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Heat-treated steels, alloy steels and free-cutting steels — Part 14 : steels for hot-formed and heat-treated springs

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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.

International Standard ISO 683/XIV was drawn up by Technical Committee ISO/TC 17, *Steel*, and circulated to the Member Bodies in March 1972.

It has been approved by the Member Bodies of the following countries:

Belgium	Hungary	Spain
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The Member Body of the following country expressed disapproval of the document on technical grounds:

U.S.A.

Heat-treated steels, alloy steels and free-cutting steels — Part 14 : steels for hot-formed and heat-treated springs

1 SCOPE AND FIELD OF APPLICATION

This International Standard gives specifications for the grades of unalloyed and alloyed steels for hot-formed springs, listed in Table 2 and intended for use in the quenched and tempered 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 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

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.

3.2 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 (c) (see Table 1), the permissible deviations given in Table 3, 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.

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

TABLE 1 – Types of condition of delivery

Requirements	Types of condition of delivery ¹⁾					
	1	1(c)	2	2(c)	4	4(c)
Chemical composition	X	X	X	X	X	X
Hardenability	—	—	X	X	—	—
Hardness in the subcritically annealed condition	—	X	—	X	—	X
Mechanical properties on the reference section of 10 mm diameter ²⁾	—	—	—	—	X	X

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

2) See footnote 2 to Table 5.

TABLE 2 – Types of steel and chemical composition guaranteed (applicable to cast analysis)¹⁾

Type of steel	C %	Si %	Mn %	P % max.	S % max.	B % min.	Cr %	Mo %	V %
1	0,72 to 0,85	0,15 to 0,40	0,50 to 0,80	0,050	0,050				
2	0,72 to 0,85	0,15 to 0,40	0,50 to 0,80	0,035	0,035				
3	0,43 to 0,50	1,50 to 2,00	0,50 to 0,80	0,040	0,040				
4	0,47 to 0,55	1,50 to 2,00	0,50 to 0,80	0,040	0,040				
5	0,52 to 0,60	1,50 to 2,00	0,60 to 0,90	0,040	0,040				
6	0,57 to 0,64	1,70 to 2,20	0,70 to 1,00	0,040	0,040				
7	0,57 to 0,64	1,70 to 2,20	0,70 to 1,00	0,040	0,040		0,25 to 0,40		
8	0,52 to 0,59	0,15 to 0,40	0,70 to 1,00	0,035	0,035		0,60 to 0,90		
9	0,56 to 0,64	0,15 to 0,40	0,70 to 1,00	0,035	0,035		0,60 to 0,90		
10	0,56 to 0,64	0,15 to 0,40	0,70 to 1,00	0,035	0,035	0,000 5	0,60 to 0,90		
11	0,42 to 0,50	1,30 to 1,70	0,50 to 0,80	0,035	0,035		0,50 to 0,75	0,15 to 0,30	
12	0,56 to 0,64	0,15 to 0,40	0,70 to 1,00	0,035	0,035		0,70 to 0,90	0,25 to 0,35	
13	0,48 to 0,55	0,15 to 0,40	0,70 to 1,00	0,035	0,035		0,90 to 1,20		0,10 to 0,20
14	0,48 to 0,56	0,15 to 0,40	0,70 to 1,00	0,035	0,035		0,90 to 1,20	0,15 to 0,25	0,07 to 0,12

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, from scrap or other materials used in manufacture, of such elements which affect the hardenability, mechanical properties and applicability.

TABLE 3 – Permissible deviations between specified analysis and product analysis

Type of steel	Permissible deviations ¹⁾								
	C %	Si %	Mn %	P %	S %	Cr %	Mo %	V %	
1 and 2	± 0,04	± 0,03	± 0,04	+ 0,005	+ 0,005				
3 to 5	± 0,02	± 0,05	± 0,04	+ 0,005	+ 0,005				
6	± 0,02	± 0,05	± 0,04	+ 0,005	+ 0,005				
7	± 0,02	± 0,05	± 0,04	+ 0,005	+ 0,005	± 0,04			
8, 9 and 10	± 0,02	± 0,03	± 0,04	+ 0,005	+ 0,005	± 0,05			
11	± 0,02	± 0,05	± 0,04	+ 0,005	+ 0,005	± 0,05	± 0,03		
12	± 0,02	± 0,03	± 0,04	+ 0,005	+ 0,005	± 0,05	± 0,03		
13	± 0,02	± 0,03	± 0,04	+ 0,005	+ 0,005	± 0,05		± 0,02	
14	± 0,02	± 0,03	± 0,04	+ 0,005	+ 0,005	± 0,05	± 0,03	± 0,02	

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.

3.2.3 Mechanical properties

3.2.3.1 With regard to the mechanical properties in relation to the martensite content in the core (see footnote to Table 4), the application of the steels shall be restricted to the thickness ranges given in Table 4.

TABLE 4 — Recommended maximum dimensions for flats and rounds

Values in millimetres

Type of steel	Maximum dimension ¹⁾	
	Flats thickness	Rounds diameter
1	8	12
2	8	12
3	14	20
4	16	24
5	8	12
6	14	20
7	16	24
8	18	28
9	22	33
10	24	35
11	30	45
12	47	70
13	27	40
14	40	60

1) The maximum dimensions given above are based on a martensite content of about 80 % in the centre of the quenched section.

3.2.3.2 If specified (types of condition of delivery 4 and 4 (c) — see Table 1), the mechanical properties of longitudinal test pieces of 10 mm diameter, which are heat treated in accordance with the data for the reference condition in Table 8 (see footnote 2 to Table 5), shall comply with the requirements of Table 5.

3.2.3.3 When ordering according to types of condition of delivery 1 (c), 2 (c) and 4 (c) (see Table 1), the maximum hardness values in the subcritically annealed condition as given in Table 6 can be agreed in addition to the other requirements; the hardness is measured after preparation of the surface in the conventional manner.

3.2.3.4 When ordering on hardenability (types of condition of delivery 2 and 2 (c) of Table 1), the Rockwell C hardness numbers given in Table 7 and the scatter bands in Figure 1 apply. In accordance with clause 7.4 of ISO/R 642, it shall be stated at the time of enquiry and order for which distance of the end quench test piece the hardness should be certified.

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 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 supplied according to types of condition of delivery 1 (c), 2 (c) and 4 (c) of Table 1 with guarantee of the maximum hardness in the subcritically annealed condition, one sample product shall be taken from each cast and from each heat treatment batch for testing in accordance with the requirements of Table 6. If the product is continuously heat treated, one sample product for each 25 t or part thereof for the carbon steels 1 and 2, for each 15 t or part thereof for the alloy steels 3 to 14, but at least one sample product for each cast, shall be taken.

4.1.2.2 For material supplied according to types of condition of delivery 4 and 4 (c) of Table 1 with guarantee of mechanical properties on the heat-treated reference section (10 mm diameter), one sample product shall be taken from each cast for testing in accordance with Table 5. For continuously heat-treated products, the last sentence of 4.1.2.1 also applies.

4.1.2.3 For material supplied according to types of condition of delivery 2 and 2 (c) of Table 1 with guarantee of the hardenability in the end-quench test, one sample product shall be taken from each cast for testing in accordance with the requirements of Table 7.

4.2 Samples and test pieces

4.2.1 The test pieces for tensile test shall be taken in the longitudinal direction (parallel to the metal fibre) from the centre of the product (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 32 or 30 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 pieces shall be in accordance with 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 end-quench hardenability test shall be made in accordance with ISO/R 642. The temperatures for quenching shall be in accordance with Table 8.

4.3.3 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.

4.3.4 In cases of dispute, the methods for the chemical analysis shall be those established by the relevant International Standard. If no 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 5 – Mechanical properties¹⁾ for longitudinal test pieces with a diameter²⁾ of 10 mm in the reference condition (see Table 8)

Type of steel	R_e min.		R_m min.		A min. %
	N/mm ²	tonf/in ²	N/mm ²	tonf/in ²	
1	880	57,1	1 180	76,2	6
2	880	57,1	1 180	76,2	6
3	1 080	69,9	1 270	82,6	6
4	1 130	73,0	1 320	85,7	6
5	1 130	73,0	1 320	85,7	6
6	1 180	76,2	1 370	88,9	5
7	1 180	76,2	1 370	88,9	5
8	1 180	76,2	1 370	88,9	6
9	1 180	76,2	1 370	88,9	5
10	1 180	76,2	1 370	88,9	6
11	1 180	76,2	1 370	88,9	6
12	1 180	76,2	1 370	88,9	6
13	1 180	76,2	1 370	88,9	6
14	1 180	76,2	1 370	88,9	6

1) R_e = yield stress (0,2 % proof stress)

R_m = tensile strength

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

2) If it is impossible to obtain a 10 mm diameter test piece, the test piece shall have the maximum diameter which can be obtained from the product.

TABLE 6 – Maximum hardness for products delivered in the subcritically annealed condition

Type of steel	HB maximum in the subcritically annealed condition
1	241
2	241
3	241
4	248
5	248
6	255
7	255
8	255
9	255
10	255
11	255
12	241
13	241
14	255

TABLE 7 — Tentative hardness limits for specified hardenability¹⁾²⁾

Distance from quenched end of test piece mm	Hardness HRC																									
	Steel 3		Steel 4		Steel 5		Steel 6		Steel 7		Steel 8		Steel 9		Steel 10		Steel 11		Steel 12		Steel 13		Steel 14			
	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.
1,5	55	63	56	64	57	65	59	66	59	66	57	65	59	66	60	65	55	63	60	65	57	65	57	65	57	65
3	50	60	52	61	55	62	58	66	59	66	56	65	59	66	60	65	54	63	60	65	56	65	56	65	56	65
5	40	53	42	56	49	60	56	65	57	65	55	64	57	65	60	65	53	62	60	65	56	64	56	64	56	64
7	33	46	36	52	43	57	50	64	51	64	54	63	56	65	59	65	52	62	60	65	55	64	55	64	55	64
9	29	42	32	47	37	54	43	62	45	63	52	63	53	64	59	65	50	61	60	65	53	63	53	63	53	63
11	26	39	29	43	34	50	38	60	40	61	48	62	50	63	57	65	49	61	60	65	50	62	52	62	52	63
13	23	36	27	41	32	46	36	58	38	59	43	61	45	62	54	65	47	60	60	65	46	61	51	63	51	63
15	21	34	26	38	31	42	34	55	37	57	39	60	41	61	49	65	45	59	59	65	43	60	50	62	50	62
20	—	31	22	35	28	39	31	48	33	50	33	57	35	58	39	65	42	57	58	64	37	57	48	62	48	62
25	—	29	21	33	27	37	28	43	30	45	30	52	32	54	37	63	40	55	56	64	35	53	47	62	47	62
30	—	27	—	32	26	36	27	41	29	43	28	48	30	50	34	60	37	52	54	63	33	50	46	62	46	62
35	—	25	—	31	26	35	26	39	28	41	27	45	29	47	32	57	36	51	50	63	32	48	46	61	46	61
40	—	24	—	29	25	34	25	38	27	40	26	42	28	44	30	54	34	49	46	63	30	45	45	61	45	61
45	—	24	—	28	24	33	24	37	26	39	25	40	27	42	28	50	33	49	43	63	29	44	44	61	44	61
50	—	23	—	27	24	33	23	36	25	38	24	39	26	41	25	47	33	48	41	63	28	43	44	60	44	60

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.

2) See last sentence of 3.2.3.4.

TABLE 8 – Conditions for heat treatment

The temperatures given below are for guidance, except those to obtain the reference heat treatment condition and those for the end-quench hardenability test. In the other cases, the actual times and temperatures shall be those that will give the properties required.

Type of steel	Rolling or forging of the steel product °C	Heat treatment to obtain the reference condition according to Table 5			End-quench test °C ± 5	Hot forming of springs °C	Subcritical annealing °C	Heat treatment of the springs		
		Quenching temperature ¹⁾ °C ± 10	Quenching agent	Tempering ²⁾ °C ± 20				Quenching ¹⁾ °C	Quenching agent	Tempering ²⁾ °C
1	1 050 to 850	835	Oil	460	—	900 to 840	640 to 700	820 to 850	Oil	400 to 550
2	1 050 to 850	835	Oil	460	—	900 to 840	640 to 700	820 to 850	Oil	400 to 550
3	1 050 to 850	865	Water	480	860	900 to 840	640 to 700	850 to 880	Water	400 to 550
4	1 050 to 850	860	Water	480	860	900 to 820	640 to 700	845 to 875	Water	400 to 550
5	1 050 to 850	855	Oil	480	850	900 to 830	640 to 700	840 to 870	Oil	400 to 550
6	1 050 to 850	845	Oil	480	850	920 to 830	640 to 700	830 to 860	Oil	400 to 550
7	1 050 to 850	845	Oil	480	850	920 to 830	640 to 700	830 to 860	Oil	400 to 550
8	1 100 to 850	845	Oil	480	850	920 to 830	640 to 700	830 to 860	Oil	400 to 550
9	1 100 to 850	845	Oil	480	850	920 to 830	640 to 700	830 to 860	Oil	400 to 550
10	1 100 to 850	845	Oil	480	850	920 to 830	640 to 700	830 to 860	Oil	400 to 550
11	1 100 to 850	865	Oil	480	860	920 to 830	640 to 700	850 to 880	Oil	400 to 550
12	1 100 to 850	845	Oil	480	850	920 to 830	640 to 700	830 to 860	Oil	400 to 550
13	1 100 to 850	865	Oil	480	850	920 to 830	640 to 700	850 to 880	Oil	400 to 550
14	1 100 to 850	865	Oil	480	850	920 to 830	640 to 700	850 to 880	Oil	400 to 550

1) Time for austenitization as a guide : 0,5 h minimum.

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

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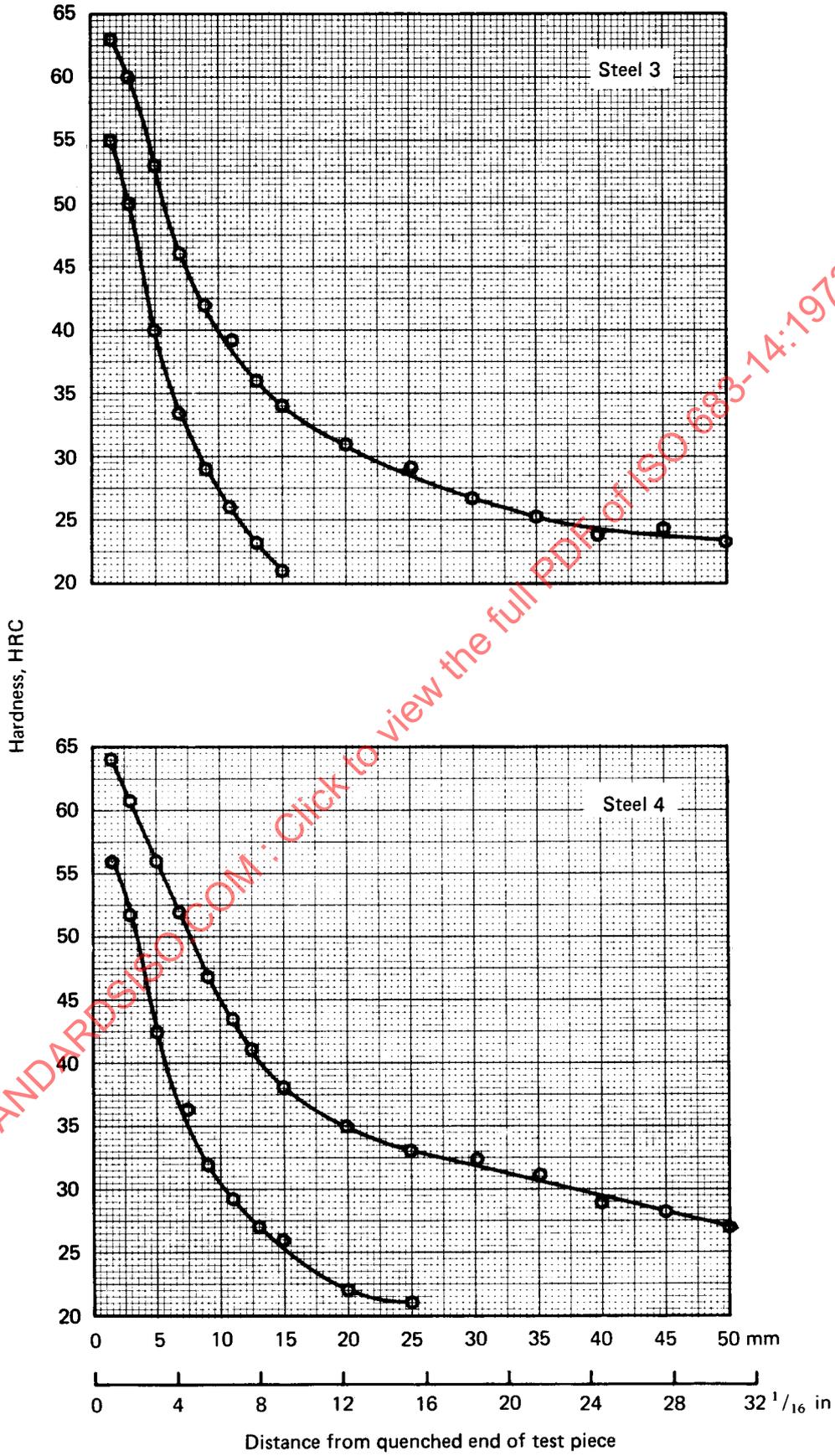


FIGURE 1a - Scatter bands for end-quench hardenability

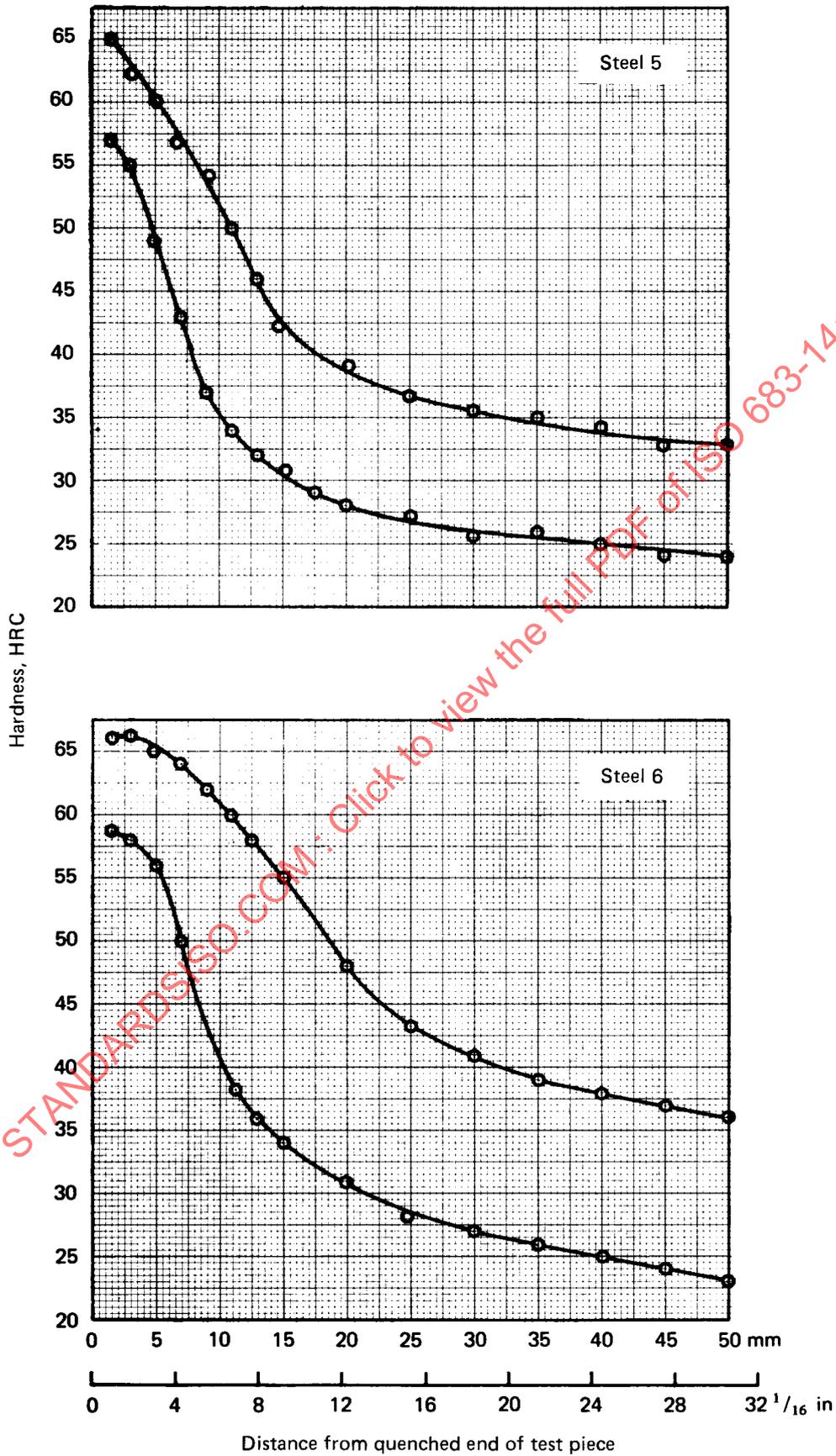
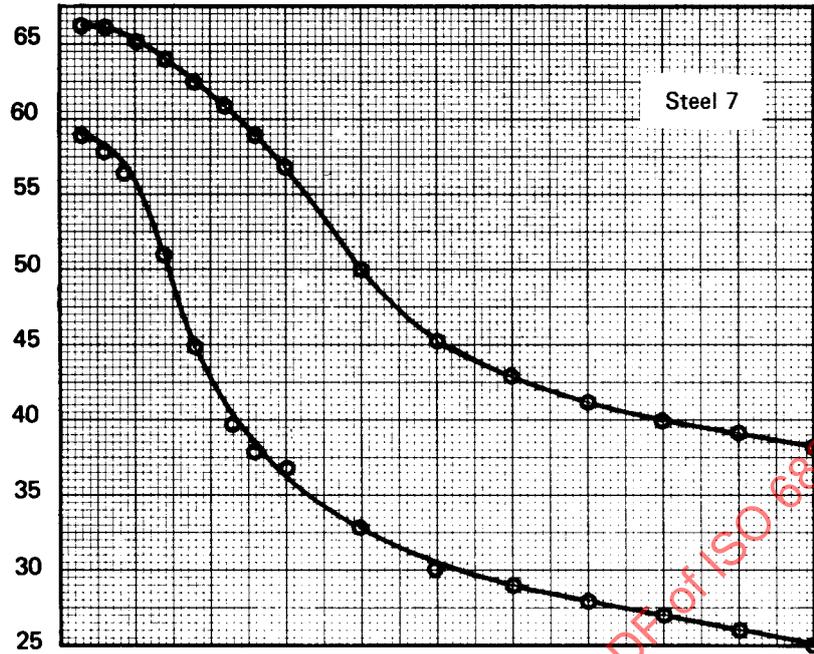


FIGURE 1b – Scatter bands for end-quench hardenability



Hardness, HRC

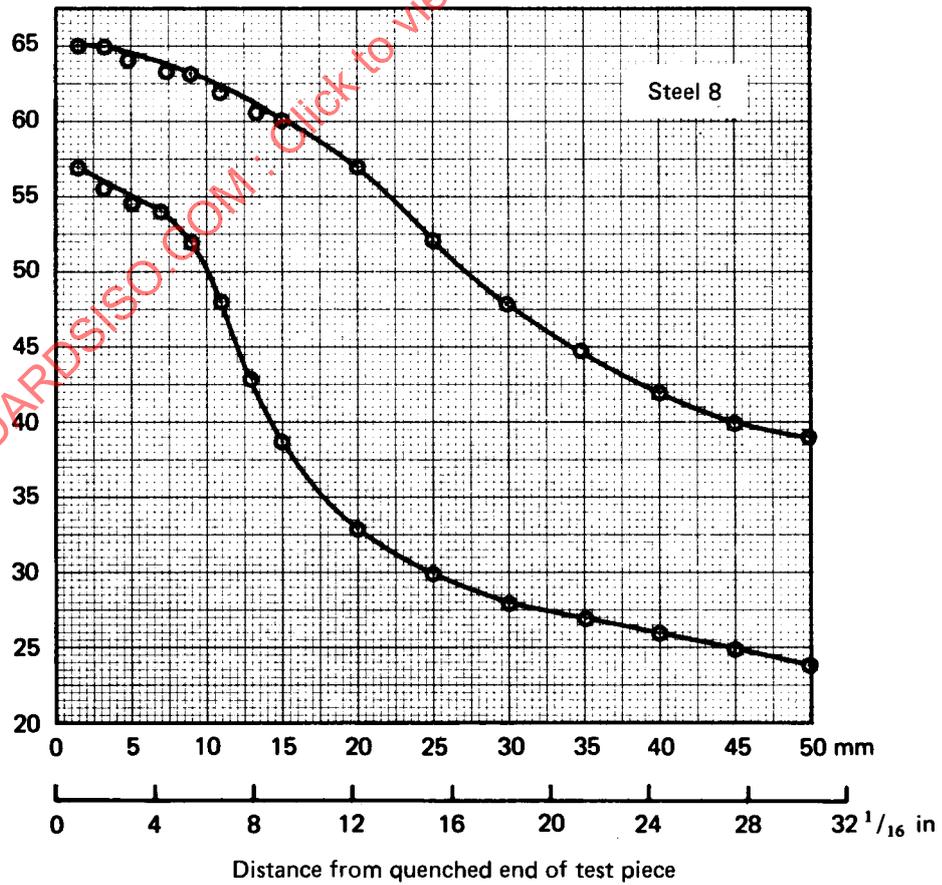


FIGURE 1c - Scatter bands for end-quench hardenability

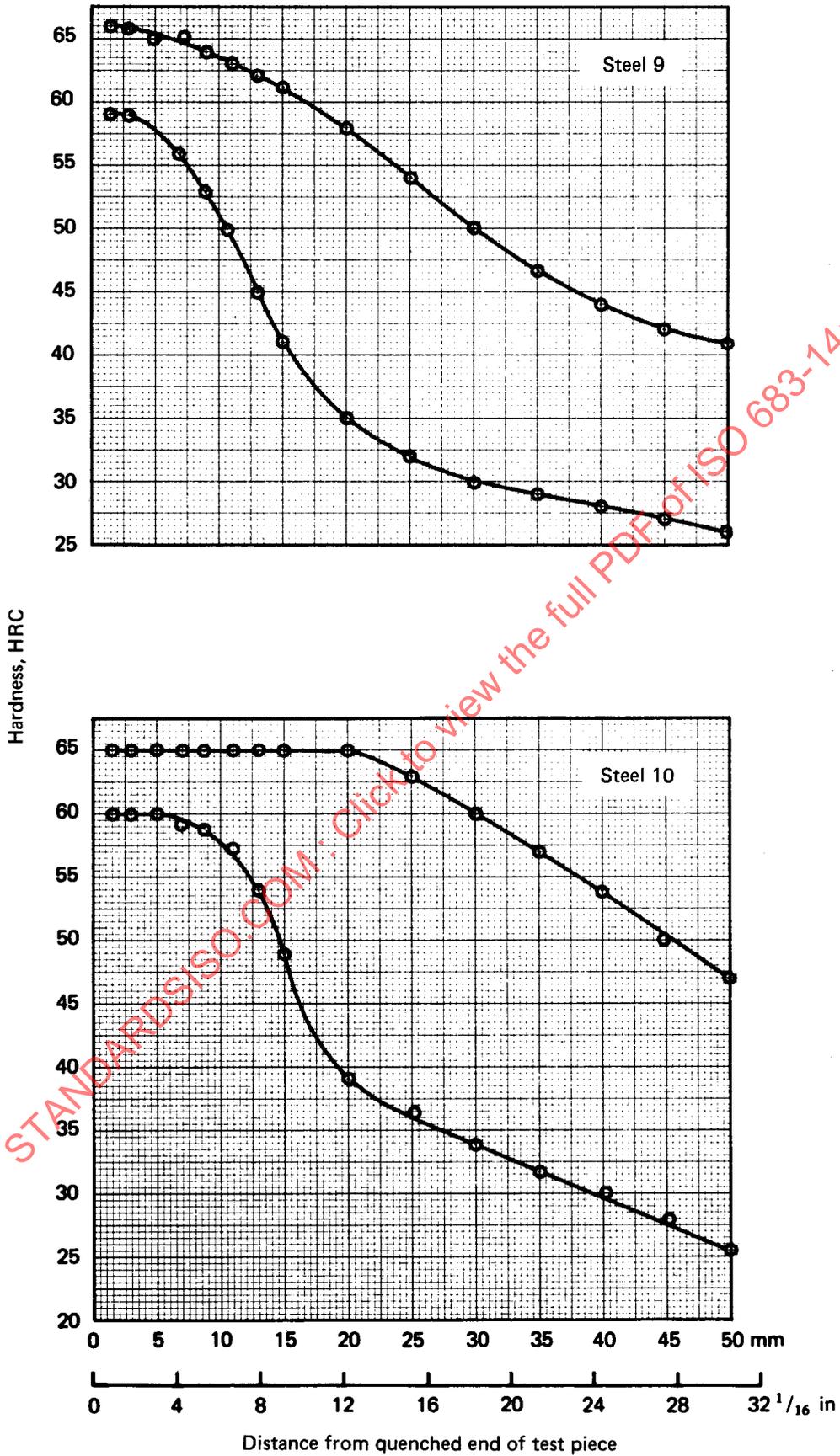


FIGURE 1d – Scatter bands for end-quench hardenability