

Transportable gas cylinders — Refillable welded steel gas cylinders — Design and construction —

Part 2: Stainless steel

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National foreword

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Foreword

This document (EN 13322-2:2003) has been prepared by Technical Committee CEN/TC 23 "Transportable gas cylinders", the secretariat of which is held by BSI.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by September 2003, and conflicting national standards shall be withdrawn at the latest by September 2003.

This European Standard has been submitted for reference into the RID and/or in the technical annexes of the ADR. Therefore in this context the standards listed in the normative references and covering basic requirements of the RID/ADR not addressed within the present standard are normative only when the standards themselves are referred to in the RID and/or in the technical annexes of the ADR.

For relationships with EC directives, RID and ADR see informative annex D, which is an integral part of this document.

This standard is one of a series of two standards concerning refillable welded steel gas cylinders of water capacities from 0,5 l up to and including 150 l for compressed, liquefied and dissolved gases:

Part 1: Carbon steel

Part 2: Stainless steel

Annexes A and B are normative. Annexes C and D are informative.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Portugal, Slovak Republic, Spain, Sweden, Switzerland and the United Kingdom.

Foreword to amendment A1

This document (EN 13322-2:2003/A1:2006) has been prepared by Technical Committee CEN/TC23 "Transportable gas cylinders", the secretariat of which is held by BSI.

This Amendment to the European Standard EN 13322-2:2003 shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by January 2007, and conflicting national standards shall be withdrawn at the latest by January 2007.

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Introduction

The purpose of this European Standard is to provide a specification for the design, manufacture, and testing of refillable, transportable, welded stainless steel gas cylinders.

The specifications given are based on knowledge of, and experience with, materials, design requirements, manufacturing processes and control during manufacture, of cylinders in common use in the countries of the CEN members.

This standard is based on the traditional calculation method. It does not cover other methods such as finite element analysis (F.E.A.) methods or experimental methods.

1 Scope

This European Standard specifies minimum requirements concerning material, design, construction and workmanship, manufacturing processes and testing of refillable transportable welded stainless steel gas cylinders of water capacities from 0,5 l up to and including 150 l for compressed, liquefied and dissolved gases. This standard is only applicable to cylinders manufactured from stainless steels having a maximum tensile strength of less than 1 100 MPa.

For acetylene service, additional requirements for the cylinder and the basic requirements for the porous mass are given in EN 1800.

This standard is primarily for industrial gases other than LPG but may also be applied for LPG.

2 Normative references

This European Standard incorporates, by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text, and publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

EN 287-1, *Approval testing of welders - Fusion welding - Part 1: Steels.*

EN 288-1, *Specification and qualification of welding procedures for metallic materials - Part 1: General rules for fusion welding.*

EN 288-3, *Specification and approval of welding procedures for metallic materials - Part 3: Welding procedure tests for the arc welding of steels.*

EN 473, *Non destructive testing - Qualification and certification of NDT personnel - General principles.*

EN 962, *Transportable gas cylinders - Valve protection caps and valve guards for industrial and medical gas cylinders - Design, construction and tests.*

EN 970, *Non-destructive examination of fusion welds - Visual examination.*

EN 1089-1, *Transportable gas cylinders - Gas cylinder identification (excluding LPG) - Part 1: Stampmarking.*

EN 1435, *Non-destructive examination of welds - Radiographic examination of welded joints.*

EN 1800, *Transportable gas cylinders - Acetylene cylinders - Basic requirements and definitions.*

EN 1968, *Transportable gas cylinders - Periodic inspection and testing of seamless steel gas cylinders.*

EN 10002-1, *Metallic materials - Tensile testing - Part 1: Method of test at ambient temperature.*

EN 10028-7, *Flat products made of steels for pressure purposes - Part 7: Stainless steels.*

EN 10045-1, *Metallic materials - Charpy impact test - Part 1: Test method.*

EN 10088-1, *Stainless steels - Part 1: List of stainless steels.*

EN 10088-2, *Stainless steels - Part 2: Technical delivery conditions for sheet/plate and strip for general purposes.*

EN 12517, *Non-destructive examination of welds - Radiographic examination of welded joints - Acceptance levels.*

EN 13445-2, *Unfired pressure vessels - Part 2: Materials*.

EN 25817, *Arc-welded joints in steel - Guidance on quality levels for imperfections (ISO 5817:1992)*.

EN ISO 3651-2, *Determination of resistance to intergranular corrosion of stainless steels - Part 2: Ferritic, austenitic and ferritic-austenitic (duplex) stainless steels - Corrosion test in media containing sulfuric acid (ISO 3651-2:1998)*.

EN ISO 6506-1, *Metallic materials - Brinell hardness test - Part 1: Test method (ISO 6506-1:1999)*.

EN ISO 11114-1, *Transportable gas cylinders - Compatibility of cylinder and valve materials with gas contents - Part 1: Metallic materials (ISO 11114-1:1997)*.

3 Terms, definitions and symbols

For the purpose of this standard, the following terms, definitions and symbols apply:

3.1 Terms and definitions

3.1.1

yield stress

value corresponding to the 0,2 % proof stress ($R_{p0,2}$), or, for austenitic steels in the solution annealed condition, 1 % proof stress ($R_{p1,0}$)

3.1.2

solution annealing

softening heat treatment for austenitic steels in which a cylinder is heated to a uniform temperature above the upper critical point (AC_3 , as defined in EN 10052) of the steel followed by rapid cooling

3.1.3

cryoforming

process where the cylinder is subjected to a controlled low temperature deformation treatment that results in a permanent increase in strength

3.1.4

cold working

plastic deformation treatment given to sheet material at ambient temperature, with the aim of permanently increasing the material strength

3.1.5

coldforming

final deformation treatment at ambient temperature given to the prefabricated cylinder, known as the preform, which results in a permanent increase in the material strength

3.1.6

batch

quantity of finished cylinders made consecutively during the same or consecutive days to the same design, size and material specifications and from the same material supplier for each pressure containing part on the same automatic welding machines and, if applicable, heat-treated under the same conditions of temperature and duration

NOTE This definition allows different suppliers to be used for the different pressure containing parts within a batch, e.g. one supplier for heads, another for bases.

3.1.7

design stress factor (F)

ratio of equivalent wall stress at test pressure (p_h) to guaranteed minimum yield stress (R_e)

3.2 Symbols

a	Calculated minimum thickness, in millimetres, of the cylindrical shell
a'	Guaranteed minimum thickness, in millimetres, of the cylindrical shell (including any corrosion allowance, see 7.1)
a_1	Calculated value of a used in the calculation of b (see 5.3.2)
a_m	Mean wall thickness, in millimetres, of the cylindrical shell of the cylinder preform
A	Percentage elongation after fracture
b	Calculated minimum thickness, in millimetres, of the cylinder end
b'	Guaranteed minimum thickness, in millimetres, of the cylinder end (including corrosion allowance, see 7.1)
C	Shape factor of dished ends
D	Outside diameter, in millimetres, of the cylinder (see Figure 1)
D_f	Diameter of former in millimetres (see Figure 10),
D_m	Mean diameter of the cylindrical shell of a cylinder preform, in millimetres
F	Design stress factor (see 3.1.7)
f_c	Cryoforming factor established by the manufacturer for each batch of cylinders
h	Height, in millimetres, of the cylindrical part of the end (see Figure 1)
H	Outside height, in millimetres, of the domed part of the end (see Figure 1)
J	Stress reduction factor (see annex A)
L	Length, in millimetres, of the cylinder
n	Ratio of diameter of bend test former (D_f) to the thickness of the test piece (t)
p_b	Measured burst pressure, in bar ¹ , above atmospheric pressure, in the burst test
p_c	Cryoforming or coldforming pressure in bar ¹ , above atmospheric pressure
p_h	Hydraulic test pressure, in bar ¹ , above atmospheric pressure
p_y	Observed yield pressure, in bar ¹ , above atmospheric pressure
r	Inside radius of the knuckle end, in millimetres (see Figure 1)
R	Inside radius of the dished end, in millimetres (see Figure 1)
R_e	Yield stress, in megapascals, as defined in 3.1.1 and used for design calculation
R_{ea}	Value of the actual yield stress in megapascals determined by the tensile test

¹ 1 bar = 10⁵ Pa = 0,1 MPa

- $R_{p0,2}$ Minimum value of 0,2 % proof stress in megapascals, guaranteed by the cylinder manufacturer for the finished cylinder, in accordance with EN 10002-1. (See Note)
- $R_{p1,0}$ Minimum value of 1,0 % proof stress in megapascals, guaranteed by the cylinder manufacturer for the finished cylinder, in accordance with EN 10002-1. (See Note)
- R_g Minimum value of tensile strength, in megapascals, guaranteed by the cylinder manufacturer for the finished cylinder
- R_m Actual value of tensile strength, in megapascals, determined by tensile test (see 8.4)
- t Actual thickness of the test specimen, in millimetres (see Figure 7)

NOTE For cryoformed and coldformed cylinders the minimum value guaranteed by the manufacturer refers only to the cylindrical part of the finished cylinder.

4 Materials and heat treatment

4.1 General

4.1.1 Materials of shells and end pressings shall be stainless steels in a condition suitable for pressing or drawing and welding and shall conform to EN 10088-1 or EN 10028-7.

4.1.2 Grades of steel used for the cylinder manufacture shall be compatible with the intended gas service (e.g. corrosive gases, embrittling gases) in accordance with EN ISO 11114-1.

4.1.3 There is a risk of sensitisation to intergranular corrosion resulting from the hot processing of austenitic and duplex stainless steels. An intergranular corrosion test in accordance with 7.3.3 shall be carried out on such stainless steels when intended to be used for corrosive applications. Corrosive gases are listed in EN 1968, and cylinders for such gases shall be stamp marked "HG" as specified in EN 1089-1.

4.1.4 The manufacturer shall be able to guarantee cylinder steel casting traceability for each cylinder.

4.1.5 All parts welded to the cylinder shall be made of compatible material with respect to the weldability.

4.1.6 The cylinder manufacturer shall obtain and provide certificates of the ladle analysis of the steel supplied for the construction of the pressure retaining parts of the cylinder and for the welding consumables.

4.1.7 Some grades of stainless steel may be susceptible to environmental stress corrosion cracking. Special precautions shall be taken in such cases.

4.1.8 The welding consumables shall be such that they are capable of giving consistent welds with minimum tensile strengths at least equal to that specified for the parent materials (R_g) in the finished cylinder.

4.1.9 Cylinders for acetylene service shall be manufactured with materials compatible with the manufacturing process of the porous mass, or an internal coating shall be applied.

4.2 Categories

The following four broad categories of stainless steels are recognised:

- $\frac{3}{4}$ ferritic;
- $\frac{3}{4}$ martensitic;
- $\frac{3}{4}$ austenitic;
- $\frac{3}{4}$ ferritic/austenitic (duplex).

The steels used shall be in accordance with EN 10088-1 or EN 10028-7.

4.3 Heat treatment

4.3.1 For cylinders subjected to coldforming or cryoforming processes, heat treatment of the pre-form component part is not required. Cold-formed or cryoformed cylinders shall not be subjected to any subsequent heat treatment or to additional heat application, such as welding.

4.3.2 For other types of stainless steel cylinders, components used for the manufacture of pressure retaining parts of the cylinders shall be annealed for martensitic and ferritic steels, or solution annealed for austenitic and duplex steels.

4.3.3 The cylinder manufacturer shall obtain and provide certificates for the heat treatment of all pressure retaining parts used for the construction of the gas cylinders.

4.4 Test requirements

The material of the finished cylinders shall satisfy the requirements of clause 7.

5 Design

5.1 General requirements

5.1.1 The calculation of the wall thickness of the pressure containing parts shall be related to the yield stress of the parent material.

5.1.2 For calculation purposes, the value of the yield stress R_e is limited to a maximum of $0,85 R_g$.

5.1.3 The internal pressure upon which the calculation of gas cylinders is based shall be the test pressure p_h .

5.1.4 A fully dimensioned drawing including the specification of the material shall be produced.

5.1.5 Cylinders for acetylene service shall be designed to allow for a test pressure of at least 60 bar.

5.1.6 Cylinders for acetylene service shall be designed and manufactured to ensure that conditions are safe for the eventual filling of the porous mass, e.g. preventing sharp edges and voids.

5.2 Calculation of cylindrical wall thickness

The wall thickness of the cylindrical shell shall not be less than that calculated using the formula:

$$a = \frac{D}{2} \sqrt{\frac{10 \cdot F \cdot J \cdot R_e \cdot \sqrt{3} \cdot p_h}{10 \cdot F \cdot J \cdot R_e}}$$

where the value of F is the lesser of $\frac{0,65}{(R_e / R_g)}$ or $0,77$.

R_e/R_g shall not exceed $0,85$.

The value of J shall be selected in accordance with annex A.

The minimum wall thickness shall also satisfy the requirements of 5.4.

5.3 Design of convex ends (see Figure 1)

5.3.1 The shape of ends of gas cylinders shall be such that the following conditions are fulfilled:

$\frac{3}{4}$ for torispherical ends (see Figure 1a): $R \leq D$; $r \geq 0,1 D$; $h \geq 4 b$ (see Figure 1a)

$\frac{3}{4}$ for ellipsoidal ends (see Figure 1b): $H \geq 0,192 D$; $h \geq 4 b$ (see Figure 1b)

5.3.2 The wall thickness of the ends of gas cylinders shall be not less than that calculated using the formula:

$$b = a_1 C$$

where

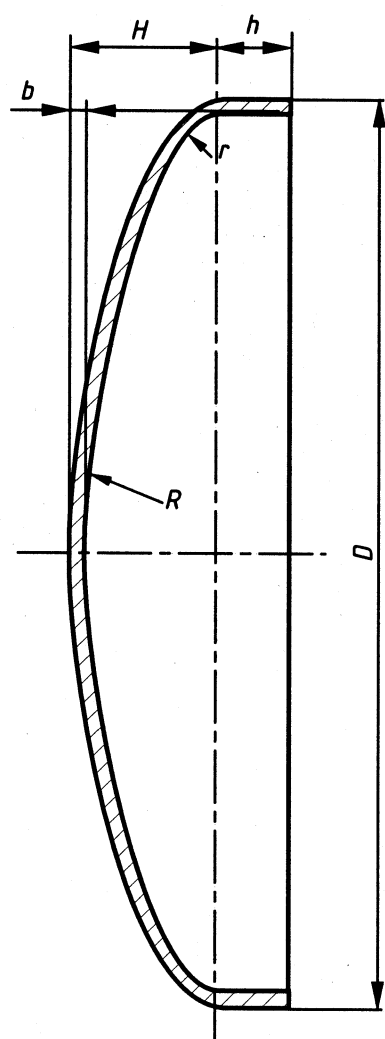
a_1 is the value of a calculated in accordance with 5.2 using $J = 1,0$;

C is a shape factor, whose value shall be obtained from the graph given in Figure 2 or Figure 3.

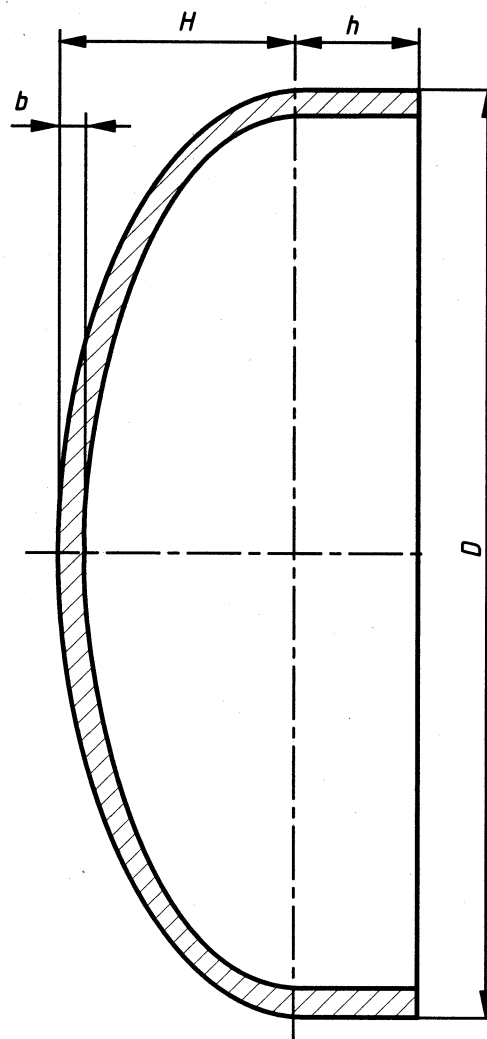
5.3.3 For cryoformed cylinders, convex ends shall be hemispherically shaped. The shape factor C shall be equal to 1.

The minimum 1,0 % proof stress to be achieved in the hemispherical ends shall be equal to:

$$R_p = R_{p0,1} (a_b \quad 2b_b)$$



a) Torispherical



b) Ellipsoidal

Figure 1 — Illustration of cylinder ends

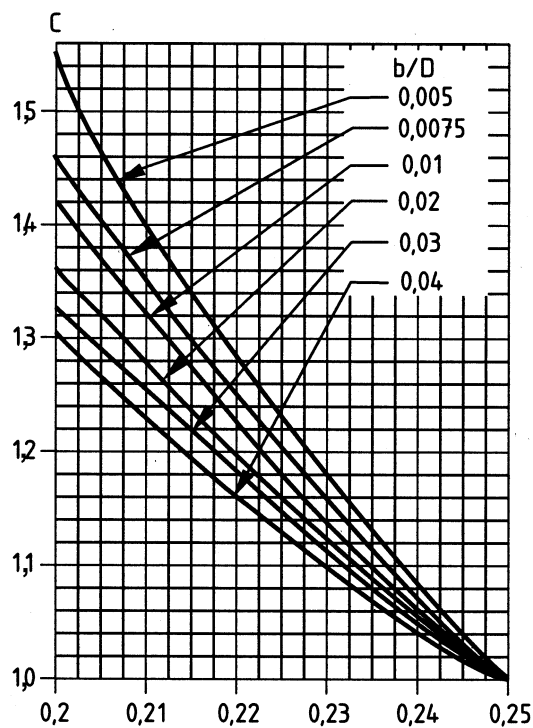


Figure 2 — Values of shape factor C for H/D between 0,2 and 0,25

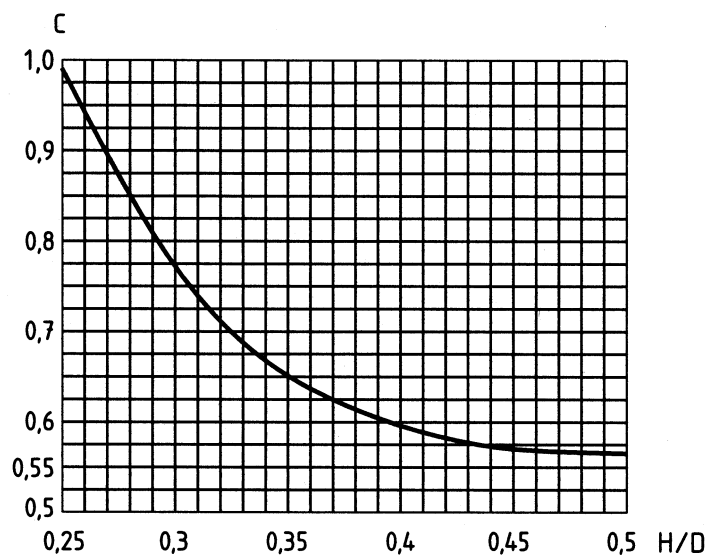


Figure 3 — Values of shape factor C for H/D between 0,25 and 0,5

5.4 Minimum wall thickness

5.4.1 The minimum wall thickness of the cylindrical shell *a* and of the end *b* shall be not less than the value derived from the appropriate one of the following formulae:

for $D \leq 100$ mm, $a = b = 1,1$ mm;

for $100 \text{ mm} < D \leq 150$ mm, $a = b = 1,1 + 0,008 (D-100)$ mm;

for $D > 150$ mm,

$$a = b = \frac{D}{250} + 0,7 \text{ mm, with an absolute minimum of } 1,5 \text{ mm.}$$

These formulae apply to cylindrical shells and ends irrespective of whether they are designed by calculation under 5.2 and 5.3 or by the pressure cycling test in 7.3.2.

5.4.2 Apart from the requirements of 5.3, 5.4 and 5.5 any cylindrical part integral with an end shall, except as qualified by 5.4.3, also satisfy the requirements given in 5.2 for the cylindrical shell.

5.4.3 Where the length of the cylindrical portion of the gas cylinder, measured between the beginning of the domed parts of the two ends, is not more than $\sqrt{2bD}$ the wall thickness shall be not less than that of the domed part (see 5.3.2).

5.5 Ends of other shapes

Ends of shapes other than those covered by 5.3 may be used provided that the adequacy of their design is demonstrated by a pressure cycling test in accordance with 7.3.2 or by stress analysis.

5.6 Design of openings

5.6.1 The location of all openings shall be restricted to the end(s) of cylinder.

5.6.2 Each opening in the cylinder shall be reinforced, either by a valve boss or pad, of weldable and compatible steel, securely attached by welding and so designed as to be of adequate strength and to result in no harmful stress concentrations. This shall be confirmed by design calculations or a pressure cycling test in accordance with 7.3.2.

5.6.3 The welds of the openings shall be separated from longitudinal and circumferential joints by a distance not less than $3a$.

6 Construction and workmanship

6.1 General

The cylinder or cylinder preform shall be produced either by:

- $\frac{3}{4}$ using seamless or longitudinally welded tube with forged ends being circumferentially welded; or
- $\frac{3}{4}$ using longitudinally welded tube with spun ends; or
- $\frac{3}{4}$ using a seamless tube, followed by hot forming where the base is sealed with added weld metal; or
- $\frac{3}{4}$ using coldworked tube or plate; or
- $\frac{3}{4}$ using welded deep drawn parts; or
- $\frac{3}{4}$ using coldforming or cryoforming of welded cylinder pre-forms.

6.2 Welding procedures

Each manufacturer, before proceeding with the production of a given design of cylinder, shall qualify all welding procedures to EN 288-1 and EN 288-3 and welders to EN 287-1. Records of such qualification shall be kept on file by the manufacturer.

6.3 Cryoforming procedure

6.3.1 Cryoforming as defined in 3.1.3 is a method to increase the mechanical properties especially of metastable austenitic steels by applying a high internal pressure to the vessel preform at cryogenic temperatures.

The relevant process parameters are the cryoforming pressure p_c and the cryoforming temperature.

The design of the finished cylinder shall be in accordance with clause 5.

6.3.2 The cryoforming operation shall be carried out at a cryoforming pressure p_c , which shall be calculated according to:

$$p_c = \frac{f_c R_{p1,0} 20 a_m}{D_m}$$

f_c depends on the cryoforming temperature, the cast analysis for each batch of cylinders and the yield strength to be achieved and shall be established by the manufacturer so that the finished cylinders satisfy the requirements as specified in clauses 5 and 7. Between batches of one design of cylinder (as defined in 7.3.1), f_c shall not vary by more than $\pm 10\%$.

6.3.3 For each cryoformed cylinder, the manufacturer shall record a pressure-time diagram of the cryoforming process where the rate of pressure increase, the achieved cryoform pressure and the holding time are shown. The rate of pressure increase shall not be more and the holding time shall not be less than that established during the design testing for the cylinder.

6.3.4 The maximum permanent deformation of the vessel's perimeter due to the cryoforming shall be no more than 15 %.

6.3.5 The cryoforming temperature shall remain constant during the process (e.g. by submerging the cylinder preform in a suitable cryogenic liquid), and shall be established during the design test.

6.4 Welded joints of pressure containing parts

6.4.1 The longitudinal joint, of which there shall be not more than one, shall be butt-welded.

6.4.2 Circumferential joints of which there shall be no more than two in the cylindrical part, shall be butt-welded in all cases for cryoformed cylinders and for all cylinders used in corrosive gas applications.

6.4.3 For acetylene service, the joints shall be designed in such a way as to eliminate the risk of damaging the porous mass.

6.5 Non-pressure-containing attachments

6.5.1 Parts which are not submitted to pressure, such as footings, handles and neckrings shall be made of steel compatible with that of the cylinder.

6.5.2 Each attachment shall be designed to permit inspection of the attachment welds, shall be clear of longitudinal and circumferential joints, and so designed as to avoid trapping water.

6.5.3 A footing or other support shall be fitted to the cylinder when required to provide stability, and attached so as to permit inspection of the bottom circumferential weld. Permanently attached footings shall be drained and the space enclosed by the footing shall be ventilated.