acetylene cylinders⟩ tare A plus the weight of the saturation gas

3.14
bundle tare
⟨acetylene cylinder bundles⟩ reference weight of the acetylene cylinder bundle including its solvent

NOTE The bundle tare is further specified in accordance with 3.14.1 to 3.14.4.

3.14.1
tare BA_{max}
⟨acetylene cylinder bundles⟩ sum of tare A for all cylinders permanently connected together by a manifold containing the maximum solvent content [therefore including the amount of the positive solvent operating range (see A.3)] plus the weights of the rigid frame and all other associated and permanently attached equipment

3.14.2
tare BS_{max}
⟨acetylene cylinder bundles⟩ sum of tare S for all cylinders permanently connected together by a manifold containing the maximum solvent content including the amount of the positive solvent operating range (see A.3) plus the weights of the rigid frame and all other associated and permanently attached equipment

3.14.3
tare BA_{min}
⟨acetylene cylinder bundles⟩ sum of tare A of all cylinders permanently connected together by a manifold containing the minimum solvent content [therefore excluding the amount of the negative solvent operating range (see A.3)] plus the weights of the rigid frame and all other associated and permanently attached equipment

3.14.4
tare BS_{min}
⟨acetylene cylinder bundles⟩ sum of tare S of all cylinders permanently connected together by a manifold containing the minimum solvent content [therefore excluding the amount of the negative solvent operating range (see A.3)] plus the weights of the rigid frame and all other associated and permanently attached equipment

3.15
maximum gross weight
⟨acetylene cylinder bundles⟩ tare BA_{max} plus the maximum acetylene content of all bundle cylinders or tare BS_{max} plus the maximum acetylene charge of all bundle cylinders, respectively

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3.16
working pressure
⟨acetylene cylinders⟩ settled pressure at a uniform reference temperature of 15 °C in a cylinder containing the specified solvent content and the maximum acetylene content

NOTE It is equal to the working pressure which is stamped on the individual cylinder.

4 Basic requirements for acetylene cylinder bundles

4.1 General

Acetylene cylinders in accordance with ISO 3807 or an equivalent applicable regulation/standard may be filled simultaneously without dismantling the bundle, provided that the conditions of this standard are fulfilled.

Acetylene cylinders in a bundle shall have the same nominal dimensions, nominal water capacity, solvent and working pressure. Only one porous material shall be used (covered by one type approval).

This clause and Annex A apply to bundles which are filled while the cylinders are assembled in the bundle. Clause 7 applies to bundles of which the cylinders are individually filled and then assembled into a bundle.

4.2 Filling conditions

4.2.1 Maximum acetylene content

The maximum acetylene content for cylinders in a bundle is specified by the manufacturer and is lower than that of individual cylinders to allow for a solvent operating range.

NOTE Often the acetylene content in acetylene cylinder bundles is 90 % of that of its individual cylinders. However, other values for the maximum acetylene content of cylinders in a bundle can be used. As a result, different values for the maximum and minimum solvent content and the maximum number of consecutive fillings have to be applied (see 4.2.2, 4.2.3 and Annex A).

4.2.2 Solvent content

The maximum and minimum solvent content are a function of the amount of the reduced maximum acetylene content to be used in the bundle (see 4.2.1) and the filling conditions for the individual acetylene cylinder and shall be derived in accordance with Annex A.

NOTE The result of the calculations is used for initially fixing tare BA_{min} and tare BA_{max} (when tare A is used) or tare BS_{min} and tare BS_{max} (when tare S is used). These calculations do not have to be carried out for every filling of the bundle.

4.2.3 Maximum number of consecutive fillings

The maximum number of consecutive fillings before the bundle has to be dismantled and the cylinders have to be checked individually and replenished with solvent is a function of the solvent operating range and shall be derived in accordance with Annex A.

NOTE In practice, the number of times that a bundle with acetone as solvent may be filled without dismantling generally does not exceed 6 when derived in accordance with Annex A.

In the case of a bundle with DMF as solvent, the need to dismantle the bundle to replenish the solvent usually coincides with the periodic inspection of the cylinders for this bundle. The number of fills before the bundle is dismantled shall not exceed 100.

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5 Assembly, marking and documentation of acetylene cylinder bundles

5.1 Assembly

Before assembling or reassembling the cylinders in a bundle, the solvent in the individual cylinders shall be replenished to the maximum solvent content.

5.2 Verification of marking and necessary documentation

The revised tare based on the maximum solvent content for each individual cylinder used in a bundle shall be shown on the cylinder.

An identification plate shall be permanently affixed to the bundle frame. Before filling an acetylene cylinder bundle, the following information shall be made available:

a) Bundle filling data:

   1) the gas name (“acetylene, dissolved”), identification number (UN-number 1001) and the chemical formula;

   2) the maximum acetylene content of the bundle, in kilograms;

   3) the working pressure, as stamped on each cylinder;

   4) the type of solvent;

   5) the last inspection date (year and month) of that cylinder within the bundle which is first due for periodic inspection;

   6) tare BA_{min} and tare BA_{max} or tare BS_{min} and BS_{max}, in kilograms;

   7) date (year) of the next periodic inspection.

b) Other information:

   — the type approval number of the bundle, if appropriate;

   — the manufacturer of the bundle;

   — the name or identification of the owner;

   — a unique identification number of the bundle;

   — the maximum gross weight of the bundle, in kilograms.

c) In addition, the following information shall be available:

   — instructions for the handling of the bundle (including the information that cylinder valves should be closed in special circumstances only).

The following identification data shall be recorded and available for the bundle each time it is filled:

— the number of consecutive fillings since the last replenishment of solvent.

NOTE This might be not necessary for bundles with DMF if the maximum number of consecutive fillings is 100.

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5.3 Documentation

For every bundle, there shall be a dossier which contains details of the complete design and filling data (especially important for bundles with acetone in order to ensure that the maximum number of consecutive fillings is not exceeded, see 4.2.3) which shall be retained by the owner of the bundle.

6 Filling inspection for acetylene cylinder bundles

6.1 Pre-fill inspection

6.1.1 Verification of marking and necessary documentation

The information required in the following lists shall be made available to the filler, for example, by providing him with appropriate documentation and by training.

Before filling an acetylene cylinder bundle, it shall be identified that:

a) the cylinders in the bundle are permitted for filling in the country of the filling station;

b) the cylinders in the bundle have not exceeded their due date for periodic inspection;

c) the cylinders in the bundle do not have a current history of problems;

d) the marking is appropriate for acetylene.

Before filling an acetylene cylinder bundle, the following information shall be made available:

1) identification of the porous material;

2) type of solvent;

3) minimum and maximum solvent content;

4) bundle tare (with information whether tare BA or tare BS is used);

5) maximum gross weight and maximum acetylene content of the bundle (if tare BA is used) or maximum acetylene charge of the bundle (if tare BS is used).

6.1.2 Inspection

Acetylene cylinder bundles shall be inspected at time of filling to ensure that:

a) the bundle frame has no apparent serious defects;

b) the manifold has no apparent serious defects;

c) the restraining systems that prevent the cylinders from moving are secure and the cylinders have not moved while in service;

d) any lifting attachments and/or fork-lift slots are free from damage that can affect the integrity of the bundle;

e) the manifold and pipework are securely attached to the frame and are undamaged;

f) flexible hoses, where fitted, are free from damage;

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g) visible surfaces of the cylinders are free from any signs of damage that affect their integrity, including dents, cuts, gouges and fire damage;

h) the bundle does not show any signs of having been immersed in water or other liquids (e.g. cylinders covered in mud or seaweed) or any signs of tampering (e.g. loosened bolts, missing panels);

i) the main outlet valve is free from contamination and is undamaged;

j) the cylinder valves are all in the open position;

k) the cylinder valves, cylinder fittings and accessories have no apparent serious defects;

l) the cylinders, manifold, valves and fittings are suitable for filling and emptying.

Before filling, it shall be established that both the main valve, where fitted, and the connection are suitable and in a satisfactory condition, as follows:

1) the connection has an appropriate thread for acetylene and the working pressure;

2) the connection is free of contaminants;

3) the main valve(s) operate(s) correctly;

4) the outlet thread is undamaged;

5) the safety device, if present, is undamaged;

6) the valve operating mechanism is operable (hand wheel or key operated);

7) the bundle connection attached correctly to the filling connector.

6.2 Solvent content

For initially establishing the maximum and minimum solvent content, see 4.2.2 and Annex A.

Before filling an acetylene cylinder bundle with acetylene, its actual solvent content shall be determined by measuring the pressure, temperature and weight of the bundle in conjunction with the appropriate documentation. Calibrated weighing scales, manometers and other instruments that have a working range and measuring accuracy appropriate for the bundle to be filled shall be used.

Acetylene cylinders take time to reach temperature equilibrium. Special care should be taken if the temperature of the cylinders is very low and/or the pressure is very high or if the bundle has been exposed to a significant environmental temperature change in the preceding 3 h.

Since the determination of the solvent content is not accurate for acetylene cylinder bundles that contain high amounts of residual gas, bundles should be emptied until a low amount of residual gas has been reached. Typically, this would amount to a pressure of less than 7 bar for bundles with a working pressure of 17 bar or higher, and to less than 4 bar for bundles with a working pressure below 17 bar.

Emptying of the bundle should be carried out slowly; a typical rate would be 1/8 of the maximum acetylene content per hour. The determination of the solvent content should not be done immediately after emptying as the cylinders will cool down considerably during emptying and will need time to reach temperature equilibrium again.

Calculation of the solvent content in the bundle shall be done in accordance with Annex B.

NOTE The result of these calculations normally is made available to the filler, e.g. in the form of a table or a chart indicating the residual acetylene content.

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If the weight of the acetylene cylinder bundle after deduction of the residual gas is below tare BS_{min} or tare BA_{min} (depending on which bundle tare the calculation is based), i.e. the solvent loss is greater than the solvent operating range, the bundle shall not be refilled with acetylene. It shall be dismantled and each individual acetylene cylinder shall be refilled with solvent to the maximum value specified for the bundle cylinder.

If the weight of the acetylene cylinder bundle after deduction of the residual gas exceeds the appropriate tare B_{max} marked on the bundle, the bundle shall be examined and the reason for the excess weight shall be determined before further handling.

6.3 Number of consecutive fillings

When the maximum number of consecutive fillings, as derived in accordance with 4.2.3, has been reached, the bundle shall not be refilled with acetylene. It shall be dismantled and each individual acetylene cylinder shall be replenished with solvent to the maximum solvent content.

6.4 Inspection during filling

It shall be verified that all cylinder valves are in the open position so that the acetylene is distributed equally to all cylinders.

All connections in the bundle shall be checked for leakage during filling.

If cylinders are cooled during filling, care shall be taken that all cylinders are cooled at approximately the same rate.

6.5 Post-fill inspection

6.5.1 Verification of tightness

After the bundle has been filled, the filler shall ensure that

— the main valve is not leaking,

— there are no other apparent leaks in the bundle.

6.5.2 Weight and pressure checks

After the bundle has been filled, it shall be verified that the maximum acetylene content of the bundle has not been exceeded. Provided that the correct amount of solvent is present, this can be achieved, for example, by checking that the actual weight does not exceed the maximum gross weight. The result shall be recorded and retained until the next replenishment of solvent.

Sufficient time shall be allowed to reach pressure equilibrium before closing the cylinder valves (only applicable if there is no main valve) or shipping.

NOTE There is no need to check that the pressure of the bundle corresponds to the working pressure under the following conditions:

— the maximum gross weight of the bundle is not exceeded; and

— the solvent content has been verified as being correct in accordance with 6.2.

However, there might be reasons to carry out a pressure check (e.g. because the bundle is difficult to fill).

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If the pressure is too high at ambient temperature and the maximum gross weight is not exceeded, it is indicative of the following possible conditions:

— deficiency of solvent;

— the solvent has become contaminated, e.g. by water;

— high concentration of other gases in the acetylene which are not soluble in the solvent used.

Conversely, too low a pressure at ambient temperature is indicative of an excessive solvent content.

7 Individual filling of acetylene bundle cylinders

Cylinders within the bundle may be filled as individual cylinders.

In this case, the acetylene cylinder bundle shall be dismantled before each filling and the acetylene cylinders shall be handled and filled as individual cylinders in accordance with ISO 11372. The maximum acetylene content of the individual cylinders does not have to be decreased.

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Annex A
(normative)

Procedure for establishing the filling conditions of acetylene cylinder bundles

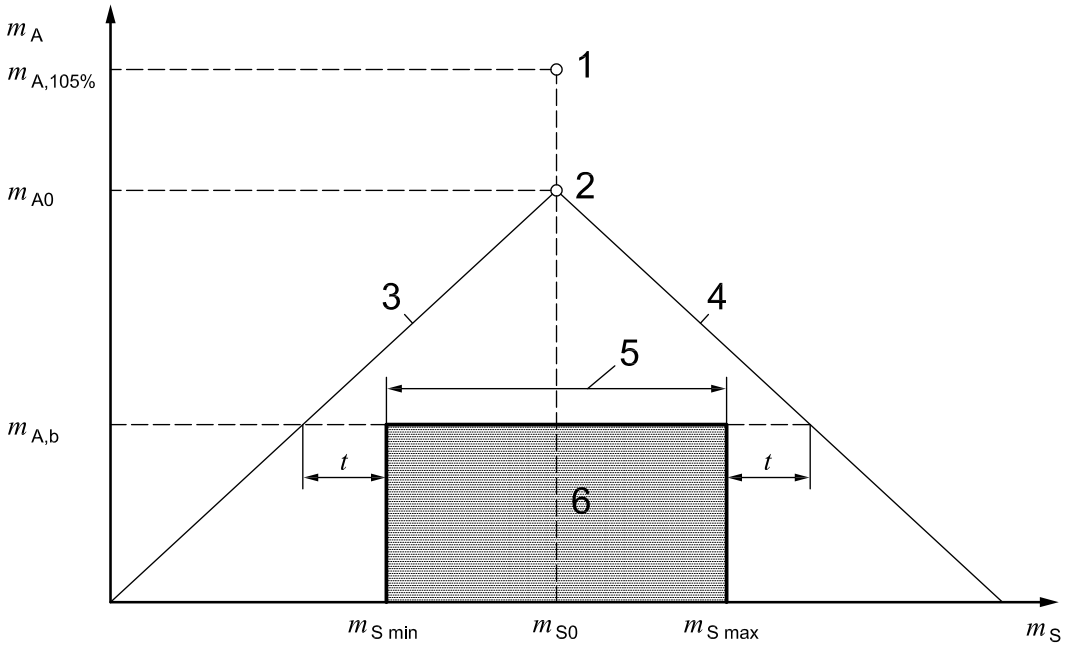
A.1 General

A.1.1 Application

This annex applies to bundles which are filled while the cylinders are assembled in the bundle.

A.1.2 Safe operating diagram

In the “Safe operating diagram”, it can be seen how the maximum and minimum solvent content and the solvent operating range are derived depending on the maximum acetylene content (specified by the manufacturer). A typical diagram is shown in Figure A.1.



Key

1	filling conditions for type testing of an individual cylinder	4	constant-volume line
2	filling conditions of individual cylinder	5	solvent operating range
3	backfire line	6	bundle filling conditions

m_S	solvent content (x-axis) in kg
m_A	acetylene content (y-axis) in kg
$m_{A,105\ \%}$	acetylene content in the cylinder for type testing in kg
m_{A0}	maximum acetylene content of individual cylinder (as defined in ISO 11372) in kg
$m_{A,b}$	maximum acetylene content of bundle cylinders in kg
m_{S0}	specified solvent content of individual cylinder (as defined in ISO 11372) in kg
$m_{S\,min}$	minimum solvent content of bundle cylinders in kg
$m_{S\,max}$	maximum solvent content of bundle cylinders in kg
t	safety solvent allowance (see A.2)

Figure A.1 — Example of safe operating diagram

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A.1.3 Backfire line

The “backfire line” in Figure A.1 is assumed to be straight (constant acetylene-to-solvent ratio) and starts at the origin (no acetylene and no solvent) and extends to the filling conditions of an individual cylinder that have been established to be safe by means of the elevated temperature test and the backfire test and also are approved by the relevant authority.

NOTE For the elevated temperature test and the backfire test, the test cylinders contain 5 % more acetylene.

The backfire line is given by:

$$m_{\mathrm{A}} = \frac{m_{\mathrm{A0}}}{m_{\mathrm{S0}}} \cdot m_{\mathrm{S}} \tag{A.1}$$

Filling conditions with the same acetylene-to-solvent ratio as approved for the individual cylinder are represented by the backfire line. Therefore, filling conditions on and below this line must also be considered as safe.

A.1.4 Constant-volume line

The “constant-volume line” in Figure A.1 represents the points where, at a specified temperature, the volume of the acetylene/solvent solution is a constant.

The volume V, in litres, of an acetylene/solvent solution at a given temperature is given by:

$$V = a_4 \cdot m_{\mathrm{A}} + a_5 \cdot m_{\mathrm{S}} \tag{A.2}$$

where a_4 and a_5 are constants with values as given in Table A.1.

The volume V_0, in litres, as given by the filling conditions for the individual cylinder, is known to be safe as it passes the elevated temperature test. It is given by:

$$V_0 = a_4 \cdot m_{\mathrm{A0}} + a_5 \cdot m_{\mathrm{S0}} \tag{A.3}$$

The volume V of an acetylene/solvent solution in an acetylene cylinder shall not exceed V_0. Filling conditions with the same volume but a lower acetylene-to-solvent ratio are given by the constant-volume line. This line is obtained by equating Equations (A.2) and (A.3) and then solving for m_{A}.

$$m_{\mathrm{A}} = \frac{a_4 \cdot m_{\mathrm{A0}} + a_5 \cdot m_{\mathrm{S0}} - a_5 \cdot m_{\mathrm{S}}}{a_4} \tag{A.4}$$

$$= m_{\mathrm{A0}} + \frac{a_5}{a_4} \cdot m_{\mathrm{S0}} - \frac{a_5}{a_4} \cdot m_S \tag{A.5}$$

$$= m_{\mathrm{A0}} + \frac{a_5}{a_4} \cdot (m_{\mathrm{S0}} - m_{\mathrm{S}}) \tag{A.6}$$

Filling conditions on the constant-volume line have the same volume but a lower acetylene-to-solvent ratio than the permissible filling conditions for individual cylinders. Therefore, filling conditions on and below this line must also be considered safe.

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The constants a_4 and a_5 have been determined experimentally for a temperature of 15 °C and the values given in Table A.1 shall be used:

Table A.1 — Values for a_4 and a_5

	Acetone	DMF
a_4 in l/kg	1,91	1,75
a_5 in l/kg	1,25	1,05
a_4/a_5	1,53	1,67

It follows that, although the filling conditions for the individual cylinder with m_{A0} and m_{S0} are the optimum operating point, any complementary ratio which lies beneath the backfire line and the constant-volume line is safe and may be used. It is this principle which permits cylinders to be filled safely in a bundle without dismantling for a certain number of consecutive fillings.

A.2 Acetylene and solvent limitations within the bundle

First, the maximum acetylene content for the bundle cylinders has to be specified. It is normally reduced to 90 % of the maximum acetylene content of the individual cylinder as defined in ISO 11372 (see 4.2.1).

The maximum and minimum solvent content and the maximum number of consecutive fillings are derived to be a function of the maximum acetylene content for the bundle cylinder based on considerations regarding the average solvent loss and the safety solvent allowance.

When cylinders are used in bundles, the acetylene content in each cylinder shall be reduced to permit an increase of the solvent operating range. There are two reasons for this.

a) Solvent loss

Each time a cylinder is emptied, a small amount of solvent is entrained with the acetylene and is lost.

L is the average loss of solvent during each cycle, in kilograms per litre, (related to the cylinder water capacity). In general, the quantities may be taken as:

Acetone loss: $L = 0{,}007\ 50$ kg/l (related to the cylinder water capacity);

DMF loss: $L = 0{,}000\ 25$ kg/l (related to the cylinder water capacity).

b) Safety solvent allowance

An allowance shall be made for the different operating characteristics of each cylinder in the bundle, the temperature, absorption rate, flow distribution of the gas in the bundle manifold, etc. This is known as the safety solvent allowance t.

The values may be taken as:

For acetone: $t = 0{,}010$ kg/l (related to the cylinder water capacity);

For DMF: $t = 0{,}025$ kg/l (related to the cylinder water capacity).

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A.3 Solvent content and maximum number of consecutive fillings

A.3.1 Calculation of the solvent content

Using the safety solvent allowance t given in A.2, the maximum solvent content $m_{S\ max}$ and the minimum solvent content $m_{S\ min}$ can be calculated for a specified acetylene content $m_{A,b}$ as follows:

$$m_{S\ min} = m_{A,b} \cdot \frac{m_{S0}}{m_{A0}} + t \tag{A.7}$$

$$m_{S\ max} = \left(m_{A0} - m_{A,b} + \frac{a_5}{a_4} \cdot m_{S0} \right) \cdot \frac{a_4}{a_5} - t \tag{A.8}$$

The additional quantity of solvent ($m_{S\ max} - m_{S0}$), which increases the tare of the acetylene cylinder, is called the revised tare and is shown on the cylinder by the addition of a plastic or metal ring or label or other suitable means. This tare shall include any changes to the individual tare, which might have resulted from the removal or addition of the various fixed components (caps or guards, etc.). For this purpose, the original cylinder stamp marking shall not be changed.

A.3.2 Calculation of the maximum 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 operating range. Using the average loss of solvent per cycle L as given in A.2, the maximum number of consecutive fillings N is calculated as follows:

$$N \leq \frac{m_{S\ max} - m_{S\ min}}{L} + 1 \tag{A.9}$$

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Annex B
(normative)

Determination of the solvent content in the bundle in the course of the filling inspection

The determination of the actual average solvent content in the bundle returned for filling with either acetone or DMF as the solvent is achieved by measuring the pressure, temperature and weight of the bundle and carrying out a subsequent calculation as described below. The result of the calculation normally is made available to the filler, e.g. in the form of a table or a chart indicating the residual acetylene content.

Measurement of the bundle weight alone will only give the sum of the weights of the solvent and acetylene in the bundle but does not indicate the shortfall or excess of its solvent and acetylene content.

The average actual acetylene-to-solvent ratio in the bundle cylinders shall be determined using the following equation:

$$F = \frac{m_A}{m_S} = \frac{10^{f(p,T)}}{1 - 10^{f(p,T)}} \tag{B.1}$$

where

F is the actual acetylene-to-solvent ratio;

m_A is the average residual acetylene content in the bundle cylinders, in kilograms;

m_S is the average actual solvent content in the bundle cylinders, in kilograms;

$f(p,T)$ is a factor dependent upon pressure, temperature and solvent.

Since the solubility of acetylene in acetone and DMF is different, there are two different equations for the calculation of $f(p,T)$.

For acetone, $f(p,T)$ is determined by the following equation:

$$f(p,T) = \frac{\log_{10}(p + 1{,}013) - 4{,}194\,5 + \dfrac{712{,}88}{T + 273{,}15}}{0{,}456\,9 + \dfrac{207{,}8}{T + 273{,}15}} \tag{B.2}$$

For DMF, $f(p,T)$ is determined by the following equation:

$$f(p,T) = \frac{\log_{10}(p + 1{,}013) - 3{,}630 + \dfrac{504{,}36}{T + 273{,}15}}{-0{,}982\,6 + \dfrac{695{,}8}{T + 273{,}15}} \tag{B.3}$$

where

p is the actual pressure in the bundle, in bar;

T is the temperature of the bundle cylinder, in degrees Celsius.

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Based on the calculated actual acetylene-to-solvent ratio F in the bundle [see Equation (B.1)], the average solvent content actually contained in the bundle cylinders is calculated as follows:

— Equation to be used for bundles for which tare BS is used:

$$m_S = \frac{m_b - \text{tareBS}_{max} + n \cdot m_{S\,max} + n \cdot m_{A,saturation}}{n \cdot (1+F)} \quad \text{(B.4)}$$

— Equation to be used for bundles for which tare BA is used:

$$m_S = \frac{m_b - \text{tareBA}_{max} + n \cdot m_{S\,max}}{n \cdot (1+F)} \quad \text{(B.5)}$$

where

m_b is the actual weight of the bundle, in kilograms;

tareBA_{max}, tareBS_{max} is the bundle tare as marked on the bundle, in kilograms;

$m_{S\,max}$ is the maximum solvent content in the bundle cylinders, in kilograms;

m_S is the average actual solvent content in the bundle cylinders, in kilograms;

m_A is the average residual acetylene content in the bundle cylinders, in kilograms;

$m_{A,saturation}$ is the saturation acetylene in the bundle cylinders, in kilograms;

n is the number of cylinders in the bundle.

NOTE Equations (B.4) and (B.5) are derived as follows.

The actual weight of the bundle as measured before filling can be expressed as follows (depending on whether tare BS or tare BA is used):

$$m_b = \text{tareBS}_{max} - n \cdot m_{A,saturation} - n \cdot m_{S\,max} + n \cdot m_S + n \cdot m_A \quad \text{(B.6)}$$

$$m_b = \text{tareBA}_{max} - n \cdot m_{S\,max} + n \cdot m_S + n \cdot m_A \quad \text{(B.7)}$$

Considering the actual acetylene-to-solvent ratio F in the bundle, as calculated according to Equation (B.1) and solving for m_S, leads to Equations (B.4) and (B.5) for calculating the actual solvent content contained in the bundle.

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