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Refillable welded steel gas cylinders

Bouteilles à gaz soudées en acier destinées à être rechargées

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Foreword

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Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 4706 was prepared by Technical Committee ISO/TC 58, *Gas cylinders.*

Users should note that all International Standards undergo revision from time to time and that any reference made herein to any other International Standard implies its latest edition, unless otherwise stated.

International Organization for Standardization
Case postale 56 • CH-1211 Genève 20 • Switzerland
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Refillable welded steel gas cylinders

0 Introduction

The purpose of this International Standard is to facilitate agreement on the design and manufacture of welded steel gas cylinders in all countries. The specifications given are based on knowledge of, and experience with, materials, design requirements, manufacturing processes and control at manufacture of cylinders in common use in the countries of the ISO member bodies.

With respect to those aspects concerning construction materials, approval of design rules and inspection during manufacture which are subject to national or international regulations, it is necessary for interested parties to ensure that, in the practical application of this International Standard, the requirements of the relevant authority are also satisfied.

1 Scope and field of application

This International Standard gives minimum requirements for certain aspects concerning material, design, construction and workmanship, procedure and test at manufacture of refillable welded steel gas cylinders of a test pressure not greater than 75 bar[1], and of water capacities from 1 L up to and including 150 L for compressed, liquefied or dissolved gases, exposed to ambient temperatures.

2 References

ISO 2604, *Steel products for pressure purposes — Quality requirements.*

ISO 3166, *Codes for the representation of names of countries.*

ISO 4978, *Flat rolled steel products for welded gas cylinders.*

ISO 6892, *Metallic materials — Tensile testing.*

ISO 7438, *Metallic materials — Bend test.*

3 Definitions and symbols

3.1 Definitions

3.1.1 yield stress : See ISO 6892.

Throughout this International Standard, the term "yield stress" means the upper yield stress, R_{eH}, or, for steels that do not exhibit a defined yield, the 0,2 % proof stress (non-proportional elongation), $R_{p0,2}$.

3.1.2 normalizing : Heat treatment in which a finished cylinder is heated to a uniform temperature above the upper critical point (AC_3) of the steel and then cooled in still air.

3.1.3 stress relieving : Heat treatment given to the finished cylinder, the object of which is to reduce the residual stresses without altering the metallurgical structure of the steel.

3.2 Symbols

a: Calculated minimum thickness, in millimetres, of the cylindrical shell.

a_b: Minimum thickness, in millimetres, of the cylindrical shell (including any corrosion allowance) guaranteed by the manufacturer.

A: Percentage elongation after fracture.

b: Calculated minimum thickness, in millimetres, of the end.

C: Shape factor (see figure 1).

D: Outside diameter, in millimetres, of the cylinder as given in the design drawing (see figure 4).

h: Height, in millimetres, of the cylindrical part of the end (see figure 4).

H: Outside height, in millimetres, of the domed part of the end (see figure 4).

J: Stress reduction factor.

L: Length, in millimetres, of the cylinder.

1) 1 bar = 10^5 Pa = 10^5 N/m^2

L_o : Original gauge length, in millimetres, in accordance with ISO 6892.

n : Ratio of diameter of bend test former to the thickness of the test piece.

N : Normalized cylinder.

p_b : Maximum pressure, in bar, attained during the burst test.

p_h : Test pressure, in bar, above atmospheric pressure.

r : Inside knuckle radius, in millimetres, of the end.

R : Inside dishing radius, in millimetres, of the end.

R_e : Minimum value of yield stress (apparent), in newtons per square millimetre, guaranteed by the cylinder manufacturer for the finished cylinder.

R_g : Minimum value of tensile strength, in newtons per square millimetre, guaranteed by the cylinder manufacturer for the finished cylinder.

R_m : Actual value of tensile strength, in newtons per square millimetre, determined by the tensile test specified in 8.2.

S : Stress relieved cylinder.

S_o : Original cross-sectional area, in square millimetres, of tensile test piece according to ISO 6892.

4 Materials

4.1 General requirements

4.1.1 The material used for the fabrication of the gas cylinder shall be steel, other than rimming quality, suitable for pressing or drawing and welding, and shall be such as to ensure no deterioration with time of the mechanical properties in the finished cylinder after heat treatment (non-ageing).

In cases where verification of this non-ageing property is required, the criteria by which it is to be specified should be agreed by the manufacturer and purchaser and included in the order.

4.1.2 All parts of welded cylinder bodies and all parts welded to the body shall be made of compatible materials.

4.1.3 The welding materials, whenever used, shall be such that they are capable of giving consistent welds with minimum tensile strength at least equivalent to that specified for the parent materials in the finished cylinder.

4.1.4 The cylinder manufacturer shall obtain and provide certificates of cast (heat) analyses of the steels supplied for the construction of the pressure-containing parts of gas cylinders, and establish means to identify the cylinders with the casts of steel from which they are made.

4.2 Chemical composition

4.2.1 Materials used for the fabrication of gas cylinders shall be of weldable quality and the following limits shall not be exceeded in the cast analysis :

carbon :	0,22 % max.
silicon :	0,45 % max.
manganese :	1,60 % max.
phosphorus :	0,04 % max.
sulfur :	0,04 % max.
phosphorus and sulfur :	0,07 % max.

Use of micro-alloying elements such as niobium (columbium), titanium and vanadium shall be confined to the following contents:

niobium (columbium) :	0,08 % max.
titanium :	0,20 % max.
vanadium :	0,20 % max.
niobium (columbium) plus vanadium :	0,20 % max.

Where other micro-alloying elements are used, their presence and amounts shall be reported, together with the above, in the steel manufacturer's certificate.

4.2.2 Should check analyses be required they shall be carried out either on specimens taken during manufacture from material in the form as supplied by the steel maker to the cylinder manufacturer or from finished cylinders. In any check analysis, the maximum permissible deviation from the limits specified for cast analyses shall conform to the values specified in the appropriate part of ISO 2604.

4.3 Applicable materials

Steels defined in ISO 4978 meet the requirements of 4.1 and 4.2. Other suitable steels which conform to the requirements of 4.2.1 may also be used, subject to acceptance by the national authority of the country where the cylinder is to be used.

4.4 Heat treatment

Cylinders shall be delivered in either the normalized or the stress-relieved condition (see 3.1.2 and 3.1.3). The cylinder manufacturer shall certify that the cylinders have been heat-treated after completion of all welding and shall certify the process of heat treatment applied.

Localized heat treatment is not permitted.

5 Design

5.1 General requirements

5.1.1 The calculation of the wall thickness of the pressure parts to resist the internal pressure in the gas cylinders shall be related to the yield stress of the material.

5.1.2 For calculation purposes, the value of the yield stress R_e is limited to a maximum of

a) 0,75 R_g for carbon stock with UTS $<$ 490 N/mm^2;

b) 0,85 R_g for high-strength micro-alloy steels with UTS $\geqslant$ 490 N/mm^2.

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 provided to the customer or independent inspection authority.

5.2 Calculation of cylindrical shell thickness

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

$$a = \frac{p_h D}{\frac{20 R_e J}{1,3} + p_h}$$

For circumferential welds : $J = 1$

For longitudinal welds :

— where each seam is radiographed completely : $J = 1$;

— where seams are spot-radiographed (see figure 5) (see 7.2.2) : $J = 0,9$;

— where seams are not radiographed (carbon steels only) : $J = 0,7$.

For the minimum wall thickness, see 5.5.

5.3 Design of ends concave to pressure

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

— for torispherical ends $R \leqslant D$: $r \geqslant 0,1\ D$: $h \geqslant 4b$ [figure 4a)]

— for ellipsoidal ends $H \geqslant 0,192\ D$: $h \geqslant 4b$ [figure 4b)]

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

$$b = \frac{p_h D C}{\frac{20 R_e}{1,3} + p_h}$$

In this formula, C is a shape factor, the value of which depends on the ratio H/D.

The value of C shall be obtained from the graph given in figure 1.

5.4 Design of ends convex to pressure for non-corrosive gases (see figure 6)

Ends convex to pressure shall have a minimum overlap of $4a$ and a thickness of at least $2a$.

5.5 Minimum wall thickness

5.5.1 Should the thickness calculated from either 5.2 or 5.3.2 be less than 2 mm or 1,8 mm when the ratio $L/D \leqslant 5$, then the minimum permissible thickness of the cylindrical portion and that of the ends shall satisfy the greatest of the following thickness criteria :

$$a = b \geqslant \frac{D}{250} + 1 \text{ mm}$$

$$a = b \geqslant 1,5 \text{ mm}$$

a and b shall not be lower than the values calculated using the formulae in 5.2 and 5.3.

A value of 1,8 mm may be substituted for 2 mm provided that the ratio L/D has a maximum value of 5 and that no minus tolerance on thickness is permitted.

5.5.2 Apart from the requirements of 5.3 and 5.5.1 any cylindrical part integral with an end shall, except as qualified by 5.5.3, also satisfy the requirements given in 5.2 for the cylindrical shell.

5.5.3 The equation given in 5.2 is not applicable 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 $\sqrt{2bD}$. In this case the wall thickness shall be not less than that of the domed part (see 5.3.2).

6 Construction and workmanship

6.1 Welding qualification

Each manufacturer, before proceeding with the production of a given design of cylinder, shall qualify the welding procedures and welders to an acceptable national standard. Records of such qualification shall be kept on file by the manufacturer.

a) Procedure qualification tests shall be made in such a manner that the welds shall be representative of those made in production.

b) Welders shall have passed the qualification tests for the specific type of work and procedure concerned.

c) Re-qualifying of the procedure, as well as the welder, shall be required if there is change in any of the essential variables as detailed in the qualification standard.

6.2 Plates and pressed parts

Before assembly, the pressure parts of the cylinders shall be visually examined for uniform quality and freedom from injurious defects.

6.3 Welded joints

6.3.1 The welding of the longitudinal and circumferential seams shall be by an automatic process.

6.3.2 The longitudinal joint, of which there shall be no more than one, shall be the butt-welded type.

6.3.3 Circumferential joints, of which there shall be no more than two, shall be butt-welded, or butt-welded with one member offset to form an integral backing strip or lap-welded. Lap-welded joints shall have a minimum overlap of four times the nominal sheet thickness and shall comply with 6.4.4.

6.3.4 The location of all openings shall be restricted to the end(s) of cylinders.

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. The welds of the openings shall be clear of longitudinal and circumferential joints.

If the leak-tightness between the valve and the cylinder is assured by a metallic seal (e.g. copper) a suitable internal valve boss may be fitted to the cylinder by a method which need not independently guarantee leak-tightness.

6.4 Welds

6.4.1 Before the cylinders are closed, longitudinal welds shall be visually examined from both sides. Permanent backing strips shall not be used with longitudinal welds.

6.4.2 All welds shall have a smooth finish without concavity and shall merge into the parent material without under-cutting or abrupt irregularity.

6.4.3 Butt welds and joggle butt welds shall have full penetration.

6.4.4 For circumferential joints having a lap weld, the leg of the fillet subject to shear stress shall be at least twice the minimum side wall thickness as calculated in accordance with 5.2.

Lap-welded joints shall only be permitted following a successful prototype fatigue test as specified in annex A.

6.5 Circularity

The out-of-roundness of the cylindrical shell shall be limited so that the difference between the maximum and the minimum outside diameter in the same cross-section is not more than 1 % of the mean of these diameters.

6.6 Non-pressure-containing attachments

6.6.1 Neckrings, footrings, handles, bosses, pads and rings not subject to pressure of the contents may be attached to the cylinder by welding, provided that such attachments are made of weldable and compatible steel.

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

6.6.3 A footring of adequate strength shall be fitted to the cylinder to provide stability, and welded so as to permit inspection of the bottom circumferential weld.

The footring shall be suitably drained and the space enclosed by the footring suitably ventilated.

6.7 Valve protection

6.7.1 Valves of cylinders of more than 5 L water capacity shall be effectively protected from damage which could cause release of gas, either by the design of the valve or of the cylinder (for example protective shroud) or by a cap which is screwed on or fitted in an equally strong manner.

6.7.2 When the design provides for a protective cap or shroud to be fitted, in no way shall it be in contact with any part of the valve.

6.7.3 The requirements of 6.7.1 may be waived when the cylinders are intended to be conveyed in crates or cradles, or when some other effective valve protection is provided.

6.8 Closure of apertures

Where cylinders are supplied without fitted valves or without safety devices, all apertures shall be fitted with a plug of suitable non-absorbent material to protect the thread and to prevent entry of moisture.

7 Radiographic examination

7.1 General

Radiographic examination, when required, shall conform to the techniques set forth in an acceptable national standard. Radiographs shall show complete penetration of weld and freedom from significant defects, especially those likely to be repeated through the batch.

7.2 Radiographic requirements

7.2.1 For cylinders with $J = 1$, the entire length of the longitudinal weld of every production shell shall be radiographed. In addition, one cylinder out of every 250 production cylinders shall have the junction of the longitudinal and circumferential seam welds radiographed as indicated in figure 5.

7.2.2 For cylinders with $J = 0{,}9$, one cylinder out of every 250 production cylinders shall have the junction of the longitudinal and circumferential seam welds radiographed as indicated in figure 5.

7.2.3 In addition to radiography carried out in accordance with 7.2.2, radiography shall also be carried out on the first production cylinder after a change in the type or size of cylinder, or the welding procedure (including machine setting), or after a break in production exceeding 4 h.

7.2.4 Should any of the radiographs show an unacceptable defect, production shall be stopped and every cylinder welded since the preceding acceptable radiograph shall be set aside until it is demonstrated that these cylinders are satisfactory,

either by radiography or by other appropriate means. Production shall not be re-started until the cause of the defect has been established and rectified, and the starting up test procedure as specified in 7.2.3 has been repeated.

7.2.5 Where more than one longitudinal welding machine is used for production, the above procedures will apply to each such machine.

8 Acceptance (batch) tests

8.1 General requirements

All tests for checking the mechanical properties of gas cylinders shall be carried out on material from finished cylinders.

Unless otherwise indicated in this International Standard, all mechanical tests shall be carried out in accordance with ISO 6892 and ISO 7438.

8.1.1 Batch

A batch shall consist 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 on the same type of automatic welding machines and heat-treated under the same conditions of temperature and duration.

8.1.2 Inspection lots

For acceptance purposes the batch shall be divided into inspection lots not exceeding 1 000 cylinders.

8.1.3 Rate of testing

The manufacturer shall endeavour to maintain the cast separated as a group and shall arrange for samples tested to represent each cast of material used.

The reduced rate of testing for large volume manufacture (above 3 000 cylinders) is subject to written agreement with the national authority once the independent inspection agency can demonstrate that the manufacturer production test results and manufacturing processes are consistently reliable, and that the volume of the run exceeds 3 000 cylinders without any major interruption of manufacture.

NOTE — For a diagram illustrating the rate of testing, refer to figure 7.

8.1.3.1 Quantity less than or equal to 3 000 cylinders

8.1.3.1.1 From the first 250 cylinders or less in each inspection lot, representative cylinders shall be taken at random, one for the burst test and one for mechanical tests.

8.1.3.1.2 From each subsequent group of 250 cylinders or less in the inspection lot, one representative cylinder shall be taken at random for either a burst test or mechanical tests.

8.1.3.2 Quantity over 3 000 cylinders

8.1.3.2.1 For less than or equal to 35 L capacity

For the first 3 000 cylinders in the batch, representative cylinders shall be taken in accordance with 8.1.3.1. From each inspection lot remaining, representative cylinders shall be taken at random, one for the burst test and one for mechanical tests.

8.1.3.2.2 For greater than 35 L capacity

For the first 3 000 cylinders in the batch, representative cylinders shall be taken in accordance with 8.1.3.1.

8.1.3.2.2.1 From the first 500 cylinders or less in each inspection lot remaining, representative cylinders shall be taken at random, one for the burst test and one for mechanical tests.

8.1.3.2.2.2 From the remaining 500 cylinders or less in such inspection lots (8.1.3.2.2.1), one representative cylinder shall be taken at random for either a burst test or mechanical tests.

8.1.4 Hydraulic burst test

The hydraulic burst test, when carried out, shall be conducted in such a manner that the following information can be reliably obtained:

a) the pressure within the cylinder when the yield point of the cylinder has been reached;

b) the maximum pressure p_b, in bar, attained during the burst test;

c) the increase in volume of the cylinder at the moment of burst.

For cylinders with ends convex to pressure, in addition to the information obtained in a), b) and c) above, the volumetric expansion of the cylinder at the test pressure p_h and any permanent set of the cylinder shall be established in accordance with d).

d) On reaching test pressure p_h, the volumetric expansion shall be measured after at least 30 s. After releasing the pressure, the expansion shall again be measured to determine permanent set. The permanent set shall not exceed 10 % of the expansion at test pressure p_h. The water pressure shall then again be increased to point of rupture p_b noting when the yield point of the cylinder has been reached.

8.1.5 Tensile test pieces required from parent material

8.1.5.1 For two-piece cylinders,

a) one tensile test piece shall be cut in the longitudinal direction from the cylindrical portion of one end of the cylinder, or

b) if there is not sufficient cylindrical length available to permit cutting the cylindrical portion, then one tensile test piece shall be taken from one end [see figure 2a)].

8.1.5.2 For three-piece cylinders, one tensile test piece in the longitudinal direction from the shell section 180° away from the weld and one tensile test piece from either of the ends shall be taken. If the two ends are of different grades or from a different supplier of material, a tensile test piece shall be taken from each end (see figure 2).

8.1.6 Test pieces required from welds

8.1.6.1 For two-piece cylinders, one tensile test piece and one root and one face bend test piece shall be taken [see figure 2a)].

8.1.6.2 For three-piece cylinders, one tensile test piece and one root and one face bend test piece on the longitudinal weld shall be taken. If the circumferential welds are made by a different process, then the same three tests (tensile, face bend and root bend) shall also be made on this weld [see figure 2b)].

8.1.6.3 All tensile and bend tests shall be in a direction transverse to the weld. The face and root of the weld in the test piece shall be machined flush to the plate surface.

The face and back of the test piece shall not be machined but shall represent the surface of the container as manufactured. The ends only may be flattened, by cold pressing, for gripping in the test machine.

8.1.7 Weld cross-sections

Any cross-section of the weld that may be made from the test piece specified in 8.1.6 shall show a sound weld. All defects contravening the requirements of 6.4.2 are inadmissible.

8.1.8 Macro-etch test of lap joints

8.1.8.1 Any fillet weld used to attach ends on cylinders shall have a test piece cut out across the fillet weld, which shall be macro-etched and visually examined in accordance with 8.1.8.2.

8.1.8.2 Examination of a fillet weld test piece shall show that there is full penetration at the root of the weld and into both members and that the shear fillet leg length is at least twice the minimum wall thickness. The contour of the weld shall be flat or convex (see figure 6).

8.2 Tensile test

8.2.1 The tensile test on parent metal shall be carried out on a test piece in accordance with the requirements of ISO 6892.

The two faces of the test piece formed by the inside and the outside surfaces of the cylinder shall not be machined.

8.2.2 The percentage elongation after fracture of the parent metal shall be not less than the values shown in table 1.

Table 1 — Values of percentage elongation after fracture A

Wall thickness of cylindrical shell a	$R_m \leqslant 490$ N/mm²	$R_m > 490$ N/mm²
	A min.	
mm	%	%
$a \geqslant 3$	29	20
$a < 3$	22	15

NOTE — The values in table 1 for percentage elongation after fracture of cylinders of wall thickness $a < 3$ mm relate to test pieces of width 20 mm and gauge length 80 mm.

8.2.3 The tensile test transverse to the weld shall be carried out on a test piece having a reduced section 25 mm wide over a length extending to 15 mm beyond each edge of the weld. Outside this central part, the width of the test piece shall increase gradually.

8.2.4 The tensile strength value obtained shall be at least equal to the specified minimum value for the parent metal, regardless of the position of fracture.

8.3 Bend tests

8.3.1 All bend tests shall be carried out in accordance with ISO 7438 on test pieces of width 25 mm. The distance between the faces of the roller supports shall be such that by bending, the test piece is left just free from the sides of the former (see figure 3). Test pieces with a weld shall be mounted in such a way that the axis of the former is in the middle of the weld.

8.3.2 On completion of the test, the test piece shall remain uncracked.

8.3.3 The ratio n between the diameter D_F of the former and the thickness a of the test piece shall be as shown in table 2.

Table 2 — Ratio n of former diameter to test piece thickness

Actual tensile strength, R_m N/mm²	Value of n
$R_m \leqslant 430$	2
$430 < R_m \leqslant 510$	3
$510 < R_m \leqslant 590$	4
$590 < R_m \leqslant 685$	5

8.4 Burst tests

8.4.1 The burst test shall be carried out hydraulically. The rate of pumping shall not exceed five times the water capacity of the cylinder per hour.

To determine the increase in volume, the mass of the empty cylinder is ascertained before the test and again when completely filled with water. After the test it is again filled with water and weighed.

The increase in volume may be determined by any other equivalent means.

8.4.2 The bursting pressure p_b is the maximum pressure met during the test and shall be

$$p_b \geqslant \frac{20\, a_b\, R_g}{D - a_b}$$

where a_b is the calculated minimum thickness, in millimetres, of the cylindrical shell in accordance with clause 5, plus any additional thickness allowance for corrosion incorporated in the design of the cylinder.

8.4.3 For cylinders made from steel having $R_g \leqslant 360$ N/mm², the minimum value of the volumetric expansion referred to in 8.4.1 shall be

20 %, if the length of the cylinder is greater than its diameter;

14 %, if the length of the cylinder is equal to or less than its diameter.

For cylinders made from steel having $360 \text{ N/mm}^2 < R_g \leqslant 490 \text{ N/mm}^2$, the minimum value of the volumetric expansion referred to in 8.4.1 shall be

15 %, if the length of the cylinder is greater than its diameter;

10 %, if the length of the cylinder is equal to or less than its diameter.

If the fracture occurs

— in an end (except where $L \leqslant 2D$),

— in a longitudinal weld, or

— in a circumferential weld other than perpendicular to the weld,

or leads to fragmentation, the cylinder shall be regarded as having failed the test.

8.4.4 During visual examination of the inside and outside of the burst cylinder any abnormality resulting from the welding operation or from the nature and condition of the metals used, and which are considered capable of impairing safety, shall be cause for rejection.

8.5 Failure to meet batch test requirements

In the event of failure to meet batch test requirements, retesting shall be carried out in accordance with 8.5.1 and 8.5.2.

8.5.1 If there is evidence of a fault in carrying out the tensile or bend test, or of an error of measurement, a second test on the same cylinder shall be performed. If the result of this test is satisfactory, the first test shall be ignored.

8.5.2 If the test has been carried out satisfactorily the procedure detailed in 8.5.2.1 or 8.5.2.2 shall be followed.

8.5.2.1 In the event of a single cylinder failing the initial mechanical or burst test, retests both mechanical and burst shall be made as shown in table 3, the retest cylinders being taken at random from the same batch.

Table 3 — Retest requirements

Inspection lot	Failure	Retest
⩽ 250	1M*	2M 1B**
⩽ 250	1B	2B 1M
> 250 ⩽ 500	1M	2M 2B
> 250 ⩽ 500	1B	1M 4B

* M : mechanical test.

** B : burst test.

8.5.2.2 In the event of more than one cylinder failing the initial tests or one or more cylinders failing the retest specified in 8.5.2.1, the batch shall be rejected. The manufacturer may, at his discretion, reheat-treat the rejected batch or repair any weld defects and reheat-treat the batch, and resubmit the cylinders as a new batch in accordance with 8.1.

9 Acceptance procedure

9.1 Pressure test

All cylinders in each batch shall be subjected to a pressure test.

It shall be observed that the pressure in the cylinder increases gradually and regularly until the test pressure p_h is reached. The cylinder shall be held long enough under test pressure to ascertain that there is no tendency to decrease in pressure and that tightness is assured.

IMPORTANT — Take particular care to ensure the safety of test personnel under all conditions of test and especially when cylinders are tested using gas as the testing medium.

9.2 Gas-tightness

The manufacturer shall employ such manufacturing techniques and apply such tests as will demonstrate to the satisfaction of the user or independent inspection authority that the cylinders do not leak.

9.3 Failure to meet pressure test requirements

Defects requiring repair to the pressure-containing welds and/or to non-pressure-containing attachments including replacements of shell or ends may be repaired provided that, after repair, reheat treatment is carried out in accordance with the requirements of 4.4 and the cylinder retested in accordance with the requirements of 9.1. Repairs shall be carried out in accordance with 6.1 and radiographic examination in accordance with clause 7.

10 Marking

Each cylinder shall be stamped, preferably on a name-plate or other appropriate permanently attached non-pressure part, with the marks detailed in 10.1 to 10.3. Marking on the ends of