INTERNATIONAL STANDARD ISO 683/XII

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Heat-treated steels, alloy steels and free-cutting steels — Part 12 : Flame and induction hardening steels

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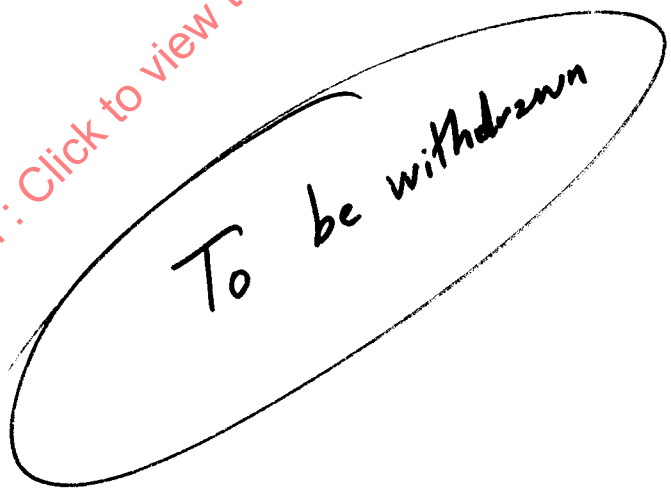

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FOREWORD

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 683/XII was drawn up by Technical Committee ISO/TC 17, *Steel.*

It was approved in December 1971 by the Member Bodies of the following countries:

Australia	Germany	South Africa, Rep. of
Austria	Hungary	Sweden
Belgium	India	Switzerland
Czechoslovakia	Italy	Thailand
Denmark	Netherlands	Turkey
Egypt, Arab Rep. of	Norway	United Kingdom
Finland	Pakistan	U.S.A.
France	Romania	

No Member Body expressed disapproval of the document.

Heat-treated steels, alloy steels and free-cutting steels — Part 12 : Flame and induction hardening steels

1 SCOPE AND FIELD OF APPLICATION

This International Standard specifies the grades of wrought unalloyed and alloyed steels for flame and induction hardening listed in Table 2 and usually intended for use in the quenched and tempered and subsequently flame or induction hardened condition.

2 REFERENCES

ISO/R 79, *Brinell hardness test for steel.*

ISO/R 80, *Rockwell hardness test (B and C scales) for steel.*

ISO/R 82, *Tensile testing of steel.*

ISO/R 83, *Charpy impact test (U-notch) for steel.*

ISO/R 377, *Selection and preparation of samples and test pieces for wrought steel.*

ISO/R 404, *General technical delivery requirements for steel.*

ISO/R 642, *Hardenability test by end quenching steel (Jominy test).*

ISO/R 643, *Micrographic determination of the austenitic grain size of steels.*

3 REQUIREMENTS

3.1 Production processes

3.1.1 Unless otherwise agreed in the order, the processes used in making the steel and the product are left to the discretion of the manufacturer, but the steel shall be killed. When he so requests, the user shall be informed what steelmaking process is being used.

3.1.2 It is recommended that the grain size of the steel — as defined in ISO/R 643 — is 5 or finer.

3.2 Chemical composition, mechanical properties and hardenability

3.2.1 *Types of condition of delivery*

The steels covered by this International Standard shall be ordered and delivered in accordance with Table 1. The type of condition of delivery according to Table 1 shall be stated at the time of enquiry and order.

3.2.2 *Chemical composition*

The chemical composition expressed by the cast analysis shall be in accordance with Table 2.

3.2.2.1 If ordered to conditions of delivery type 1 or 1(a) (see Table 1), the following deviations between the limiting values specified in Table 2 and the product analysis of products up to 160 mm (6.3 in) diameter or equivalent dimensions shall apply. Above 160 mm (6.3 in) diameter, the deviations shall be stated at the time of enquiry and order.

3.2.2.2 If ordered to types of condition of delivery 2, 2(a), 3, 3(a), 4, 4(a), 4(g), 5 and 5(g), the mechanical properties or hardenability and ability to surface harden specified in Tables 4, 7 and 8 shall be the governing criteria for acceptance. In such cases, the cast analysis may deviate slightly from the figures shown in Table 2.

3.2.3 *Mechanical properties*

3.2.3.1 If specified, the mechanical properties shall be those shown in Tables 4, 5, 6, 7 or 8.

3.2.3.1.1 The values apply to test pieces, taken on rounds in the direction of the metal fibre, the axis of the test piece corresponding to that shown in Figure 1.

3.2.3.1.2 For rectangular sections, the ranges for equivalent diameters are given in Figure 2.

3.2.3.1.3 For other sections, the equivalent diameter shall be agreed at the time of enquiry and order.

3.2.3.2 The mechanical properties in the quenched and tempered condition as given in Table 4 are those which can be obtained for one of the conditions given below:

1) For a reference test bar of 16 mm diameter, taken from the product to be delivered either by machining

TABLE 1 – **Types of condition of delivery**

Requirements	Types of condition of delivery[1]										
	1	1(a)	2	2(a)	3	3(a)	4	4(a)	4(g)	5	5(g)
Chemical composition	X	X	X	X	X	X	X	X	X	X	X
Hardenability (end quench test)	–	–	X	X	–	–	–	–	–	–	–
Hardness in a condition of delivery other than quenched and tempered	–	X	–	X	–	X	–	X	X	–	–
Surface hardness after surface hardening	–	–	–	–	–	–	–	–	X	–	X
Mechanical properties of											
– quenched and tempered test bar of 16 mm diameter	–	–	–	–	X	X	–	–	–	–	–
– quenched and tempered ruling section[2]	–	–	–	–	–	–	X	X	X	–	–
– quenched and tempered product in dimensions of delivery	–	–	–	–	–	–	–	–	–	X	X

1) The numbers indicating the types of condition of delivery follow a coordinated series of numbers throughout all relevant ISO publications.

2) See footnote to clause 3.2.3.2 (2).

TABLE 2 – **Types of steel and chemical composition gauranteed** (applicable to cast analysis)[1]

Type of steel	C %	Si %	Mn %	P % max.	S %[2] max.	Cr %	Mo %	Ni %
1	0.33 to 0.39	0.15 to 0.40	0.50 to 0.80	0.035	0.035			
2	0.38 to 0.44	0.15 to 0.40	0.50 to 0.80	0.035	0.035			
3	0.43 to 0.49	0.15 to 0.40	0.50 to 0.80	0.035	0.035			
4	0.48 to 0.55	0.15 to 0.40	0.60 to 0.90	0.035	0.035			
5	0.50 to 0.57	0.15 to 0.40	0.40 to 0.70	0.035	0.035			
6	0.42 to 0.48	0.15 to 0.40	0.50 to 0.80	0.035	0.035	0.40 to 0.60		
7	0.34 to 0.40	0.15 to 0.40	0.60 to 0.90	0.035	0.035	0.90 to 1.20		
8	0.38 to 0.44	0.15 to 0.40	0.60 to 0.90	0.035	0.035	0.90 to 1.20		
9	0.38 to 0.44	0.15 to 0.40	0.50 to 0.80	0.035	0.035	0.90 to 1.20	0.15 to 0.30	
10	0.38 to 0.44	0.15 to 0.40	0.70 to 1.00	0.035	0.035	0.40 to 0.60	0.15 to 0.30	0.40 to 0.70
11	0.37 to 0.43	0.15 to 0.40	0.50 to 0.80	0.035	0.035	0.60 to 0.90	0.15 to 0.30	0.70 to 1.00

1) Elements not quoted in the table shall not be intentionally added to the steel without the agreement of the purchaser, other than for the purpose of finishing the heat. All reasonable precautions shall be taken to prevent the addition of such elements from scrap or other materials used in manufacture, which affect the hardenability, mechanical properties and applicability.

2) By agreement at the time of enquiry and order, the steels can be supplied with a controlled sulphur content of 0.020 to 0.035 %.

TABLE 3 – **Permissible deviations between specified analysis and product analysis**

Type of steel	Permissible deviations[1]							
	C %	Si %	Mn %	P %	S %	Cr %	Mo %	Ni %
1 to 5	± 0.03	± 0.03	± 0.04	+ 0.005	+ 0.005	–	–	–
6, 7, 8	± 0.02	± 0.03	± 0.04	+ 0.005	+ 0.005	± 0.05	–	–
9	± 0.02	± 0.03	± 0.04	+ 0.005	+ 0.005	± 0.05	± 0.03	–
10, 11	± 0.02	± 0.03	± 0.04	+ 0.005	+ 0.005	± 0.05	± 0.03	± 0.03

1) ± means that in one cast and in more than one product analysis the deviation may occur over the upper value *or* under the lower value of the specified range in Table 2 but not both at the same time.

from a location according to Figure 1 or by forging, and then quenched and tempered according to the temperatures and times listed in Table 9 (types of condition of delivery 3 and 3(a) of Table 1).

2) For a ruling section[1], to be specified at the time of enquiry and order, which is quenched and tempered according to the temperatures listed in Table 9 (types of condition of delivery 4, 4(a) and 4(g) of Table 1).

For location of the test bar, see 4.2.1.

3) For the product to be delivered in the quenched and tempered condition of delivery (types of condition of delivery 5 and 5(g) of Table 1).

For location of the test bar, see 4.2.1.

3.2.3.3 If the products are delivered in a condition other than quenched and tempered, a maximum hardness according to Table 5, measured after preparation of the surface in the conventional manner, may be agreed in addition to the other requirements (types of condition of delivery 1(a), 2(a), 3(a), 4(a) and 4(g) of Table 1).

Mechanical properties for the normalized condition for the types of steel 1 to 5 are given for information in Table 6.

3.2.3.4 When ordering on hardenability (types of condition of delivery 2 and 2(a) of Table 1), the Rockwell C hardness numbers given in Table 7 and the scatter bands in Figure 3 apply.

3.2.3.5 When it is required that the ability to harden on the surface be checked, this shall be stated in the enquiry and order (types of condition of delivery 4(g) and 5(g) of Table 1). In this case, the values specified in Table 8 shall be taken as basis.

3.3 Tolerances on dimensions and mass

The tolerances allowable on dimensions and mass shall be stated in the order as long as there are no ISO International Standards to cover them.

4 TESTING

4.1 Number of sample products

4.1.1 *Chemical composition*

The cast analysis is given by the manufacturer. If a product analysis is required by the purchaser, at least one sample product shall be taken from each cast.

4.1.2 *Mechanical properties and hardenability*

4.1.2.1 For material not supplied in the finally heat-treated condition (types of condition of delivery 1(a), 2, 2(a), 3, 3(a), 4, 4(a) and 4(g) of Table 1), one sample product shall be taken from each cast for testing in accordance with the requirements of Tables 4, 5, 6, 7 and 8 where applicable.

4.1.2.2 For material supplied in the finally heat-treated condition (types of condition of delivery 5 and 5(g) of Table 1), one sample product shall be taken from each size grouping from each heat treatment batch for testing in accordance with Table 4. If the product is continuously heat-treated, one sample product for each 25 t or part thereof for the carbon steels 1 to 5, for each 15 t or part thereof for the alloy steels 6 to 11, but at least one sample product for each cast, shall be taken.

4.2 Samples and test pieces

4.2.1 The test pieces for tensile test and impact test shall be taken in the longitudinal direction of the products according to Figure 1.

1) In the selection of a steel, one of the most important considerations is whether the mechanical properties required can be obtained from the steel in the size and shape at the time of heat treatment. That portion, which is most important from the point of view of the mechanical properties obtained by heat treatment, is referred to as the ruling section, and the ruling section shall always be expressed in terms of the diameter of an equivalent round bar (see Figure 2).

4.2.2 The bar from which the test piece for the end-quench hardenability test is machined shall be a forged or rolled round piece 30 to 32 mm in diameter representing the full cross-section of the product. Larger cross-sections shall be rolled or forged to these dimensions. By special agreement a cast test piece may be used in lieu of a rolled or forged test piece. Further conditions to be observed when preparing the test piece shall be as in ISO/R 642.

4.2.3 For product analyses, the selection of samples shall be carried out in conformity with the requirements of ISO/R 377.

4.2.4 General conditions for selection and preparation of samples and test pieces for steel shall be in accordance with ISO/R 377.

4.3 Test methods

4.3.1 The tensile test shall be made in accordance with ISO/R 82.

4.3.2 The impact test shall be made in accordance with ISO/R 83. Unless otherwise specified at the time of enquiry and order, the impact value shall be determined by the arithmetic average of the results obtained by the breaking of three test pieces next to one another in the test sample or test bar.

4.3.3 The end-quench hardenability test shall be made in accordance with ISO/R 642. The temperatures for quenching shall be in accordance with Table 9.

4.3.4 As long as there is no ISO International Standard available, the methods to be used for hardening the surface and for checking the surface hardness shall be agreed at the time of enquiry and order.

4.3.5 The Brinell hardness test shall be made in accordance with ISO/R 79. The Rockwell hardness test shall be made in accordance with ISO/R 80.

4.3.6 In cases of dispute, the methods for the chemical analysis shall be those established by the relevant ISO International Standards. If no ISO International Standards are available, the methods may be agreed upon and specified at the time of enquiry and order.

4.4 Retests

4.4.1 For retests for mechanical properties, clause 6.5 of ISO/R 404 is valid.

4.4.2 For retests for the product analysis, clause 7.6 of ISO/R 404 is valid.

4.5 Certification of the tests

For certification of the tests, section 4 of ISO/R 404 is valid, acceptable documents being namely

- statement of compliance with the order (see 4.1.1), or
- report based on quality control (see 4.1.2), or
- works certificate (see 4.1.3), or
- test certificate (see 4.2.1), or
- certificate of acceptance (see 4.2.2).

5 DEFECTS AND DIMENSIONAL TOLERANCES

The conditions given in section 8 of ISO/R 404 are valid for

- surface defects (see 8.1),
- rectification (see 8.2),
- internal defects (see 8.3),
- dimensional tolerances (see 8.4) and
- reclaiming (see 8.5).

TABLE 4 — **Mechanical properties for the quenched and tempered condition**[1)]

Type of steel	$\phi \leqslant 16$ mm (0.63 in)				16 mm (0.63 in) $< \phi \leqslant 40$ mm (1.58 in)				40 mm (1.58 in) $< \phi \leqslant 100$ mm (3.94 in)				100 mm (3.94 in) $< \phi \leqslant 160$ mm (6.3 in)				160 mm (6.3 in) $< \phi \leqslant 250$ mm (9.85 in)			
	R_e min.	R_m	A min.	KU min.	R_e min.	R_m	A min.	KU min.	R_e min.	R_m	A min.	KU min.	R_e min.	R_m	A min.	KU min.	R_e min.	R_m	A min.	KU min.
	N/mm² (tonf/in²)	N/mm² (tonf/in²)	%	J	N/mm² (tonf/in²)	N/mm² (tonf/in²)	%	J	N/mm² (tonf/in²)	N/mm² (tonf/in²)	%	J	N/mm² (tonf/in²)	N/mm² (tonf/in²)	%	J	N/mm² (tonf/in²)	N/mm² (tonf/in²)	%	J
1	420 (27.2)	620 to 760 (40.1 to 49.2)	17	25	360 (23.3)	580 to 730 (37.6 to 47.3)	19	25	320 (20.7)	540 to 690 (35.0 to 44.7)	20	25	–	–	–	–	–	–	–	–
2	450 (29.1)	660 to 800 (42.7 to 51.8)	16	20	390 (25.2)	620 to 760 (40.1 to 49.2)	18	20	340 (22.0)	580 to 730 (37.6 to 47.3)	19	20	–	–	–	–	–	–	–	–
3	480 (31.1)	700 to 840 (45.3 to 54.4)	14	15	410 (26.5)	660 to 800 (42.7 to 51.8)	16	15	370 (24.0)	620 to 760 (40.1 to 49.2)	17	15	–	–	–	–	–	–	–	–
4	510 (33.0)	740 to 880 (47.9 to 57.0)	13	–	440 (28.5)	700 to 840 (45.3 to 54.4)	15	–	400 (25.9)	660 to 800 (42.7 to 51.8)	16	–	–	–	–	–	–	–	–	–
5	510 (33.0)	740 to 880 (47.9 to 57.0)	12	–	430 (27.8)	690 to 830 (44.7 to 53.7)	14	–	400 (25.9)	640 to 780 (41.4 to 50.5)	15	–	–	–	–	–	–	–	–	–
6	640 (41.4)	880 to 1 080 (57.0 to 69.9)	12	20	540 (35.0)	780 to 930 (50.5 to 60.2)	14	25	440 (28.5)	690 to 830 (44.7 to 53.7)	15	25								
7	740 (47.9)	930 to 1 130 (60.2 to 73.2)	11	20	630 (40.8)	830 to 980 (53.7 to 63.5)	13	25	510 (33.0)	740 to 880 (47.9 to 57.0)	14	25	–	–	–	–	–	–	–	–
8	780 (50.5)	980 to 1 180 (63.4 to 76.4)	11	20	670 (43.4)	880 to 1 080 (57.0 to 69.9)	12	25	560 (36.3)	780 to 930 (50.5 to 60.2)	14	25	–	–	–	–	–	–	–	–
9	880 (57.0)	1 080 to 1 270 (69.9 to 82.2)	10	20	760 (49.2)	980 to 1 180 (61.5 to 76.4)	11	25	640 (41.4)	880 to 1 080 (57.0 to 69.9)	12	25	560 (36.3)	780 to 930 (50.5 to 60.2)	13	25	510 (33.0)	740 to 880 (47.9 to 57.0)	14	25
10	830 (53.7)	1 030 to 1 230 (66.7 to 79.6)	10	30	740 (47.9)	930 to 1 130 (60.2 to 73.2)	11	30	640 (41.4)	830 to 980 (54.4 to 63.5)	12	30	540 (35.0)	740 to 880 (47.9 to 57.0)	13	30	–	–	–	–
11	830 (53.7)	1 030 to 1 230 (66.7 to 79.6)	10	30	780 (50.5)	980 to 1 180 (63.5 to 76.4)	11	30	690 (44.7)	880 to 1 080 (57.0 to 69.9)	12	30	640 (41.4)	830 to 980 (53.7 to 63.5)	12	30	540 (35.0)	740 to 880 (47.9 to 57.0)	13	30

1) R_e = yield stress (0.2 % proof stress)

R_m = tensile strength

A = percentage elongation after fracture ($L_o = 5\,d_o$)

KU = impact strength with U-notch

TABLE 5 – **Maximum hardness for products delivered in a condition other than quenched and tempered**

Type of steel	HB maximum in condition		
	as rolled	treated for improved machinability	cold-drawn
1	If required, to be agreed between purchaser and supplier at the time of enquiry and order	183	235
2		197	248
3		207	255
4		217	269
5		223	269
6		223	277
7		235	285
8		241	293
9		241	293
10		217	269
11		229	277

TABLE 6 – **Mechanical properties of the types of steel 1 to 5 for the normalized condition**[1)2)]

Type of steel	R_e min.		R_m	A min.
	16 mm (0.63 in) $< \phi \leqslant$ 40 mm (1.58 in)	40 mm (1.58 in) $< \phi \leqslant$ 100 mm (3.94 in)	16 mm (0.63 in) $< \phi \leqslant$ 100 mm (3.94 in)	
	N/mm² (tonf/in²)	N/mm² (tonf/in²)	N/mm² (tonf/in²)	%
1	270 (17.5)	250 (16.3)	490 to 640 (31.7 to 41.4)	21
2	300 (19.4)	270 (17.5)	540 to 690 (35.0 to 44.7)	19
3	330 (21.4)	300 (19.4)	590 to 740 (38.2 to 47.9)	17
4	340 (22.0)	310 (20.1)	610 to 760 (39.5 to 49.2)	16
5	340 (22.0)	310 (20.1)	610 to 760 (39.5 to 49.2)	16

1) The values are given for guidance in case these steels are surface hardened in the normalized condition.

2) R_e = yield stress (0.2 % proof stress)

R_m = tensile strength

A = percentage elongation after fracture ($L_o = 5\,d_o$)

TABLE 7 — **Tentative hardness limits for specified hardenability** [1)]

Distance from quenched end of test piece	Hardness HRC											
	Steel 6		Steel 7		Steel 8		Steel 9		Steel 10		Steel 11	
mm	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.
1.5	54	62	51	58	53	60	53	60	53	60	53	60
3	49	60	50	58	52	60	53	60	53	60	51	60
5	40	57	48	58	50	60	52	60	52	60	50	59
7	32	52	44	57	47	59	51	60	50	59	49	58
9	28	46	39	55	44	58	50	60	47	58	48	58
11	25	42	36	52	40	56	48	59	42	57	46	57
13	23	40	33	50	37	54	45	59	38	55	44	57
15	22	38	31	48	35	52	43	58	35	54	43	56
20	20	35	26	42	30	46	38	56	30	48	39	55
25	–	33	24	39	27	42	35	53	28	42	36	53
30	–	31	22	37	25	40	34	51	26	40	34	51
35	–	29	20	36	23	38	33	48	25	38	33	49
40	–	28	–	35	22	37	32	47	24	37	32	48
45	–	27	–	34	21	36	32	46	24	37	31	46
50	–	26	–	33	20	35	32	45	23	36	30	45

1) The hardness values are tentative and may be adjusted as more information becomes available. The hardness values are based primarily on steels having a grain size of 5 and finer as defined in ISO/R 643.

TABLE 8 — **Hardness at the surface hardened zones** [1)]

Type of steel	Hardness at the surface hardened zones, HRC min.
1	50
2	52
3	55
4	56
5	57
6	55
7	52
8	54
9	54
10	54
11	54

1) The minimum surface hardness values shall be obtainable on material either in the normalized and subsequently surface hardened condition or in the quenched and tempered and subsequently surface hardened condition and also after tempering at 150 to 180 °C for about 1 h, if such a treatment is applied. The values may not be obtained if the surface is decarburized.

TABLE 9 – **Conditions for heat treatment**

The temperatures given below are for guidance, but the actual temperatures chosen shall be those that will give the properties required.

Type of steel	Quenching[1] °C	Quenching agent	Tempering[2] °C	End-quench test °C
1	840 to 880	water or oil	550 to 660	–
2	830 to 870	oil or water	550 to 660	–
3	820 to 860	oil or water	550 to 660	–
4	810 to 850	oil or water	550 to 660	–
5	805 to 845	oil or water	550 to 660	–
6	820 to 860	oil or water	550 to 660	850 ± 5
7	825 to 865	oil or water	540 to 680	845 ± 5
8	820 to 860	oil or water	540 to 680	840 ± 5
9	820 to 860	oil or water	540 to 680	840 ± 5
10	830 to 860	oil or water	540 to 660	845 ± 5
11	830 to 860	oil or water	540 to 660	845 ± 5

1) Time for austenitizing as a guide: 0.5 h minimum.

2) Time for tempering as a guide: 1 h minimum.

NOTE – Quenching temperatures at the lower end of the range shall be used for water, and at the upper end for oil.

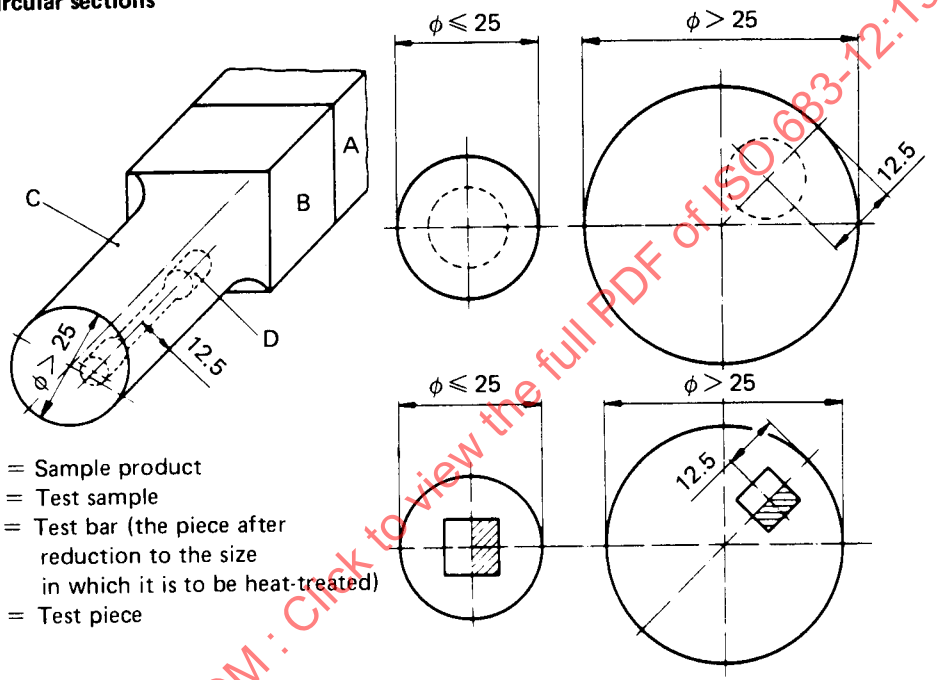
Dimensions in millimetres

Tensile test piece

Impact test piece

notch

Circular sections



A = Sample product
B = Test sample
C = Test bar (the piece after reduction to the size in which it is to be heat-treated)
D = Test piece

Rectangular sections

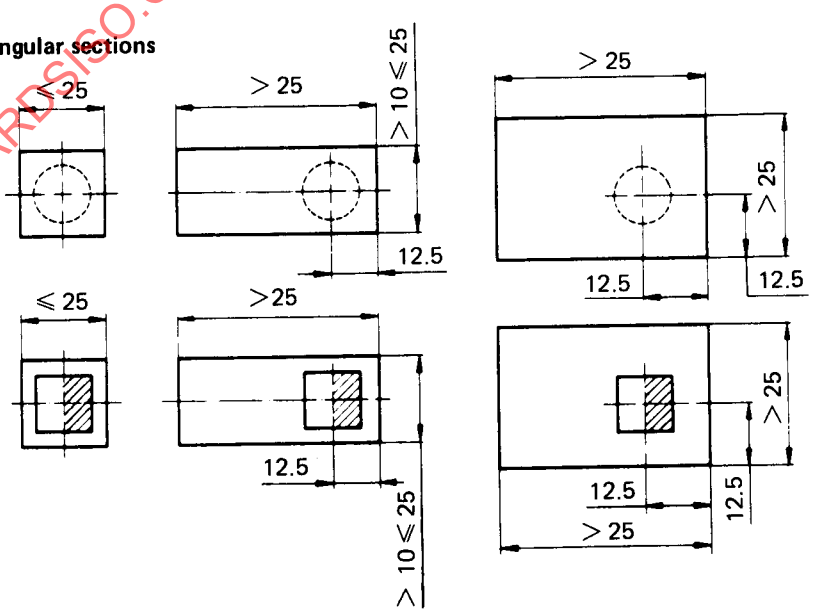


FIGURE 1 – **Location of the test pieces in the products**