# International Standard 4394/1

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION•МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ•ORGANISATION INTERNATIONALE DE NORMALISATION

# Fluid power systems and components — Cylinder barrels —
# Part 1 : Requirements for steel tubes with specially finished bores

*Transmissions hydrauliques et pneumatiques — Tubes pour vérins — Partie 1 : Caractéristiques des tubes en acier à alésage de finition spéciale*

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**Descriptors** : fluid power, hydraulic fluid power, pneumatic fluid power, pneumatic cylinders, steel tubes, dimensions, dimensional tolerances, equipment specifications, designations.

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# Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards institutes (ISO member bodies). The work of developing International Standards is carried out through ISO technical committees. Every member body interested in a subject for which a technical committee has been set up has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work.

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.

International Standard ISO 4394/1 was developed by Technical Committee ISO/TC 131, *Fluid power systems and components,* and was circulated to the member bodies in April 1977.

It has been approved by the member bodies of the following countries :

| | | |
|---|---|---|
| Australia | Finland | Romania |
| Austria | Germany, F.R. | South Africa, Rep. of |
| Belgium | Hungary | Spain |
| Brazil | India | Sweden |
| Bulgaria | Italy | Switzerland |
| Canada | Mexico | Turkey |
| Chile | Netherlands | United Kingdom |
| Czechoslovakia | Poland | |

The member bodies of following countries expressed disapproval of the document on technical grounds :

France
Japan
USA



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# Fluid power systems and components — Cylinder barrels — Part 1 : Requirements for steel tubes with specially finished bores

## 0 Introduction

In fluid power systems, power is transmitted and controlled through a fluid (liquid or gas) under pressure within an enclosed circuit. One component of such systems is the fluid power cylinder. This is a device which converts power into linear mechanical force and motion. It consists of a movable element, i.e. a piston and piston rod, operating within a cylindrical bore.

This part of ISO 4394 covers only one specific type of steel tubing suitable for fluid power cylinders. Other parts of the same International Standard will be prepared to cover the requirements of cylinder tubes in other materials commonly used in the hydraulic and pneumatic industries.

## 1 Scope and field of application

**1.1** This part of ISO 4394 specifies the mechanical properties, dimensional tolerances, surface finishes and technical delivery conditions for round steel tubes, seamless or welded type, hot or cold worked condition, with plain ends and having specially finished bores with or without metal removal.

**1.2** The tubes defined by this part of ISO 4394 are intended for use as barrels in a wide variety of fluid power cylinders.

NOTE — Steel should not be considered as the only material suitable for such applications.

**1.3** This part of ISO 4394 defines the tube dimensions by inside diameter and thickness, or inside diameter and outside diameter.

**1.4** Annex A specifies the tolerances on outside diameters for cold finished or machined tubes.

**1.5** Annex B establishes a range of preferred thicknesses for metric bore sizes for fluid power cylinders. Tables of thicknesses are included for both cold finished and hot finished steel tubes.

**1.6** Annex C provides a recommended method of ordering.

## 2 References

ISO 64, *Steel tubes — Outside diameters.*

ISO/R 286, *ISO system of limits and fits — Part 1 : General, tolerances and deviations.*

ISO 404, *Steel and steel products — General technical delivery requirements.*[1)]

ISO/R 486, *Surface roughness.*

ISO 1302, *Technical drawings — Method of indicating surface texture on drawings.*

ISO 2937, *Plain end seamless steel tubes for mechanical application.*

ISO 3304, *Plain end seamless precision steel tubes — Technical conditions for delivery.*

ISO 3305, *Plain end welded precision steel tubes — Technical conditions for delivery.*

ISO 3320, *Fluid power systems and components — Cylinder bores and piston rod diameters — Metric series.*

ISO 6506, *Metallic materials — Hardness test — Brinell.*[2)]

1) At present at the stage of draft. (Revision of ISO/R 404-1964.)

2) At present at the stage of draft.

## 3 Definitions

**3.1 cylinder** : A device which converts fluid power into linear mechanical force and motion.

**3.2 cylinder bore** : The internal diameter of the cylinder.

**3.3 tube** : A rigid line whose size is its outside diameter. Tube is available in varied wall thicknesses.

NOTE – An International Standard giving definitions of other terms used, is in preparation.

## 4 Symbols and abbreviations

The following symbols are used in this International Standard :

$D$ = nominal outside diameter of the tube

$d$ = nominal inside diameter of the tube

$a$ = nominal thickness of the tube

$R_m$ = tensil strength at ambient temperature

$R_{eL}$ = lower yield stress

$R_{p0,2}$ = 0,2 % proof stress (this figure will be used if the yield stress is not clearly indicated)

$S_o$ = cross-sectional area of gauge length

$A$ = elongation after fracture on gauge length = $5{,}65\sqrt{S_o}$

$R_a$ = arithmetical mean division from the mean line of the profile (see ISO/R 468)

HBS = Brinell hardness number (see ISO 6506)

## 5 Manufacture of base tubes

### 5.1 Manufacturing process

Where appropriate, use ISO 2937, ISO 3304, and ISO 3305 to meet the technical and quality requirements in manufacturing seamless or welded base tubes, without special finishing, supplied in the hot or cold worked condition.

### 5.2 Mechanical properties

**5.2.1** The mechanical properties shall be in accordance with tables 1 and 2.

**5.2.2** Unless otherwise agreed, the supplier shall select the steel to meet the mechanical properties from tables 1 and 2 as specified by the purchaser.

**5.2.3** Unless otherwise agreed, it is at the discretion of the manufacturer to supply the tubes in the necessary heat-treated condition to achieve the mechanical properties shown in tables 1 and 2.

### 5.3 Chemical composition

**5.3.1** Limit sulphur and phosphorus to 0,05 % max. each.

**5.3.2** If the tubes are to be subjected to a subsequent welding operation, conform the steel analysis for all grades to the following requirements :

a) the carbon content shall not exceed 0,25 %;

b) the carbon equivalent ($C_{eq}$), as defined by the formula :

$$C_{eq} = \%\,C + \frac{\%\,Mn}{6} + \frac{\%\,Ni + \%\,Cu}{15} + \frac{\%\,Cr + \%\,Mo + \%\,V}{5}$$

shall be :

for grades HP 1, 2, 4, 5 : $C_{eq} \leqslant 0{,}50$

for grades HP 3, 6 : $C_{eq} \leqslant 0{,}55$.

## 6 Special finishing of base tubes

The supplier and purchaser are to agree to the special finishing process required to achieve the bore tolerances and surface finishes specified by the International Standard.

## 7 Tolerances of specially finished tube

### 7.1 Ordering

Refer to annex C for the method of ordering.

### 7.2 Inside diameter

**7.2.1** In accordance with ISO/R 286, the following five classes of tolerances are recognized : H8, H9, H11, H12 and H13.

**7.2.2** Tolerances include geometrical variations such as ovality, lobing and taper.

**7.2.3** Tolerances H8 and H9 can normally be supplied only if the ratio of the tube inside diameter to thickness is less than 20 : 1.

**Table 1 — Preferred steel grades — Mechanical properties at ambient temperature — Tubes with lower tensile properties and greater ductility**

| Steel grade | $R_m$ min. | HBS | $R_{eL}$ or $R_{p0,2}$ min. | | | $A$ min. |
|---|---|---|---|---|---|---|
| | | | $a \leqslant 10$ mm | 10 mm $< a \leqslant$ 20 mm | 20 mm $< a \leqslant$ 50 mm | |
| | MPa | | MPa | MPa | MPa | % |
| HP 1 | 360 | 102 | 235 | 225 | 215 | 24 |
| HP 2 | 490 | 140 | 335 | 310 | 285 | 21 |
| HP 3 | 550 | 163 | 460 | 450 | 420 | 17 |

**Table 2 — Preferred steel grades — Mechanical properties at ambient temperature — Tubes with higher tensile properties**

| Steel grade | $R_m$ min. | HBS | $R_{eL}$ or $R_{p0,2}$ min. | $A$ min. |
|---|---|---|---|---|
| | MPa | | MPa | % |
| HP 4 | 450 | 126 | 380 | 10 |
| HP 5 | 550 | 163 | 440 | 10 |
| HP 6 | 640 | 190 | 540 | 10 |

NOTES (Tables 1 and 2)

1 Values quoted in megapascals (MPa) will rule. For convenient reference to other systems of values, use the following conversion factors :

1 MPa = 1 N/mm²

1 MPa = 0,64 75 tonf/in² (1 tonf = 2 240 lbf)

1 MPa = 0,101 98 kgf/m²

2 Brinell hardness numbers (HBS) are shown for reference purposes only.

**7.2.4** Tolerance H11 can normally be supplied only if the ratio of the tube inside diameter to thickness is less than 25 : 1.

**7.2.5** Special tolerances are to be agreed between the purchaser and supplier, if the material is quenched and tempered at the request of the purchaser.

## 7.3 Outside diameter

**7.3.1** The following two classes of tolerances are recognized :

a) Class 1 — for cold finished or machined tubes, tolerances are as shown in annex A.

b) Class 2 — for hot finished tubes, tolerances shall be ± 1 % of the nominal outside diameter (minimum ± 0,5 mm).

**7.3.2** Tolerances include geometrical variations such as ovality, lobing and taper.

## 7.4 Thickness and eccentricity

**7.4.1** If the inside diameter and thickness are specified, then the thickness measured at any cross-section along the tube length shall not vary from the nominal thickness by more than ± 10 % (this figure includes eccentricity).

**7.4.2** If the inside diameter and outside diameter are specified, restrict the eccentricity so that the minimum thickness (a min.) anywhere along the tube does not fall more than 10 % below the minimum mean thickness implied by the diametral tolerances, i.e.

$$a_{min} \geqslant 0{,}9 \times \frac{D_{min} - d_{max}}{2}$$

**7.4.3** Use a factor of 0,875 mm for hot finished tubes where wider tolerances are specified as in ISO 2937.

## 7.5 Straightness

**7.5.1** Define the measure of straightness in this International Standard as the maximum deviation that can be measured with feeler gauges between the tubes and a straightedge of 1 000 mm length resting on the external surface of the tube and parallel to its axis.

**7.5.2** As an alternative to 7.5.1, support the tubes by two rollers placed at intervals of 1 000 mm and measure the maximum deviation from straightness while rotating the tubes. Applying this method, the deviation from straightness is half the value of the total indicator reading (TIR).

**7.5.3** For tubes 1 000 mm and longer, measure the deviation over 1 000 mm lengths set at consecutive intervals of 500 mm, starting at one end.

**7.5.4** For tubes shorter than 1 000 mm, measure their entire length and do not show a deviation, for any given length, which exceeds values deduced from the figure.

NOTE — As a consequence of the manufacturing process, cylinder tubes which have been push-bored internally will possess a bore axis straighter than 0,5 : 1 000 (class A in 7.5.6). When checking tolerances, the methods in 7.5.1 through 7.5.4 will not apply in this instance. If required, special methods for measuring the straightness of the bore can agreed between the purchaser and supplier.

**7.5.5** The following three classes of straightness are recognized :

a) Class A — 0,50 : 1 000 (1 : 2 000)

b) Class B — 1,00 : 1 000 (1 : 1 000)

c) Class C — 1,50 : 1 000 (1 : 666)

## 7.6 Length

**7.6.1** When specified, the tolerances for cut length tubes shall be as shown in table 3.

**Table 3 — Tolerances for cut length tubes**

Dimensions in millimetres

| Length | | Tolerance |
|---|---|---|
| over | to | |
| 0 | 2 000 | + 3<br>0 |
| 2 000 | 5 000 | + 5<br>0 |
| 5 000 | | + 10<br>0 |

**7.6.2** The tolerances in table 3 include the possible out-of-squareness of the ends of the tubes.

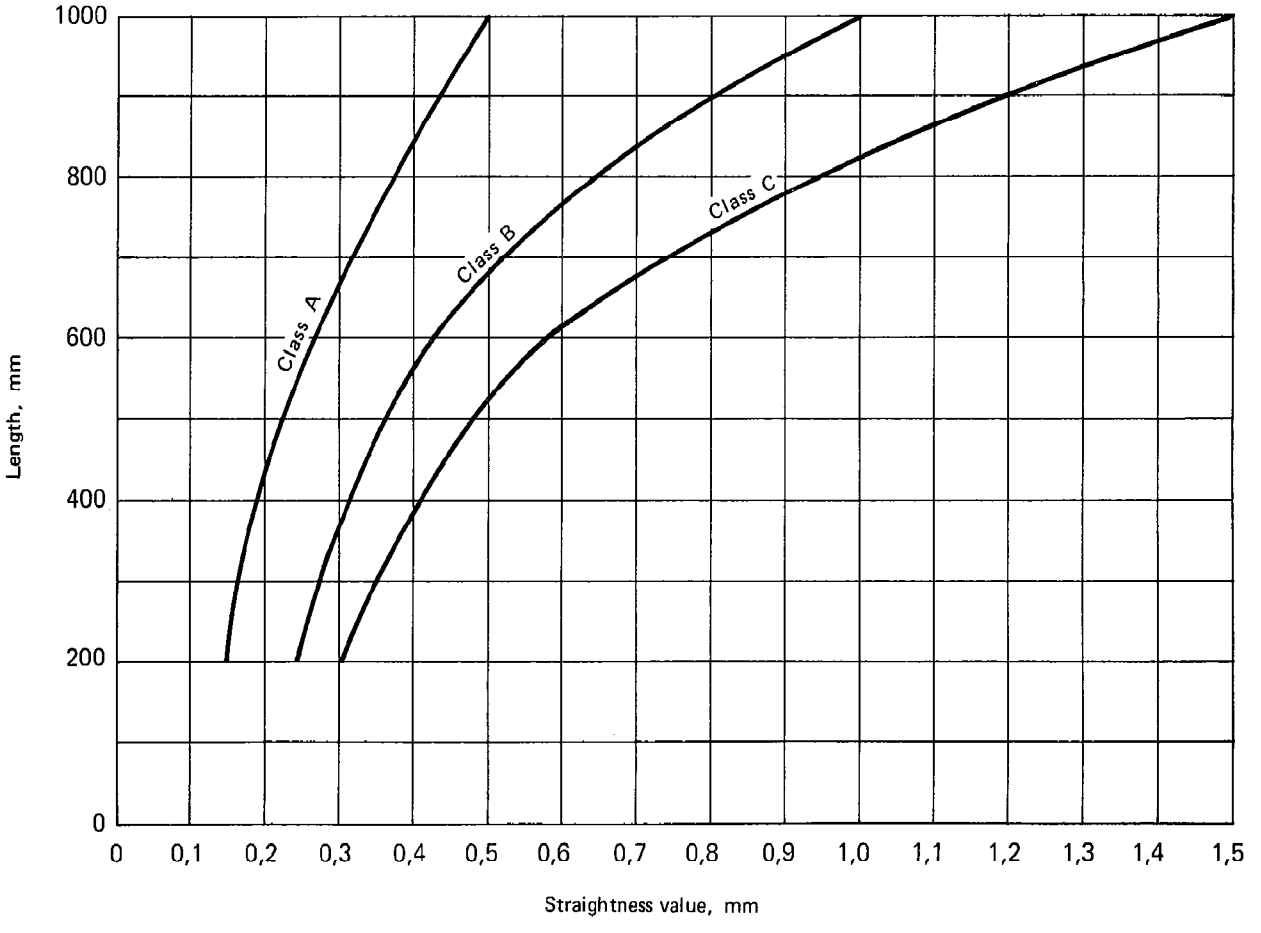


**Figure — Permissible deviation from straightness : tubes shorter than 1 000 mm**

# 8 Surface finish

## 8.1 Bore surface

**8.1.1** Specify bore surface finish values with $R_a$, in accordance with ISO/R 468.

**8.1.2** Use recognized equipment for the measurement of the surface finish.

**8.1.3** On a bore surface with a longitudinal or no predominant lay, for example cold drawn surfaces, traverse the stylus circumferentially and approximately perpendicular to the tube axis.

**8.1.4** On tube surfaces with a predominantly circumferential lay, for example honed or burnished surfaces, obtain measurements by longitudinal traverses.

**8.1.5** Take measurements at four positions around the circumference and spaced approximately 90° apart.

**8.1.6** Take three measurements at each position, the measuring zones being not less than 6 mm apart and not less than 25 mm from an end of the cylinder tube.

**8.1.7** Use the numerical $R_a$ rating as the arithmetic mean of all readings taken.

NOTE — No individual reading is to be more than 25 % greater than the nominal $R_a$ values, except as specified in 8.1.9 and 8.1.10.

**8.1.8** Use the classes of rating shown in table 4 for tubes with drawn or machined surfaces.

NOTE — The computation of the rating of surface finish does not include the effect of isolated defects. Subject to agreement between purchaser and supplier, defects such as pits, scores, etc. which are to be assessed by visual inspection or other appropriate means may be acceptable depending on their location and on the particular application for which the tube is required.

**8.1.9** In tubes with a drawn bore, the surface finish is normally supplied to classes "e"and "f", as shown in table 4, and variations up to nominal $R_a$ + 35 % are acceptable.

**8.1.10** The maximum permissible surface imperfections for tubes with a drawn bore surface are shown in table 5.

## 8.2. Outside surface

The outside surface shall exhibit a mill finish equivalent to the method of manufacturing base tubes described in 5.1.

**Table 4 — Classes of surface finish**

| | Classes | | | | | |
|---|---|---|---|---|---|---|
| | a | b | c | d | e | f |
| | Nominal $R_a$ values | | | | | |
| µm | 0,125 | 0,2 | 0,4 | 0,8 | 1,6 | 3,2 |
| Roughness numbers as in ISO 1302 | — | N4 | N5 | N6 | N7 | N8 |

**Table 5 — Maximum permissible surface imperfections for tubes with drawn bore surface**

| Outside diameter mm | | Thickness range mm | | Permissible depth of imperfection µm | |
|---|---|---|---|---|---|
| Over | Up to and including | Over | Up to and including | Scores | Pits |
| — | 63 | | 2,6 | 25 | 40 |
| | | 2,6 | 6,3 | 25 | 50 |
| | | 6,3 | | 25 | 65 |
| 63 | 112 | | 3,2 | 40 | 65 |
| | | 3,2 | 4,5 | 40 | 75 |
| | | 4,5 | | 50 | 100 |
| 112 | 130 | All | | 50 | 100 |
| 130 | 200 | All | | 80 | 150 |
| 200 | | All | | 100 | 200 |

## 9 Protection and packing

The supplier's normal practice for protection and packing shall be adopted, unless the supplier and purchaser have agreed beforehand to special requirements for protection and packing.

## 10 Test certification

**10.1** Supply cylinder tubes with or without test certification.

**10.2** Deliver cylinder tubes without certification, unless otherwise specified at the time of inquiry or order.

**10.3** If the purchaser requires test certification, carry out the test procedure and number of tests in accordance with a previous special agreement.

**10.4** See ISO 404 for the classes of certification which can be specified.

## 11 Identification statement (reference to this International Standard)

Use following statement in test reports, catalogues and sales literature when electing to comply with this International Standard :

"Requirements for steel tubes with specially finished bores for fluid power cylinder barrels conform to ISO 4394/1, *Fluid power systems and components — Cylinder barrels — Part 1 : Requirements for steel tubes with specially finished bores.*"

# Annex A

## Tolerances on outside diameters for cold finished or machined tubes

**Table 6 — Tolerances on outside diameters of class 1 tubes**

Values in millimetres

| Outside diameters | | Tolerances (±) |
|---|---|---|
| Over | Up to and including | |
| – | 30 | 0,10 |
| 30 | 40 | 0,15 |
| 40 | 50 | 0,20 |
| 50 | 60 | 0,25 |
| 60 | 70 | 0,30 |
| 70 | 80 | 0,35 |
| 80 | 90 | 0,40 |
| 90 | 100 | 0,45 |
| 100 | 120 | 0,50 |
| 120 | 140 | 0,65 |
| 140 | 150 | 0,75 |
| 150 | 160 | 0,80 |
| 160 | 170 | 0,85 |
| 170 | 180 | 0,90 |
| 180 | 190 | 0,95 |
| 190 | 200 | 1,0 |
| 200 | 210 | 1,05 |
| 210 | 220 | 1,10 |
| 220 | 230 | 1,15 |
| 230 | 240 | 1,20 |

**A.1** As a result of distortion during any final heat treatment, the diameter variations are greater with the permissible values being as follows :

Thickness/outside diameter :

$\geq$ 1/20 : the values given in table 6

$<$ 1/20 but $\geq$ 1/40 : 1,5 times the values given in table 6

$<$ 1/40 but $\geq$ 1/60 : twice the values given in table 6

**A.2** The permissible variations in the tube outside diameter include ovality.

# Annex B

# Preferred sizes for steel hydraulic and pneumatic cylinder tubes

## B.1 Cylinder barrels made from cold finished tubes

**B.1.1** Preferred sizes appropriate for cylinders made from cold finished steel tubes are listed in table 7 by inside diameter, wall thickness and outside diameter.

The inside diameter sizes, from 25 mm to 200 mm, are selected from ISO 3320.

**B.1.2** Specify the tube dimensions by either inside diameter and wall thickness or inside diameter and outside diameter.

## B.2 Cylinder barrels made from hot finished tubes

**B.2.1** Preferred sizes appropriate for cylinders made from hot finished steel tubes are listed in table 8 by inside diameter and outside diameter.

The inside diameter sizes, from 63 mm to 400 mm, are selected from ISO 3320.

The outside diameter sizes of hot finished tubes are selected from ISO 64.

**B.2.2** Specify the tube dimensions for hot finished tubes by the inside diameter and outside diameter only.

**Table 7 — Preferred sizes for cylinder barrels made from cold finished steel tubes**

Dimensions in millimetres

| Bore | Wall thickness | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1,5 | 2,0 | 2,5 | 3,0 | 3,5 | 5,0 | 6,0 | 7,5 | 10,0 | 12,5 | 15,0 | 20,0 |
| | Outside diameters | | | | | | | | | | | |
| **25** | 28 | – | – | 31 | – | 35 | – | 40 | – | – | – | – |
| **32** | 35 | 36 | – | 38 | – | 42 | – | 47 | – | – | – | – |
| **40** | – | – | 45 | 46 | – | 50 | – | 55 | – | – | – | – |
| **50** | – | – | 55 | 56 | – | 60 | – | 65 | 70 | 75 | – | – |
| **63** | – | – | 68 | 69 | – | 73 | 75 | 78 | 83 | 88 | – | – |
| **80** | – | – | 85 | 86 | – | 90 | 92 | 95 | 100 | 105 | 110 | – |
| **100** | – | – | 105 | 106 | – | 110 | 112 | 115 | 120 | 125 | 130 | – |
| **125** | – | – | – | – | 132 | 135 | 137 | 140 | 145 | 150 | 155 | 165 |
| **160** | – | – | – | – | 165 | 170 | – | 175 | 180 | 185 | 190 | 200 |
| **200** | – | – | – | – | – | 210 | – | 215 | 220 | 225 | 230 | 240 |

**Table 8 — Preferred sizes for cylinder barrels made from hot finished steel tubes**

Dimensions in millimetres

| Bore | Outside diameters | | | |
|---|---|---|---|---|
| **63** | 76,1 | 82,5 | 88,9 | 101,6 |
| **80** | 101,6 | 108 | 114,3 | 127 |
| **100** | 127 | 133 | 139,7 | 152,4 |
| **125** | 152,4 | 159 | 168,3 | 177,8 |
| **160** | 193,7 | 219,1 | 244,5 | – |
| **200** | 244,5 | 273 | 298,5 | – |
| **250** | 273 | 298,5 | 323,9 | 355,6 |
| **320** | 355,6 | 368 | 406,4 | 419 |
| **400** | 419 | 457 | 508 | 559 |

# Annex C

## Method of ordering

State the following in the inquiry and order when purchasing :

a) method of manufacture, i.e. seamless or welded;

b) the number and title of this International Standard;

c) if the tubes are subjected to a welding operation (see 5.3.2);

d) the grade of mechanical properties (see tables 1 and 2);

e) any special requirements relating to heat treatment (see 5.2.3);

f) tube cross-sectional dimensions,

either

1) inside diameter and wall thickness, in which case the required inside diameter tolerance class shall be stated (see 7.2);

or

2) inside diameter and outside diameter, in which case the required tolerance classes of both diameters shall be stated (see 7.2 and 7.3); a further eccentricity tolerance to 7.4.2 may also be specified;

NOTE — where the base tube is in the hot finished condition, use method 2) only.

g) required degree of straightness (see 7.5.5);

h) required class of bore surface finish (see 8.1.7 and 8.1.8);

j) length and total number of lengths, or total length in specified random lengths;

k) any special requirements for protection or packing (see clause 9);

m) the name of the inspecting authority, if any;

n) if test certification and/or analysis certificates are required (see clause 10).