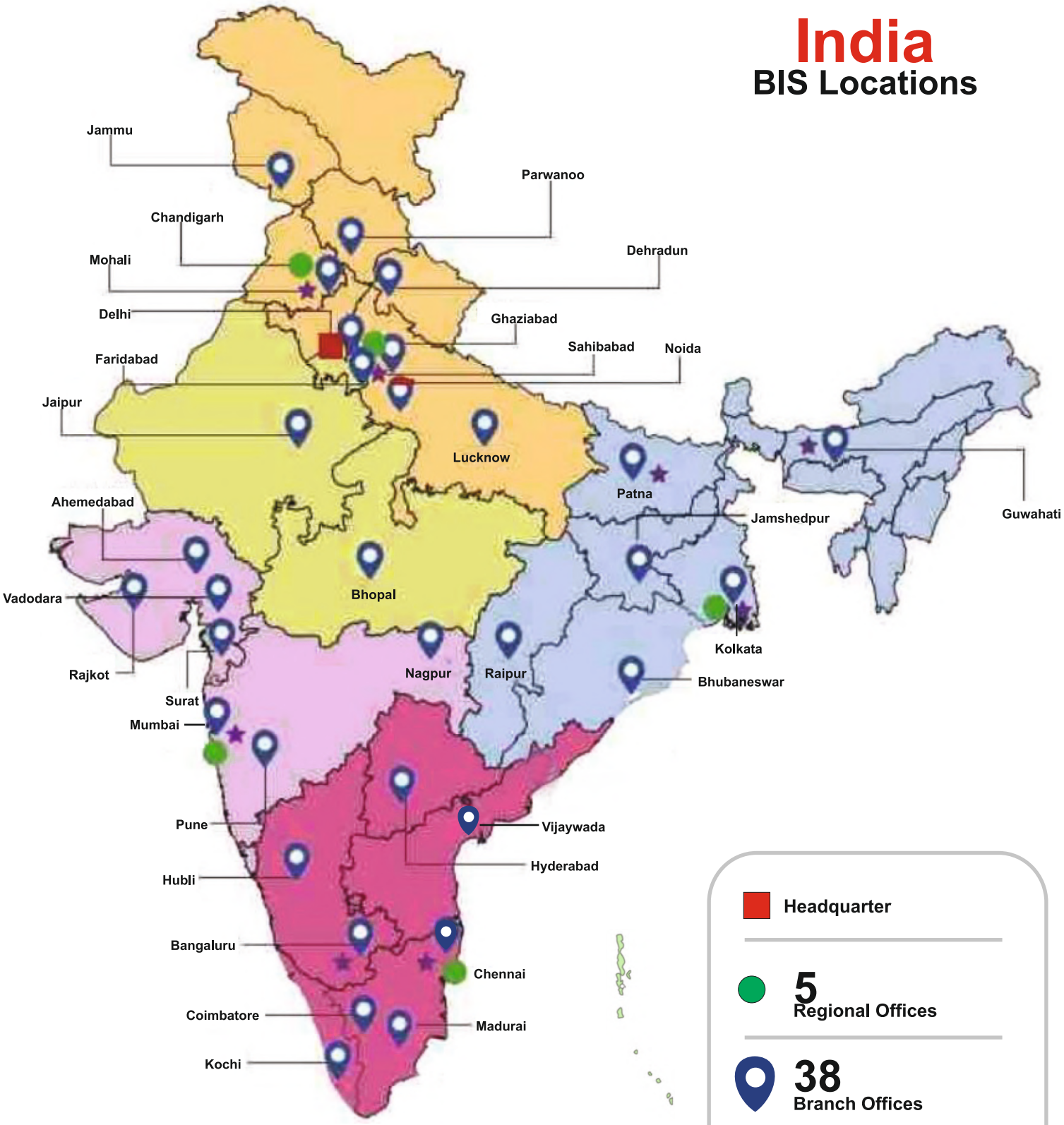
INDIAN STANDARDS ON METALLOGRAPHY AND HEAT TREATMENT

BUREAU OF INDIAN STANDARDS
Ministry of Consumer Affairs
Food and Public Distribution
Government of India

भारतीय मानक ब्यूरो
उपभोक्ता मामले, खाद्य और
सार्वजनिक वितरण मंत्रालय
भारत सरकार

India
BIS Locations



Headquarter

5 Regional Offices

38 Branch Offices

8 Laboratories

— Training Institute (NITS)

सत्यमेव जयते

मानकः पथप्रदर्शकः

Azadi Ka Amrit Mahotsav

ABOUT BIS

Bureau of Indian Standards (BIS), the National Standards Body (NSB) of India was established under the *BIS Act*, 1986 and came into existence on 1 April 1987 assuming the functions of the erstwhile Indian Standards Institution (ISI). The ISI was established on 6 January 1947. *The BIS Act*, 2016 came into force on 12 October 2017 superseding BIS Act 1986. *The BIS Act*, 2016 provides for the establishment of a national standards body for the harmonious development of the activities of standardization, conformity assessment and quality assurance of goods, articles, processes, systems and services and for matters connected therewith or incidental thereto.

BIS through its core activities of standardization and conformity assessment, has been benefiting the national economy by providing safe, reliable and quality goods; minimizing health hazards to consumers; protecting the environment; controlling over proliferation of varieties; promoting exports and imports substitutes, etc. The standardization and conformity assessment schemes of BIS apart from benefitting the consumers and industry also support various public policies especially in areas of product safety, consumer protection, food safety, environment protection, building and infrastructure development, etc.

BIS also represents India in international standards bodies like International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC) and participates actively in the international standardization work undertaken by these bodies. BIS presents the national viewpoints on new areas taken up for international standardization and on various draft international standards during the process of development of these standards so that the country's interest is protected and reflected in these standards. This also enables the BIS technical committees to consider adoption of the international standards as Indian Standards, with or without modifications, in order to enable our products and services to integrate with global trade and commerce.

What are Standards?

Standard is a document, established by consensus and approved by a recognized body, that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context.

Importance of Standardization

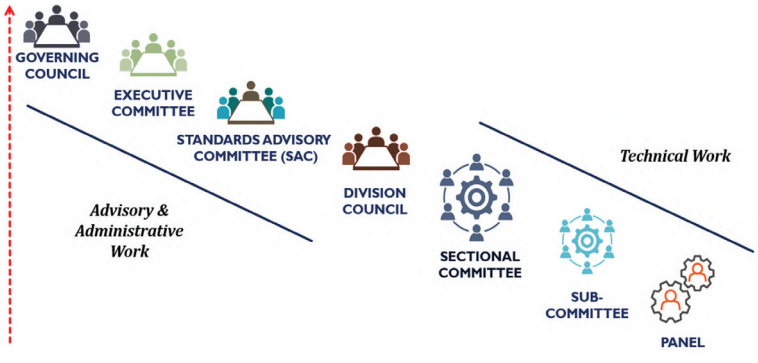
Standardization is the process of developing technical standards through consensus of different parties.This standardization aims to address one or all of compatibility, interchangeability, variety control, safety, environment protection, product protection and fitness for purpose. Standards provide numerable benefits to the technologists, producers, consumers and traders besides defining purpose for each of these entities.

Standards can be formulated at various levels ranging from an individual to National (IS) through to International level (ISO). Also, depending on the subject in hand, standards can be made on various aspects such as terminology, specification, sampling, testing, code of good practice and model form of contract.

STANDARDIZATION ACTIVITY OF BIS

Standardization Structure

There are 16 Technical Departments formulating standards in various subject areas. Corresponding to these departments 16 division councils exist. Each division council has several sectional committees working under it. The standards cover important segments of economy and help the industry in upgrading the quality of their goods and services.

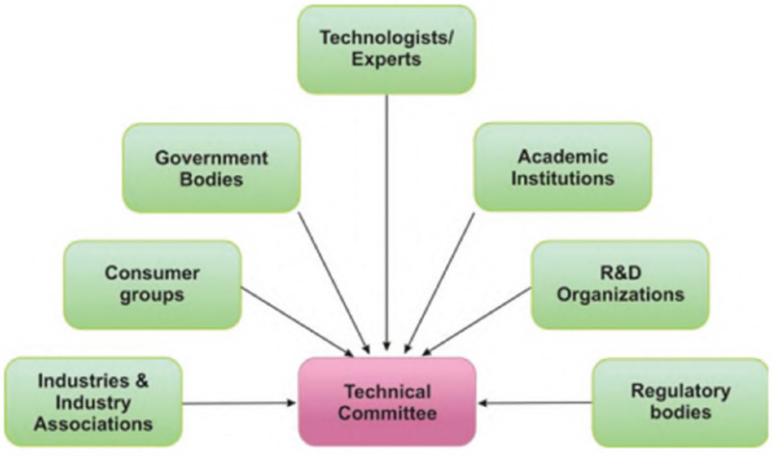


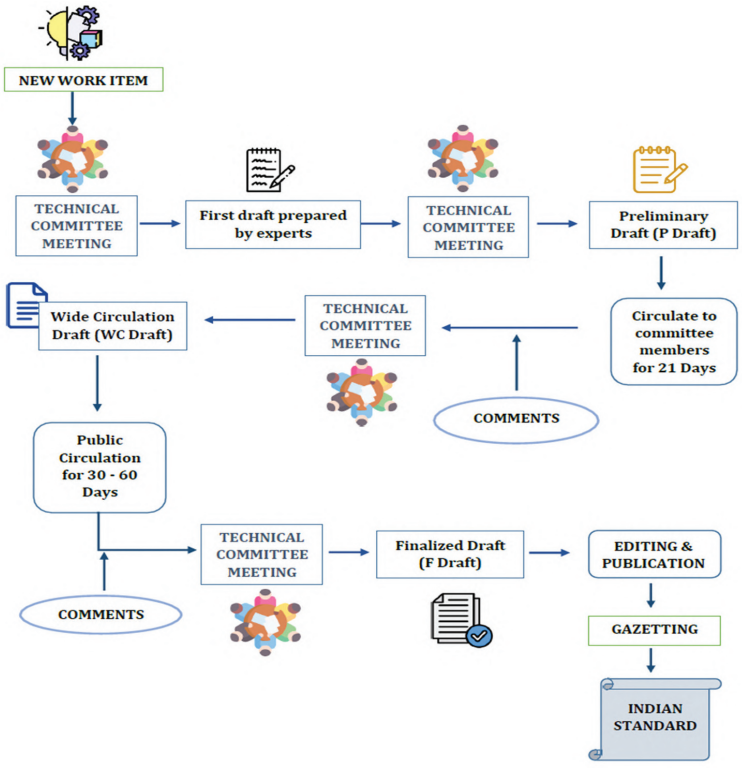
Ayush Division Council (AYDC)	Chemical Division Council (CHDC)	Civil Engineering Division Council (CEDC)	Electro-Technical Division Council (ETDC)
Electronics & Telecommunication Division Council (LITDC)	Food and Agriculture Division Council (FADC)	Mechanical Engineering Division Council (MEDC)	Management and Systems Division Council (MSDC)
Metallurgical Engineering Division Council (MTDC)	Medical Equipment & Hospital Planning Division Council (MHDC)	Petroleum, Coal & Related Products Division Council (PCDC)	Production and General Engineering Division Council (PGDC)
Transport Engineering Division Council (TEDC)	Textile Division Council (TXDC)	Water Resources Division Council (WRDC)	Service Sector Division Council (SSDC)

Standards Formulation Process

The Indian Standards are developed by technical committees that are representative of various stakeholders having interest in the relevant subject of standardization under the scope of such committees through a process of consultation so that views of all are given due consideration and a consensus is evolved in formulating a standard. The stakeholders involved in national standardization can broadly be categorized as industry, consumers/ users, technologists (R&D and scientific institutions, academia, individual subject experts, etc) and government departments/regulators.

The process of standards development of BIS is aligned with accepted international best practices that are based on the core principles of openness, transparency, impartiality and consensus. The process begins with the identification of the standardization needs of the given sector or subject following which the development of the standard is taken up and planned bythe relevant technical committee. Apart from consultation within the technical committees, draft standards are also open for public views/comments.





Standards Development Process Flow

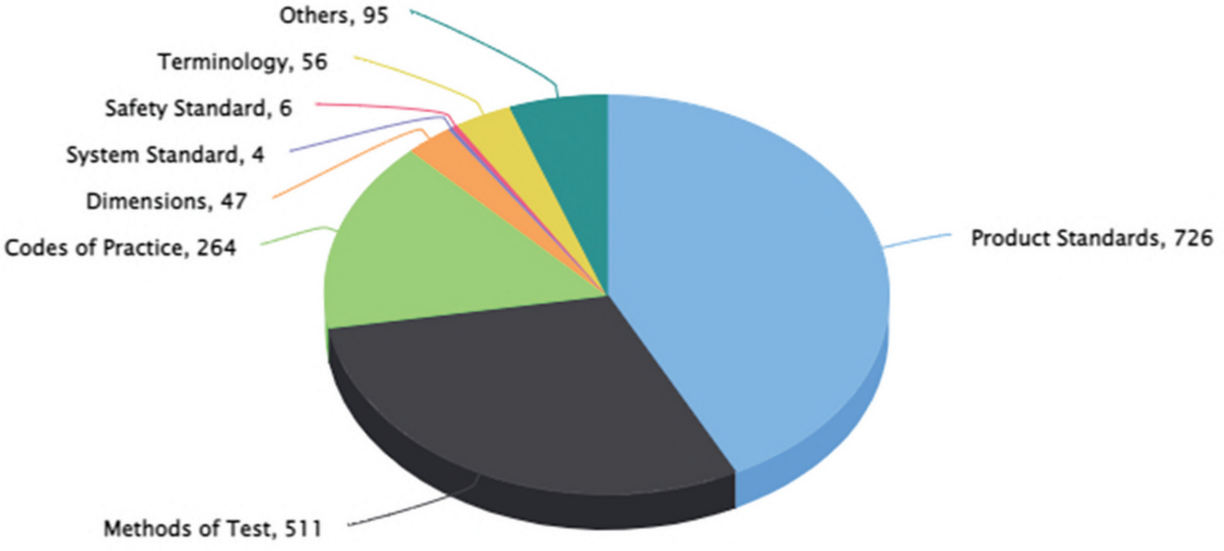
INTRODUCTION TO METALLURGICAL ENGINEERING DEPARTMENT (MTD), BIS:

Metallurgical Engineering Department(MTD) is one of the 15 technical departments of BIS with the scope "*Standardization in the field of metallurgy and metallurgical engineering including ferrous and non-ferrous metals, alloy and their products, ores and minerals, foundry, refractories and powder metallurgy, heat-treatment, corrosion protection, metallic and non-metallic coating (excluding paints, pigments and enameling) and welding (excluding electrical welding equipment) and Nanomaterials and technologies*".

MTDC is division council of MTD department.

Total standards published by MTD (as of March 2022): **1709**

Aspect wise distribution is as follows:



BIS is a founder member of International Organization for Standardization (ISO) and is actively involved in development of International Standards by acting as Participating (P) member or

Observer (O) member on various Technical Committees, Sub-Committees, Working Groups, etc.

MTD, BIS is a 'P' member in 57 committees and 'O' Member in 31 committees of ISO.

LIST OF TECHNICAL COMMITTEES WORKING UNDER MTDC

Under MTDC, there are 20 Sectional Technical Committees working in various subject areas. List of committees with their scope is as follows:

T.C. Number	T.C. Name	SCOPE
MTD03	Mechanical Testing of Metals	*Standardization in the field of mechanical testing of metals*
MTD04	Alloy Steels and Forging	*Standardization in the field of steel and wrought steel products including classification, designation and coding of steels*
MTD06	Pig iron and Cast iron	*Standardization in the field of pig iron, various types of cast iron castings*
MTD07	Ores and Feed Stock for Aluminium Industry, its Metals/Alloys and Products	*Standardization in the field of Aluminium Ores and other feed stock for Aluminium industry and Standardization in the field of Aluminium Metals, their alloys and products*

T.C.	T.C. Name	SCOPE
MTD08	Ores and Feed Stock for Copper Industry, its Metals/ Alloys and Products	*Standardization in the field of copper ores and other feed stock for copper industry and standardization in the field of copper metals, their alloys and products*
MTD09	Ores and Feed Stock for Non-Ferrous (Excluding Aluminium and Copper) Industry, their Metals/ Alloys and Products	*Standardization in the field of Non-Ferrous Ores and other feed stock for Non-Ferrous Industry and Standardization in the field of Non-Ferrous Metals, their alloys and products. (Excluding Standardization in the field of Ores and Feed Stock for Aluminium and Copper Industry and their Metals, Alloys and Products)*
MTD10	Precious Metals	*Standardization in the field of precious metals*
MTD11	Welding General and its Applications	*Standardization in the field of welding fundamentals, \ consumables, equipments (other than electrical), testing, training, safety etc. and all welding processes including joining, surfacing, repairing and thermal cutting, soldering, brazing, friction welding, explosive, ultrasonic welding, beam welding (laser and electron beam), etc.*
MTD13	Ores and Feed Stock for Iron and Steel Industry	*Standardization in the field of Ferrous ores, Ferro Alloys, Sponge Iron/Direct Reduced Iron and other Metallic additions/Feedstock used in the Iron and Steel making Industry*
MTD14	Foundry and Steel Castings	*Standardization in the field of foundry materials, foundry practices and steel castings*
MTD15	Refractories	*Standardization in the field of refractories*
MTD16	Alloy Steels and Forging	*Standardization in the field of alloy & special steels and forging, including classification, designation and coding of related steels*
MTD19	Steel Tubes, Pipes and Fittings	*Standardization in the field of steel tubes, pipes and fittings including classification, designation and coding of steel tubes*
MTD21	Non-Destructive Testing	*Standardization in the field of non-destructive testing*
MTD22	Metallography and Heat-Treatment	*Standardization in the field of metallography and heat-treatment of ferrous and non-ferrous metals and alloys*
MTD24	Corrosion Protection and Finishes	*Standardization in the field of corrosion, passivation and protection of metals, metal products in different applications, characteristics of protective and decorative metallic coatings, anodic oxide coatings, applied by electrolysis, hot dipping, thermal spraying, chemical means their testing and inspection methods*
MTD25	Powder Metallurgical materials and Products	*Standardization in the field of powder metallurgical materials*
MTD26	Industrial Fuel-Fired Furnaces	*Standardization in the field of industrial fuel fired furnaces*
MTD33	Nanotechnologies	*Standardization in the field of Nanomaterials and Nanotechnologies*
MTD34	Methods of Chemical Analysis of Metals	*Standardization in the field of chemical/instrumental analysis of ferrous, non-ferrous metals, ores and other raw materials*

IMPORTANT STANDARDS OF MTD

Following is the list of important Indian standards formulated by MTD:

Gold and Silver jewellery/artefacts standards

BIS is operating Hallmarking Scheme of gold and silver jewellery/artefacts. This Hallmarking scheme is based on the following Indian Standards formulated by MTD.

1.	IS 1417	Gold and Gold alloys, jewellery/artifacts – fineness and marking.
2.	IS 2112	Silver and silver alloys, jewellery artifacts – fineness and marking.
3.	IS 15820	General requirements for competence of assaying and hallmarking centre

Ferrous and Non-Ferrous product standards

MTD has formulated following important standards on Ferrous and Non-Ferrous products:

1.	IS 191	Copper – Specification
2.	IS 737	Wrought aluminium and aluminium alloy sheet and strip for general engineering purposes – Specification
3.	IS 1239 (Several Parts)	Steel tubes, tubulars and other wrought steel fittings – Specification
4.	IS 2062	Hot rolled medium and high tensile structural steel – Specification
5.	IS 2830	Carbon steel cast billet ingots, billets, blooms and slabs for re-rolling into steel for general structural purposes – Specification
6.	IS 4367	Alloy steel forgings for general industrial use – Specification
7.	IS 5522	Stainless steel sheets and strips for utensils – Specification
8.	IS 12444	Copper Wire Rods for Electrical Applications – Specification
9.	IS 15392	Aluminium and aluminium alloy bare foil for food packaging - Specification

Destructive and Non-Destructive Test standards

1.	IS 1500 (Several Parts)	Metallic materials – Brinell hardness test
2.	IS 1586 (Several Parts)	Metallic materials – Rockwell hardness test
3.	IS 1608 (Several Parts)	Metallic materials – Tensile testing
4.	IS 2417	Glossary of terms used in ultrasonic non-destructive testing
5.	IS 3415	Glossary of terms used in magnetic particle flaw detection
6.	IS 3658	Code of practice for liquid penetrant flaw detection

7.	IS 3703	Recommended practice for magnetic particle flaw detection
8.	IS 4904	Calibration blocks for use in ultrasonic non – Destructive testing – Specification
7.	IS 12965	Glossary of terms used in electromagnetic (Eddy Current) testing
8.	IS 12710	Acoustic emission testing – Glossary of terms
9.	IS 13805	General standard for qualification and certification of non - Destructive testing personnel – Specification

Chemical Analysis standards

1.	IS 228 (Several Parts)	Methods for chemical analysis of steels
2.	IS 504 (Several Parts)	Chemical analysis of aluminium and its alloys parts 1 to 12

Miscellaneous Standards

1.	IS 814	Covered electrodes for manual metal arc welding of carbon and carbon manganese steel – Specification
2.	IS 822	Code of procedure for inspection of welds
3.	IS 1068	Electroplated coatings of nickel plus chromium and copper plus nickel plus chromium - Specification
4.	IS 1987	High silica sand for use in foundries – Specification
5.	IS 2629	Recommended practice for hot-dip galvanizing of iron and steel
6.	IS 2644	High strength steel castings for general engineering and structural purposes – Specification
7.	IS 4736	Specification for hot – Dip zinc coatings on mild steel tubes
8.	IS 9139	Specification for malleable iron shots and grits for use in foundries
9.	IS 15769	Flux cored (Tubular) electrodes for gas shielded and self - Shielded metal welding of carbon or carbon - Manganese steel

METALLOGRAPHY AND HEAT-TREATMENT

- Metallography and Heat-Treatment Sectional Committee, MTD 22 is one of the 20 sectional committees working under MTDC with the scope "*Standardization in the field of metallography and heat-treatment of ferrous and non-ferrous metals and alloys*".
- This committee has formulated total 39 standards. Complete list of standards formulated by this committee is placed below:

S.N.	IS No.	TITLE
1	IS 1956 (Part 1) : 1976	Glossary of terms relating to iron and steel Part 1 general metallurgy heat treatment and testing (First Revision)
2	IS 3848 : 1981ISO 642:1999	Method for end quench test for hardenability of steel (First Revision)
3	IS 4075 : 1985	Method for macrostreak flaw test for steel (First Revision)
4	IS 4163 : 2021 ISO 4967:2013	Steel - Determination of content of non-metallic inclusions - Micrographic method using standard diagrams
5	IS 4748 : 2021ISO 643 : 2019	Steel - Micrographic determination of the apparent grain size
6	IS 5699 : 1970	Methods for chill testing of cast iron
7	IS 6396 : 2000ISO 3887:2017	Methods of measuring decarburized depth of steel (Second Revision)
8	IS 6416 : 2022	Method for measuring case-depth of steel (Second Revision)
9	IS 7739 (Part 1) : 1975	Code of practice for preparation of metallographic specimens Part 1 general features
10	IS 7739 (Part 2) : 1975	Code of practice for preparation of metallographic specimens Part 2 electrolytic polishing
11	IS 7739 (Part 3) : 1975	Code of practice for preparation of metallographic specimens Part 3 aluminium and its alloys and their examination
12	IS 7739 (Part 4) : 1975	Code of practice for preparation of metallographic specimens Part 4 copper and its alloys and their examination
13	IS 7739 (Part 5) : 1976	Code of practice for preparation of metallographic specimens Part 5 iron and steel and their examination
14	IS 7739 (Part 6) : 1975	Code of practice for preparation of metallographic specimens Part 6 lead and its alloys and their examination
15	IS 7739 (Part 7) : 1975	Code of practice for preparation of metallographic specimens Part 7 magnesium and its alloys and their examination
16	IS 7739 (Part 8) : 1975	Code of practice for preparation of metallographic specimens Part 8 nickel and its alloys and their examination
17	IS 7739 (Part 9) : 1975	Code of practice for preparation of metallographic specimens Part 9 gold silver platinum palladium and their alloys
18	IS 7739 (Part 10) : 1975	Code of practice for preparation of metallographic specimens Part 10 tin and its alloys and their examination

S.N.	IS No.	TITLE
19	IS 7739 (Part 11) : 1976	Code of practice for preparation of metallographic specimens Part 11 zinc and its alloys and their examination
20	IS 7754 : 1975	Method for designation of the microstructure of graphite in cast iron
21	IS 8860 : 1978	Code of practice for heat treatment of aluminium alloys
22	IS 9415 : 1980	Method for determination of hardenability and grain size of tool steels by penetration fracture test
23	IS 10138 : 2010 ISO 3763:1976	Macroscopic methods for determination of non-metallic inclusion content in wrought steels (Second Revision)
24	IS 11371 : 2022	Method for macroetch testing inspection and rating of wrought steel products
25	IS 12037 : 1987 ISO 4968 : 1979	Specification for macrographic examination of steel by sulphur print Baumann Method
26	IS 12211 : 1987 ISO 5949 :1983	Specification for micrographic method for assessing the distribution of carbides in tool steels and bearing steels using reference photomicrographs
27	IS 12366 : 1988	Recommended practice for heat treatment of titanium and titanium alloys
28	IS 12378 : 1988	Method for macroetch test for titanium alloys
29	IS 12573 : 2010	Method for macroetch test for wrought aluminium and aluminium alloy products (First Revision)
30	IS 13417 : 1992	Code of practice for heat treatment of steels
31	IS 13484 : 1992	Method for macroetch test for copper and copper alloys
32	IS 13605 : 1992	Method for macroetch test for zinc and zinc alloys
33	IS 13655 : 1993	Guidelines for heat treatment of cast iron
34	IS 13691 : 1993 ISO 4970:1979	Steel – Determination of total or effective thickness of thin surface – Hardened layers
35	IS 14598 : 1998	Heat treatment of maraging steel – Code of practice
36	IS 15426 : 2004 ISO 14250:2000	Steel – Metallographic characterization of duplex grain size and distributions
37	IS 15839 : 2021 ISO 13520:2015	Determination of ferrite content in austenitic stainless steel castings
38	IS 17174 : 2020 ISO 16574:2015	Determination of Percentage of Resolvable Pearlite in High Carbon Steel Wire Rod
39	IS 17175 : 2020 ISO 16573:2015	Steel Measurement Method for the Evaluation of Hydrogen Embrittlement Resistance of High Strength Steels

List of important Indian standards on Metallography and Heat-Treatment:

Sl No.	IS Number	IS Title
1	IS 3848	Method for end quench test for hardenability of steel (*first revision*)
2	IS 4075	Method for macrostreak flaw test for steel (*first revision*)
3	IS 4163	Steel – Determination of content of non-metallic inclusions — Micrographic method using standard diagrams (*fourth revision*)
4	IS 4748	Steel — Micrographic determination of the apparent grain size(*third revision*)
5	IS 7739 (Part I)	Code of practice for preparation of metallographic specimens Part I General features
6	IS 8860	Code of practice for heat treatment of aluminium alloys
7	IS 13417	Code of practice for heat treatment of steel

IS 13417 CODE OF PRACTICE FOR HEAT TREATMENT OF STEEL

SCOPE

This standard describes the heat treating procedures, temperature schedules, equipment requirement and other details relating to the heat treatment of plain carbon and low alloy steels.

TYPES OF HEAT TREATMENT

The various types of heat treatments generally applied to carbon and low alloy steels are as follows:

a) **Stress relieving -** The process consists in heating the material slowly and uniformly to a suitable temperature below the transformation range (AC, for ferritic steels), holding at this temperature for a predetermined time, followed by slow and uniform cooling to minimize the development of new internal stresses.

b) **Normalising -** Normalising is accomplished by heating carbon steel to about 50°C above the upper critical line of the iron-iron carbide diagram that is; above AC_3 for hypoeutectoid steels and AC_1 for hypereutectoid steels, followed by cooling in still or agitated air.

c) **Annealing -** Annealing denotes the heating of steel above a suitable temperature holding for appropriate time, followed by cooling at a suitable rate. Steels may be annealed to achieve softness, produce desired microstructure, enhance ductility, relieve internal stresses, improve machinability, etc.

d) **Hardening -** Hardening of steel involves heating to a temperature from 30-50°C above AC_3 (for hypereutectoid steels) and above point AC_1 (for hypereutectoid steels) holding until the completion of phase transformation, followed by cooling at a rate greater than the critical cooling rate.

e) **Special Heat Treatment**

i. **Martempering -** Martempering or more appropriately termed 'marquenching' is an elevated temperature quenching procedure aimed at reducing cracking, distortion and residual stresses in steels. Martempering involves, quenching steel from the austenitizing temperature, into a hot liquid maintained or just below the MS temperature holding in the quenching medium to ensure temperature equalization throughout the workpiece, followed by air cooling to room temperature

ii. **Austempering -** Austempering of steel consists in isothermal transformation of the austenite at a temperature lower than that of pearlite formation and above that of martensite formation, resulting in the formation of a bainitic microstructure. Austempering is usually substituted for conventional quenching and tempering to obtain increased ductility and notch toughness at a given hardness and to also reduce cracking and distortion.

iii. **Patenting -** Patenting is a heat treatment process that is applied to high carbon steel wire rods and 'in process' wires to develop a fine sorbitic structure that is amenable to large area reductions in cold drawing to high strength levels.

f) **Case Hardening**

i. **Carburizing -** Carburizing of steel consists of increasing the surface carbon content so that upon heat treatment, a hard layer of martensite is produced.

ii. **Carbonitriding -** Carbonitriding is carried out by addition of ammonia to the gas carburizing atmosphere so as to simultaneously saturate the surface of steel with both carbon and nitrogen. Carbonitriding is generally applied to components of complex shapes, for example gears which are prone to warping,

iii. **Nitriding -** Nitriding consists in saturating the surface of steel with nitrogen by heating it in an ammonia atmosphere at a temperature of 500° - 600°C. Nitriding increases the hardness, wear resistance, endurance limit, corrosion resistance of the surface layer by creating a thin case containing alloy nitrides. The nitriding treatment can also be carried out by heating steel parts in molten cyanide cyanate baths containing salts of sodium and potassium.

iv. **Cyaniding -** Cyaniding is performed by heating steel in a bath of molten alkali- cyanides, mixed with chlorides and carbonates to saturate the surface with carbon and nitrogen simultaneously. Generally the salt bath contains about 30% NaCN, 40% Na_2CO_3 and 30% NaCl.

g) **Surface Hardening**

i. **Induction hardening -** In induction hardening, localized heating of the surface to its austenitizing temperature is accomplished by eddy current induced by an alternating magnetic field which surrounds the steel. The depth of hardened layer decreases with increasing current frequency. This treatment is generally used for crank shafts, cam shafts, gears, automobile components, etc.

ii. **Flame hardening -** This treatment is similar to induction hardening but employs high temperature flame to austenitize the surface of steel. The temperature flame is obtained by combustion of a mixture of fuel gas such as acetylene or propane with oxygen or air. Flame heads are used for burning the mixture and are of slit-type (having a single orifice in the form of a slit) or of multiple orifice type. This technique is generally used for large work such as mill rolls, heavy shafts, large gears and dies, machine ways etc.

iii. '**Laser Surface Hardening**' and '**Electron Beam Heat Treating**' can also be employed for austenitizing the steel for surface hardening.

INSPECTION AND TESTING OF HEATTREATED MATERIAL

a) **Visual Inspection :** Visual inspection of the heat treated articles is conducted to see whether the articles are free from surface defects, such a, cracks, distortion, warpage, scale etc. Extremely fine defects (internal cracks) that are hardly visible may be checked by special crack-detecting methods as agreed upon between the manufacturer and the customer.

b) **Mechanical Testing :** Heat treated parts may be subjected to various mechanical tests, such as hardness, tensile strength, yieId strength, percentage elongation, reduction in area and impact strength. Hardness measurements are to be routinely performed to as a heat treatment process check. Parts and configurations which do not permit measurement of hardness must be, during heat treatment, accompanied by test specimens from the same stock.

c) **Microscopic Examination :** Microscopic examination may be carried out from time-to-time by the heat treater as a valuable tool to monitor the quality of incoming steel stock, for in-process quality control and for customer inspection. Inspection of incoming steel stock is necessary prior to machining and subsequent heat treatment for detecting excessive decarburization or segregation, surface defects such as cracks and qualifying an alloy's hardenability according to grain size.

d) **Test Report :** If desired by the customer, the heat treater shall supply a test certificate incorporating the results of all tests carried out on the heat treated material.

IS 3848 METHOD FOR END QUENCH TEST FOR HARDENABILITY OF STEEL

SCOPE

This standard prescribes the method for determining the hardenability of steel by end quench or Jominy test.

PRINCIPLE OF THE TEST

The test consists in heating a test piece to a given temperature for a specified period of time followed by water quenching at one end and measuring the hardness at various points, from the quenched end along the length of the test piece in order to determine the hardenability of the steel by variation of this hardness.

TABLE 1 REFERENCE NUMBERS

Reference Number	Description	Value
1	Total length of test piece	100 ± 0.5 mm
2	Diameter	$25^{+0.5}_{-0}$
3	Time during which the test piece is maintained at the heating temperature	30 ± 5 min
4	Maximum time lag between removal of the test piece from the furnace and	5 sec
	the start of quenching	
5	Temperature of water	5 to 30°C
6	Inside diameter of vertical water supply pipe	12.5 ± 0.5 mm
7	Height of free water jet (that is, without test piece in position)	65 ± 10 mm
8	Distance from tip of nozzle to the bottom of test piece	12.5 ± 0.5 mm
9	Depth of flats for the measurement of hardness	0.4 to 0.5 mm

TEST PROCEDURE

1. Heating of the Test Piece

- The test piece shall be heated uniformly and then maintained for not less than 30 min at the specified temperature. For particulartypes of furnaces, this duration may be laid down as a result of previous experience, establishing the minimum time necessary for the centre of the piece to reach the desired temperature.
- Precautions shall be taken to avoid any decarburization of the test piece as well as its carburization or a marked oxidation.

2. Hardening of the Test Piece

- The hardening apparatus consists essentially of a means of fixing and centralizing the test piece placed vertically above the water jet. The water pipe shall contain a quick action tap, as well as a system to vary the flow rate of water. The length of the water supply pipe behind the tap shall be at least 50 mm in order-to ensure non-turbulent water flow. The device may also contain a disc allowing rapid opening and closing at the water jet.
- The test piece support shall enable automatic centralizing of the test piece above the water supply pipe and holding it during spraying. It shall be dry while the test piece is in position; splashing of water onto the test piece shall be avoided while it is being placed in position and before the actual hardening starts.

MEASUREMENT OF HARDNESS AFTER HARDENING

- Two flats for measuring the hardness shall be ground on the surface 180Ú apart and parallel to the axis of the test piece, along its entire length.
- The test piece shall then be secured in a suitable holder and measurements of Rockwell hardness, on **C scale** shall be carried out on the axis of the flats.
- The hardness measurements may also be made on the Vickers scale with a 30 kgf load.

Presentation of results

- Drawing of the Hardness Curves – Hardness curves shall be obtained by plotting distance d on the abscissa and the corresponding hardness values on the ordinate.
- Description of the Hardenability Characteristics of a Particular Steel

  a) By drawing its hardness curve; or

  b) By the hardness at three points, one point being 1.5 mm from the hardened end and the other two points fixed by agreement; or

  c) By the hardness at two points situated at distances fixed by agreement; and

  d) By the hardness at one specified distance from the quenched end.
- Specification for the hardenability of the product.

  a) By the curve(s) of depth of hardness which is either a curve above which the Jominy curve of depth of hardness of the steel shall be found, or a curve below which the Jominy curve of depth of hardness of the steel shall be found; or the two limits of scatter defining the area in which the curve of the steel shall be found.

  b) By particular points of the curve giving, the depth of hardness and which may be the upper limit or the lower limit or a range between the two limits, either by the distance from the quenched face for a given hardness or by the hardness at a given distance from the quenched end.

IS 4163 STEEL — DETERMINATION OF CONTENT OF NON-METALLIC INCLUSIONS — MICROGRAPHIC METHOD USING STANDARD DIAGRAMS

SCOPE

This International Standard specifies a micrographic method of determining the non-metallic inclusions in rolled or forged steel products having a reduction ratio of at least 3 using standard diagrams. This method is widely used to assess the suitability of a steel for a given use. However, since it is difficult to achieve reproducible results owing to the influence of the test operator, even with a large number of specimens, precautions should be taken when using the method.

PRINCIPLE

The method consists of comparing the observed field to the chart diagrams defined in this International Standard and taking in consideration separately each type of inclusion.

- Group A (sulfide type): highly malleable, individual grey particles with a wide range of aspect ratios (length/width) and generally rounded ends;
- Group B (aluminate type): numerous non deformable, angular, low aspect ratio (generally < 3), black or bluish particles (at least three) aligned in the deformation direction;
- Group C (silicate type): highly malleable, individual black or dark grey particles with a wide range of aspect ratios (generally > 3) and generally sharp ends;
- Group D (globular oxide type): non deformable, angular or circular, low aspect ratio (generally < 3), black or bluish, randomly distributed particles;
- Group DS (single globular type): circular, or nearly circular, single particle with a diameter > 13 ìm.

DETERMINATION OF THE CONTENT OF INCLUSIONS

Method of observation

— by projection on to ground glass,
— by observation by means of an eyepiece.

Actual examination

Method A

The entire polished surface is examined and, for each type of inclusion, a note is made of the reference number which lies to the side of the standard diagram which corresponds to the worst field examined, in the fine and thick series.

Method B

The entire polished surface is examined and each field of the specimen is compared with the standard diagrams. The reference number of the field (indicated to the side of the standard diagrams) which best corresponds to the field examined for each type of inclusion is noted, in the fine and thick series.

IS 4748 STEEL — MICROGRAPHIC DETERMINATION OF THE APPARENT GRAIN SIZE

SCOPE

This document specifies a micrographic method of determining apparent ferritic or austenitic grain size in steels. It describes the methods of revealing grain boundaries and of estimating the mean grain size of specimens with unimodal size distribution. Although grains are three-dimensional in shape, the metallographic sectioning plane can cut through a grain at any point from a grain corner, to the maximum diameter of the grain, thus producing a range of apparent grain sizes on the two-dimensional plane, even in a sample with a perfectly consistent grain size.

GRAINS

- ❖ Grain closed polygonal shape with more or less curved sides, which can be revealed on a flat cross-section through the sample, polished and prepared for micrographic examination
- ❖ Austenitic grain crystal with a face-centred cubic crystal structure which may, or may not, contain annealing twins
- ❖ Ferritic grain crystal with a body-centred cubic crystal structure which never contains annealing twins

GENERAL

index

positive, zero or possibly negative number G which is derived from the mean number m of grains counted in an area of 1 mm2 of the section of the specimen.

intercept

N

number of grains intercepted by a test line, either straight or curved

intersection

P

number of intersection points between grain boundaries and a test line, either straight or curved

PRINCIPLE

The grain size is revealed by micrographic examination of a polished section of the specimen prepared by an appropriate method for the type of steel and for the information sought.

This average size is characterized either:

a) by an index obtained

1) usually by comparison with standard charts for the measurement of grain size;

2) or by counting to determine the average number of grains per unit area;

b) or by the mean value of the intercepted segment

1) "Bechet-Beaujard" method by etching with aqueous saturated picric acid solution

2) "Kohn" method by controlled oxidation

3) "McQuaid-Ehn" method by carburization at 925 °C

4) Proeutectoid ferrite method

5) Bainite or gradient-quench method

6) Sensitization of austenitic stainless and manganese steels

7) Other methods for revealing prior-austenitic grain boundaries

A) Characterization by an index

1) Formulae

The index is defined by Formula (1):

$$m = 8\,x\,2^{G}$$

This formula may be stated as Formula (2):

$$G = \frac{\lg m}{\lg 2} - 3$$

or Formula (3):

$$G = \frac{\lg m}{0.301} - 3$$

2) Planimetric method

3) Estimation of the index

B) Characterization by the intercept method

1) Linear intercept segment method

2) Circular intercept segment method

IS 6416 METHODS FOR MEASURING CASE DEPTH OF STEEL

SCOPE

This standard prescribes the following five methods of measuring case depth (CD) of steel hardened by carburizing, nitriding, carbonitriding, cyaniding or induction and flame hardening:

a) Hardness method,
b) Chemical method,
c) Macrostructure method,
d) Microscopic method; and
e) Fracture method.

TERMINOLOGY

Effective Case Depth– It is the perpendicular distance from the surface to that point of the core of the piece at which hardness is equal to the values shown in table.

Total Case Depth–It is the perpendicular distance from the surface to that point at which the change in chemical composition, hardness or microstructure of the case and core no longer can be distinguished.

Type of Steel Steel with Carbon, Percent	HV	HRC	HRA	Treatment
0.28 to 0.32	350	35	68	Flame or induction hardened
0.33 to 0.42	400	40	70	
0.43 to 0.52	450	45	73	
Over 0.53	500	50	76	
Case hardening steels	550	-	-	Carburized, and hardenedand tempered
Nitriding and carbonitriding	Values to be mutually agreed upon			Nitrided and carbonitrided

a) Hardness method

i. Principle

This method consists of cutting the specimen at right angle to the hardened case, preparing the surface suitably for testing and making a hardness traverse on the case and core of the specimen.

ii. Preparation of Surface to be Examined

iii. Hardness Measurement

Hardness testers that produce small shallow indentations shall be used. Testers used to produce diamond pyramid or Knoop hardness numbers are recommended. The test load will be between

0.98 and 98.1 Newtons (0·1 and 10 kgf). Rockwell A or C scales produce a comparatively deeper indentation and these can be used in case of flame or induction hardened cases.

b) Chemical Method

This method is generally applicable only to carburized cases, but may be used for nitrided, cyanided or carbonitrided cases. The procedure consists in determining the carbon content (and nitrogen when applicable) at various depths below the surface of a test specimen. This method is considered the most accurate for measuring total case depth of carburized cases.

c) Macrostructure method

Macroscopic method of determination of case depth is recommended for routine process control, primarily because of short time required for determinations and minimum of specialized equipments and trained personnel needed. This method is mostly applied to hardened and carburized specimens.

d) Microscopic method

The test consists in determining the depth of preparation. Hardened surface under a metallurgical microscope. In the case of nitride parts where depth is thin, this method is recommended.

e) Fracture method

This method of measuring case depth by fracture test is applicable for carburized steel for routine process control purposes. Recognizing the need for a quick shop-floor test, this standard has been prepared to provide a guide for procedure to be adopted for rapid determination of case- depth in carburized steels. However, this method shall not be used as a referee method.

IS 7739 CODE OF PRACTICE FOR PREPARATION OF METALLOGRAPHIC SPECIMENS PART I GENERALFEATURES

SCOPE

This standard (Part I) covers the recommended methods of selection : size, cutting, cleaning and mounting of metallographic specimens for microscopic examination.

OTHER PARTS IN THE STANDARD

IS 7739 (Part II) : 1975 - Code of practice for preparation of metallographic specimens Part II Electrolytic polishing

- **Scope -** This standard (Part II) covers electrolytic polishing of metal specimens for metallographic observation.

IS 7739 (Part III) : 1975 - Code of practice for preparation of metallographic specimens Part III Aluminium and its alloys and their examination

- **Scope-** This standard (Part III) covers the polishing, etching and examination of aluminium and its alloys.

IS 7739 (Part IV) : 1975 - Code of practice for preparation of metallographic specimens Part IV copper and its alloys and their examination.

- **Scope -** This standard (Part IV) covers the polishing, etching and examination of copper and its alloys.

IS 7739 (Part V) : 1976 - Code of practice for preparation of metallographic specimens Part V iron and steel and their examination.

- **Scope -** This standard (Part V) covers the polishing, etching and examination of iron and steel.

IS 7739 (Part VI) : 1975 - Code of practice for preparation of metallographic specimens Part VI lead and its alloys and their examination.

- **Scope -** This standard (Part VI) covers polishing, etching and examination of lead and its alloys.

IS 7739 (Part VII) : 1975 - Code of practice for preparation of metallographic specimens Part VII Magnesium and its alloys and their examination

- **Scope -** This standard (Part VII) covers the polishing, etching and examination of magnesium and its alloys

IS 7739 (Part VIII) : 1975 - Code of practice for preparation of metallographic specimens Part VIII Nickel and its alloys and their examination

- **Scope -** This standard (Part VIII) covers the polishing, etching and examination of nickel and its alloys.

IS 7739 (Part IX) : 1975 - Code of practice for preparation of metallographic specimens Part IX Gold, silver, platinum, palladium and their alloys

- **Scope-** This standard (Part IX) covers the polishing, etching and examination of gold, silver, platinum, palladium and their alloys.

IS 7739 (Part X) : 1975 –Code of practice for preparation of metallographic specimens Part X Tin and its alloys and their examination

- **Scope -** This standard (Part X) covers the polishing, etching and examination of tin and its alloys.

IS 7739 (Part XI) : 1976 –Code of practice for preparation of metallographic specimens Part XI Zinc and its alloys and their examination

- **Scope-** This standard (Part XI) covers the polishing, etching and examination of zinc and its alloys.

CUTTING OF SPECIMENS

a) Dragging of the metal by the cutting edge. Lubrication during cutting tends to keep dragging at a minimum.

b) Flame cutting completely alters the structure of the metal at the flame cut edge. If flame cutting is necessary to remove the specimen, it should be cut sufficiently large so that it may be recut to the proper size by some other method.

c) Heating of hardened structure during cutting, thus tempering the material. This heating may be minimized by keeping the work cooled by water during cutting.

d) Where grinding or spark-machining techniques have been used to remove specimens from hard materials, care shall be taken to fully remove the affected layers by prolonged grinding on the coarse paper.

MOUNTING OF SPECIMENS

a) Mechanical mountings

b) Electroplated mountings

c) Cast and cement-like mountings

d) Thermosetting and Thermoplastic Materials.

The nominal Brinell hardness values of the moulding materials, using a 10 mm ball and 500 kg load, are as follows:

Moulding Material Thermoplastic	**Nominal Brinell Hardness**
Polystyrene	19-22
Methyl methacrylate : Soft	17-20
Hard	27
Thermosetting	
Aniline formaldehyde	30
Phenol-formaldehyde (Bakelite)	42

CLEANING, GRINDING AND POLISHING OF SPECIMENS

Rusted fractures may be cleaned with a diluted solution of ammonium citrate or phosphoric acid. In studying the underlying steel in a galvanized specimen, the zinc coating shall be removed before polishing. The zinc may be removed by solution in cold nitric acid (HNO_3) or in diluted sulphuric acid (H_2SO_4). The HNO_3 method requires care to prevent overheating, since large samples will generate considerable heat. By placing the cleaning container in cold water during the stripping of the zinc, the underlying steel will not be attacked after the removal of zinc.

IS 4075 METHOD FOR MACROSTREAK FLAW TEST FOR STEEL (First Revision)

SCOPE

This standard prescribes the method for carrying out the macrostreak flaw test for steel. The standard, however, does not lay down or establish limits of acceptability. This test is essentially used for determination of the presence of inclusions above 0.5 mm.

PRINCIPLE OF TEST

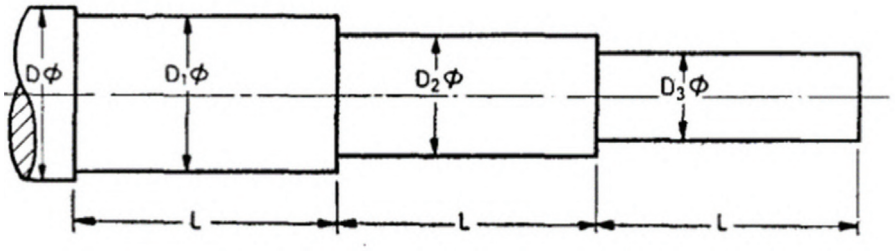
The test consists in determining the presence of flaws on machined surface of hot-rolled or forged steel. The test piece shall be machined to specified dimensions and inspected for flaws under good illumination with unaided eye or with low magnification up to 15 X or with both. In some cases, test pieces may be machined to smaller dimensions for further examination after the original surfaces are inspected.

TEST PIECE

a) The test piece (see figure in Table 1) shall be machined to the dimensions given in Table 1. The machined surface shall not be rough but shall be fairly smooth. The surface roughness of the test piece shall not exceed 6.3 *m*m *Ra*.

b) Steel of section other than round shall be forged down to a round section and used as the test piece.

TABLE 1 DIMENSIONS OF TEST PIECE



NOMINAL DIAMETER	DIAMETER OF THE FIRST STEP	DIAMETER OF THE SECOND STEP	DIAMETER OF THE THIRD STEP	LENGTH OF EACH STEP
D	D_1	D_2	D_3	*L*
Below 30	*D* – 2	–	–	64
30 to 75	*D* –4	*D* ´2/3	*D* ´1/2	64
above 75	*D* –6	*D* ´2/3	*D* ´1/2	64

TEST PROCEDURE

a) The length and the number of streak flaws shall be determined on each step of the machined test piece.

b) The length and the number of flaws shall be determined under good illumination either with an unaided eye or with low magnification up to15 X or both. Two streak flaws within a distance of 0.5 mm in the longitudinal direction or 0.2 mm in the transverse direction between them shall be counted as one streak flaw.

- **METHOD OF ESTIMATION**

a) The streak flaw shall be determined by its length and number.

b) The number of streak flaw shall be given for each step of the specimen by converting the number if streak flaw belonging to the same notation into the number per 100 cm^2 area. This shall be referred to as 'the conversion number'. The conversion number shall always be rounded off to the first figure.

c) The total severity of the flaws will be a summation of the product of notation and the conversion numbers.

TABLE 2 NOTATION OF STREAK FLAW

NOTATION OF MACROSTREAK FLAW	LENGTH OF MACROSTREAK FLAW	NOTATION OF MACROSTREAK FLAW	LENGTH OF MACROSTREAK FLAW
(1)	(2)mm	(1)	(2)mm
1	Over 0.5 to 1.0 incl	15	Over 12.0 to 15.0 incl
2	Over 1.0 to 2.0 incl	20	Over 15.0 to 20.0 incl
3	Over 2.0 to 3.0 incl	25	Over 20.0 to 25.0 incl
4	Over 3.0 to 4.0 incl	30	Over 25.0 to 30.0 incl
5	Over 4.0 to 5.0 incl	40	Over 30.0 to 40.0 incl
6	Over 5.0 to 6.0 incl	50	Over 40.0 to 50.0 incl
7	Over 6.0 to 8.0 incl	60	Over 50.0 to 60.0 incl
8	Over 8.0 to 10.0 incl	70	Over 60.0
9	Over 10.0 to 12.0 incl		

IS 8860 CODE OF PRACTICE FOR HEAT TREATMENT OF ALUMINIUM ALLOYS

SCOPE

This standard describes the heat-treating procedures, temperature schedules, equipment requirements and other details relating to the heat-treatment of aluminium alloys.

TYPES OF HEAT TREATMENT

a) *Annealing*– is carried out to soften work-hardened and heat-treated alloy structures and to relieve internal stresses. Aluminium alloy castings are also subjected to a 'stabilizing' anneal for stabilizing its properties and dimensions.

b) *Solution Heat-Treatment*– is carried out to effect solid solution of the alloying constituents and to improve the mechanical properties of the alloys.

c) *Precipitation Treatment*– is carried out to provide hardening by precipitation of constituents from solid solution.

EQUIPMENT FOR HEAT TREATMENT

a) Heating Media

b) Pyrometric Equipment

c) Quenching Equipment

d) Rinsing Equipment

SOLUTION HEAT-TREATMENT

a) **Temperature –**Aluminium alloy products, including alclad material shall be solution heat-treated within the specified temperature range.

b) **Soaking Time**– After reaching the solution temperature range, the charge should be held within that temperature range for sufficient time for the necessary solution to take place and to ensure that the specified properties will be developed.

c) **Reheat-Treatment**– The heat treatment of a material which has previously been heat-treated shall be considered a reheat-treatment. Accordingly, the first heat treatment of a material purchased in the heat-treated condition shall be considered a reheat-treatment.

d) **Quenching**

i. *Wrought Alloys*–Wrought alloy products (except forgings) should be quenched by total immersion in water of sufficient volume or circulation, or both, so that the water temperature at the completion of the quenching operation and removal of the load will be not more than 40°C.

ii. *Castings and Forgings*– Castings should be quenched by total immersion in water at 65 to 100°C. Forgings should be quenched by total immersion in water at 60 to 70°C.

e) **Control Stretching**– To relieve the residual stresses induced during solution heat-treatment, extrusions, rolled products and complex forgings should be subjected to a controlled stretching operation to the extent of 1.5-2.5 percent.

f) **Retardation of Age-Hardening**– Any necessary cold-working fabrication operation on the solution-treated alloys-should be performed while it is still in soft condition, and should be completed within two hours or so, before age-hardening reaches any significant proportion.

PRECIPITATION HEAT TREATMENTS

Recommended Precipitation Treatment –The recommended time-temperature cycles are specified in Table 1 which are typical for various forms, sizes, and methods of manufacture, and may not exactly describe the optimum treatment for specific product. However, in general, for products of large cross-sectional area or mass (such as plate), the longer time – lower temperature precipitation treatments are to be preferred to ensure maximum uniformity of properties.

ANNEALING

a) Annealing of Work-Hardened Wrought Alloys

b) Annealing of Heat-Treated Wrought Alloys

c) Annealing (Stress-Relieving) of Cast Alloys

d) Annealing of Alclad Articles

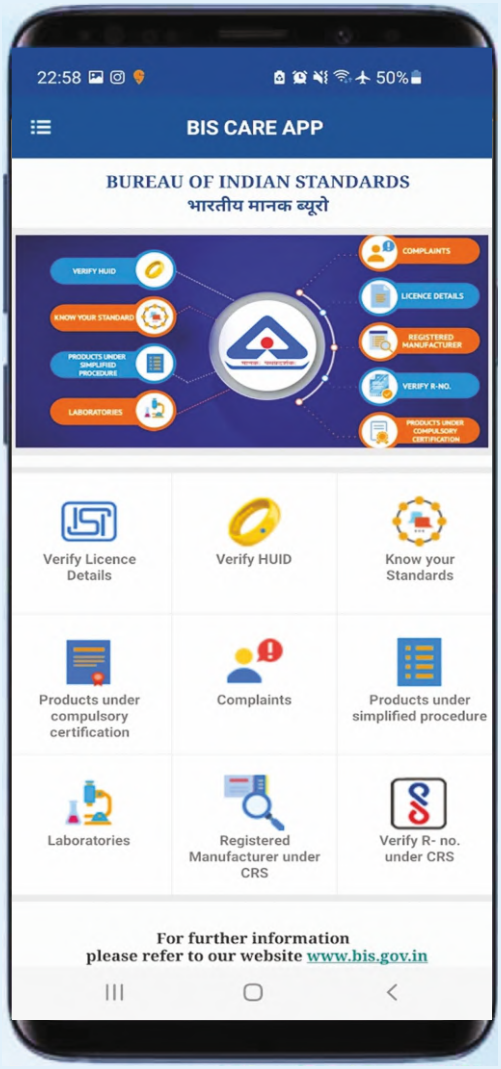
TESTS ON HEAT-TREATED MATERIAL

a) Mechanical Properties

b) Eutectic Melting and High-Temperature Oxidation

c) Intergranular Corrosion and Alclad Diffusion.

d) Improper Heat Treatment



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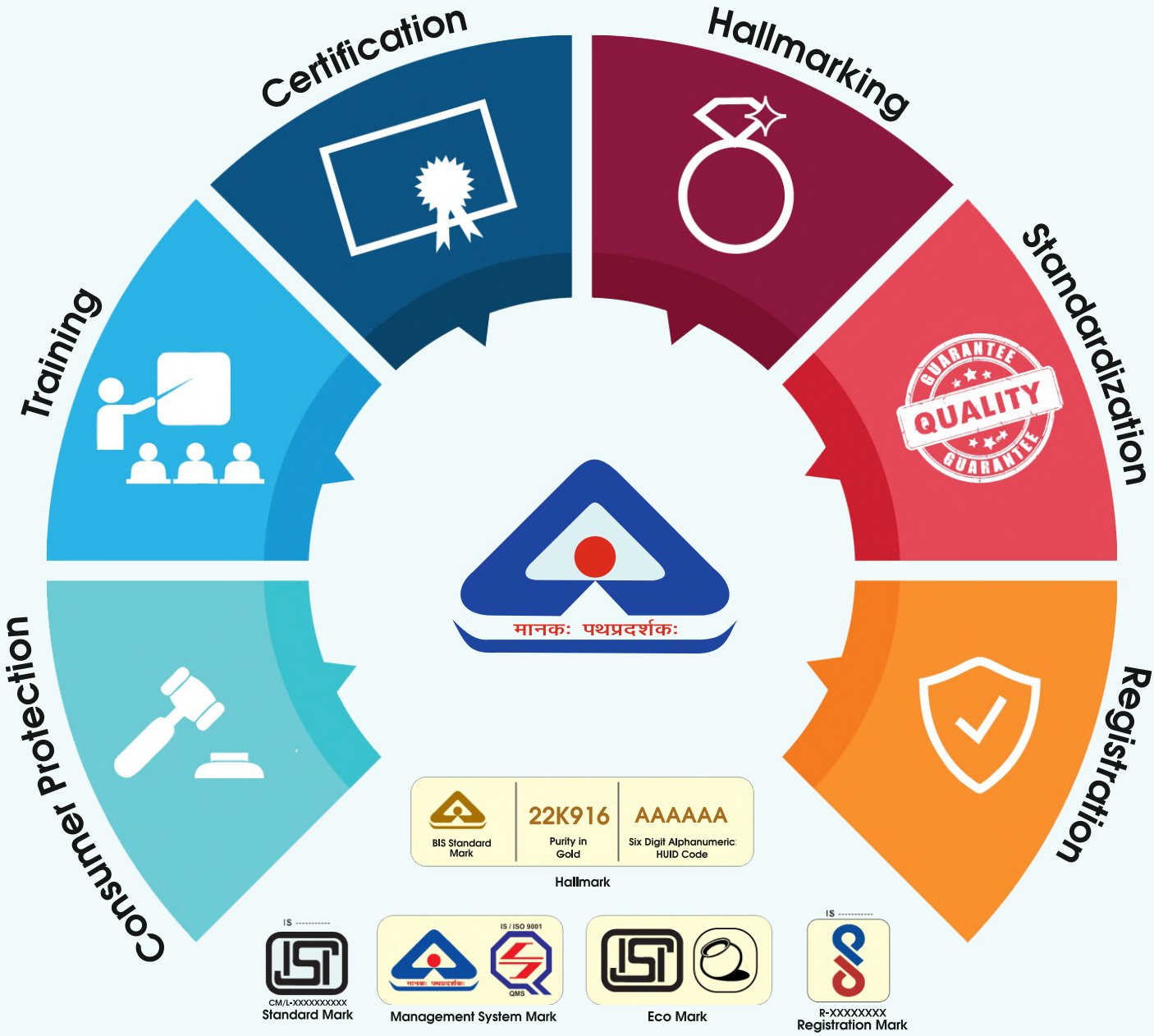

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