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R 683 / XI

HEAT-TREATED STEELS, ALLOY STEELS AND FREE-CUTTING STEELS

PART 11

WROUGHT CASE HARDENING STEELS

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BRIEF HISTORY

The ISO Recommendation R 683/XI, *Heat-treated steels, alloy steels and free-cutting steels – Part 11 : Wrought case hardening steels,* was drawn up by Technical Committee ISO/TC 17, *Steel,* the Secretariat of which is held by the British Standards Institution (BSI).

Work on this question led to the adoption of Draft ISO Recommendation No. 1366, which was circulated to all the ISO Member Bodies for enquiry in December 1967. It was approved, subject to a few modifications of an editorial nature, by the following Member Bodies :

Australia	Hungary	South Africa, Rep. of
Austria	India	Spain
Belgium	Israel	Sweden
Canada	Italy	Switzerland
Colombia	Japan	Thailand
Czechoslovakia	Korea, Rep. of	Turkey
Denmark	Netherlands	U.A.R.
Finland	New Zealand	United Kingdom
France	Norway	U.S.A.
Germany	Romania	U.S.S.R.

The following Member Bodies opposed the approval of the Draft :

Brazil
Poland

This Draft ISO Recommendation was then submitted by correspondence to the ISO Council, which decided to accept it as an ISO RECOMMENDATION.

ISO Recommendation | R 683/XI | October 1970

HEAT-TREATED STEELS, ALLOY STEELS AND FREE-CUTTING STEELS

PART 11

WROUGHT CASE HARDENING STEELS

1. SCOPE

1.1 This ISO Recommendation covers grades of wrought

- unalloyed steels,
- chromium steels,
- manganese-chromium steels,
- nickel-molybdenum steels,
- chromium-molybdenum steels,
- nickel-chromium steels,
- nickel-chromium-molybdenum steels,

usually intended for use in the case hardened condition.

1.2 This ISO Recommendation comprises the three series of steels listed in Table 2 which differ in their sulphur content. The sulphur contents for each series are

- a maximum of 0.035 % for all grades;
- a range of 0.020 to 0.035 % for all grades (steels designated with suffix **a**);
- a range of 0.030 to 0.050 % for unalloyed steels (steels designated with suffix **b**).

The second and third series have improved machinability.

2. REQUIREMENTS

2.1 **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 should be killed. When he so requests, the user should be informed what steelmaking process is being used.

2.2 **Chemical composition and mechanical properties**

2.2.1 The steels covered by this ISO Recommendation should be ordered and delivered in accordance with Table 1.

The type of condition of delivery according to Table 1 should be stated at the time of enquiry and order.

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

Requirements	Types of condition of delivery*																					
	1	2	2(b)	2(c)	2(d)	2(e)	5	5(b)	5(c)	5(d)	5(e)	7	8	8(b)	8(c)	8(d)	8(e)	9	9(b)	9(c)	9(d)	9(e)
Chemical composition	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Hardenability	–	X	X	X	X	X	–	–	–	–	–	–	X	X	X	X	X	–	–	–	–	–
Hardness																						
– maximum value as wrought	–	–	X	–	–	–	–	X	–	–	–	–	–	X	–	–	–	–	X	–	–	–
– maximum value as annealed	–	–	–	X	–	–	–	–	X	–	–	–	–	–	X	–	–	–	–	X	–	–
– range as treated for improved machinability	–	–	–	–	X	–	–	–	–	X	–	–	–	–	–	X	–	–	–	–	X	–
– maximum value as cold drawn	–	–	–	–	–	X	–	–	–	–	X	–	–	–	–	–	X	–	–	–	–	X
Mechanical properties for simulated case-hardened test bars	–	–	–	–	–	–	X	X	X	X	X	–	–	–	–	–	–	X	X	X	X	X
Grain size	–	–	–	–	–	–	–	–	–	–	–	X	X	X	X	X	X	X	X	X	X	X

* The numbers indicating the types of condition of delivery follow a co-ordinated series of numbers throughout all relevant ISO Recommendations.

2.2.2 The chemical compostion expressed by the cast analysis should be in accordance with Table 2.

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

Type of steel	C %	Si %	Mn %	P %** max.	S %**	Cr %	Mo %	Ni %
1 1a 1b	0.07 to 0.13	0.15 to 0.40	0.30 to 0.60	0.035	0.035 max. 0.020 to 0.035 0.030 to 0.050	–	–	–
2 2a 2b	0.12 to 0.18	0.15 to 0.40	0.30 to 0.60	0.035	0.035 max. 0.020 to 0.035 0.030 to 0.050	–	–	–
3 3a 3b	0.12 to 0.18	0.15 to 0.40	0.60 to 0.90	0.035	0.035 max. 0.020 to 0.035 0.030 to 0.050	–	–	–
4 4a	0.17 to 0.23	0.15 to 0.40	0.60 to 0.90	0.035	0.035 max. 0.020 to 0.035	0.70 to 1.00	–	–
5 5a	0.13 to 0.19	0.15 to 0.40	1.0 to 1.30	0.035	0.035 max. 0.020 to 0.035	0.80 to 1.10	–	–
6 6a	0.17 to 0.23	0.15 to 0.40	0.40 to 0.70	0.035	0.035 max. 0.020 to 0.035	–	0.20 to 0.30	1.60 to 2.00
7 7a	0.15 to 0.21	0.15 to 0.40	0.60 to 0.90	0.035	0.035 max. 0.020 to 0.035	0.85 to 1.15	0.15 to 0.25	–
8 8a	0.17 to 0.23	0.15 to 0.40	0.60 to 0.90	0.035	0.035 max. 0.020 to 0.035	0.30 to 0.50	0.40 to 0.50	–
9 9a	0.12 to 0.18	0.15 to 0.40	0.60 to 0.90	0.035	0.035 max. 0.020 to 0.035	0.80 to 1.10	–	1.3 to 1.7
10 10a	0.11 to 0.17	0.15 to 0.40	0.35 to 0.65	0.035	0.035 max. 0.020 to 0.035	1.4 to 1.7	–	1.3 to 1.7
11 11a	0.10 to 0.16	0.15 to 0.40	0.35 to 0.65	0.035	0.035 max. 0.020 to 0.035	0.60 to 0.90	–	2.75 to 3.25
12 12a	0.17 to 0.23	0.15 to 0.40	0.60 to 0.90	0.035	0.035 max. 0.020 to 0.035	0.35 to 0.65	0.15 to 0.24	0.40 to 0.70
13 13a	0.14 to 0.20	0.15 to 0.40	0.60 to 0.90	0.035	0.035 max. 0.020 to 0.035	0.80 to 1.1	0.15 to 0.25	1.2 to 1.6
14 14a	0.11 to 0.17	0.15 to 0.40	0.30 to 0.60	0.035	0.035 max. 0.020 to 0.035	0.80 to 1.1	0.20 to 0.30	3.0 to 3.5
15 15a	0.12 to 0.18	0.15 to 0.40	0.25 to 0.55	0.035	0.035 max. 0.020 to 0.035	1.1 to 1.4	0.20 to 0.30	3.8 to 4.3

* Elements not quoted in Table 2 should 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 should 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.

** By agreement between the purchaser and manufacturer, steels 4 to 15a may be ordered with an upper limit of sulphur and phosphorus less than 0.035 %.

2.2.2.1 If ordered to condition of delivery type 1 or 7 (see Table 1), the following permissible deviations between the values specified in Table 2 and the product analysis of products up to 160 mm (6.3 in) diameter should apply. Above 160 mm (6.3 in) diameter, the permissible deviations should be stated at the time of enquiry and order.

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

Type of steel	Permissible deviations*							
	C %	Si %	Mn %	P %	S %**	Cr %	Mo %	Ni %
1 1a 1b	± 0.02	± 0.03	± 0.04	+ 0.005	± 0.005	–	–	–
2 2a 2b	± 0.02	± 0.03	± 0.04	+ 0.005	± 0.005	–	–	–
3 3a 3b	± 0.02	± 0.03	± 0.04	+ 0.005	± 0.005	–	–	–
4 4a	± 0.02	± 0.03	± 0.04	+ 0.005	± 0.005	± 0.05	–	–
5 5a	± 0.02	± 0.03	± 0.06	+ 0.005	± 0.005	± 0.05	–	–
6 6a	± 0.02	± 0.03	± 0.04	+ 0.005	± 0.005	–	± 0.03	± 0.05
7 7a	± 0.02	± 0.03	± 0.04	+ 0.005	± 0.005	± 0.05	± 0.03	–
8 8a	± 0.02	± 0.03	± 0.04	+ 0.005	± 0.005	± 0.05	± 0.04	–
9 9a	± 0.02	± 0.03	± 0.04	+ 0.005	± 0.005	± 0.05	–	± 0.05
10 10a	± 0.02	± 0.03	± 0.04	+ 0.005	± 0.005	± 0.05	–	± 0.05
11 11a	± 0.02	± 0.03	± 0.04	+ 0.005	± 0.005	± 0.05	–	± 0.07
12 12a	± 0.02	± 0.03	± 0.04	+ 0.005	± 0.005	± 0.05	± 0.03	± 0.03
13 13a	± 0.02	± 0.03	± 0.04	+ 0.005	± 0.005	± 0.05	± 0.03	± 0.05
14 14a	± 0.02	± 0.03	± 0.04	+ 0.005	± 0.005	± 0.05	± 0.03	± 0.07
15 15a	± 0.02	± 0.03	± 0.04	+ 0.005	± 0.005	± 0.05	± 0.03	± 0.07

* ± means that in one cast 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.

** For the steels whose designation has no suffix letter, the permissible deviation is + 0.005 % S.

2.2.2.2 If ordered to condition of delivery other than types 1 and 7, the mechanical properties or hardenability specified in Tables 4, 5 and 6 should be the governing criteria for acceptance. In such cases, the cast analysis may deviate slightly from the values shown in Table 2.

2.2.3 If ordered to condition of delivery types 5(b), 5(c), 5(d), 5(e), 9(b), 9(c), 9(d) or 9(e), the mechanical properties obtained on *one* reference bar of 11, 30 or 63 mm diameter, as stated on the order, should be those shown in Table 4.

The values apply to test pieces taken on simulated case hardened rounds in the direction of the metal fibre, the axis of the test piece corresponding to the requirements of clause 3.2.2.

2.2.4 If the products are delivered in the condition of delivery types 2(b) to 2(e), 5(b) to 5(e), 8(b) to 8(e) or 9(b) to 9(e) of Table 1, the hardness values, measured after preparation of the surface in the conventional manner, according to Table 5 can be agreed in addition to the other requirements.

2.2.5 When ordering on end-quench hardenability (types of condition of delivery 2 to 2(e) and 8 to 8(e) of Table 1), the Rockwell C hardness numbers given in Table 6 and the scatter bands in Figures 1, 2 and 3 apply. The quenching temperatures should be in accordance with the values given in Table 7.

2.2.6 If steel having a controlled grain size is required, as indicated by the types of condition of delivery 7, 8 to 8(e) and 9 to 9(e) of Table 1, then the grain size of the steel, determined in accordance with clause 3.3.6 should be 5 and finer for fine-grained steels and 5 and coarser for coarse-grained steels.

2.2.7 If ordered to condition of delivery types 2(d), 5(d), 8(d) or 9(d), a definite microstructure for improved machinability can be agreed instead of a hardness range at the time of enquiry and order.

3. TESTING

3.1 Number of sample products

3.1.1 *Chemical composition.* The cast analysis is given by the manufacturer. If a product analysis is required by the purchaser, at least one sample product should be taken from each cast.

3.1.2 *Mechanical properties, hardenability and grain size*

3.1.2.1 For material not supplied in the heat-treated condition, one sample product should be taken from each cast for testing in accordance with the requirements of Tables 4, 5 or 6.

3.1.2.2 For material supplied in the heat-treated condition, one sample product should be taken from each size grouping from each heat-treatment batch for testing in accordance with Tables 4, 5 and 6. If the product is continuously heat treated, one sample product for each 15 t or part thereof, but at least one sample product for each cast, should be taken.

3.2 Samples and test pieces

3.2.1 The reference test bar should be manufactured by hot forging the test sample to the nearest smaller diameter of reference test bars (see clause 2.2.3).

3.2.2 The test pieces for tensile test and impact test should be taken from the test bar in the longitudinal direction. The axes of test pieces should correspond to the axes of 11 mm and 30 mm test bars and should be 12.5 mm from the surface of 63 mm test bars.

3.2.3 The bar from which the test piece for the end-quench hardenability test is to be machined should be a forged or rolled round piece 32 mm or 30 mm in diameter, representing the full cross-section of the product. Larger cross-sections should 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 should be in accordance with ISO Recommendation R 642, *Hardenability test by end quenching steel (Jominy test).*

3.2.4 For product analyses, the selection of samples should be carried out in conformity with the requirements of ISO Recommendation R 377, *Selection and preparation of samples and test pieces for wrought steel.*

3.2.5 For grain size measurements, the sampling should be agreed at the time of enquiry and order.

3.2.6 General conditions for selection and preparation of test samples and test pieces for steel should be in accordance with ISO Recommendation R 377.

3.3 Test methods

3.3.1 The tensile test should be made in accordance with ISO Recommendation R 82, *Tensile testing of steel.*

3.3.2 The impact test should be made in accordance with ISO Recommendation R 83, *Charpy impact test (U-notch) for steel.* Unless otherwise specified at the time of enquiry and order, the impact value should 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.

3.3.3 The end-quench hardenability test should be made in accordance with ISO Recommendation R 642. The temperatures for quenching should be in accordance with Table 7.

3.3.4 The Brinell hardness test should be made in accordance with ISO Recommendation R 79*, *Brinell hardness test for steel.* The rockwell C scale hardness test should be made in accordance with ISO Recommendation R 80*, *Rockwell hardness test (B and C scales) for steel.*

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

3.3.6 The determination of grain size should be made in accordance with ISO Recommendation R 643, *Micrographic determination of the austenitic grain size of steels.*

3.4 Retests

3.4.1 For retests for mechanical properties, clause 6.5 of ISO Recommendation R 404, *General technical delivery requirements for steel,* is valid.

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

3.5 Certification of the tests

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

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

4. DEFECTS AND DIMENSIONAL TOLERANCES

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

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

* 2nd edition, 1968.

TABLE 4 – **Mechanical properties for reference test bars in the simulated case hardened condition***

Type of steel	11 mm diameter			30 mm diameter				63 mm diameter			
	R_e min.	R_m	A min.	R_e min.	R_m	A min.	KCU min.	R_e min.	R_m	A min.	KCU min.
	kgf/mm² (tonf/in²)	kgf/mm² (tonf/in²)	%	kgf/mm² (tonf/in²)	kgf/mm² (tonf/in²)	%	kgf.m/cm²	kgf/mm² (tonf/in²)	kgf/mm² (tonf/in²)	%	kgf.m/cm²
1, 1a	30 (19.0)	50 to 85 (31.7 to 53.9)	13	25 (15.8)	40 to 70 (25.4 to 44.5)	15	7	–	–	–	–
1b	30 (19.0)	50 to 85 (31.7 to 53.9)	13	25 (15.8)	40 to 70 (25.4 to 44.5)	15	–	–	–	–	–
2, 2a	35 (22.2)	60 to 95 (38.1 to 60.3)	12	27 (17.1)	45 to 75 (28.6 to 47.6)	14	6	–	–	–	–
2b	35 (22.2)	60 to 95 (38.1 to 60.3)	12	27 (17.1)	45 to 75 (28.6 to 47.6)	14	–	–	–	–	–
3, 3a	40 (25.4)	65 to 100 (41.3 to 63.5)	10	30 (19.0)	50 to 80 (31.7 to 50.8)	12	5	–	–	–	–
3b	40 (25.4)	65 to 100 (41.3 to 63.5)	10	30 (19.0)	50 to 80 (31.7 to 50.8)	12	–	–	–	–	–
4, 4a	55 (34.9)	85 to 120 (53.9 to 76.2)	10	40 (25.4)	60 to 90 (38.1 to 57.1)	13	5	30 (19.0)	50 to 75 (31.7 to 47.6)	16	5
5, 5a	65 (41.3)	95 to 130 (60.3 to 82.5)	9	50 (31.7)	80 to 110 (50.8 to 69.8)	10	5	45 (28.6)	70 to 95 (44.4 to 60.3)	12	5
6, 6a	60 (38.1)	90 to 125 (57.1 to 79.3)	9	45 (28.6)	65 to 95 (41.3 to 60.3)	12	6	40 (25.4)	60 to 85 (38.1 to 53.9)	14	6
7, 7a	70 (44.4)	105 to 140 (66.6 to 88.9)	8	55 (34.9)	85 to 115 (53.9 to 73.0)	10	5	50 (31.7)	75 to 105 (47.6 to 66.6)	11	5
8, 8a	65 (41.3)	95 to 130 (60.3 to 82.5)	9	50 (31.7)	75 to 105 (47.6 to 66.7)	11	5	45 (28.6)	65 to 90 (41.3 to 57.1)	13	5
9, 9a	65 (41.3)	100 to 135 (63.5 to 85.7)	8	55 (34.9)	85 to 115 (53.9 to 73.0)	10	5	50 (31.7)	75 to 105 (47.6 to 66.6)	11	5
10, 10a	70 (44.4)	105 to 140 (66.6 to 88.9)	8	65 (41.3)	95 to 125 (60.3 to 79.4)	9	5	55 (34.9)	85 to 115 (53.9 to 73.0)	10	5
11, 11a	65 (41.3)	100 to 135 (63.5 to 85.7)	8	60 (38.1)	90 to 120 (57.1 to 76.2)	10	6	55 (34.9)	80 to 110 (50.8 to 69.8)	11	6
12, 12a	65 (41.3)	100 to 135 (63.5 to 85.7)	8	50 (31.7)	75 to 105 (47.6 to 66.7)	11	6	–	65 to 90 (41.3 to 57.1)	13	6
13, 13a	75 (47.6)	110 to 145 (69.8 to 92.1)	8	65 (41.3)	95 to 125 (60.3 to 79.4)	9	5	55 (34.9)	85 to 115 (53.9 to 73.0)	10	5
14, 14a	80 (50.8)	115 to 150 (73.0 to 95.2)	8	75 (47.6)	110 to 140 (69.8 to 88.9)	8	5	65 (41.3)	95 to 125 (60.3 to 79.4)	9	6
15, 15a	90 (57.1)	130 to 165 (82.5 to 104.8)	7	85 (53.9)	125 to 155 (79.4 to 98.4)	7	5	80 (50.8)	120 to 150 (76.2 to 95.2)	8	5

* R_e = yield stress (0.2 % proof stress)
R_m = tensile strength
A = percentage elongation after fracture ($L_o = 5\ d_o$)
KCU = impact strength with U-notch.

TABLE 5 – **Maximum hardness for products delivered in conditions of delivery types 2(b) to 2(e), 5(b) to 5(e), 8(b) to 8(e) or 9(b) to 9(e) of Table 1**

Type of steel	HB maximum in condition				
	as wrought	annealed	treated for improved machinability		cold-drawn
			min.	max.	
1, 1a, 1b	If required, to be agreed between purchaser and manufacturer at the time of enquiry and order	131	–	–	will be approximately 50 HB higher than that for the annealed condition
2, 2a, 2b		143	–	–	
3, 3a, 3b		156	–	–	
4, 4a		197	149	197	
5, 5a		207	156	207	
6, 6a		207	156	207	
7, 7a		207	156	207	
8, 8a		207	156	207	
9, 9a		207	156	207	
10, 10a		217	170	217	
11, 11a		229	179	229	
12, 12a		212	161	212	
13, 13a		229	179	229	
14, 14a		241	192	241	
15, 15a		255	207	255	

TABLE 6 – **Tentative hardness limits for specified hardenability***

Distance from quenched end of test piece	Hardness HRC																							
	Steels 4, 4a		Steels 5, 5a		Steels 6, 6a		Steels 7, 7a		Steels 8, 8a		Steels 9, 9a		Steels 10, 10a		Steels 11, 11a		Steels 12, 12a		Steels 13, 13a		Steels 14, 14a		Steels 15, 15a	
mm	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	40	48	38	46	40	48	39	47	40	48	38	46	38	46	37	45	40	48	39	47	38	46	39	47
3	34	46	36	46	36	45	38	47	36	47	35	46	37	46	36	45	37	47	38	46	37	46	39	47
5	28	41	32	44	27	41	35	46	30	43	32	44	37	46	34	44	32	44	36	45	36	46	39	47
7	22	35	29	42	23	37	32	44	26	39	30	42	35	45	31	42	27	41	33	44	35	45	39	47
9	–	31	26	39	21	33	29	41	23	36	28	40	33	44	29	41	23	35	31	44	34	45	39	47
11	–	28	24	37	–	29	26	39	20	34	26	38	30	42	27	39	–	32	29	43	33	44	38	46
13	–	26	22	34	–	27	23	36	–	32	24	37	28	40	25	38	–	30	27	42	31	43	38	46
15	–	24	20	33	–	25	22	35	–	30	22	35	26	39	23	37	–	29	26	41	30	43	38	46
20	–	21	–	30	–	22	20	33	–	27	20	32	24	37	20	35	–	26	23	38	26	41	37	45
25	–	–	–	28	–	21	–	31	–	25	–	30	22	35	–	32	–	24	21	36	24	39	36	45
30	–	–	–	27	–	21	–	30	–	24	–	29	21	34	–	29	–	23	20	35	23	37	35	44
35	–	–	–	27	–	20	–	29	–	23	–	28	20	34	–	29	–	23	20	34	22	36	34	44
40	–	–	–	27	–	20	–	28	–	22	–	27	–	34	–	28	–	22	–	34	21	35	33	44
45	–	–	–	26	–	20	–	28	–	22	–	26	–	33	–	28	–	22	–	33	21	35	31	43
50	–	–	–	25	–	–	–	28	–	22	–	26	–	33	–	27	–	22	–	33	20	34	30	43

* The hardness values are tentative and may be adjusted as more information becomes available. The hardness values are based on steels having a grain size of 5 and finer, as defined in ISO Recommendation R 643, *Micrographic determination of the austenitic grain size of steel.*

TABLE 7 – **Conditions for heat treating test bars**

Type of steel	End quench test	Simulated case hardening test		
	Quenching* °C	Quenching* °C	Quenching agent	Tempering** °C
1, 1a, 1b	–	900 ± 10	Water	180 ± 10
2, 2a, 2b	–	890 ± 10		180 ± 10
3, 3a, 3b	–	890 ± 10		180 ± 10
4, 4a	900 ± 5	890 ± 10	Oil	180 ± 10
5, 5a	900 ± 5	880 ± 10		180 ± 10
6, 6a	900 ± 5	870 ± 10		180 ± 10
7, 7a	900 ± 5	880 ± 10		180 ± 10
8, 8a	900 ± 5	900 ± 10		180 ± 10
9, 9a	900 ± 5	870 ± 10		180 ± 10
10, 10a	900 ± 5	870 ± 10		180 ± 10
11, 11a	850 ± 5	860 ± 10		180 ± 10
12, 12a	900 ± 5	880 ± 10		180 ± 10
13, 13a	900 ± 5	870 ± 10		180 ± 10
14, 14a	850 ± 5	850 ± 10		180 ± 10
15, 15a	850 ± 5	840 ± 10		180 ± 10

* Time for austenitizing as a guide : 0.5 hour minimum.

** Time for tempering as a guide : 1 hour minimum.

TABLE 8 – **Conditions for treatment of the steels**

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

Type of steel	Carburizing* temperature °C	Core hardening** temperature °C	Case hardening temperature °C	Quenching agent	Tempering*** °C
1, 1a, 1b	880 to 950	880 to 920	770 to 810	Water	150 to 200
2, 2a, 2b	880 to 950	870 to 910	770 to 810	Water	150 to 200
3, 3a, 3b	880 to 950	870 to 910	770 to 810	Water, oil	150 to 200
4, 4a	880 to 950	870 to 910	790 to 830	Oil	150 to 200
5, 5a	880 to 950	860 to 900	800 to 840	Oil	150 to 200
6, 6a	880 to 950	850 to 890	780 to 820	Oil	150 to 200
7, 7a	880 to 950	860 to 900	800 to 840	Oil	150 to 200
8, 8a	880 to 950	880 to 920	800 to 840	Oil	150 to 200
9, 9a	880 to 950	850 to 890	780 to 820	Oil	150 to 200
10, 10a	880 to 950	850 to 890	800 to 840	Oil	150 to 200
11, 11a	880 to 950	840 to 880	780 to 820	Oil	150 to 200
12, 12a	880 to 950	860 to 900	800 to 840	Oil	150 to 200
13, 13a	880 to 950	850 to 890	790 to 830	Oil	150 to 200
14, 14a	880 to 950	830 to 870	760 to 800	Oil	150 to 200
15, 15a	880 to 950	820 to 860	750 to 790	Oil, air	150 to 200

* The carburizing temperature will depend on the chemical composition of the steel, the mass of the product, and the carburizing medium.

** If the steels are direct hardened, they should be quenched from a temperature between the core hardening and case hardening temperatures.

*** Time for tempering as a guide : 1 hour minimum.

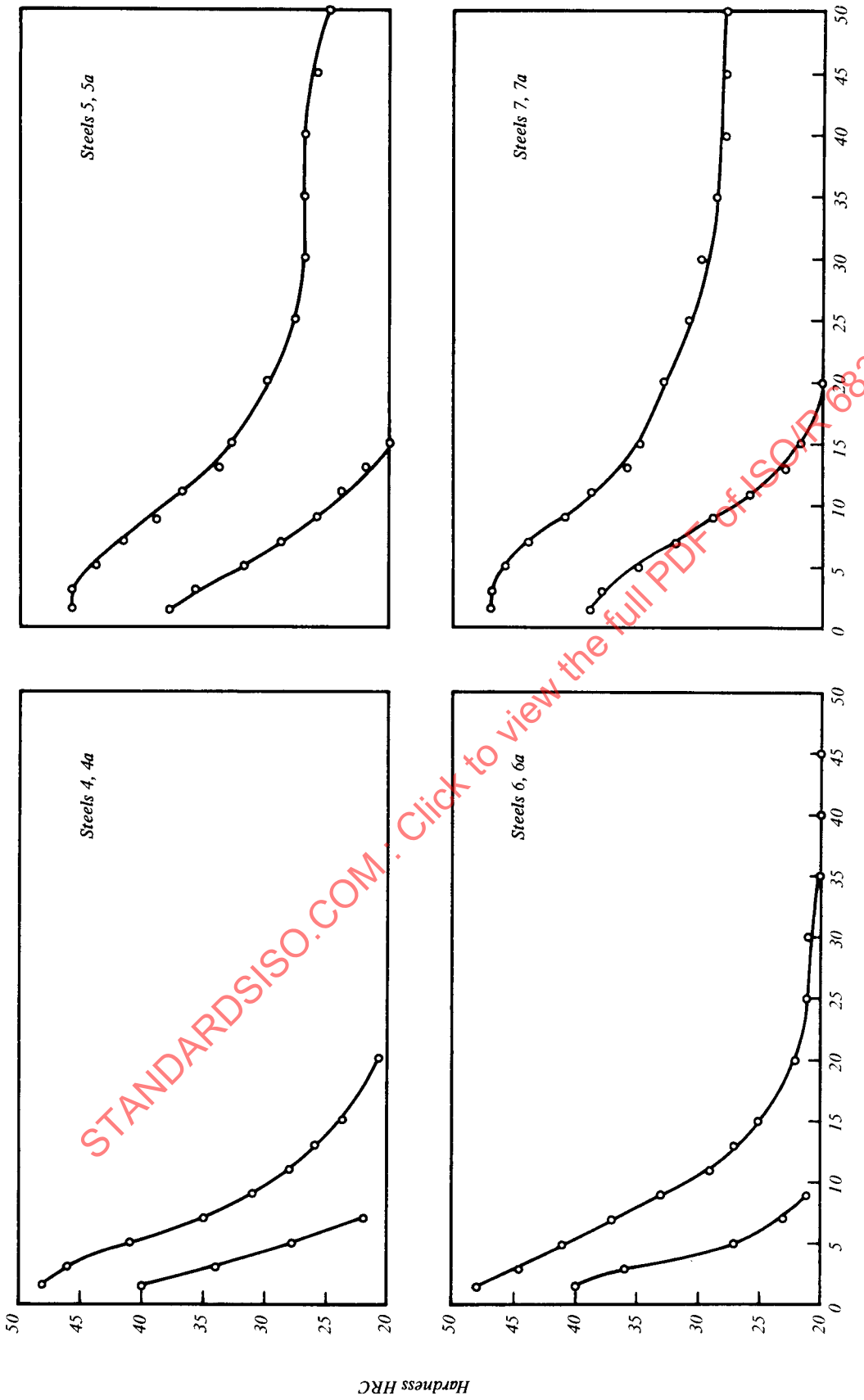

FIG. 1 – Scatter bands for end quench hardenability :
Steels 4 and 4a, 5 and 5a, 6 and 6a, 7 and 7a