Minutes of 5th meeting of panel 4 of MTD 4

Scope: Development/revision of Standards on Semis (ingots/billet/blooms) for plain carbon and alloy steels for re-rolling or forging stock

Venue: CISCO Webex, VC Date:02 March 2023,1500-1600h

Sl No	Organization	Name of expert	Email ID	Role in panel
1	SAIL-ISP	Sh Saikat Kumar de	saikat6028@gmail.com	Convener
2	Mukand Sumi Steels Ltd	Sh M M Rao Sh Sunil Nair	mmrao@mukandsumi.com sunilnair@mukandsumi.com	Member(Absent)
3	Tata Steel Long products	Dr T Bhaskar	t_bhaskar@tatasteellp.com	Member(Absent)
4	Bharat forge	Sh Sagar Bapat	sagarbapat@bharatforge.com	Member(Absent)
5	JSW, Salem	Sh B M Hasan	bm.hasan@jsw.in	Member(Absent)
6	CHW forge	Nomination awaited		Member
7	Saarloha Steels Ltd	Nomination awaited		Member
8	L&T	Nomination awaited		Member
9	AIFI	Murali shankar R Siva prasad	muralishankar@superautoforge.net rsreddy@rachamallu.com trupti@indianforging.org(invitee)	Member
10	CMD-2	Sh Shivam Ahuja	cmd2@bis.gov.in	invitee

The members discussed on the proposal for having a single standard for semis/bars covering unalloyed as well as low and medium alloyed steels for forgings for general engineering purposes under IS 4368.

During the discussions, it was opined that it would be appropriate to revise IS 4368:1967 suitably so that it assumes the position of single standard for semis for forging purposes, superseding the remaining 2 standards on semis for forgings namely IS 1875 and IS 13352, produced through ingot casting as well as concast route.

Draft standard is given at Annex-1

Meeting ended with a vote of thanks to the Chair.

Annex-1

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.

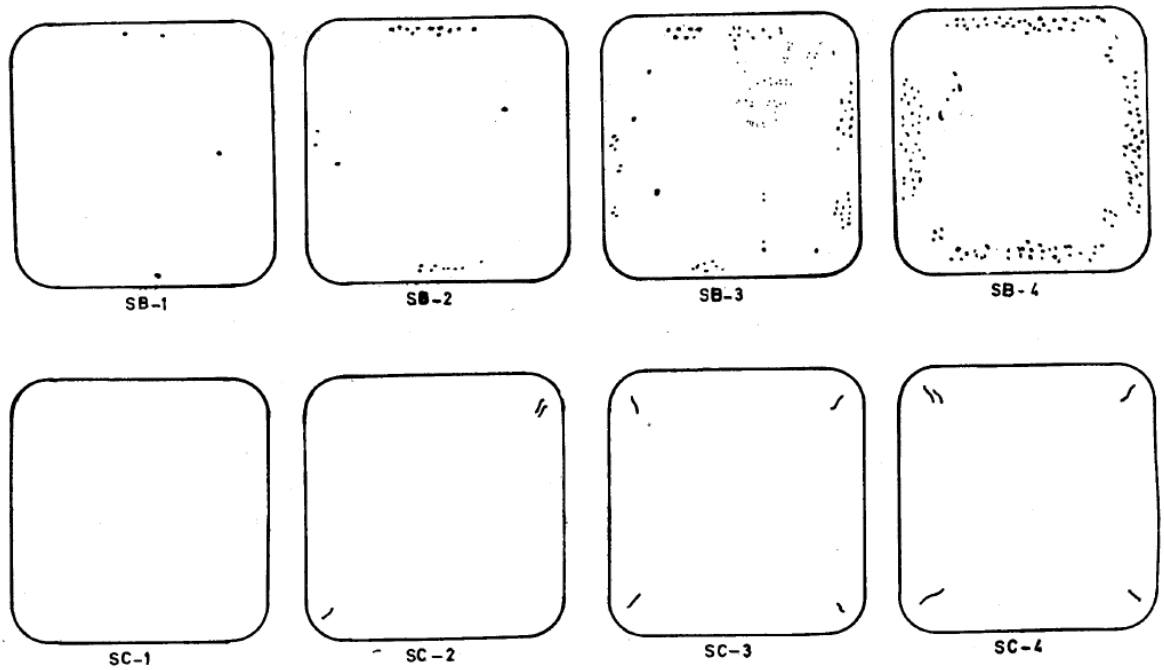
6.2 Internal Defects

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.

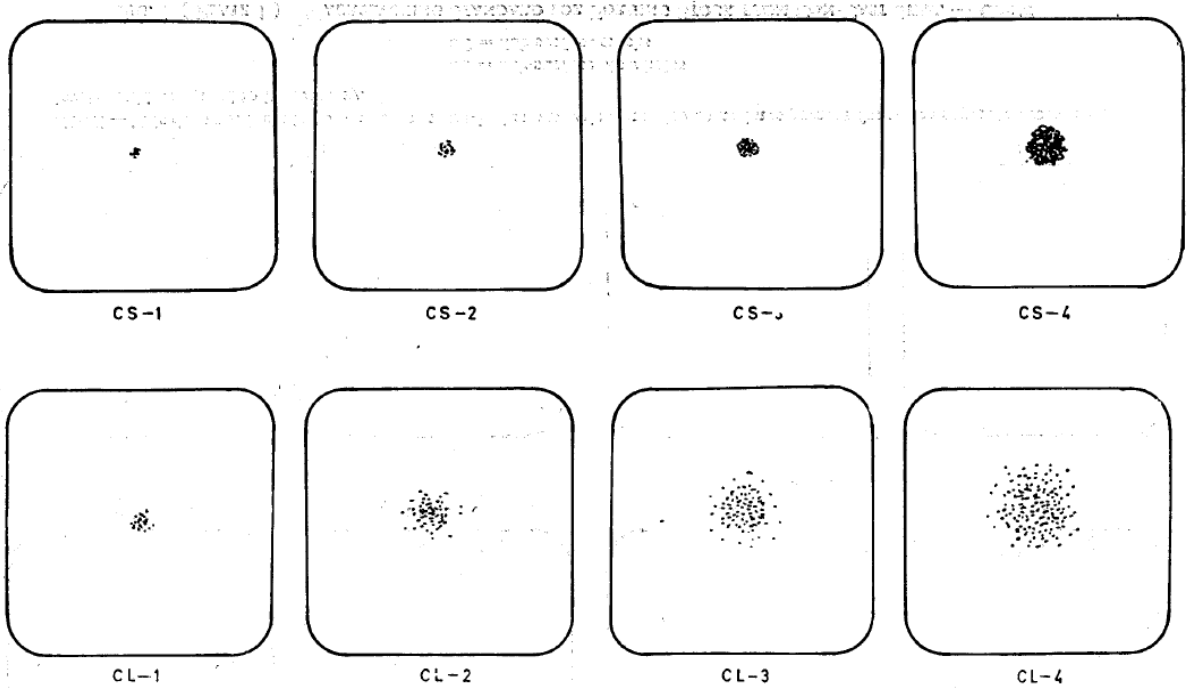
6.2.4 The forging stock shall be by and large homogenous and free from large, segregated inclusions and macrostreaks when examined by macroetching the longitudinal section.



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.

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.

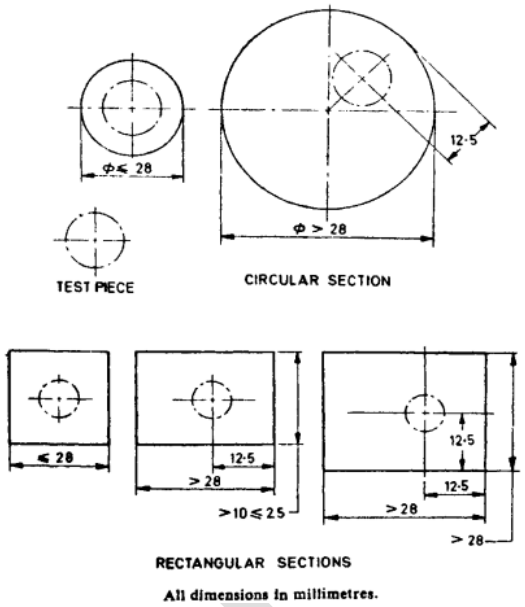


Fig 2 LOCATION OF THE TENSILE TEST PIECES IN THE PRODUCTS

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.

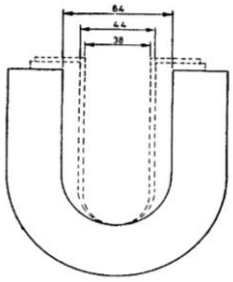
13.4 Decarburized depth: Decarburization depth shall be assessed as per IS 6396.

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;

ANNEX A

TABLE A. 1 LADLE ANALYSIS
(Clauses 7.1)

Designation	CONSTITUENT, PERCENT									
	C	Si	Mn	Ni	Cr	Mo	V	Al[a]	S[b]	P
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
UNALLOYED STEEL										
10C4	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
15C8	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
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
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										
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	-	-	-	-	0.035 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
20Cr4	0.18-0.23	0.15-0.35	0.60-0.90	-	0.90-1.20	-	-	-	0.030 max	0.030 max
30Cr4	0.28-0.33	0.15-0.35	0.60-0.90	-	0.90-1.20	-	-	-	0.030 max	0.030 max
35Cr4	0.33-0.38	0.15-0.35	0.60-0.90	-	0.90-1.20	-	-	-	0.030 max	0.030 max
40Cr4	0.35-0.45	0.10-0.35	0.60-0.90	-	0.90-1.20	-	-	-	0.035 max	0.035 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	0.14-0.19	0.10-0.35	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	0.17-0.22	0.10-0.35	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
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	0.12-0.18	0.15-0.35	0.35-0.65	3.00-3.50	0.60-1.00	-	-	-	0.030 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
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	0.16-0.21	0.15-0.35	0.60-0.90	-	0.90-1.20	0.15-0.25	-	-	0.030 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
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
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
25Cr4Mo2	0.23-0.28	0.15-0.35	0.60-0.90	-	0.90-1.20	0.15-0.30	-	-	0.030 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
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	0.38-0.45	0.10-0.35	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
CHROMIUM VANADIUM STEEL										

42Cr6V1	0.38-0.46	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
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
20Ni2Cr2Mo2	0.17-0.23	0.15-0.35	0.60-0.90	0.40-0.70	0.40-0.60	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
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
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	0.38-0.43	0.15-0.35	0.70-1.00	0.40-0.70	0.40-0.60	0.15-0.30	-	-	0.030 max	0.030 max
40Ni6Cr4Mo2	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

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) Sulphur in the range of 0.020-0.035% or any other range may be agreed to between the manufacturer and purchaser. For 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.

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
65C6	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

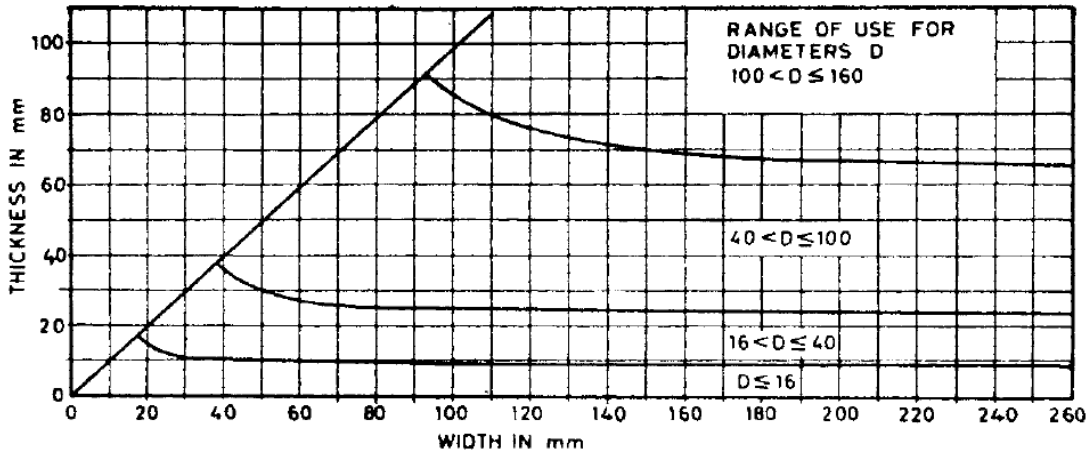


Fig A.1 APPLICABILITY OF THE VALUES, GIVEN IN TABLE A.2 FOR ROUND SECTION, TO RECTANGULAR SECTION

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