Item 2.1

5. revision of IS 11587

Please find the draft as given at Appendix-1

Item 2.1

16. revision of IS 4368

Please find the draft as given at Appendix-2

Appendix-1

Draft Indian Standard

SPECIFICATION FOR STRUCTURAL WEATHER RESISTANT STEELS

(First Revision)

ICS 77.140.20

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

Wrought Steel Products Sectional Committee, MTD 4

FOREWORD

This Indian Standard (First Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by Wrought Steel Products Sectional Committee had been approved by the Metallurgical Engineering Division Council.

This standard was first published in 1986. While reviewing the standard, in the light of experience gained during these years, the Committee decided to revise it to bring in line with that present practices being followed by the Indian industry.

The atmospheric corrosion resistance of these steels is approximately four times to that of carbon structural steel. Welding is of fundamental importance, and it is pre-supposed that suitable welding procedures will be adopted for welding the steels. These steels are intended for applications where weight saving along with improved atmospheric corrosion resistance is important.

The Indian Standards referred in this standard are subject to revision and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards

In this revision the following changes have been made:

a) Chemical and mechanical properties have been modified; Permissible Variation for Product Analysis also modified;
b) New grade designation system has been adopted; simultaneously old designations have also been given in Annex A;
c) New grades have been added;
d) Some of the Clauses are rearranged and modified.
e) Amendment No. 1 has been incorporated.

For all the tests specified in this standard (chemical/physical/others), the method as specified in relevant ISO Standard may also be followed as an alternate method.

In the formulation of this standard, due consideration has been given to the trade practices followed in the country in this field. Due consideration has also been given to international co-ordination among the standards prevailing in different countries:

ISO 630-5: 2014 ‘Structural steels with improved atmospheric corrosion resistance’,
ISO 5952: 2019 ‘Hot Rolled Structural quality with improved atmospheric corrosion resistance’,
DIN EN 10025-5: 2019 ‘Structural steels with improved atmospheric corrosion resistance’,
ASTM A606: 2018 ‘Hot-Rolled and Cold-Rolled, with Improved Atmospheric Corrosion Resistance’
ASTM A709: 2021 ‘Standard Specification for Structural Steel for Bridges’
ASTM A871:2020 ‘High-Strength Low-Alloy Structural Steel Plate with Atmospheric Corrosion Resistance’,
JIS G 3125: 2021 ‘Superior atmospheric corrosion resisting rolled steels’

The composition of the Committee responsible for the formulation of this standard is given in Annex B.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2: 1960 ‘Rules for rounding off numerical values (revised). The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard
SPECIFICATION FOR STRUCTURAL WEATHER RESISTANT STEELS
(First Revision)

1 SCOPE

1.1 This standard covers the requirements for hot-rolled and cold-rolled structural weather resistant steels (flat and long products) in the form of plates, sheets, strips, sections, flats, bars and rods for welded, riveted or bolted construction requiring atmospheric corrosion resistance.

1.2 The grades in this standard except ISH310WR contain additional alloying elements and provide a level of corrosion resistance substantially better than that of carbon steels with or without copper addition. When properly exposed to the atmosphere, steel can be used bare (unpainted) for many applications.

1.3 ISH 340WP available in 2 grades: Grade1 for sheets and plates (in flat or coil form): Intended for structural purposes where guaranteed mechanical properties, weldability and suitability for forming simple cold pressed parts are required. Grade2 for sheets, plates (in flat or coil form) and sections: Intended for general engineering purposes with guaranteed mechanical properties and weldability.

1.4 The guidelines for thicknesses in which products of the steel grades and qualities specified in this document can be supplied are given in Table A below. However, max thickness grade wise as per table 3A will be applicable.

Table A — Product forms for the different steel grades with improved atmospheric corrosion resistance depending on their thickness

Designation	Flat products Nominal thickness, mm			Long products Nominal thickness or diameter, mm		
				Sections	Bars	Rods
	≤ 16	≤ 100	≤ 200	≤ 63	≤ 150	≤ 60
ISH235WR, ISH245WR, ISH310WR, ISH345WR, ISH355WR, ISH365WR1, ISH365WR2			Yes	Yes	Yes	Yes
ISH245WP, ISH340WP, ISH355WP, ISH360WP	Yes			Yes		
ISH400WR, ISH415WR, ISH450WR, ISH460WR1, ISH460WR2, ISH500WR, ISH600WR, ISH700WR		Yes		Yes		

2 REFERENCES

The following standards contain provisions, which through reference in this text constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below:

IS No.	*Title*
228(in various parts)	Methods of chemical analysis of steels
808: 2021	Dimensions for hot rolled steel beam, channel and angle sections (*fourth revision*)
1173: 1978	Specification for hot rolled and slit steel tee bars (*second revision*)
1252:1991	Hot rolled steel bulb angles –Dimensions (*first revision*)
1599: 2019/ ISO 7438: 2016	Metallic materials – Bend test (*fourth revision*)
1608(Part 1): 2022/ ISO 6892-1: 2019	Metallic materials – Tensile testing - Part 1 Method of test at room temperature (*fifth revision*)
1730: 1989	Steel plates, sheets, strips and flats for structural and general engineering purposes – Dimensions (*second revision*)
1732:1989	Steel bars, round and square for structural and general engineering purposes – Dimensions *(second revision)*
1757(Part 1): 2020/ ISO 148-1: 2016	Metallic materials – Charpy pendulum impact test Part 1 Test method (*fourth revision*)
1852:1985	Specification for rolling and cutting tolerances for hot rolled steel Products (*fourth revision*)
1863:1979	Specification for rolled steel bulb flats (*first revision*)
1956 (various parts)	Glossary of terms relating to iron and steel (*second revision*)
2314:1986	Specification for steel sheet piling sections (*first revision*)
3803 (Part 1): 1989	Steel – Conversion of elongation values: Part 1 Carbon and low alloy steels (*second revision*)
3954:1991	Hot rolled steel channel sections for general engineering purposes – Dimensions (*first revision*)
4923:2017	Hollow steel sections for structural use – Specification (*third revision*)
8910: 2022/ ISO 404: 2013	General technical delivery requirements for steel and steel products (*second revision*)
12779: 1989	Rolling and cutting tolerances for hot rolled parallel flange beam and column sections
10842 (Part 2): 2019	Destructive Tests on Welds in Metallic Materials - Cold Cracking Tests for Weldments — Arc Welding Processes part 2 self-Restraint Tests (*first revision*)
IS 4225:2022/ ISO 17557:2016	Steel — Ultrasonic Testing of Steel Flat Products of Thickness Equal to or Greater than 6 mm
IS/ISO 16160: 2012	Hot-rolled steel sheet products — Dimensional and shape tolerances (*first revision*)
IS/ISO 16162: 2012	Cold-rolled steel sheet products — Dimensional and shape tolerances (*first revision*)
IS 4748:2021/ ISO 643:2019	Steels - Micrographic determination of the apparent grain size

3 TERMINOLOGY

For the purpose of this standard the definitions given in IS 1956 and the following definitions shall apply.

3.1 As-rolled - Delivery condition without any special rolling i.e. Conventional hot rolling without any normalized rolling or thermos-mechanical rolling and/or heat treatment like normalizing or quenching.

3.2 Normalizing Rolling – A hot rolling process in which the final deformation is carried out within a certain temperature range equivalent to normalizing temperature, leading to a material condition equivalent to that obtained after normalizing, such that the specified mechanical properties would still be met in the event of any subsequent normalizing.

NOTE In international publications for both the normalizing rolling, as well as the thermo-mechanical rolling, the expression "controlled rolling" may be found. However, in view of the different applicability of the products a distinction of the terms is necessary.

3.3 Normalized– Produced by heating to a suitable temperature above the transformation range (austenitizing) followed by air cooling.

3.4 Thermo-Mechanical Rolling –A hot rolling process in which the final deformation is carried out in a certain temperature range leading to a material condition with certain properties that cannot be achieved or repeated by heat treatment alone.

Note: The term "Thermo-Mechanical Control Process" can also be used.

NOTE 1 Subsequent heating above 580 °C may lower the strength values.

NOTE 2 Thermo-mechanical rolling can include processes with an increasing cooling rate with or without tempering including self-tempering but excluding direct quenching and quenching and tempering.

NOTE 3 In some publications the word TMCP (Thermo-mechanical Control Process) is also used.

3.5 Steel with improved atmospheric corrosion resistance (Weather resistance steels) –
Steel in which a certain number of alloying elements, such as P, Cu, Cr, Ni, etc., have intentionally been added in order to increase its resistance to atmospheric corrosion, by forming an auto-protective oxide layer on the base metal under the influence of weather conditions; these steels are commonly known as "weathering steels"

4 SUPPLY OF MATERIALS

General requirements relating to the supply of material shall conform to IS 8910.

5 DESIGNATION AND GRADES

5.1 Weathering Steels covered by this standard shall be designated by their yield strength.
This standard specifies

- 19 steel grades are covered in Table 1A, 3A, 4 and 5 for hot rolled steel (designated by ISH) and
- 2 steel grades are covered in Table 1B, 3B and 4 for cold rolled steel (designated by ISC).

Grades are subdivided into classes WR and WP which differ primarily in their phosphorus contents; grades ISH365 and ISH460 are subdivided into classes WR1 and WR2 which differ primarily in alloying element requirements for Si, Cr, Cu, and Ni (see Table 1A).
Class WR denotes weathering steel has an improved atmospheric corrosion resistance; class WP denotes weathering steel with higher levels of phosphorus.

Each grade is available in up to four (4) qualities. These grades and qualities differ in their specified mechanical properties and impact energy requirements. The qualities on basis of impact energy requirements are as follows:

— Quality A: no impact testing
— Quality BR: impact testing at +20 °C
— Quality B0: impact testing at 0 °C
— Quality C and C1: impact testing at –20 °C

NOTE Quality C1 specifies a higher minimum impact energy than C.

5.2 Application

Class A steels satisfy only moderate loading conditions (Applicable to ISH355WP).

Class B steels are intended for use in welded structures or structural parts, subjected to normal loading conditions (Applicable to ISH235WR, ISH245WR and ISH365WR1).

Class C steels are to be used in cases where, owing to loading conditions and the general design of the structure, some resistance to brittle fracture is necessary (Applicable to ISH355WR).

Class D steels are to be used for structures or structural parts where, owing to loading conditions and the general design of the structure, a high resistance to brittle fracture is necessary (Applicable to ISH235WR, ISH245WR, ISH355WR, ISH355WP and ISH365WR1).

5.3 Basis for order

While placing an order for the purchase of material covered by this standard, the purchaser should specify the following:

a) Designation (Grade and Quality for Hot rolled steel. Grade for Cold rolled steel);
b) Product Form (plate, section, bar, sheet or strip);
c) Quantity (mass or number);
d) Nominal dimensions - thickness, width and length (for cut lengths);
e) Condition;
f) Quality (A, BR, B0 and C or C1)

6 MANUFACTURE

6.1 The manufacturing process of the steel is left to the discretion of the manufacturer or as per agreement between manufacturer and purchaser. If required, secondary refining in the form of ladle refining, vacuum degassing may follow steel making.

6.2 The method of deoxidation are designated as follows:
— FN - Rimming steel not permitted. This Option is applicable to Qualities A, BR and B0;
— FF - Fully killed steel containing nitrogen binding elements in amounts sufficient to bind the available nitrogen (for example, minimum 0.020% total aluminium). The usual guideline is minimum aluminium to nitrogen ratio of 2:1, when no other nitrogen binding elements are present. This Option shall be applicable to Qualities C & C1. On mutual agreement Qualities A, BR and B0 can be used this option.

6.3 The products may be rolled and supplied in as-rolled or normalized or normalizing rolling or controlled rolling or thermo-mechanical rolling and accelerated cooling conditions as per the agreement between the purchaser and the manufacturer/supplier.

6.4 The manufacturer can supply sheets, plates and sections either in hot rolled and if required in as skin passed or cold rolled and annealed condition only or hot rolled followed by cold finishing or cold rolled and annealed. In case of cold rolled finished supply, there shall, however, be no adverse effects on the properties of the product. The manufacturing process adopted for cold rolling/finishing shall be furnished by the supplier.

6.5 Hot rolled sheets and strips shall be descaled if so requested by the purchaser, using either acid pickling or shot blasting. Hot rolled and cold rolled Steel sheets and strips which have been descaled by acid pickling or shot blasting shall be oiled, if so requested by the purchaser.

6.6 Surface condition

Oxide or scale in hot-rolled steel sheet is subject to variations in thickness, adherence and colour. Removal of the oxide or scale by pickling or blast cleaning may disclose surface imperfections not readily visible prior to this operation.

6.7 Oiling

As a deterrent to rusting, a coating of oil is usually applied to hot-rolled, descaled steel sheet, but sheet may be furnished unoiled, if required. The oil is not intended as a forming lubricant and shall be easily removable with degreasing chemicals. When requested, the manufacturer shall advise the purchaser which type of oil has been used.

6.8 Corrosion resistance

The resistance of these steels to atmospheric corrosion is due to the formation of a protective oxide layer. The formation of this protective layer depends not only on chemical composition, such as the distinctive differences between the analyses of the various grades, but also on a number of factors such as surrounding atmosphere, design, etc., over which the steel producer has no control. See Annexes B and C for information on estimating the corrosion resistance and cautions concerning the use of these steels.

7 CHEMICAL COMPOSITION

7.1 Ladle Analysis

The ladle analysis or heat analysis of the steel, when carried out by the method specified in the relevant parts of IS 228 or any other established instrumental/chemical method, shall conform to the requirements as given in Table 1A and Table 1B. This analysis shall be made from a test sample, preferably taken during casting/teeming of the heat. In case of dispute, the procedure given in IS 228 and its relevant parts shall be the referee method and where test methods are not specified shall be as agreed to between the purchaser and the manufacturer/supplier. The ladle analysis shall be reported in the test certificate.

The ladle analysis shall be determined once per cast.

7.2 Product Analysis

The permissible variation in the case of product analysis from the limits specified in Table 1A and Table 1B shall be as given in Table 2.

7.2.1 If a product analysis has been agreed upon at the time of enquiry and order, the purchaser shall specify the frequency if not once per cast. The product analysis shall be carried out on the finished product from the standard position.

7.3 Carbon equivalent value (CEV)

Steel grades specified are of weldable quality. If agreed to between the manufacturer/supplier and the purchaser, the weather resistant steel up to and including 50 mm thick plates,

- for steel grade ISH235WR, a maximum carbon equivalent value of 0.44 %, and
- for steel grade ISH355WR, a maximum carbon equivalent value of 0.54 % based on heat analysis shall apply.

For other grades CEV may be mutually agreed between purchaser and supplier. The carbon equivalent value can be calculated using the formula:

$$\text{Carbon equivalent value (CEV)} = C + \frac{Mn}{6} + \frac{(Cr+Mo+V)}{5} + \frac{(Ni+Cu)}{15}$$

7.3.1 If the weather resistant steels are to be used unpainted, it is advisable to select the welding electrodes with matching weathering characteristics.

7.3.2 Lower limits for carbon equivalent values may be agreed to between the contracting parties.

7.3.3 Weldability

The steels specified in this document do not have unlimited suitability for the various welding processes, since the behavior of a steel during and after welding depends not only on the material but also on the dimensions and shape and on the manufacturing and service conditions of the components.

If filler metal without improved atmospheric corrosion resistance is used ensure that the weld itself is weather resistant.
Before welding, any surface layer which has already been formed should be removed to a distance of 10 mm to 20 mm from the joint edges.

General requirements for arc welding of the steels specified in this document shall be as given in IS 10842 part2.

For Grade ISH340WP and ISC300WP - The Plates and sections shall be suitable for gas and metal arc welding. The Sheets shall be suitable for gas and metal arc welding as well as suitable for spot and seam welding processes. Special precautions should be taken when welding steel grades of class WP with a high phosphorus content.

NOTE
1) With increasing product thickness and strength level cold cracking can occur. Cold cracking is caused by the following factors in combination:
— The amount of diffusible hydrogen in the weld metal;
— A brittle structure of the heat affected zone;
— Significant tensile stress concentrations in the welded joint.
2) Special precaution should be taken when welding grades ISH245WP, ISH340WP, ISH355WP, ISH360WP, ISC300WP and ISC315WP with a high phosphorous content.
3) In case of assembling by riveting and bolting, precautions should be taken with regard to the choice of rivets and bolts to be used for assemblies in order to prevent the start of the corrosion process.

Table 1A Chemical Composition for Hot Rolled Steel

(*Clauses 5.1, 7.1 and 7.2*)

Designation		Ladle Analysis, Percent, Max											
Grade	Quality	C	Si	Mn	P [b]	S [b]	N	Addition of "N" binding elements [c]	Cr	Cu	Ni	V	Others
ISH235WR	B0 C	0.13	0.40	0.20-0.60	0.035	0.035 0.030	0.009 [d, e] -	- Yes	0.40-0.80	0.25-0.55	0.65	-	
ISH245WR	A, BR, B0	0.18	0.15-0.65	1.25	0.035	0.035	-	Yes	0.45-0.75	0.30-0.50	0.05-0.30	-	
ISH245WP	A	0.15	0.10 min	0.55	0.06-0.16	0.040	-	-	0.24-1.31	0.20-0.60	0.20-0.70	-	
ISH310WR	A	0.22	-	1.25	-	0.040	-	-	-	0.20 min	0.65	-	
ISH340WP [h]	A	0.10	0.28-0.72	0.25-0.45	0.075-0.14	0.030	-	-	0.35-0.60	0.30-0.60	0.20-0.47	0.05	Mo-0.05, Nb-0.04, Al-0.08
ISH345WR	BR	0.23	0.40	0.50-1.60	0.035	0.045	-	-	0.35	0.60	0.45	0.15	Mo-0.15, Nb-0.05
ISH355WR [g]	A, BR, B0 C, C1	0.19 0.16	0.15-0.50	0.50-1.50	0.035 0.030	0.035 0.030	0.009 [d, e] -	- Yes	0.40-0.80	0.25-0.55	0.65	0.10	Mo-0.30, Zr-0.15
ISH355WP [g]	B0 C	0.12	0.20-0.75	0.60 [f]	0.070-0.15	0.035 0.030	0.009 [e]	- Yes	0.30-1.25	0.25-0.55	0.65	-	
ISH360WP [g]	C	0.17	0.40	1.0	0.07-0.10	0.050	-	-	0.70-1.0	0.25-0.55	0.65	0.10	
ISH365WR 1	A, BR, B0	0.18	0.15-0.65	1.40	0.035	0.035	-	Yes	0.45-0.75	0.30-0.50	0.05-0.30	-	
ISH365WR 2	A, BR, B0	0.18	0.55	1.40	0.035	0.035	-	Yes	0.30-0.55	0.20-0.35	-	-	
ISH400WR	BR	0.15	0.15-0.55	2.00	0.020	0.006	0.006	Yes	0.45-0.75	0.30-0.50	0.05-0.30		
ISH415WR	B0, C, C1	0.20	0.15-0.50	0.50-1.35	0.040	0.050	-	Yes	0.30-0.70	0.20-0.50	0.50	0.01-0.10	Mo-0.10, Nb-0.05
ISH450WR	B0, C, C1	0.20	0.15-0.50	0.50-1.35	0.040	0.050	-	Yes	0.30-0.70	0.20-0.50	0.50	0.01-0.10	Mo-0.10, Nb-0.05
ISH460WR 1	B0	0.18	0.15-0.65	1.40	0.035	0.035	-	Yes	0.45-0.75	0.30-0.50	0.05-0.30	-	
ISH460WR 2	B0	0.18	0.55	1.40	0.035	0.035	-	Yes	0.30-0.55	0.20-0.35	-	-	
ISH500WR	B0	0.11	0.15-0.55	2.0	0.020	0.006	0.006	Yes	0.45-0.75	0.30-0.50	0.05-0.30	-	
ISH600WR	BR, B0	0.11	0.15-0.55	2.0	0.020	0.006	0.006	Yes	0.45-0.75	0.30-0.50	0.05-0.30	0.05	Mo-0.30, Nb-0.05
ISH700WR	C	0.11	0.15-0.55	2.0	0.015	0.006	0.006	Yes	0.45-1.20	0.30-1.50	0.05-2.0	0.05	Mo-0.60, B-0.005

Notes

a) When the steel is killed by aluminium the total aluminium content should not be less than 0.02 percent. When steel is silicon killed the silicon content shall not be less than 0.1 percent. When the steel is aluminium silicon killed the silicon content shall not be less than 0.03 percent and total aluminium content shall not be less than 0.01 percent. (see 6.2 for killing options).

b) For long products, the P and S content can be 0,005% higher.

c) The steel shall contain at least one of the following elements: At total ≥0.020 %, Nb: 0.015 % to 0.060 %, V: 0.02 % to 0.15%, Ti: 0.02 % to 0.10 %. If these elements are used in combination, at least one of them shall be present with the minimum content indicated.

d) It is permissible to exceed the specified values provided that for each increase of 0,001 % N, the maximum P content shall be reduced by 0,005 %; the N content of the ladle analysis, however, shall not be more than 0,012 %.
e) The maximum value for nitrogen does not apply if the chemical composition shows a minimum total A1 content of 0,020 %, or if sufficient, other N binding elements are present. The N binding elements shall be mentioned in the inspection document.
f) The upper limit of Mn may be 1.0% *Max* by agreement between the purchaser and the supplier.
g) Chemical composition for thicknesses over 16 mm is subject to agreement between the manufacturer and the purchaser.
h) Total incidental elements shall be 0.15 max
i) Any element other than those listed in this table, which is added intentionally, shall be indicated to the purchaser.
j) Restricted chemistry can be agreed mutually between purchaser and supplier.

Table 1B Chemical Composition for Cold Rolled Steel

(*Clauses 5.1, 7.1 and 7.2*)

Designation	Ladle Analysis, Percent, Max										
Grade	C	Si	Mn	P	S	N	Cr	Cu	Ni	V	Others
ISC300WP	0.10	0.28-0.72	0.25-0.45	0.075-0.14	0.030	-	0.35-0.60	0.30-0.60	0.20-0.47	0.05	Mo-0.05, Nb-0.04, Al-0.08
ISC315WP	0.12	0.20-0.75	0.60	0.070-0.15	0.035	0.009	0.30-1.25	0.25-0.55	0.65	-	

Table 2 Permissible Variation for Product Analysis

(*Clause 7.2*)

Element	Range of specified element, %	Permissible Variation Over/Under the Specified Limit, % max
Carbon	≤0.15	0.03 [b]
	>0.15≤0.22	0.04
Silicon	≤0.80	0.06 [b]
Manganese	≤ 2.00	0.10 [b]
Phosphorus	≤ 0.04	0.01 [b]
	Over 0.04 to 0.15	[a]
Sulfur	≤ 0.05	0.01 [b]
Vanadium	≤0.10	0.01
	>0.10≤0.25	0.02
Niobium	≤ 0.06	0.01
Titanium	≤ 0.15	0.01
Copper	≤ 1.00	0.03
	Over 1.00 to 1.20	0.05
Nickel	≤ 1.00	0.03
	>1.00≤1.50	0.05
Chromium	≤0.90	0.04
	>0.90≤ 2.00	0.06
Molybdenum	≤0.20	0.01
	>0.20≤0.40	0.03
	>0.40≤0.65	0.04
Nitrogen	≤ 0,030	0,005
Boron	≤ 0.006	0.001

a) Product analysis not applicable.
b) For ISH340WP - Carbon: Permissible Variation Over the Specified Limit, 0.02 % max.
- Manganese: Permissible Variation Over/Under the Specified Limit, 0.05 % max.
- Silicon: Permissible Variation Over/Under the Specified Limit, 0.03 % max.
- Sulfur: Permissible Variation Over/Under the Specified Limit, 0.005 % max.
- Phosphorus: Permissible Variation Over/Under the Specified Limit, 0.005 % max.

8. SELECTION AND PREPARATION OF TEST SAMPLES

8.1 The position from which test samples are taken shall be so located in the product as to yield the clearest possible information regarding properties in the cross-sectional and longitudinal planes. The recommended locations for taking test samples for plates, sheets, strips, sections, flats, bars and rods are indicated in Fig. 1. Selection of location of test pieces may also be mutually agreed to between the purchaser and the manufacturer/supplier.
The sampling position of test piece shall be at a quarter-width from the edge of the sheet, strip and plate. If this is infeasible, the sampling should be made as close to the aforementioned position as possible. Tensile and bend test piece direction shall be as per below table.

Class of Steel Product	***Direction of Test Piece***
Plates, Sheets and Strips	Crosswise (Transverse)
Sections	Lengthwise for each type
Flats, bars (round hexagonal, etc) and rods	Lengthwise

Alternative test piece direction may also be mutually agreed to between the purchaser and the manufacturer/supplier.

8.2 Wherever practicable, the rolled surface of the steel shall be retained on the two opposite sides of the test samples.

8.3 In case of flat test samples for tensile test, both surfaces are normally to be left on the test specimen for sheets, strips, and plate up to 32 mm thick. At least one rolled surface shall be left on rectangular test samples taken from plate more than 32 mm thick. Round test samples are permitted, but should only be adopted for thickness exceeding 20 mm.

8.4 In case of flats up to 16 mm thick, the test sample shall undergo, if possible, no machining whatsoever prior to use as a test piece. If this is not possible, the test sample shall undergo the minimum amount of machining.

8.5 Bars below 28mm and rods shall be tested without machining. In case of bars having diameters or thicknesses between 28 and 71 mm, the bars may be symmetrically reduced by machining. For bars having diameters or thicknesses exceeding 71 mm, the test sample may be taken from the position shown in Fig. 1.

8.6 In the case of plates, sheets, strips, sections, flats, and bars, bend tests are to be carried out on rectangular test samples which, as far as possible, should be of the full thickness of the product. In the case of sections, flats and plates exceeding 28 mm in thickness, it is permissible to remove metal from one side of the test sample before using it as a test piece. The rolled surface of the test piece shall be on the outer side of the bend during the test.

8.7 Test samples shall be cut in such a manner that deformation is avoided as far as possible. If shearing or flame-cutting is employed, an adequate allowance shall be left for removal by machining.

8.8 Test samples taken from rolled steel which have undergone deformation through bending or twisting-shall in all cases be straightened cold. If the deformation is too severe to allow cold straightening, it is permissible in the case of materials to be delivered in the annealed or normalized condition, to carry out straightening under the application of heat, provided the temperature does not exceed 650°C. While straightening test samples, care shall be taken to avoid any cold-working or temperature rise which will alter the properties of the samples as compared with the finished product which they represent.

8.9 Test samples shall not be subjected to heat treatment unless the material from which they are cut is similarly and simultaneously treated with the material before testing. Any slight straightening of test samples which may be required shall be done cold.

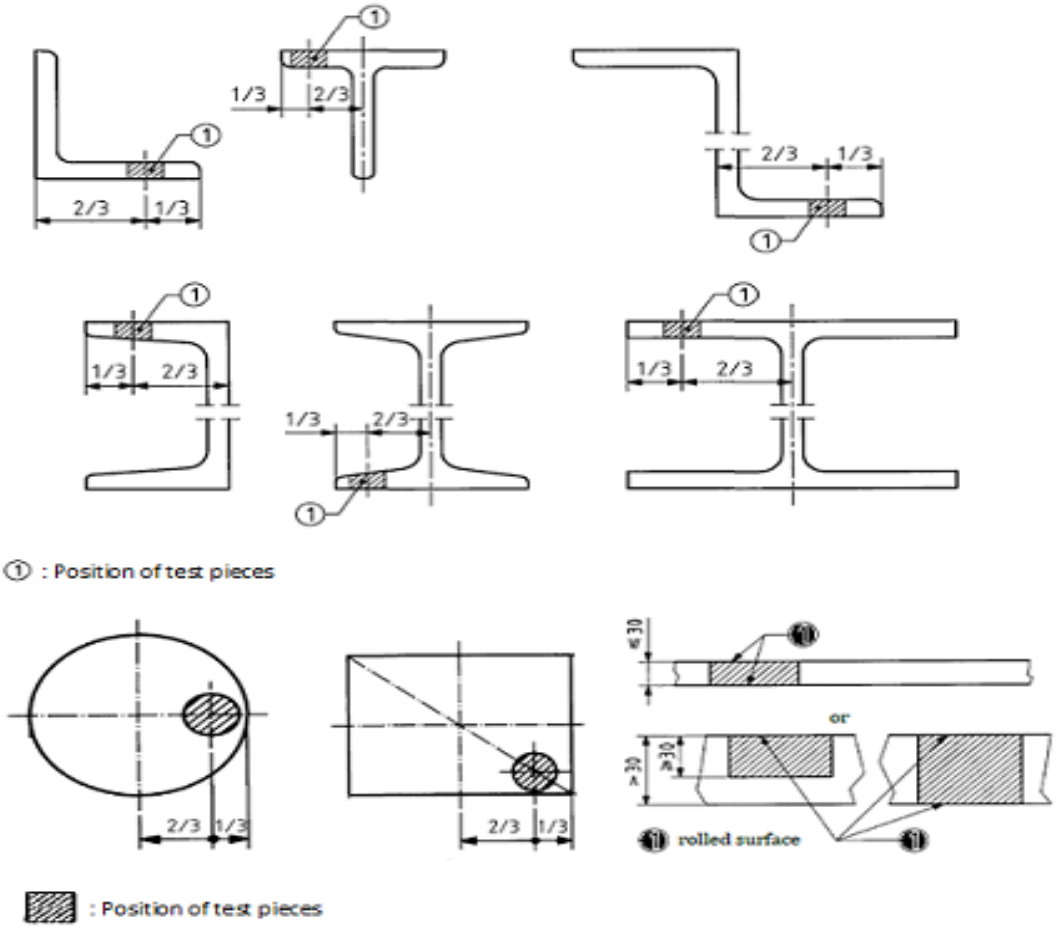


FIG. 1 STRUCTURAL STEEL SECTIONS, POSITION AND ORIENTATION OF SAMPLE

9 MECHANICAL PROPERTIES

9.1 Tensile Test

Yield strength, tensile strength and percentage elongation, when determined in accordance with IS 1608 (Part 1), shall conform to the requirements as given in Table 3A and Table 3B.

For the specified yield strength, the upper yield strength (*R*eH) shall be determined.
If a yield phenomenon is not present, the 0.2% proof strength (*R*p 0.2) shall be determined.

9.1.1 In case of sections, the thickness of which is not uniform throughout the profile, the limits of sizes given in Table 3A shall be applied according to the actual maximum thickness of the piece adopted for testing.

9.1.2 Should a tensile test piece break outside the middle half of the gauge length (*see* IS 1608 (Part 1)) and the percentage elongation obtained is less than that specified, the test may be discarded at the manufacturer/supplier's option and another test made from the sample sheet, plate, strip, section, flat, bar or rod.

9.1.3 Number of Tensile Tests

Hot rolled steel - Number of test samples shall be 2 from each cast/heat and same form, grade, quality and delivery condition irrespective of cast/heat size.

Cold-rolled steel - Take one tensile from each lot of steel sheets/strips of the same heat, the same thickness, the same rolling condition. If the lot exceeds 50 t in mass, take additional tensile test pieces for every 50t.

9.1.4 Tensile Test Pieces

The tensile strength, yield strength and percentage elongation of steel shall be determined from standard test pieces. The test shall be carried out as on the standard test pieces prepared in accordance with IS 1608 (Part 1).

9.1.4.1 Test pieces with a non-proportional gauge length, other than $5.65\sqrt{S_o}$ may be used in which case the elongation values shall be converted to $5.65\sqrt{S_o}$ in accordance with IS 3803 (Part 1).

9.2 BENDTEST

Bend test shall be conducted in accordance with IS 1599.

For bend test, the test piece at room temperature shall withstand bend through 180° to an internal diameter not greater than that given in Table 4 without cracking.

For grade ISC315WP, bend test is optional and shall be performed only when specified by the purchaser. For this the bend test piece shall be 15 mm to 50 mm in width, and have an appropriate length which is about twice the width. The test piece shall be bent manually with a vise through 180° along the length direction of the test piece as shown in Fig. 2 with an internal spacing of 1*t*. If bending with a vise is not possible, other suitable means of bending may be used.

9.2.1 Number of Bend Test

Hot rolled steel - Number of test samples shall be 2 from each cast/heat and same form, grade, quality and delivery condition irrespective of cast/heat size.

Cold-rolled steel - Take one sample from each lot of steel sheets/strips of the same heat, the same thickness, the same rolling condition. If the lot exceeds 50 t in mass, take additional tensile test pieces for every 50t.

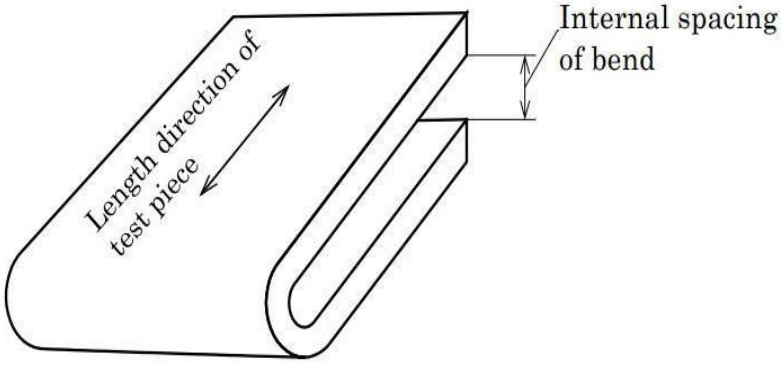


FIG. 2 DIRECTION OF BEND TEST

9.2.2 Bend Test Pieces

When sections permit, these shall be not less than 40 mm wide. If the manufacturer/supplier so desires, round, square, hexagonal and flat bars and structural sections shall be bent in the full section as rolled.

9.2.2.1 In all bend test pieces, the rough edges arising as a result of shearing may be removed by filing or grinding or machining, but the test pieces shall receive no other preparation.

9.2.2.2 The test pieces shall not be annealed or otherwise subjected to heat treatment unless the material from which they are cut is similarly treated, in which case the test pieces shall be similarly treated with the material, before testing.

9.3 IMPACT TEST

9.3.1 The impact test on V notched test pieces shall be carried out in accordance with IS 1757-1. The impact properties of Charpy V-notch test pieces shall comply with the values specified in Table 5. The orientation of the specimens shall be longitudinal unless transverse orientation is agreed between purchaser and manufacturer.
The impact properties of steel grade ISH class WP are verified only when specified at the time of the order.
For grades with quality C and C1 contained in Table 5 with nominal thickness <6 mm, the ferritic grain size shall be ≥ 6, verified by the method as described in IS 4748, if specified at the time of the order.

9.3.2 Impact test shall normally be carried out on products having thickness/diameter greater than or equal to 12 mm. For nominal thicknesses $12 < t < 40$ mm, standard 10 mm x 10 mm test pieces shall be machined in such a way that one side is not further away than 2 mm from a rolled surface, for nominal thicknesses ≥ 40 mm impact test pieces shall be taken from 1/4*t* position. The notch axis shall be perpendicular to the rolled surface.

9.3.3 In the case of nominal product thickness 6 mm ≤ t ≤ 12 mm, sub-sized test pieces shall be machined. The largest possible standard sub-sized test piece (7.5 mm or 5.0 mm) shall be used. The notch shall be perpendicular to the surface of the product. Where sub-sized test pieces are used, the minimum impact energy values given in Table 5 shall be reduced in proportion to the cross-sectional area of the test piece.

9.3.4 Impact tests shall not be required for nominal thickness t < 6 mm.

9.3.5 The test sample shall be taken from the thickest product. One test sample shall be taken from thickest product per cast/heat. If the test sample taken from the thickest product rolled from a cast meets the requirements, the whole cast shall be deemed to meet the requirements of the test, if not, the test shall be performed on a product of next lower thickness rolled from same cast, if it meets the requirements specified, this particular thickness as also other sections of lower thickness shall be deemed to satisfy this specification. If this thickness also does not meet the requirements, the test shall be carried out on the next lower thickness and so on, because the toughness of the product will be dependent on the rolling direction as well as on the product size.

9.3.6 The minimum impact values given in Table-5 apply for the mean of three test pieces. One individual value may be lower than the specified value, provided that it is not less than 70 % of the specified value.

Three additional test pieces shall be taken from the same sample in accordance with 9.3.5 and tested in any one of the following cases:

— if the average of three impact values is lower than the minimum average value specified;

— if the average value meets the specified requirement, but two individual values are lower than the minimum average value specified;

— if any one value is lower than 70 % of the minimum average value specified.

The average value of the six tests shall be not less than the minimum average value specified. Not more than two of the individual values may be lower than the minimum average value specified and not more than one may be lower than 70 % of this value.

9.3.7 Impact test at different temperatures and grades other than specified in Table 5 may be mutually agreed between the purchaser and the manufacturer/supplier accordingly the impact test values may be mutually agreed between the purchaser and the manufacturer/supplier.

10 FLATTENING TEST

10.1 Flattening test shall be carried out for circular hollow section if specified at the time of enquiry or order. If agreed upon between the manufacturer/supplier and the purchaser, this test may also be carried out on rectangular hollow sections.

10.2 A ring not less than 40 mm in length shall be cut for every 40 tonnes or part thereof and the inner and outer edges of the ring shall be rounded off.

10.3 The ring shall be flattened cold between the parallel plates with the weld, if any, at 45° in accordance with IS 2328. No opening shall occur by fracture in the weld until the distance between the plates is less than 75 percent of the original outside diameter. The test shall continue until the weld, if any, opens and the weld shall show no sign of incomplete fusion. No crack or breakage in the metal elsewhere than the weld shall occur until the distance between the plates is 2/3 of the original outside diameter.

Table 3A – Tensile properties at room temperature for hot rolled steel

(*Clauses 5.1, 9.1 and 9.1.1*)

Grade	Quality	**Minimum yield strength, R_{eH}[a]** MPa						**Minimum Tensile strength, R_m[a] MPa**			**Position of test pieces [a]**	**Minimum percentage elongation after fracture [a, b], %** Nominal thickness [d], mm								
		Nominal thickness [d], mm						Nominal thickness [d], mm				L_0 = 50mm	L_0 = 200mm	L_o = 80 mm			L_o = 5.65 $\sqrt{S_o}$			
		≤16	> 16 ≤ 40	> 40 ≤ 63	> 63 ≤ 100	> 100 ≤ 150	> 150 ≤ 200	< 3	≥ 3 ≤ 100	>100 ≤150				>1.5 ≤ 2.0	> 2.0 ≤ 2.5	> 2.5 < 3.0	≥ 3 ≤ 40	> 40 ≤ 63	> 63 ≤ 100	> 100 ≤150
ISH235WR	B0, C	235	225	215	215	195	-	360-510	360-510	350-500	l t	-	-	19 17	20 18	21 19	26 24	25 23	24 22	22 22
ISH245WR	A, BR,B0	245	235	215	215	205 t>125 : 195	195	410-540	410-540	410-540[h]	t	23	17	-	-	-	18[i]	18	18	18
ISH245WP	A	245	235	-	-	-	-	410	410	-	t	25	-	-	-	-	-	-	-	-
ISH310WR	A	310	300	-	-	-	-	450	450	-	l	22	-	-	-	-	-	-	-	-
ISH340WP	A	t≤12.5 : 340	-	-	-	-	-	480 min	t≤12.5: 480 min	-	t	-	-	-	-	-	t≤12.5: 22 [i]	-	-	-
ISH345WR	A, BR	345	345	345	345	-	-	450	450	-	t	21	18	-	-	-	-	-	-	-
ISH355WR	B0, C, C1	355	345	335	325 t>80: 315	295	-	510-680	470-630	450-600	l t	-	-	16 14	17 15	18 16	22 20	21 19	20 18	18 18
ISH355WP	B0, C	355	345	-	-	-	-	490[e]	t≤16: 490 t>16: 470-630[f]	-	l t	- t≤6: 22	- 6<t≤16: 15	16 14	17 15	18 16	22[f] 20[g]	- -	- -	- -
ISH360WP	C	t≤12: 355	-	-	-	-	-	500	t≤12: 500	-	t	-	-	-	-	-	t ≤12:20 [i]	-	-	-
ISH365WR 1	A, BR, B0	365	355	335	325	305 t>125 : 295	295	490-610	490-610	490-610 [h]	t	21	15	-	-	-	17 [i]	17	17	17
ISH365WR 2	A, BR, B0	365	355	335	325	305 t>125 : 295	295	490-610	490-610	490-610 [h]	t	21	15	-	-	-	17 [i]	17	17	17
ISH400WR	BR	400	400	400	400	-	-	490-640	490-640	-	t	21	15	-	-	-	17 [i]	17	17	-
ISH415WR	B0, C, C1	415	415	390	-	-	-	520	t≤40: 520	-	l t	- 15	- 13	15 13	15 13	15 13	19 17	18 16	- -	- -
ISH450WR	B0, C, C1	450	450	430	-	-	-	550	t≤40: 550	-	l t	- 14	- 12	14 12	14 12	14 12	17 15	16 14	- -	- -

ISH460WR 1	B0	460	450	430	420	-	-	570-720	570-720	-	t	20	-	-	-	-	16 [i]	16	16	-
ISH460WR 2	B0	460	450	430	420	-	-	570-720	570-720	-	t	20	-	-	-	-	16 [i]	16	16	-
ISH500WR	B0	500	500	500	500	-	-	570-720	570-720	-	t	20	-	-	-	-	16 [i]	16	16	-
ISH600WR	BR, B0	600	600	600	600	-	-	700	690	-	t	16	-	-	-	-	14 [i]	14	14	-
ISH700WR	C	700	700	700	-	-	-	780-930	t≤63: 780-930	-	t	16	-	-	-	-	14 [i]	14	-	-

Notes

1 MPa = 1 N/mm2.

a) For plate and wide flats with widths ≥ 600 mm, the direction transverse (t) to the rolling direction applies. For all other products, the values apply for the direction parallel (l) to the rolling direction.

b) For thicknesses up to 3 mm, use either L_o = 50 mm or L_o = 80 mm. For thicknesses of 3 mm inclusive to 6 mm inclusive, use $L_o = 5.65\sqrt{S_o}$, or L_o = 50 mm. For thickness over 6 mm, use $L_o = 5.65\sqrt{S_o}$ or L_o = 200 mm. In case of dispute, however, only the results obtained on a proportional test piece will be valid for material 3 mm and over in thickness. Unless specified on the order, the manufacturer may use either a proportional or fixed gage length specimen. When the test value is reported, the specimen used shall be reported.

c) For plate, applicable up to 12 mm; for wide flats, bars, and sections, applicable up to 40 mm.

d) Manufacturer should be contacted for possible thickness limits (*see clause 1.4*).

e) For ISH355WP steel sheet and strip of under 3 mm in thickness, the tensile strength of 510 N/mm2 or over is applicable by agreement between the purchaser and the manufacturer.

f) For plate, applicable up to 12 mm; for wide flats, bars, and sections, applicable up to 40 mm.

g) For ISH355WP grade, minimum Elongation 21% agreement between the purchaser and the manufacturer. In this case Yield Strength shall be 345Mpa minimum for t≤12mm, 325Mpa minimum for t 12-40mm and Tensile strength shall be 480Mpa minimum for t≤40mm.

h) The given tensile strength values shall be applicable up to 200mm thickness also.

i) The given elongation values shall be applicable for thickness <3mm also.

Table 3B – Tensile properties at room temperature for cold rolled steel
(*Clauses 5.1 and 9.1*)

Grade	**Yield Strength**, R_{eH}, Min MPa[5)]	**Tensile Strength** R_m, Min MPa[5)]	**Percentage Elongation** At Gauge Length 5.65√So, Min	**Percentage Elongation** At Gauge Length 50mm, Min
ISC300WP	300	440	26	-
ISC315WP*	315	450	-	26[a]

Notes

1 MPa = 1 N/mm2.
* Applicable thickness 0.6 to 2.3mm
a) Other values may also be applied subject to mutual agreement between manufacturer and purchaser.

Table 4 – Bend test
(*Clauses 5.1 and 9.2*)

Grade	**Internal Bend Diameter**, Max Nominal thickness, mm	**Inside Radius**, Max Nominal thickness, mm	
	t≤25	t≤6	t>6-16
ISC300WP	1t	-	-
ISC315WP	1t	-	-
ISH310WR	-	2.5t [c]	-
ISH340WP	t≤12.7: 1t	-	-
ISH355WR	3t [a]	-	-
ISH355WP	3t [a]	0.5t [b]	1.5t
ISH360WP	3t [a]	-	-

Notes
't' is the thickness/diameter of the test piece
a) Round bars 25 mm and under internal bend diameter shall be 2t. Round bars >25 mm internal bend diameter shall be 3t.
b) For ISH355WP steel sheet and strip of 6.0 mm or under in thickness, the inside radius of 1.0 times the thickness is applicable by agreement between the purchaser and the manufacturer.
c) On agreement the suggested radii should be used as minimums for 90° bends in actual shop practice

11 INTERNAL SOUNDNESS

Ultrasonic testing may be agreed upon at the time of the order. If specified at the time of the order, ultrasonic testing shall be carried out for flat products in nominal thicknesses ≥ 6 mm, except for hot rolled strip and plate cut from strip in accordance with IS 4225.
For sections and bars, test methods and acceptance criteria may be mutually agreed between the purchaser and the manufacturer/supplier.

12 RETEST

12.1 If a test does not give the specified results, two additional tests shall be carried out at random on the same lot. Both retests shall conform to the requirements of this standard; otherwise, the lot shall be rejected.

12.2 Re-heat Treatment

If any heat treated material fails to meet the mechanical requirements specified, the supplier may re-heat treat the material and in that case, all mechanical properties shall be re-evaluated.

Table 5—Longitudinal Charpy V-notch properties [a]
(*Clauses 5.1, 9.3.1, 9.3.3, 9.3.6 and 9.3.7*)

Designation		Minimum impact energy, J, at test temperature, °C			
Grade	**Quality**	**RT [b]**	**0**	**- 20**	**-30**
ISH235WR	B0	-	27	-	-
	C	-	-	27	-
ISH245WR	BR	27	-	-	-
	B0	-	27	-	-
	C	-	-	27	-
ISH345WR	BR	27	-	-	-
ISH355WR	B0	-	27	-	-
	C	-	-	27	-
	C1	-	-	40	27
ISH355WP	B0	-	27	-	-
	C	-	-	27	-
ISH360WP	C	-	-	27	-
ISH365WR1 ISH365WR2	BR	27	-	-	-
	B0	-	27	-	-
ISH400WR	BR	27	-	-	-
ISH415WR ISH450WR	B0	-	27	-	-
	C	-	-	20[c]	-
	C1	-	-	-	20[d]
ISH460WR1 ISH460WR2 ISH500WR	B0	-	27	-	-
ISH600WR	BR	27	-	-	-
	B0	-	27	-	-
ISH700WR	C	-	-	27	-

a) For nominal thicknesses ≤12mm, Where sub-sized test pieces are used (see 9.3.3), the minimum impact energy values given shall be reduced in proportion to the cross-sectional area of the test piece.
b) RT = Room Temperature
c) Thickness ≤12mm and 27J min can be agreed
d) Thickness >12mm and 27J min can be agreed

13 FREEDOM FROM DEFECTS

13.1 All finished steel shall be well and cleanly rolled to the dimensions, sections and masses specified. The finished material shall be reasonably free from surface flaws; laminations; rough/jagged and imperfect edges and all other harmful defects.

13.2 Minor surface defects may be removed by the manufacturer/supplier by grinding provided the thickness is not reduced locally by more than 4 percent below the minimum specified thickness. Reduction in thickness by grinding greater than 4 percent but not exceeding 7 percent may be made subject to mutual agreement between the purchaser and the manufacturer/supplier.

13.2.1 Subject to agreement with the purchaser, surface defects which cannot be dealt with as in **13.2** may be repaired by chipping or grinding followed by welding and inspection by a mutually agreed procedure such that,

a) after complete removal of the defects and before welding, the thickness of the item is in no place reduced by more than 20 percent;

b) welding is carried out by approved procedure by competent operators with approved electrodes and that the welding is ground smooth to the correct nominal thickness; and

c) subsequent to the finish grinding, the item maybe required to be normalized or otherwise heat-treated at the purchaser's discretion.

14 DIMENSIONS AND TOLERANCES

14.1 Unless otherwise agreed to between the purchaser and the manufacturer, the nominal dimensions of rolled steel products conforming to this specification shall be in accordance with the relevant Indian Standards. Currently available Indian Standards are listed in Table 6.

Table 6 Indian Standards which give nominal dimensions of rolled steel products
(*Clause* 14.1)

Sl No	PRODUCT	RELEVANT INDIAN STANDARD
i)	Beam, column, channel and angle sections including parallel beam and column sections	IS 808
ii)	Tee bars	IS1173
iii)	Bulb angles	IS 1252
iv)	Plates, sheet and strip	IS 1730
v)	Flats	IS 1731
vi)	Round and square bars	IS 1732
vii)	Bulb flats	IS 1863
viii)	Sheet, piling sections	IS 2314
ix)	Channel sections	IS 3954
x)	Hollow sections	IS 4923

14.2 Unless otherwise agreed to between the purchaser and the manufacturer/supplier, the rolling and cutting tolerances for steel products conforming to this standard shall be those specified in IS 1852 or IS/ISO 16160 for hot rolled steel sheet, strip and sections, IS 12779 for Parallel beam and column section and IS/ISO 16162 for cold rolled sheet and strip. Other tolerances may be followed within the total tolerance range as specified in IS 1852, IS/ISO 16162 and IS 12779 as applicable.

15 CALCULATION OF MASS

Material shall be supplied on the basis of actual weight. If weighing is not possible, the mass of the steel shall be calculated on the basis of steel density 7.85 g/cm^3.

16 DELIVERY

Subject to prior agreement between the manufacturer and the purchaser, a suitable protective treatment may be given to the material after rolling.

16.1 Conditions of Delivery

The products covered by this specification are delivered in the as-rolled, normalized-rolled,

normalized and thermo-mechanical processed condition. Delivery condition shall be mutually agreed between the purchaser and the manufacturer/supplier.

17 MARKING AND PACKING

17.1 Plates, sheets, sections, bars and flats may be supplied in bundles, and strips and rods either in bundles or coils. Each bundle/coil shall carry a tag or label/sticker bearing the cast number or identification mark or lot number traceable to the cast number and the manufacturer‘s name or trade mark. Alternatively, top sheet/plate or strips in each bundle shall be legibly marked with the cast number or identification mark or lot number traceable to the cast number, name of the manufacturer or trade mark.

17.2 Unless otherwise agreed the packing shall be adequate to ship the material safely and in good condition.

17.3 BIS Certification Marking

The material may also be marked with Standard Mark.

17.3.1 The product (s) conforming to the requirements of this standard may be certified as per the conformity assessment schemes under the provisions of the *Bureau of Indian Standards Act*, 2016 and the Rules and Regulations framed there under, and the products may be marked with the Standard Mark.

ANNEX A
(Informative)
(Foreword)

Mapping of old Grade and new grade designation system is as follows:

S. No.	New Grade	Old Grade
1	ISH355WP	WR-Fe 480A and WR-Fe 490H
2	ISH355WR	WR-Fe 480B
3	ISH360WP	WR-Fe 500
4	ISC315WP	WR-Fe 490C

Mapping of Grades with possible other specifications for reference

BIS Grade	BIS 11587	IRSM 41/97	JIS 3125	ISO 630-5	ISO 5952	EN 10025-5	ASTM	
	Grade	Grade	Grade	Grade	Grade	Grade	Specification	Grade
ISH 235WR				S235W	HSA235W	S235J0W S235J2W		
ISH 245WR				SG245W1	HSA245W			
ISH 245WP							ASTM A423	Gr1
ISH310WR							ASTM A606	Type 2 & Type 4
ISH345 WR							ASTM A709	Gr50(345) & Gr50S
ISH 340WP		Grade1 & Grade2						
ISH355WR	WR-Fe480B			S355W	HSA355W2	S355J0W S355J2W S355K2W		
ISH355WP	WR-Fe480A WR-Fe490H		SPA-H	S355WP	HSA355W1			
ISH 360WP	WR-Fe500							
ISH 365WR1				SG365W1	HSA365W			
ISH 365WR2				SG365W2				
ISH400WR				SG400W				
ISH 415WR						S420J0W S420J2W	ASTM A871	Gr60
ISH 450WR						S460J0W S460J2W	ASTM A871	Gr65
ISH 460WR1				SG460W1				
ISH 460WR2				SG460W2				
ISH 500WR				SG500W				
ISH 600WR							ASTM A709	
ISH 700WR				SG700W				
ISC 300WP		Grade1						
ISC 315WP	WR-Fe490C		SPA-C				ASTM A606	Type 2

Annex B
(informative)
Guidelines for estimating the atmospheric corrosion resistance of low-alloy steels

B.1 General

This annex presents a method for estimating the atmospheric corrosion resistance of low-alloy weather-resistant steels from chemical composition data.

The method utilizes predictive formulae based on the steel composition to calculate indices of atmospheric corrosion resistance.

As many indices have been used around the world, it is necessary to consider the different environments and the chemical composition of the steel when choosing an index. As any index may be inappropriate based on the above, it is necessary for the purchaser and supplier to decide on the type of index to use and the requirement levels of that index for the expected environment.

B.2 Terminology

Low-alloy steels mean iron-carbon alloys containing greater than 1 % but less than 5 %, by mass, of total alloying elements.

NOTE Most “low-alloy weather-resistant steels” contain additions of both chromium and copper, and can also contain additions of silicon, nickel, phosphorus, or other alloying elements which enhance atmospheric corrosion resistance.

B.3 Procedure

B.3.1 Formulae for predicting the corrosion penetration of low-alloy steels after 15.5 years of exposure to various atmospheres, based on the chemical composition of the steel, were published by Legault and Leckie. The formulae are based on extensive data published by Larrabee and Coburn.

B.3.2 For use with these guidelines, the Legault-Leckie formula for an industrial atmosphere (Kearny, N.J., USA) was modified to allow calculation of an atmospheric corrosion resistance index based on chemical composition. The modification consisted of deletion of the constant and changing the signs of all the terms in the formula. The modified formula for calculation of the atmospheric corrosion resistance index (I) is given below. The higher the index, the more corrosion resistant is the steel.

$$I = 26.01\,(\%\,Cu) + 3.88\,(\%\,Ni) + 1.20\,(\%\,Cr) + 1.49\,(\%\,Si) + 17.28\,(\%\,P) - 7.29\,(\%\,Cu)\,(\%\,Ni) - 9.10\,(\%\,Ni)\,(\%\,P) - 33.39\,(\%\,Cu)^2$$

B.3.3 The predictive formula should be used only for steel compositions within the range of the original test materials in the Larrabee-Coburn data set. These limits are as follows:

— $0.012 \leq Cu \leq 0.51$
— $0.05 \leq Ni \leq 1.1$
— $0.10 \leq Cr \leq 1.3$
— $0.10 \leq Si \leq 0.64$
— $0.01 \leq P \leq 0.12$

B.3.4 The minimum acceptable atmospheric corrosion index should be a matter of negotiation between the manufacturer/supplier and the purchaser.

Annex C
(informative)
Additional information for the use of steel with improved atmospheric corrosion resistance

The corrosion-inhibiting effect of the auto-protective oxide layer relates to the nature of its constituents and to the particular distribution and concentration of alloying elements in it. The resistance to atmospheric corrosion resistance depends on weather conditions giving a succession of dry and wet periods for the forming of the auto-protective oxide layer of the base metal. The protection afforded depends on the environmental and other conditions prevailing at the site of the structure.

Provisions should be made in the design and fabrication of the structure, for the auto-protective oxide layer on the surface to form and regenerate itself unimpeded. It is the responsibility of the designer to include corrosion of unprotected steels in his or her calculation and, as far as is necessary, to compensate for this by increasing the thickness of the product.

Conventional surface protection is recommended when the content of particular chemical substances in the air is significant. It is absolutely necessary where the structure is in contact with water for long periods, is permanently exposed to moisture, or is to be used in a marine atmosphere. Before painting, the products should be descaled. Under comparable conditions, the susceptibility to corrosion of steel with improved atmospheric corrosion resistance under painting is less than that for conventional structural steels.

The surface of structures which are not exposed to the elements, but may be subject to the build-up of condensation, should be appropriately ventilated. Otherwise, a suitable surface protection is necessary. Generally valid statements on the corrosion process cannot be made, due to the extent to which the process depends on the prevailing climatic conditions and the details of the structure.

Appendix-2

STEEL INGOTS, BILLETS, BLOOMS, SLABS AND BARS FOR FORGING - SPECIFICATION

1 SCOPE

This standard covers the requirements for unalloyed and low & medium alloyed steel ingots, rolled or forged or continuously cast billets, blooms, slabs and bars for forgings for general engineering purposes.

2 REFERENCES

The following Indian Standard contain provisions which through reference in this text, constitute provision of this standard. At the time of publication, the editions indicated were valid. All standards are subjects to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below:

IS No.	***Title***
228 (Various Parts)	Methods for chemical analysis of steel
1500 (Part 1) : 2019 / ISO 6506-1 : 2014	Metallic Materials - Brinell Hardness Test Part 1 Test Method (*fifth revision*)
1599 : 2019 / ISO 7438 : 2016	Metallic Materials - Bend Test (*Fourth Revision*)
1608 (Part 1) : 2022 / ISO 6892-1 : 2019	Metallic materials -Tensile Testing Part 1 Method of test at room temperature (*sixth revision*)
1852 : 1985	Rolling and cutting tolerances for hot rolled steel products (*fourth revision*)
1956 (Various Parts)	Glossary of terms relating to iron and steel
3848 : 1981	Method for end quench test for hardenability of steel
4075 : 1985	Method for macrostreak flaw test for steel
4163 : 2021 / ISO 4967 : 2013	Steel - Determination of Content of Nonmetallic Inclusions - Micrographic Method Using Standard Diagrams (*third revision*)
4748 : 2021 / ISO 643 : 2019	Steels - Micrographic Determination of the Apparent Grain Size (*second revision*)
6396 : 2000	Methods of measuring decarburized depth of steel (*second revision*)
8811 : 1998	Method for Emission Spectrometric Analysis of Plain Carbon and low alloy Steels Point to Plane Technique
8910 : 2022 / ISO 404 : 2013	General technical delivery requirements for steel and steel products (*second revision*)
9684 : 1980	Technical conditions for the supply of hot rolled billets blooms, slabs and bars for closed die forgings
10138 : 2010	Macroscopic Methods for Determination Of Non-Metallic Inclusion Content In Wrought Steels (*second revision*)
11371 : 2022	Method for macroetch test for wrought steel products
12037 : 1987	Macrographic examination by Sulphur print (Baumann method)

3 TERMINOLOGY

For the purpose of this standard, the definitions given in IS 1956 shall apply.

4 SUPPLY OF MATERIAL

4.1 General requirements relating to the supply of steel shall conform to IS 8910.

5 MANUFACTURE

5.1 Unless otherwise agreed to between the purchaser and the manufacturer, the processes used for making steel shall be left to the discretion of the manufacturer. The steel shall be fully killed.

5.2 When so desired, the purchaser and manufacturer may agree to a particular secondary steel making / refining technology including degassing etc.

5.3 Ingot, continuously cast billet, bloom or slab shall be reasonably free from pipe, marked segregation and other harmful internal and surface defects. Sufficient discard shall be made to ensure freedom from defects as stipulated in **6**. The method o evaluating the internal and surface defects and their acceptance for such material may be mutually agreed to at the time of enquiry and order between the purchaser and the manufacturer.

5.4 Stocks made from ingot, continuously cast billet, bloom or slab shall have total reduction of at least 6:1 (measured by cross section of the initial cast product to the final forging stock). The stock may be manufactured by hot rolling or forging.

5.5 Higher reduction ratios for specific applications can be mutually agreed to between the purchaser and the manufacturer. However, lower reduction ratios can be agreed to between the purchaser and the manufacturer at the time of enquiry and order subject to a minimum of 2:1 and without impairing the end use of the steel.

5.6 Ingot, continuously cast billet, bloom or slab without any reduction shall not be directly used as stock for forging except at the risk of the purchaser.

6 FREEDOM FROM DEFECTS

6.1 Surface and Sub-Surface Defects

6.1.1 The forging stock shall be free from harmful surface and sub-surface defects, which may impair the forgeability and or the end use of the steel.

6.1.2 If necessary, the billet or bloom (including continuously cast) before rolling/forging and bars shall be suitably conditioned to ensure the quality of the forging stock.

6.1.3 Unless otherwise specified, the manufacture shall be at liberty to choose the method of conditioning subject to the following conditions:

a) It shall not have any injurious effects on the product
b) The conditioning shall be allowed only in the longitudinal direction. Conditioning in the transverse direction shall not be allowed, except for surface inspection purposes.
c) The depth of conditioning shall not exceed 1 mm for every 15 mm of dimensions concerned, up to a maximum depth of 20 mm.
d) The width of the conditioning shall be at least four times its greatest depth
e) In the case of slabs, the depth of conditioning on the wide surface shall not exceed 1 mm for every 10 mm of dimensions concerned, up to a maximum depth of 20 mm. The maximum depth of conditioning on two parallel sides at opposite locations shall not exceed one and a half times the maximum allowed for one side
f) While conditioning the material, the dimensions of the product shall not go below the minimum dimensions permitted according to the tolerances specified until and unless otherwise agreed to between the manufacturer and the purchaser
g) The transition between conditioned and non-conditioned areas shall be gradual. All heavy swarf or slag shall be removed

6.1.4 In special cases, particularly where it is necessary on large material and is not injurious, greater depth of conditioning may be permitted by special agreement between the manufacturer and the purchaser.

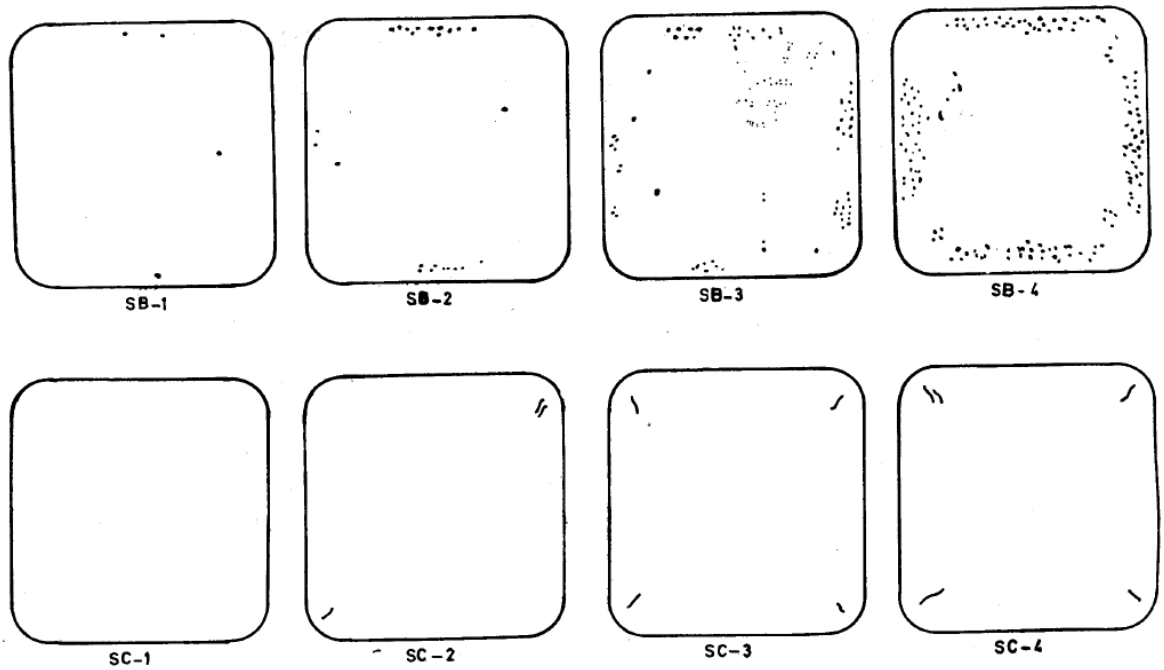
6.2 Internal Defects

6.2.1 The forging stock shall also be free from harmful internal defects like centre looseness, corner crack, half way cracks, concentrated pin holes, voids, flakes, etc which may impair the forgeability and or the end use of the steel.

6.2.2 The transverse section of the forging stock shall be suitably inspected by sulphur print/ macro etching as per IS 12037 / IS 11371. For acceptance criteria of the stock produced from concast steel, reference can be made to Plate 1 and Plate 2 of Fig. 1 to arrive at mutually acceptable limits of a certain type of defects present either singularly or in combination depending upon the subsequent manufacturing operation and the end use of the product. However, the acceptance norms shall be as agreed to between the manufacturer and the purchaser.

6.2.3 The forging stock shall be free from coarse dendrities, if so desired by the purchaser.

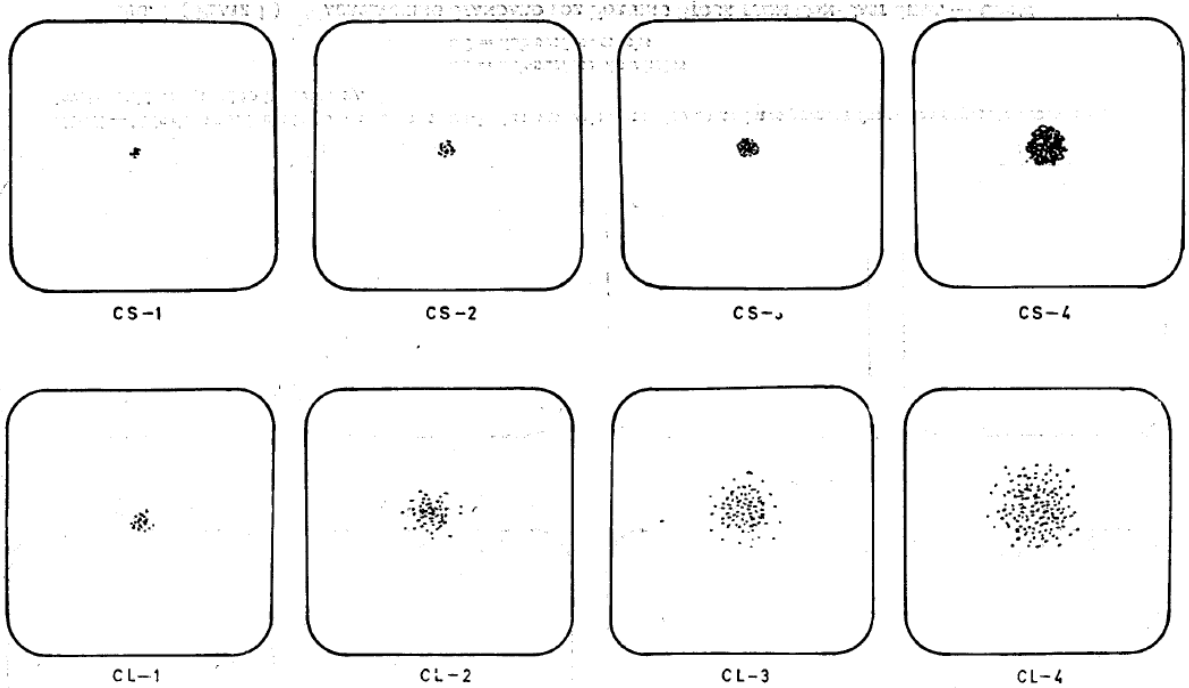
6.2.4 The forging stock shall be by and large homogenous and free from large, segregated inclusions and macrostreaks when examined by macroetching the longitudinal section.



NOTE — This does not include non-metallic macro-inclusions which are also sometimes present for which separate acceptance level should be agreed to it necessary.

SB = Sub-surface blow holes
SC = Sub-surface cracks

FIG. 1 (PLATE 1) MACROETCHING STANDARD FOR FORGING STOCK FROM CON-CAST STEEL — *Contd*



NOTE — Centre piping and centre cracking are not permissible in any degree.

CS = Centre segregation
CL = Centre looseness

FIG. 1 (PLATE 2) MACROETCHING STANDARD FOR FORGING STOCK FROM CON-CAST STEEL

7 CHEMICAL COMPOSITION

7.1 The ladle analysis of the steel, when carried out by the method specified in the relevant parts of IS 228 or IS 8811 or any other established instrumental/chemical method, shall be as given in Table A.1. In case of dispute the procedure given in relevant parts of IS 228 shall be referee method. However, where method is not given in IS 228 and its relevant parts, the referee method shall be as agreed to between the purchaser and the manufacturer.

7.2 Elements wherever not specified in Table A.1 shall not be added other than for the purpose of finishing the heat, and shall not exceed the following limits:

Constituent	Percent, Max
Chromium	0.25
Nickel	0.25
Molybdenum	0.05
Copper	0.25
Vanadium	0.05
Boron	0.0003
Tin	0.05

NOTES

1. All reasonable precautions shall be taken to prevent the addition of such elements, which affect the hardenability, mechanical properties and applicability.
2. Trace elements (Cr+Ni+Mo) when added together shall not exceed 0.50 percent.
3. % Copper + 10 x (% Tin) shall not exceed 0.50 percent.

7.3 Where necessary, more restricted ranges of chemical composition may be specified subject to mutual agreement between the manufacturer and the purchaser.

7.4 Check Analysis

Check analysis shall be carried out on the finished product if specified by the purchaser. Permissible variations in the case of check analysis from the limits of ladle analysis specified in Table A.1 shall be as given in Table 1. Variation shall not be applicable both over and under the specified limits in several determinations in one heat.

8 DIMENSIONAL TOLERANCES

8.1 Unless otherwise agreed to between the purchaser and the manufacturer/supplier, the tolerances as given in 8.2 to 8.9 shall apply.

8.2 In case of billets, blooms and slabs (including continuously cast), the tolerances shall be as given in Table 2.

8.3 The length of billets, blooms and slabs shall be agreed to at the time of enquiry and order. A tolerance of -0 +150 mm shall be permitted on the specified length.

8.4 In the case of slabs, the bend and camber shall not exceed 8 mm/m of slab length subject to a maximum of 40 mm. In the case of billets and blooms, the bend shall not exceed 5 mm/m.

8.5 For rolled square billets, corner radius shall be about 15 percent of the nominal size or as agreed.

8.6 Rolled steel bars shall be true to the prescribed dimensions within the tolerances specified in IS 1852. The length of bars shal1 be agreed to at the time of enquiry and order. The cutting tolerance for all lengths of hot rolled bars shall be -0, + 100 mm.

8.7 The tolerance on straightness shall be 3 mm for every meter length of machine straightened bars. For as rolled bars, the straightness tolerance shall be as agreed to between the purchaser and supplier.

8.8 If agreed at the time of enquiry and order, for supply of hot rolled billets, blooms, slabs and bars for closed die forging, the tolerances shall be in accordance with IS 9684.

8.9 Subject to mutual agreement between the purchaser and the manufacturer, the material may be supplied to closer tolerances also.

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Table 1 VARIATION FOR CHECK ANALYSIS

(*Clause* 7.4)

Element	Limiting values of the ladle (heat) analysis	Permissible deviation (±) for the product analysis for nominal size, mm		
		Up to 250	Over 250 up to 500	Over 500
	% mass fraction	% mass fraction	% mass fraction	To be mutually agreed
Carbon	up to 0.45	0.02	0.04	
	Over 0.45 to 0.90	0.03	0.05	
Silicon	up to 0.40	0.03	0.04	
	Over 0.40 to 2.00	0.05	0.06	
	Over 2.00	To be mutually agreed		
Manganese	up to 1.20	0.04	0.06	
	Over 1.20 to 2.00	0.05	0.07	
Nickel	up to 1.00	0.03	0.03	
	Over 1.00 to 2.20	0.05	0.05	
	Over 2.00 to 5.00	0.07	0.07	
Chromium	up to 0.80	0.03	0.04	
	Over 0.80 to 2.20	0.05	0.06	
	Over 2.20 to 5.50	0.11	0.13	
	Over 5.50	To be mutually agreed		
Molybdenum	up to 0.40	0.03	0.04	
	Over 0.40 to 1.20	0.04	0.05	
Vanadium	up to 0.15	0.02	0.02	
	Over 0.15 to 0.30	0.03	0.03	
Aluminium	≤ 0.060	0.005	To be mutually agreed	
	Over 0.060	To be mutually agreed		
Sulphur		0.005	0.010	
Phosphorus		0.005	0.010	

Note

1) The deviation of the product analysis in one heat for a given element may occur over the upper value or under the lower value of the specified range of the ladle analysis, but not both at the same time.
2) For sulphur controlled steels, the permitted variation in the product analysis of sulphur is ± 0.005%. However, for steels with a minimum sulphur range of 0.020% according to ladle analysis, sulphur in the product should not have less than 0.017%, unless otherwise agreed.

Table 2 Tolerances in billets, blooms and slabs
(*Clause* 8.2)

Product	Width Across Flat mm	Thickness mm	Tolerances on Width/Thickness mm
(1)	(2)	(3)	(4)
Billets	Up to and including 75	—	± 1.5
	> 75 to 125	—	± 3.0
	> 125 to 150	—	+4.0 -3.0
	Over 150	—	+6.0 -3.0
Blooms	Up to and including 150	—	+4.0 -3.0
	Over 150	—	+6.0 -3.0
Slabs	—	Up to and including 150	+ 3.0 -4.0
		Over 150	+3.0 -6.0
	Up to and including 300	—	+3.0 -6.0
	Over 300	—	+5.0 -10.0

9 CONDITIONS OF DELIVERY

9.1 Steels covered by this standard shall be ordered and delivered on any one or a combination of the following basis:

a) Chemical Composition
b) As rolled or forged, normalized or annealed
c) Maximum Hardness
d) Hardenability (Jominy)
e) Mechanical Properties and
f) Grain Size

10 TEST

10.1 Tensile Test - For steels ordered on the basis of mechanical properties, the tensile tests shall be carried out in accordance with IS 1608 (Part 1). The test pieces shall be taken in the longitudinal direction as shown in Fig. 2. The required tensile properties shall be as mutually agreed or else as given in Table A.2.

10.2 Hardness Test - For steels ordered on the basis of hardness, the hardness test shall be carried out in accordance with IS 1500 (Part 1). The hardness requirements of the test pieces shall be mutually agreed.

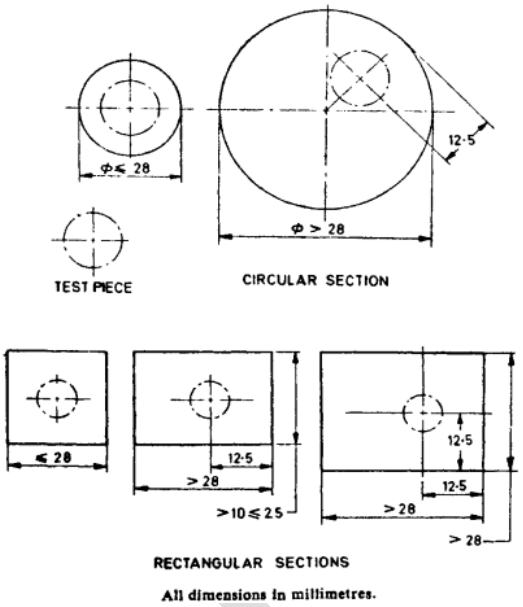


Fig 2 LOCATION OF THE TENSILE TEST PIECES IN THE PRODUCTS

10.3 Hardenability Test - For steels ordered on the basis of hardenability, the complete end-quench hardenability band and hardness, at fixed distance shall be as agreed to between the manufacturer and the purchaser or else as given in Table A.3. The minimum and maximum limits of a specified hardness range shall be consistent with the hardness obtainable in the full range of the specified chemical limits. The method of testing hardenability steel shall be in accordance with IS 3848.

10.4 Grain Size - Unless otherwise agreed, the steel when tested for grain size in accordance with IS 4748 shall show grain size of 5 to 8 for inherently fine-grained steel. Grain size outside the range of 5 to 8 may be supplied on mutual agreement. The grain size shall be considered satisfactory if 75 percent of grains are within the specified limit, and the remaining 25 percent of the grains falling either one size below or above the range but not spread at both ends of the range.

11 SAMPLING

11.1 If check analysis is required, at least one sample shall be taken from each cast. Samples for check analysis shall be taken midway between the centre and outside of the material.

11.2 For bars supplied on the basis of mechanical properties, in the case of bars up to 100 mm size, the test samples shall be selected from finished parts at the rate of one sample from each lot, provided the quantity from one cast does not exceed 25 metric tonnes. Where the quantity from each cast exceeds 25 metric tonnes, one more test sample shall be selected. When more than one diameter or thickness of bar is rolled from the same cast, one additional test sample shall be selected from each diameter or thickness of bar. For other sections the sampling rate shall be as per mutual agreement.

11.3 For material supplied on the basis of maximum hardness, at least one sample shall be taken from each cast from each size of each heat treatment batch. If the material is continuously heat-treated, one sample shall be taken from each 10 tonnes or part thereof, but at least one sample from each cast shall be taken.

11.4 For material supplied to other conditions of delivery, at least one sample shall be taken from each cast for testing.

11.5 Higher sampling rate may be agreed to at the time of enquiry and order.

12 RETESTS

12.1 Retest for check Analysis

If the results of the product analysis do not meet the composition requirements given in Table A.1 and 1, unless otherwise agreed to between the purchaser and the manufacturer, two new samples shall be taken on different pieces from the same cast. Should the two analyses satisfy the requirements, the lot represented shall be accepted. Should either of the tests fail, the material shall be taken as not complying with this standard.

12.2 Retest for Hardness Test in the Normalized / Annealed Condition

Should any of the test pieces fail to pass the tests specified, two further test samples shall be selected from the same heat treatment batch for testing in respect of each failure. The consignment shall be considered to conform to the requirements if both the additional tests are satisfactory. Should either of the samples fail, the manufacturer shall have the right, if he so desires, to reheat-treat the product in any suitable manner before two fresh samples are taken for testing. Should the two tests satisfy the requirements of this standard, the lot represented shall be accepted. Should either of the samples fail, the material shall be taken as not complying with this standard.

12.3 Retest for Mechanical Tests on Test Pieces

Should any of the test pieces fail to pass the tests specified, two further samples shall be selected from the same size grouping for testing in respect of each failure. The fresh test bars shall be treated under the same conditions and tested. The consignment shall be considered to conform to the requirements if both the additional tests are satisfactory. Should either of the test pieces fail, the material shall be taken as not complying with this standard.

13 ADDITIONAL REQUIREMENTS

13.1 If agreed to between the purchaser and the manufacturer at the time of enquiry and order, any or a combination of the following tests may also be carried out as additional requirements to ensure that the steels meet the quality requirements of the purchaser. The sampling frequency and acceptable level for each or any of these additional tests shall be mutually agreed to at the time of enquiry and order.

13.2 HOT UPSET TEST

13.2.1 The forging stock surface shall be able to withstand Hot Upset Test as described below:

Upset test from every heat is to be carried out in the following manner:

a) A sample of height equal to 2 times the diameter/thickness is to be taken.

b) The sample is hot upset to 50 percent of the original height.

The outside surface should not indicate any crack or lap after upsetting.

13.2.2 For general forging purposes, the permissible depth of seam shall be 1 percent of the forging stock diameter / thickness or 0.5 mm whichever is less.

13.3 INCLUSION RATING

13.3.1 Nonmetallic inclusions in rolled or forged steel products having a reduction ratio of at least 3 shall be determined in accordance with IS 4163 (Method A). The worst field of each inclusion from each sample shall be recorded as a rating for the sample. The inclusion rating for the samples shall not exceed the following limits:

a) For air melted quality:

Inclusion Type	Thin	Thick
A	3	2
B	3	2
C	3	2
D	3	2
DS	-	2

b) For vacuum, ESR or secondary refined quality requirements shall be Subject to mutual agreement between the manufacturer and the purchaser.

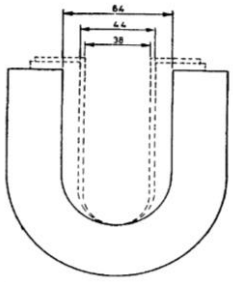
13.4 Decarburized depth: Decarburization depth shall be assessed as per IS 6396.

13.5 BEND TEST

13.5.1 Bend test shall be carried as per IS 1599 for grades 14C6, 15C8, 20C8, 25C8, 30C8, 35C8 and 45C8. Where the dimensions permit, test pieces 230 mm long and 32 mm square with edges rounded off shall be machined lengthwise from each sample and bent cold by direct pressure round a former of diameter appropriate to the grade of steel as shown in Fig. 3 until the sides of the test piece are parallel.

13.5.2 Smaller sizes shall be bent in full section by a former having a diameter proportional to that specified for a 32 mm square test piece. Each bend test shall comply with the requirements without a fracture.

13.5.3 Subsequently, the ends of the test pieces for grades 14C6, 15C8, 20C8, 25C8, 30C8 and 35C8 shall be brought together by direct pressure and the test piece shall not fracture.



64 for 45C8
44 for 30C8 & 35C8
38 for 14C6, 15C8, 20C8 & 25C8

Fig 3 BEND TEST

All dimensions in millimeters

13.6 Cleanliness of the steel can also be assessed by any or a combination of the fo

a) Blue Fracture test as per IS 10138
b) Step Machined test as per IS 10138
c) Magnetic Particle inspection as per IS 10138
d) Macrostreak Flaw test as per IS 4075

However, this is not applicable for re-sulphurized steel grades according to Table A.1.

13.7 Other Tests:

a) Ultrasonic Test
b) Blank hardening test for core strength guarantee
c) Microstructure for machinability including banding

The method of testing and requirements shall be as mutually agreed.

14 MARKING

14.1 All bars of above 40 mm diameter or equivalent section and shall be stamped or suitably marked at the end with material designation, heat number and manufacturer's name or trademark. Bars of smaller sections shall be tied in suitable bundles which will carry tags giving the information. Each ingot, billet, bloom and slab shall be legibly stamped or painted with the cast number. The ends of ingots, billets, blooms, slabs and bars may be suitably colour coded to mark the grade of the material as per agreement between the purchaser and the manufacturer.

14.2 BIS Certification Marking

The product(s) conforming to the requirements of this standard may be certified as per the conformity assessment schemes under the provisions of the Bureau of Indian Standards Act, 2016 and the Rules and Regulations framed thereunder, and the product(s) may be marked with the Standard Mark.

15 ORDERING INFORMATION

While placing an order for the product(s) covered by this standard, the purchaser should specify clearly the following:

a) Grade designation;
b) Description regarding product form, size, length, etc;
c) Condition of delivery;
d) Tests required;
e) Method for manufacture;

f) Additional requirements as per Clause 13; and
f) Any special requirements;

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ANNEX A

TABLE A. 1 LADLE ANALYSIS
(Clauses 7.1)

Designation	CONSTITUENT, PERCENT										
	C	Si	Mn	Ni	Cr	Mo	V	Al[a]	Cu	S[b]	P
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
UNALLOYED STEEL											
10C4[e]	0.15 max	0.15-0.35	0.30-0.60	-	-	-	-	-	-	0.045 max	0.045 max
14C6	0.10-0.18	0.15-0.35	0.40-0.70	-	-	-	-	-	-	0.040 max	0.040 max
15C4	0.12-0.18	0.15-0.40	0.30-0.60	0.40 max	0.40 max	0.10 max	-	-	0.30 max	0.035 max	0.025 max
15C8[e]	0.10-0.20	0.15-0.35	0.60-0.90	-	-	-	-	-	-	0.035 max	0.035 max
20C8	0.15-0.25	0.15-0.35	0.60-0.90	-	-	-	-	-	-	0.035 max	0.035 max
25C8	0.20-0.30	0.15-0.35	0.60-0.90	-	-	-	-	-	-	0.035 max	0.035 max
30C8	0.25-0.35	0.10-0.35	0.60-0.90	-	-	-	-	-	-	0.035 max	0.035 max
35C8	0.30-0.40	0.10-0.35	0.60-0.90	-	-	-	-	-	-	0.035 max	0.035 max
40C8	0.35-0.45	0.10-0.35	0.60-0.90	-	-	-	-	-	-	0.035 max	0.035 max
45C8	0.40-0.50	0.10-0.35	0.60-0.90	-	-	-	-	-	-	0.035 max	0.035 max
50C8	0.45-0.55	0.10-0.35	0.60-0.90	-	-	-	-	-	-	0.035 max	0.035 max
55C6	0.50-0.57	0.10-0.35	0.40-0.70	-	-	-	-	-	-	0.035 max	0.035 max
55C8	0.50-0.60	0.10-0.35	0.60-0.90	-	-	-	-	-	-	0.035 max	0.035 max
65C6	0.60-0.70	0.15-0.35	0.50-0.80	-	-	-	-	-	-	0.035 max	0.035 max
20C14	0.17-0.23	0.15-0.35	1.20-1.50	-	-	-	-	-	-	0.030 max	0.030 max
22C6	0.18-0.25	0.10-0.40	1.30-1.65	0.40 max	0.40 max	0.10 max	-	-	0.30 max	0.035 max	0.025 max
33C14	0.30-0.36	0.15-0.35	1.20-1.50	-	-	-	-	-	-	0.030 max	0.030 max
20C15	0.16-0.24	0.10-0.35	1.30-1.70	-	-	-	-	-	-	0.035 max	0.035 max
27C15	0.22-0.32	0.10-0.35	1.30-1.70	-	-	-	-	-	-	0.035 max	0.035 max
37C15	0.32-0.42	0.10-0.35	1.30-1.70	-	-	-	-	-	-	0.035 max	0.035 max
38C15	0.35-0.41	0.15-0.35	1.35-1.65	-	-	-	-	-	-	0.030 max	0.030 max
43C15	0.40-0.46	0.15-0.35	1.35-1.65	-	-	-	-	-	-	0.030 max	0.030 max
47C15	0.42-0.50	0.10-0.35	1.30-1.70	-	-	-	-	-	-	0.035 max	0.035 max
RESULPHURIZED STEEL											

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10C8S10	0.15 max	0.15-0.35	0.60-0.90	-	-	-	-	-	-	0.08-0.13	0.035 max
11C10S25	0.08-0.18	0.10-0.35	0.80-1.20	-	-	-	-	-	-	0.20-0.30	0.045 max
14C14S14	0.10-0.18	0.10-0.35	1.20-1.50	-	-	-	-	-	-	0.10-0.18	0.045 max
40C10S18	0.35-0.45	0.25 Max	0.80-1.20	-	-	-	-	-	-	0.14-0.22	0.060 max
40C15S12	0.35-0.45	0.25 Max	1.30-1.70	-	-	-	-	-	-	0.08-0.15	0.035 max
46V1S3	0.42-0.50	0.60 Max	0.60-1.00	-	-	-	0.08-0.13		-	0.045-0.065	0.035 max
SILICON ALLOYED STEEL											
36Si7	0.33-0.40	1.50-2.00	0.80-1.00	-	-	-	-	-	-	0.035 max	0.035 max
55Si7	0.50-0.60	1.50-2.00	0.80-1.00	-	-	-	-	-	-	0.035 max	0.035 max
NICKEL STEEL											
40Ni14	0.35-0.45	0.10-0.35	0.50-0.80	3.20-3.60	0.30 max	-	-	-	-	0.035 max	0.035 max
CHROMIUM STEEL											
15Cr3	0.12-0.18	0.10-0.35	0.40-0.60	-	0.50-0.80	-	-	-	-	0.035 max	0.035 max
16Cr4	0.13-0.18	0.15-0.35	0.60-0.90	-	0.90-1.20	-	-	-	-	0.030 max	0.030 max
17Cr3	0.14-0.20	0.15-0.40	0.60-0.90	-	0.70-1.00	-	-	-	0.40 max	0.035 max	0.025 max
20Cr4[d]	0.17-0.23	0.15-0.40	0.60-0.90	-	0.90-1.20	-	-	-	-	0.035 max	0.030 max
28Cr4	0.24-0.31	0.40 max	0.60-0.90	-	0.90-1.20	-	-	-	0.40 max	0.035 max	0.025 max
30Cr4	0.28-0.33	0.15-0.35	0.60-0.90	-	0.90-1.20	-	-	-	-	0.030 max	0.030 max
34Cr4	0.30-0.37	0.10-0.40	0.60-0.90	-	0.90-1.20	-	-	-	0.40 max	0.035 max	0.025 max
35Cr4	0.33-0.38	0.15-0.35	0.60-0.90	-	0.90-1.20	-	-	-	-	0.030 max	0.030 max
37Cr4	0.34-0.41	0.10-0.40	0.60-0.90	-	0.90-1.20	-	-	-	0.40 max	0.035 max	0.025 max
40Cr4	0.35-0.45	0.10-0.35	0.60-0.90	-	0.90-1.20	-	-	-	-	0.035 max	0.035 max
41Cr4	0.38-0.45	0.10-0.40	0.60-0.90	-	0.90-1.20	-	-	-	0.40 max	0.035 max	0.025 max
45Cr4	0.43-0.48	0.15-0.35	0.60-0.90	-	0.90-1.20	-	-	-	-	0.030 max	0.030 max
50Cr4	0.45-0.55	0.10-0.35	0.60-0.90	-	0.90-1.20	-	-	-	-	0.035 max	0.035 max
55Cr3	0.50-0.60	0.10-0.35	0.60-0.80	-	0.60-0.80	-	-	-	-	0.035 max	0.035 max
SILICON MANGANESE STEEL											
37Mn5Si5	0.33-0.41	1.10-1.40	1.10-1.40	-	-	-	-	-	-	0.035 max	0.035 max
MANGANESE CHROMIUM STEEL											
16Mn5Cr4[d]	0.14-0.19	0.10-0.40	1.00-1.30	-	0.80-1.10	-	-	-	-	0.035 max	0.035 max
20Mn5Cr2	0.17-0.23	0.15-0.35	1.20-1.50	-	0.35-0.70	-	-	-	-	0.030 max	0.030 max
20Mn5Cr5[d]	0.17-0.22	0.10-0.40	1.00-1.40	-	1.00-1.30	-	-	-	-	0.035 max	0.035 max
43Mn6Cr2	0.40-0.46	0.15-0.35	1.35-1.65	-	0.35-0.70	-	-	-	-	0.030 max	0.030 max

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SILICON CHROMIUM STEEL											
45Cr36Si12	0.40-0.50	2.75-3.25	0.30-0.60	-	8.50-9.50	-	-	-	-	0.035 max	0.035 max
55Si6Cr3	0.50-0.60	1.20-1.60	0.50-0.80	-	0.50-0.80	-	-	-	-	0.035 max	0.035 max
NICKEL MOLYBDENUM STEEL											
20Ni7Mo2	0.17-0.22	0.15-0.35	0.45-0.65	1.65-2.00	-	0.20-0.30	-	-	-	0.035 max	0.035 max
MANGANESE MOLYBDENUM STEEL											
35Mn6Mo3	0.30-0.40	0.10-0.35	1.30-1.80	-	-	0.20-0.35	-	-	-	0.035 max	0.035 max
35Mn6Mo4	0.30-0.40	0.10-0.35	1.30-1.80	-	-	0.35-0.55	-	-	-	0.035 max	0.035 max
NICKEL CHROMIUM STEEL											
13Ni13Cr3	0.10-0.15	0.15-0.35	0.40-0.70	3.00-3.50	0.60-1.00	-	-	-	-	0.035 max	0.035 max
14Cr6Ni6	0.12-0.17	0.15-0.40	0.40-0.60	1.40-1.70	1.40-1.70	-	-	-	-	0.035 max	0.035 max
15Ni9Cr1	0.12-0.18	0.15-0.35	0.35-0.65	2.00-2.50	0.20-0.50	-	-	-	-	0.030 max	0.030 max
15Ni13Cr3[d]	0.12-0.18	0.15-0.40	0.35-0.65	3.00-3.50	0.60-1.00	-	-	-	-	0.035 max	0.030 max
15Ni16Cr5	0.12-0.18	0.10-0.35	0.40-0.70	3.80-4.30	1.00-1.40	-	-	-	-	0.035 max	0.035 max
16Ni3Cr2	0.12-0.20	0.15-0.35	0.60-1.00	0.60-1.00	0.40-0.80	-	-	-	-	0.035 max	0.035 max
16Ni4Cr3	0.13-0.19	0.15-0.40	0.70-1.00	0.80-1.10	0.60-1.00	-	-	-	0.40 max	0.035 max	0.025 max
17Ni6Cr6	0.14-0.20	0.15-0.40	0.50-0.90	1.40-1.70	1.40-1.70	-	-	-	0.40 max	0.035 max	0.025 max
18Ni5Cr4	0.16-0.21	0.15-0.40	0.60-0.90	1.20-1.50	0.90-1.20	-	-	-	0.40 max	0.035 max	0.025 max
30Ni16Cr5	0.26-0.34	0.10-0.35	0.40-0.70	3.90-4.30	1.10-1.40	-	-	-	-	0.035 max	0.035 max
31Ni11Cr3	0.27-0.35	0.15-0.35	0.35-0.65	2.50-3.00	0.60-1.00	-	-	-	-	0.030 max	0.030 max
35Ni5Cr2	0.30-0.40	0.10-0.35	0.60-0.90	1.00-1.50	0.45-0.75	-	-	-	-	0.035 max	0.035 max
36Ni5Cr3	0.32-0.40	0.15-0.35	0.50-0.80	1.00-1.50	0.50-0.90	-	-	-	-	0.030 max	0.030 max
36Ni13Cr3	0.32-0.40	0.15-0.35	0.35-0.65	3.00-3.50	0.60-1.00	-	-	-	-	0.030 max	0.030 max
CHROMIUM MOLYBDENUM STEEL											
7Cr4Mo6	0.12 Max	0.15-0.60	0.40-0.70	-	0.70-1.10	0.45-0.65	-	-	-	0.035 max	0.035 max
10Cr9Mo10	0.15 Max	0.50 Max	0.40-0.70	-	2.00-2.50	0.90-1.10	-	-	-	0.035 max	0.035 max
15Cr4Mo2	0.13-0.18	0.15-0.35	0.60-0.90	-	0.90-1.20	0.15-0.25	-	-	-	0.030 max	0.030 max
15Cr13Mo6	0.10-0.20	0.15-0.35	0.40-0.70	-	2.90-3.40	0.45-0.65	-	-	-	0.035 max	0.035 max
18Cr4Mo2[d]	0.15-0.21	0.15-0.40	0.60-0.90	-	0.90-1.20	0.15-0.25	-	-	-	0.035 max	0.030 max
20Cr4Mo2	0.17-0.23	0.15-0.35	0.60-1.00	-	0.90-1.20	0.15-0.25	-	-	-	0.030 max	0.030 max
20Cr2Mo5	0.17-0.23	0.10-0.40	0.70-1.00	-	0.30-0.60	0.40-0.50	-	-	0.40 max	0.035 max	0.025 max
21Cr4Mo2	0.26 Max	0.10-0.35	0.50-0.80	-	0.90-1.20	0.15-0.30	-	-	-	0.035 max	0.035 max
22Cr3Mo5S	0.19-0.24	0.10-0.40	0.70-1.00	-	0.70-1.00	0.40-0.50	-	-	0.40 max	0.020-0.040	0.025 max

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22Cr4Mo4	0.20-0.25	0.15-0.35	0.60-0.90	-	0.90-1.20	0.35-0.45	-	-	-	0.030 max	0.030 max
24Cr4Mo2	0.20-0.27	0.10-0.40	0.60-0.90	-	0.90-1.20	0.15-0.30	-	-	0.40 max	0.035 max	0.025 max
25Cr4Mo2[d]	0.22-0.29	0.10-0.40	0.60-0.90	-	0.90-1.20	0.15-0.30	-	-	-	0.035 max	0.030 max
25Cr13Mo6	0.20-0.30	0.10-0.35	0.40-0.70	-	2.90-3.40	0.45-0.65	-	-	-	0.035 max	0.035 max
30Cr4Mo2	0.28-0.33	0.15-0.35	0.60-0.90	-	0.90-1.20	0.15-0.30	-	-	-	0.030 max	0.030 max
32Cr6Mo2	0.27-0.37	0.15-0.35	0.30-0.60	-	1.00-1.50	0.15-0.30	-	-	-	0.030 max	0.030 max
34Cr4Mo4	0.30-0.37	0.10-0.40	0.60-0.90	-	0.90-1.20	0.15-0.30	-	-	0.40 max	0.035 max	0.025 max
35Cr4Mo2	0.33-0.38	0.15-0.35	0.60-0.90	-	0.90-1.20	0.15-0.30	-	-	-	0.030 max	0.030 max
40Cr4Mo2[d]	0.38-0.45	0.10-0.40	0.60-0.90	-	0.90-1.20	0.15-0.30	-	-	-	0.035 max	0.035 max
40Cr4Mo3	0.35-0.45	0.10-0.35	0.50-0.80	-	0.90-1.20	0.20-0.35	-	-	-	0.035 max	0.035 max
45Cr4Mo2	0.43-0.48	0.15-0.35	0.60-0.90	-	0.90-1.20	0.15-0.30	-	-	-	0.030 max	0.030 max
50Cr4Mo2	0.46-0.54	0.10-0.40	0.50-0.80	-	0.90-1.20	0.15-0.30	-	-	0.40 max	0.035 max	0.025 max
CHROMIUM VANADIUM STEEL											
42Cr6V1	0.37-0.47	0.10-0.35	0.50-0.80	-	1.40-1.70	-	0.07-0.12	-		0.035 max	0.035 max
50Cr4V1	0.45-0.55	0.15-0.40	0.70-1.10	-	0.90-1.20	-	0.10-0.20	-		0.035 max	0.035 max
50Cr4V2	0.45-0.55	0.10-0.35	0.50-0.80	-	0.90-1.20	-	0.15-0.30	-		0.035 max	0.035 max
51Cr4V4	0.47-0.55	0.10-0.40	0.60-1.00	-	0.80-1.10	-	0.10-0.25	-	0.40 max	0.025 max	0.025 max
58Cr4V1	0.53-0.63	0.15-0.35	0.80-1.10	-	0.90-1.20	-	0.07-0.12	-		0.035 max	0.035 max
NICKEL CHROMIUM MOLYBDENUM STEEL											
15Ni5Cr4Mo1	0.12-0.18	0.10-0.35	0.60-1.00	1.00-1.50	0.75-1.25	0.08-0.15	-	-	-	0.035 max	0.035 max
15Ni7Cr2Mo2	0.12-0.18	0.15-0.35	0.40-0.70	1.60-2.00	0.40-0.60	0.15-0.30	-	-	-	0.030 max	0.030 max
15Ni7Cr4Mo2	0.12-0.18	0.10-0.35	0.60-1.00	1.50-2.00	0.75-1.25	0.10-0.20	-	-	-	0.035 max	0.035 max
15Ni17Cr3Mo2	0.12-0.18	0.15-0.35	0.30-0.60	4.00-4.50	0.70-1.00	0.15-0.30	-	-	-	0.030 max	0.030 max
16Ni8Cr6Mo2	0.12-0.20	0.10-0.35	0.40-0.70	1.80-2.20	1.40-1.70	0.15-0.25	-	-	-	0.035 max	0.035 max
16Ni12Cr6Mo5	0.13-0.20	0.15-0.35	0.80-1.20	2.80-3.20	1.40-1.80	0.40-0.60	-	-	-	0.030 max	0.030 max
17Ni6Cr4Mo2	0.14-0.20	0.15-0.40	0.60-0.90	1.20-1.60	0.80-1.10	0.15-0.25	-	-	0.40 max	0.035 max	0.025 max
18Ni6Cr7Mo3	0.15-0.21	0.15-0.40	0.50-0.90	1.40-1.70	1.50-1.80	0.25-0.35	-	-	0.40 max	0.035 max	0.025 max
20Ni2Cr2Mo2[d]	0.17-0.23	0.15-0.40	0.60-0.95	0.40-0.70	0.35-0.70	0.15-0.25	-	-	-	0.035 max	0.035 max
20Ni7Cr2Mo2	0.17-0.23	0.15-0.35	0.40-0.70	1.60-2.00	0.40-0.60	0.15-0.30	-	-	-	0.035 max	0.035 max
25Ni13Cr5Mo2	0.20-0.30	0.15-0.35	0.35-0.60	3.00-3.50	1.00-1.50	0.15-0.30	-	-	-	0.030 max	0.030 max
30Ni12Cr12Mo6	0.25-0.35	0.15-0.35	0.35-0.60	2.50-3.50	2.50-3.50	0.50[c]-0.70	-	-	-	0.030 max	0.030 max
30Ni8Cr8Mo4	0.26-0.34	0.10-0.40	0.50-0.80	1.80-2.20	1.80-2.20	0.30-0.50	-	-	0.40 max	0.035 max	0.025 max
31Ni7Cr3Mo2	0.27-0.35	0.15-0.35	0.60-0.90	1.60-2.00	0.60-1.00	0.15-0.30	-	-	-	0.030 max	0.030 max

31Ni10Cr3Mo6	0.27-0.35	0.10-0.35	0.40-0.70	2.25-2.75	0.50-0.80	0.40-0.70	-	-	-	0.035 max	0.035 max
34Ni6Cr6Mo2	0.30-0.38	0.10-0.40	0.50-0.80	1.30-1.70	1.30-1.70	0.15-0.30	-	-	0.40 max	0.035 max	0.025 max
36Ni4Cr4Mo2	0.32-0.40	0.10-0.40	0.50-0.80	0.90-1.20	0.90-1.20	0.15-0.30	-	-	0.40 max	0.035 max	0.025 max
39Ni7Cr3Mo2	0.36-0.43	0.15-0.35	0.60-0.90	1.60-2.00	0.60-1.00	0.15-0.30	-	-	-	0.030 max	0.030 max
40Ni2Cr2Mo2	0.37-0.44	0.10-0.40	0.70-1.00	0.40-0.70	0.40-0.60	0.15-0.30	-	-	-	0.035 max	0.030 max
40Ni6Cr4Mo2[d]	0.35-0.45	0.10-0.35	0.40-0.70	1.20-1.60	0.90-1.30	0.10-0.20	-	-	-	0.035 max	0.035 max
40Ni6Cr4Mo3	0.35-0.45	0.10-0.35	0.40-0.70	1.25-1.75	0.90-1.30	0.20-0.35	-	-	-	0.035 max	0.035 max
40Ni10Cr3Mo6	0.36-0.44	0.10-0.35	0.40-0.70	2.25-2.75	0.50-0.80	0.40-0.70	-	-	-	0.035 max	0.035 max
47Ni7Cr3Mo2	0.44-0.50	0.15-0.35	0.60-0.90	1.60-2.00	0.60-1.00	0.15-0.30	-	-	-	0.030 max	0.030 max
CHROMIUM MOLYBDENUM VANADIUM STEEL											
40Cr13Mo10V2	0.35-0.45	0.10-0.35	0.40-0.70	-	3.00-3.50	0.90-1.10	0.15-0.25	-	-	0.035 max	0.035 max
CHROMIUM MOLYBDENUM ALUMINIUM STEEL											
40Cr7Al10Mo2	0.35-0.45	0.10-0.35	0.40-0.70	-	1.50-1.80	0.10-0.25	-	0.90-1.30	-	0.035 max	0.035 max
45Cr6Al10Mo2	0.40-0.50	0.15-0.50	0.60 Max	-	1.30-1.70	0.15-0.30	-	0.70-1.20	-	0.030 max	0.030 max
STEELS WITH BORON											
20C13BT	0.17-0.23	0.40 max	1.10-1.40	-	-	B: 0.0008-0.0050			0.40 max	0.035 max	0.025 max
30C13BT	0.27-0.33	0.40 max	1.15-1.45	-	-	B: 0.0008-0.0050			0.40 max	0.035 max	0.025 max
39C13BT	0.36-0.42	0.40 max	1.15-1.45	-	-	B: 0.0008-0.0050			0.40 max	0.035 max	0.025 max
16Mn5Cr5BT	0.14-0.19	0.15-0.40	1.00-1.30	-	0.80-1.10	B: 0.0008-0.0050			0.40 max	0.035 max	0.025 max
27Mn5Cr2BT	0.24-0.30	0.40 max	1.10-1.40	-	0.30-0.60	B: 0.0008-0.0050			0.40 max	0.035 max	0.025 max
33Mn5Cr2BT	0.30-0.36	0.40 max	1.20-1.50	-	0.30-0.60	B: 0.0008-0.0050			0.40 max	0.035 max	0.025 max
39Mn6Cr2BT	0.36-0.42	0.40 max	1.40-1.70	-	0.30-0.60	B: 0.0008-0.0050			0.40 max	0.035 max	0.025 max

Note:

a) When required, the steels shall be supplied in fully Aluminium killed condition and the total Aluminium content shall be within 0.020-0.050%. When the steel is aluminium killed or killed with both Aluminium and Silicon, the requirements of minimum Silicon content shall not apply except for grades alloyed with Silicon (≥0.50%).

b) For grades specifying maximum Sulphur, Sulphur in the range of 0.020-0.035% or any other range may be agreed to between the manufacturer and purchaser. For such grades specifying sulphur range, a letter 'S' shall be added at the end of grade designation.

c) The lower limit of Mo may be 0.30% upon agreement between the purchaser and the manufacturer.

d) Cu may be 0.40% max upon agreement between the purchaser and the manufacturer.

e) Si may be 0.40% max, Cu may be 0.30% max, Cr may be 0.40% max, Mo may be 0.10% max and Ni may be 0.40% max upon agreement between the purchaser and the manufacturer.

- In the case of steels with hardenability requirements, minor deviations from the specified limits are permitted (with the exception of sulphur and phosphorus), provided that they do not exceed 0.01% for carbon and the values indicated in Table 1 for the other elements.

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- In special cases, it may be desirable that the range of carbon or other elements content should be more closely controlled than in the range specified above. When this is necessary, restricted ranges of carbon or other elements may be agreed to between the manufacturer and the purchaser.

Appendix-2

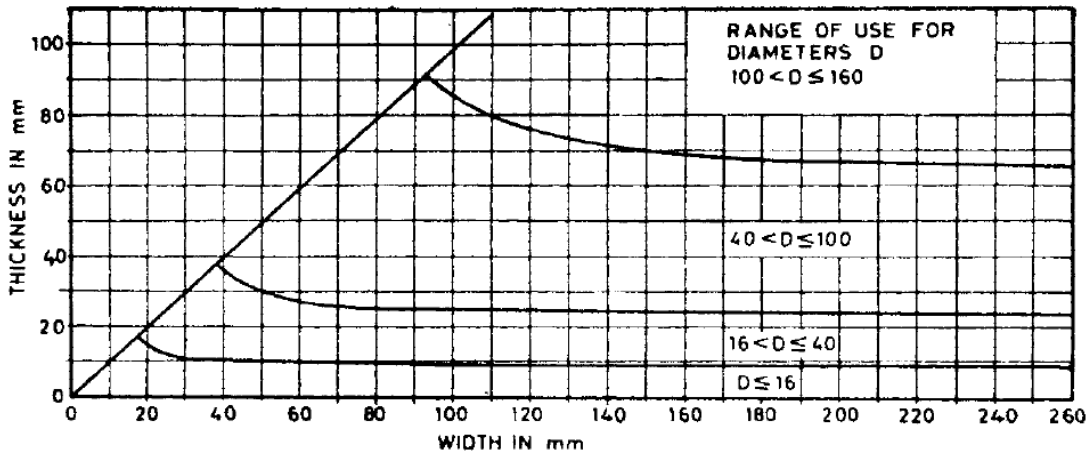
TABLE A. 2 TENSILE PROPERTIES

(Clauses 10.1)

Grade	Tensile Strength *Min* (MPa)	Yield Strength *Min* (MPa)	Elongation ($GL = 5{\cdot}65\sqrt{S_o}$), *Min*, Percent	Normalizing Temperature (°C) (For information only)
(1)	(2)	(3)	(4)	(6)
14C8	370	200	26	880—910
15C8	410	220	25	880—910
20C8	430	230	24	880—910
25C8	460	250	22	880—910
30C8	490	270	21	860—890
35C8	540	280	20	850—880
45C8	620	320	15	830—860
55C8	710	350	13	810—840
65C8	740	370	10	800—830

Note:

1) The properties given in the table refer to ruling section upto 100 mm in the as rolled or as forged and normalized condition and are applicable to test samples taken along the direction of grain flow. For higher section as well as for the supply in the hardened and tempered condition, the properties shall be as agreed to between the purchaser and the manufacturer.
2) The properties are applicable to test piece taken on rounds. For rectangular sections the ranges for equivalent section shall be as given in Fig. A.1



Appendix-2

Fig A.1 APPLICABILITY OF THE VALUES, GIVEN IN TABLE A.2 FOR ROUND SECTION, TO RECTANGULAR SECTION

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TABLE A.3 Provisional Limiting Rockwell Hardness for End Quench Test
(Clause 10.3)

Steel Grade	Limits of Spread	Hardness HRC at a Distance from End Quench Face in mm														
		1.5	3	5	7	9	11	13	15	20	25	30	35	40	45	50
27C15	Maximum	55	54	51	48	45	42	39	37	33	31	29	28	27	27	26
	Minimum	46	43	37	31	27	23	20	-	-	-	-	-	-	-	-
16Mn5Cr4	Maximum	47	46	44	41	37	35	34	33	31	30	29	28	27	-	-
	Minimum	39	35	31	28	24	22	20	-	-	-	-	-	-	-	-
20Mn5Cr5	Maximum	49	49	48	46	44	42	41	40	37	35	34	33	31	-	-
	Minimum	41	39	36	33	31	29	27	25	23	21	-	-	-	-	-
40Cr4	Maximum	61	61	60	59	58	56	54	52	46	42	40	38	37	36	35
	Minimum	53	52	50	47	44	40	37	35	30	27	25	23	22	21	20
14Cr6Ni6	Maximum	47	47	46	45	43	42	41	39	37	35	3$	34	33	-	-
	Minimum	39	38	36	35	32	30	28	26	24	22	20	20	-	-	-
40Cr4Mo3	Maximum	61	61	61	60	60	59	59	58	56	53	51	48	47	46	45
	Minimum	53	53	52	51	50	48	45	43	38	35	34	33	32	32	32
42Cr4Mo2	Maximum	61	61	61	60	60	59	59	58	56	53	51	48	47	46	45
	Minimum	53	53	52	51	50	48	45	43	38	35	34	33	32	32	32
50Cr4V2	Maximum	65	65	64	64	63	63	62	61	60	58	56	55	54	53	53
	Minimum	57	56	56	55	53	52	50	48	44	41	40	39	38	37	37