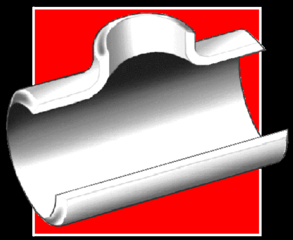
Section 10

General Information

This Section contains miscellaneous topics and general information applicable to stainless steel tubular products.



General Delivery Standards - ISO 404

This summary of stainless steel product delivery standards is based on the general technical delivery standards for steel and steel products, ISO 404, Steel and Steel Products - General Technical Delivery Standards. Specific delivery requirements are defined in product standards such as the ASTM standards as summarised in Section 2, 3 and 4 of this manual.

Dimensions and Tolerances

The dimensions and tolerances are specified in the appropriate product standards. Products produced to purchaser drawings must conform to product standards as appropriate.

Manufacture

- **Materials**. Materials are specified in the product standard or otherwise agree with the purchaser.
- **Manufacturing Processes**. These include all operations up to the product delivery. They are at the discretion of the manufacturer unless specified in the product standard, or otherwise agreed with the purchaser.
- **Mechanical Properties**. These refer to the as-delivered dimensions, condition and impact energy values from representative tests. They conform to product standards or purchaser requirements whenever specified.
- **Marking**. This includes: Identification to ensure traceability with the documentation, manufacturer's marks, and items specified in the product standard or as agreed with the purchaser.
- **Documentation**. The type of inspection document specified to be supplied with the product determines the inspection and testing that is performed on the product. It includes:
  - Identification to ensure traceability with the product.
  - Certification and/or test report information prepared in accordance with requirements for the product.

  If an intermediary between manufacturer and purchaser changes product state or dimensions, that intermediary must also certify compliance with the new conditions.

Finish - Surface and Internal Quality

- **General**. A workmanlike finish is required for all products. Minor imperfections that occur during manufacture are not considered cause for rejection, detailed requirements being specified in the product standard or as agreed with the purchaser. Standards ISO 7788 and ISO 9443 specifically address surface quality requirements.
- **Detection of defects**. Special techniques for the detection of defects include the use of radiography, ultrasonics, eddy current detection, magnetic detection etc. The methods and number of samples to be tested are specified in the product standard or as agreed with the purchaser.
- **Removal of discontinuities**. Surface discontinuities may be removed by mechanical or thermal means, provided that the dimensions and properties of the product remain within limits specified in the order, or in the product, dimensional or surface quality standards.
- **Repairs by welding**. Local repairs by welding may be permitted by the product standard, or by purchaser or inspector agreement.

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General Delivery Standards - ISO 404

Ordering Information

Item	Notes
Quantity	Length, number of pieces
Product form and Specification	Product standard or drawing reference
Nominal dimensions	As product standard
Tolerances	Dimensional and quantity tolerances
Designation of steel	Grade
Delivery condition	Type of heat treatment, surface treatment, etc
Specific requirements	Surface and internal quality. (Refer to finish information on page10-12.)
Inspection Document	Type of documentation and specific requirements
Quality Assurance System	As applicable, e.g. ISO 9001, ISO 9002 or ISO 9003
Marking, packaging and loading	Requirements
Optional (supplementary) requirements	As provided for in the product standard. These include inspection and test requirements

Testing

- **Types of inspection and testing**. The purchaser states the type of inspection document required and thereby indicates the inspection and testing required. This falls into two basic categories:
  - Nonspecific inspection and testing. This involves provision by the manufacturer of a certificate of compliance with the order or a test report. If a test report is required the purchaser specifies the characteristics for which test results are required, unless they are covered by the product specification.
  - Specific inspection and testing. This involves performance of specified inspections and tests as required for the ISO 10474 defined inspection certificate types 3.1 A or 3.1 B or 3.1 C, or inspection test record type 3.2.
- **Location**. Inspection and testing is performed at the manufacturer's works or at an agreed facility or accredited establishment.
- **Personnel**. One or more inspection representatives are assigned to act on behalf of the purchaser. These may be as designated in official regulations, provided by the manufacturer (independent of the production process), or provided by the purchaser.
- **Testing Frequency**. The product to be tested and the amount of testing to be performed on that product is defined in the product standard and/or the purchase order. These aspects should be defined as follows:
  - ***Test unit*** - the number of pieces or tonnage of the product to be accepted or rejected on the basis of tests performed. A test unit may be composed of the same cast (heat), the same casting sequence, the same heat treatment condition or batch, the same product form, and/or the same thickness.
  - ***Sample product*** - the item selected from a test unit for inspection and/or test. The number of sample products for each test unit is to be defined.
  - ***Sample*** - the material taken from a sample product for the preparation of test pieces. The number of samples from each sample product is required.
  - ***Test pieces*** - a part with specified dimensions prepared from a sample for submission to a given test. The number of test pieces per sample is required.
  - ***General requirements for sample preparation*** for mechanical tests and chemical analysis are detailed in ISO 377-1 and ISO 377-2. Specific requirements are detailed in the product standard and/or purchase order.
- **Test Methods**. Test methods are defined in the product standard and/or agreed with the purchaser. International Standards exist, covering the testing and analysis of iron and steel, and are listed on the next page.
- **Test Equipment**. Equipment used for testing and inspection shall be calibrated and adjusted against certified equipment, and records maintained.
- **Assessment of Results of Sequential Tests**. A group or series of tests from which the average and individual results are used to demonstrate that a requirement has been satisfied, is called a sequential test.

General Delivery Standards - ISO 404

Summary of Testing Standards

List of ISO testing standards from ISO 404

ISO	Title
ISO 83: 1976	Steel - Charpy impact test (U-notch)
ISO 148: 1983	Steel - Charpy impact test (V-notch)
ISO 642: 1979	Hardenability test by end quenching (Jominy test)
ISO 3651-1: 1976	Austenitic stainless steels - Determination of resistance to intergranular corrosion - Part 1: Corrosion test in nitric acid medium by measurement or loss in mass (Huey test)
ISO 3651-2: 1976	Austenitic stainless steels - Determination of resistance to intergranular corrosion - Part 2: Corrosion test in a sulphuric acid/copper sulphate medium in the presence of copper turnings (Moneypenny Strauss test)
ISO 6506: 1981	Metallic materials - Hardness test - Brinell test
ISO 6507-1: 1982	Metallic materials - Hardness test - Vickers test - Part 1: HV 5 100
ISO 6507-2: 1983	Metallic materials - Hardness test - Vickers test - Part 2: HV 0,2 to less than HV 5
ISO 6508: 1986	Metallic materials - Hardness test - Rockwell test (scales A - B - C - D - E - F - G - H - K)
ISO 6892: 1984,	Metallic materials - Tensile testing
ISO 7438: 1985	Metallic materials - Bend test
ISO/TR 9769: 1991	Steel and iron - Review of available methods of analysis (chemical)

List of BS testing standards quoted in BS 3799 and BS 4825

BS	Title
BS 131	Methods for notched bar tests, Part 2 The Charpy V-notch impact test on metals
BS 240	Method for Brinell hardness test and for verification of Brinell hardness testing machines
BS 427	Method for Vickers hardness test and for verification of Vickers hardness testing machines
BS 891	Methods for hardness test (Rockwell method) and for verification of the hardness testing machines (Rockwell method)
BS 903 : Part A26	Physical testing of rubber, Part A 26 Determination of hardness (Note. This is applicable to seals in unions)
BS 1134	Assessment of surface texture

List of testing related standards quoted in ASTM standards

ASTM Number	Title
A 262	Practice E - Intergranular Corrosion Test
A 370	Mechanical Testing of Steel Products
A 751	Chemical Analysis of Steel Products
A 763	Practice for Detecting Susceptibility to Intergranular Attack in Ferritic Stainless Steels
A 880	Practice for Criteria for Use in Evaluation of Testing Laboratories and Organisations for Examination and Inspection of Steel, Stainless Steel and Related Alloys
E 4	Practice for Force Verification of Testing Machines
E 6	Terminology Relating to Methods of Mechanical Testing
E 8 (and E 8M)	Test Methods for Tension Testing of Metallic Materials (E 8M is metric version)
E 10	Test Method for Brinell Hardness of Metallic Materials
E 18	Test Method for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials
E 23	Test Methods for Notched Bar Impact Testing of Metallic Materials
E 29	Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
E 59	Method for Sampling Steel and Iron for Determination of Chemical Composition
E 83	Practice for Verification and Classification of Extensometers
E 112	Test Method for Determining Average Grain Size
E 165	Practice for Liquid Penetration Inspection Method
E 190	Method for Guided Bend Test for Ductility of Welds
E 213	Practice for Ultrasonic Examination of Metal Pipe and Tubing
E 309	Practice for Eddy-Current Examination of Steel Tubular Products Using Magnetic Saturation
E 340	Test Method for Microetching Metals and Alloys
E 381	Method of Macroetch Testing Steel Bars, Billets, Blooms and Forgings
E 426	Practice for Electromagnetic (Eddy-Current) Examination of Seamless and Welded Tubular Products, Austenitic Stainless Steel, and Similar Alloys

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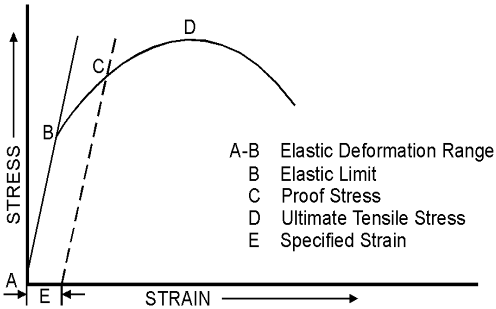
Testing Stainless Steel Products

This subsection describes in outline some common methods used for testing stainless steel tubular products. Tests are performed to certify that the product conforms to specification and purchaser requirements.

There are two main categories of tests: destructive tests in which the parent material or representative samples of the product are tested, and nondestructive tests performed on the finished product.

Tensile Test

This is probably the most revealing of the mechanical tests that can be performed upon a specimen of pipe or tubular product material. A longitudinal specimen[1] of known cross sectional area is taken from the material and gripped at each end, and then pulled apart until fracture occurs. By recording the gradually increasing load applied and the extension during loading a Stress-Strain Graph can be plotted (see diagram).



Notes
- Stress = Force per unit area,
  Example units: Pounds per square inch (psi or lbf/in^2), Newtons per square meter (N/m^2), Pascal (Pa).
  1 ksi = 1x10^3 psi, 1 Pa = 1 N/m^2; 1 MPa = 1x10^6 Pa.
- Strain = Increase in length per unit length

Initially the graph is a straight line, and the material can be expected to return to its original dimensions when the load is removed.

The graph deviates from the straight line at point B, when it enters the plastic region. The deformation is permanent after this load has been applied.

The test piece continues to stretch and also weakens so that the elongation increases even though the load is decreased. Eventually the test piece fractures.

From this graph the following values can be computed.

- **Tensile Strength** (D). The maximum tensile stress that the material is capable of sustaining.
- **Yield Strength or Proof Stress** (C). The load at which the sample is permanently elongated by a specific percentage of the original length. The percentage elongation (corresponding to the distance E on the graph) is commonly set at 0.2% The dotted line to C on the graph is drawn parallel to line A-B.)
- **Elongation**. This is a measure of the extension of the test piece at the point of fracture. The fractured test piece is carefully fitted together and the distance between gauge marks on the test piece is measured and compared with original gauge length. The increase in length is expressed as a percentage of the original length.
- **Elastic Limit or Yield Point** (B). The stress at which the test piece is permanently deformed.
- **Modulus of Elasticity**. In the tensile test, the ratio between Stress and Strain within the elastic deformation range (A-B) is known as Young's Modulus of Elasticity.
- **Reduction of Area**. This is the reduction in cross-sectional area of the test piece after tensile fracture expressed as a percentage of the original cross-sectional area.

Note
1 The longitudinal specimen may be a full size tubular section with metal plugs fitted in the ends to allow gripping by the test machine, or for larger tube sizes a strip may be cut from the tube. Transverse tension tests may also be performed using a ring expansion method or for larger tube sizes (e.g. greater than 8 in NPS) a transverse strip may be cut/flattened.

Testing Stainless Steel Products

Hardness Tests

These tests determine the resistance of a material to indentation. (See page 10-14 also)

- **Brinell Hardness Test**. A standard size hardened steel ball is indented into the surface of material by an applied standard load for a duration of 15 seconds. Typically a 10 mm ball with 3000, 1500 or 500 kgf load, or a 5 mm ball with 750 kgf load is used. The diameter of the impression is measured accurately by microscope and converted to a hardness value using tables. (Brinell testing is not suitable for tubular products less than 51 mm in outside diameter, or less than 5.1 mm wall thickness.)
- **Vickers Diamond Hardness Test**. This determines hardness by measuring the impression left in material by a diamond pyramid under a standard load for a specified time. The square impression is accurately measured, and its area calculated. The Vickers Hardness Number is calculated by dividing the load (kg) by the area of impression (mm^2).
- **Rockwell Hardness Test**. This determines hardness by measuring the depth to which a diamond cone or hardened steel ball, under specific load, penetrates the material. Two loads are used, a minor load (10 kgf) and then a major load (100 or 150 kgf), the difference in indentation being used by the Rockwell Hardness machine to determine the Rockwell number.
  The number increases with increasing hardness and is displayed or printed by the machine. Two scales are most frequently used, a B scale with a 100 kgf load and 1.588 mm steel ball, and a C scale with a 150 kgf load and diamond cone.
  A Rockwell superficial hardness machine is used for testing very thin wall thicknesses, the minor load used being 3 kgf and the major load being 15, 30 or 45 kgf. The superficial hardness scales used are then 15T, 30T or 45T with a 1.588 mm steel ball, or 15N, 30N or 45N with a diamond cone.

Impact Tests

In this type of test, a sample is subjected to sudden force to measure its toughness or resistance to shock.

- **Charpy Impact Test**. In this test a specimen is supported at both ends and subjected to a blow by a Pendulum immediately behind a prepared notch, either 'U' or 'V' shape in cross section. The energy absorbed in fracturing the specimen is measured by the height to which the pendulum rises after breaking the test piece. These tests can be carried out at various temperatures to determine the performance of material at either elevated or cryogenic temperatures.
  At higher temperature specimens fracture by a ductile mechanism, absorbing much energy. At low temperatures they fracture it a brittle manner absorbing less energy. Within the transition range a mixture of ductile and brittle fracture is observed. Minimum test results for absorbed energy, fracture appearance, lateral expansion or a combination of these, may be specified.

Manipulating Tests

These tests prove the ductility of certain tubular products and confirm the soundness of welds.

- **Bend Tests**. A bend test involves bending a sufficient length of full size pipe through 90° or 180° degrees around a mandrel having 12 or 8 times the nominal pipe diameter. This checks the ductility and weld soundness of pipe (2 in and under) used for coiling. Transverse guided bend tests may also be specified to check the ductility of fusion welds. These involve bending the root or face of the weld in a specimen against a plunger.
- **Flange Test**. This tests the ability of boiler tubes to withstand bending into a tube sheet. It involves the tube having a flange turned over a right angles to the tube body.
- **Flattening Test**. This is usually applied to tube and involves flattening a sample of tube between two parallel faces without the tube showing flaws or cracks.
  The length of the test piece and degree to which it is to be flattened (i.e. the distance between the parallel faces) are specified.
- **Flare or Drift Test**. This is an alternative to the flange test for certain types of pressure tube. A cone is forced into the end of the tube. The end of the tube is expanded by a specified increase in diameter without splits or cracks. The included angle of drift is also specified.

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Testing Stainless Steel Products

Corrosion Testing

Various corrosion tests are available using different corrosive environments to indicate the performance of material under heavy duty applications.

- **Weld Decay Test**. This test detects inter-crystalline corrosion and involves the use of boiling copper sulphate/sulphuric acid solution. Test samples are first sensitised and then immersed in the solution for 72 hours. After the immersion the samples are bent through 90 degrees and are considered satisfactory if no cracks are present.
- **Strauss Test**. This test detects inter-crystalline corrosion and involves the use of boiling copper sulphate/sulphuric acid solution which must contain solid electrolytic copper. The test samples are immersed in the solution for 15 hours. After immersion the samples are bent through 90 degrees and are considered resistant to inter-crystalline corrosion if they bend without cracking.
- **Huey Test**. This test detects the susceptibility of a material to inter-granular attack and involves the use of boiling nitric acid. The test samples are immersed in the solution at a concentration of 65% by weight for five 48 hour periods. The effect of the acid on the material is measured by the loss in weight after each period and the corrosion rate assessed as a thickness loss in a given time.
- **Potentiostat Test** This is a method of determining the corrosion properties of stainless steel by producing polarisation curves which relate electrode potentials and a current flow. The shapes of the curves, which are very sensitive to microstructure and composition, provide a critical method of assessing the corrosion properties of stainless steel.

Non-Destructive Tests

Non-destructive tests do not damage the material or product being tested. Frequently they are built into production processes, as is the case with pipe tested using eddy current equipment.

- **Ultrasonic Testing**. This test involves ultrasonic sound waves being aimed, via a coupling medium, at the material to be tested. A proportion are bounced back at the interface but the remainder enter the material and bounce from the internal surface, to the external surface, where a transducer converts them into electrical energy. This is then monitored on a cathode ray tube where results are compared with those from a calibration standard. Any deviations from the standard are visible, thus indicating cracks or internal defects.
- **Eddy-Current Testing**. This involves inducing eddy currents into the material by exciting a coil which surmounts two narrow search coils surrounding the material. Any discontinuities in material are found by comparing the electrical conditions that exist in the two search coils. The fault signals are amplified and can be shown on a cathode ray tube or as an audible signal.
- **Hydrostatic Testing**. This is used to test the manufactured items under a pressure equivalent to or greater than pressure to be encountered in service. It involves filling the tube with water, which cannot be compressed, and increasing the pressure inside the tube to that specified.
- **Magnetic Particle Testing**. This method of testing is used when trying to detect discontinuities in material of ferromagnetic structure. The method is based on the principle that an imperfection will cause a distortion in the magnetic field pattern of a magnetised component. The imperfection can be revealed by applying magnetic particles to the component during or after magnetisation.
- **Radiographic (X-Ray) Testing**. This is usually used to determine whether a weld is sound. It involves subjecting a weld or weld area to an X-ray source with an X-ray sensitive film plate on the under side of the weld. The results are shown on the developed film (a photomicrograph) and interpreted according to specification.
- **Dye-Penetrant Test**. This is used to detect cracks and involves spraying a dye on the area to be tested. After allowing time for penetration the surplus dye is removed and the area is then sprayed with a white developer. Any faults are revealed as coloured lines or spots caused by the developer absorbing the dye seeping from the cracks. If more sensitive results are required, a fluorescent dye is used and the same process is followed. When viewed under ultraviolet light any defects show as a highly fluorescent line or spot.

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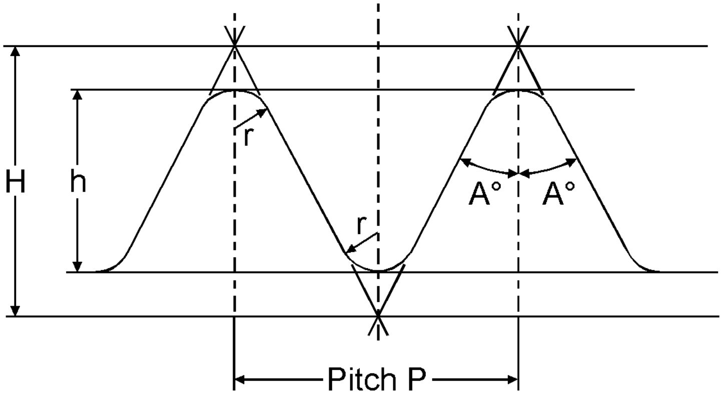
Pipe Threads - General

This subsection contains summary information and data on pressure tight threads for pipes and fittings as defined in the American National Standard ANSI/ASME B1.20.1 - 1983 (reaffirmed 1992), and British Standard BS 21 : 1985.

Note
- ANSI/ASME B1.20.1 - 1983 is the result of a complete rewrite of ANSI B2.1 1968. (ANSI/ASME B1.20.2M is a metric translation, however this is not referenced in relevant ASTM standards and is therefore not covered in this manual.)
- BS 21 implements the basic thread requirements in ISO 7/1-1982.)

Basic thread forms



The basic thread form (from BS 21) is as shown in the diagram above and applies to both internal and external threads. ANSI/ASME B1.20.1 is the same, except that the crest and root of the thread is flat. The symbols are defined as follows:
P = Pitch, derived from the number of threads per inch.
H = Height of the triangle of the thread profile, perpendicular to the thread axis for both parallel and tapered threads.
h = Height of the thread profile between the crest and root, perpendicular to the thread axis. ANSI/ASME B1.20.1 defines the maximum and minimum truncation allowed at the crest and root, this being measured from the apex of the thread profile triangle.
r = Radius of rounded crests and roots as defined in BS 21. The crest and root are flat in ANSI/ASME B1.20.1, although some rounding may occur; the width of the flat is equivalent to the truncation in height.
A = Angle between the thread face the perpendicular to the thread axis. This is the same for both parallel and tapered threads.

❍ **BS 21**. Based in Whitworth form:
P(mm) = 2.54/Number of threads per inch (n)
H(mm) = 0.960491P
h (mm) = 0.640327P
r (mm) = 0.137329P
A = 27.5°

❍ **ANSI/ASME B1.20.1.**
P (in) = 1/Number of threads per inch (n)
H (in) = 0.866025P
h (in) = 0.800000P
Truncation of crest or root = 0.033P min for any n, from 0.062P max (n = 8) to 0.096P max (n = 27)
A = 30°

Tapered Threads

Tapered (or jointing) threads are pipe threads for joints made pressure tight by the mating of an internal parallel or tapered thread with an external tapered thread (external parallel threads are not suitable for pressure tight joints). The basic form of a tapered thread (from BS 21) is as shown in the following diagram. The ANSI/ASME B1.20.1 General Purpose Taper Pipe Thread, NPT (National (American) Standard, Pipe, Thread), has the same basic form, although terms used to describe it may differ, as do the dimensional definitions.

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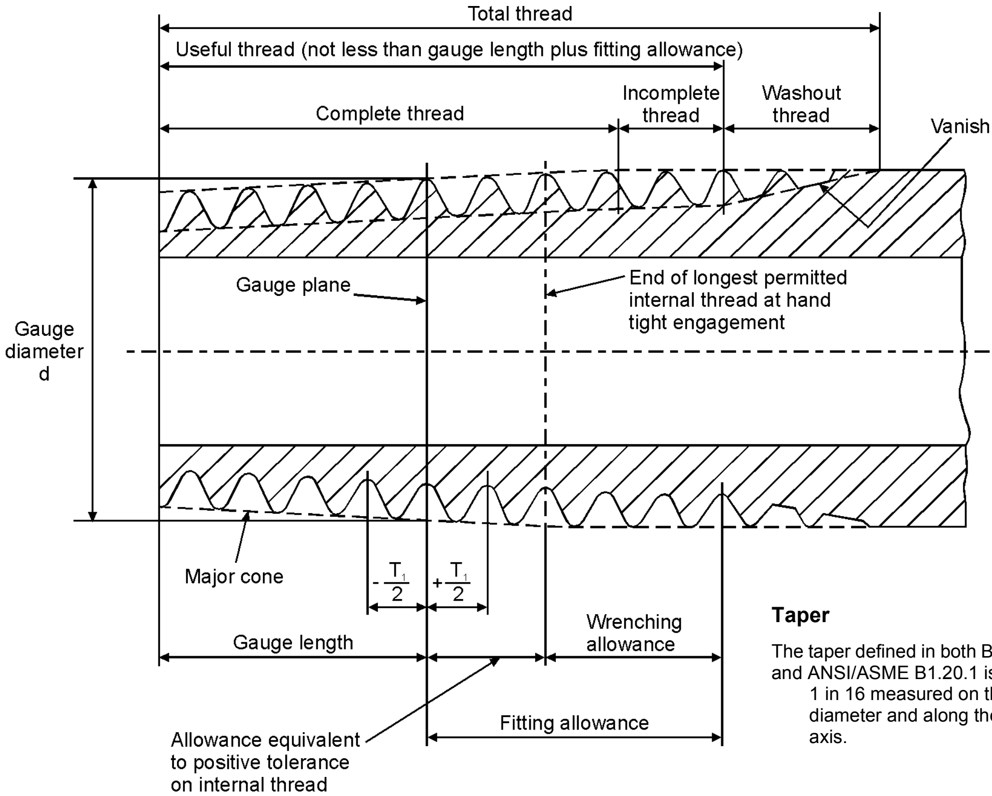
Pipe Threads - General



Taper

The taper defined in both BS 21 and ANSI/ASME B1.20.1 is:
1 in 16 measured on the diameter and along the axis.

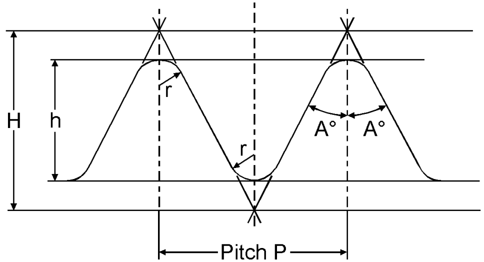
Terms used to define a tapered pipe thread are as follows:

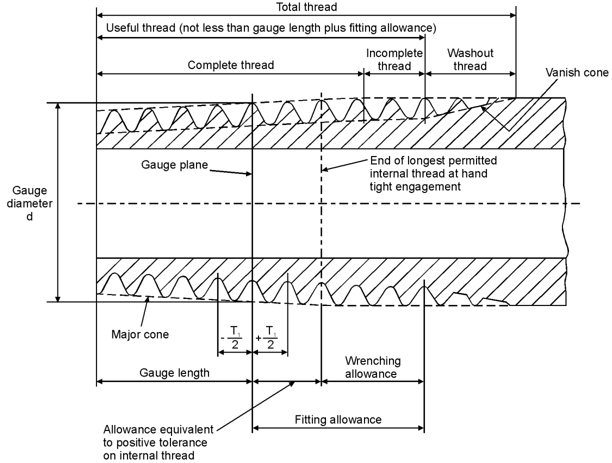
- **Gauge**. The gauge may be an internally threaded ring gauge or externally threaded plug gauge, of specified dimensions, used to ensure or determine the accuracy of tapered threads (and parallel internal threads). The use of a gauge allows thread accuracy to be determined without the use of elaborate inspection methods.
- **Gauge diameter, d**. This is the basic major diameter of the thread (external or internal) at the gauge plane, where the gauge diameter is equal to the major cone diameter. In ANSI/ASME B1.20.1 this is the point of 'hand-tight engagement'.
- **d_1**. This is the basic minor diameter of the thread at the gauge plane (d1 = d - 1.280 645P in BS 21).
- **d_2**. This is the basic pitch diameter of the thread at the gauge plane (d2 = d - 0.640327P in BS 21). This is dimension E in the ANSI/ASME B1.20.1 table following.
- **T_1, T_2**. T_1 is the tolerance on the position of the gauge plane for external threads. T_2 is the equivalent tolerance for internally tapered threads.
- **Complete thread**. That part of the thread where it is fully formed at both the crest and root.
- **Incomplete thread**. In this part of the thread the root is fully formed but the crest is truncated.
- **Washout thread**. In this part of the thread the root is not fully formed.
- **Fitting allowance**. This provides for assembly with an internal thread at the upper limit of the tolerance.
- **Wrench allowance**. This is provided for wrenching beyond the position of hand engagement. ANSI/ASME B1.20.1 requires that pressure tight joints to be made up wrench-tight with a sealant (usually containing a lubricant to prevent galling with stainless steels).

Parallel Threads

BS 21 states that internal parallel thread may be used with external taper pipe thread to provide a pressure tight seal for use at low pressures only.

Pipe Threads - BS 21 : 1985 (BSP taper, or BSPT)





P(mm) = 2.54/Number of threads per inch (25.4 mm)
H(mm) = 0.960491P
h (mm) = 0.640327P
r (mm) = 0.137329P
A = 27.5°
Taper of thread = 1 in 16 measured on diameter

Example Designations:

$R^1/2$

$R_C{}^1/2$

$R_P{}^1/2$

where:
- R = Designation letter for taper external pipe threads.
- R_C = Designation letter for taper internal threads.
- R_P = Designation letter for parallel internal threads
- $^1/2$ = Thread size designation

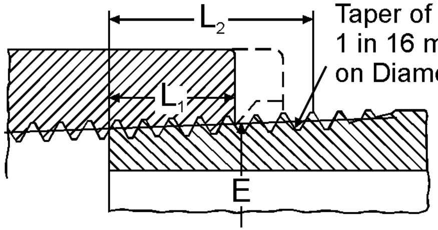
Parallel Internal Threads:

Basic diameters for parallel internal threads are as given for the gauge plane (d, d_1 and d_2) of equivalent taper threads in the table below.

Basic dimensions and limits for British Standard Pipe taper threads, BSPT (BS 21 : 1985)

Thread Size Designation	Number of Threads in 25.4 mm	Pitch, P	Depth of Thread h	Basic Diameters at Gauge Plane: Major (Gauge Diameter) d	Minor Diameter d_1	Pitch Diameter d_2	Gauge Length: Basic		Tolerance $T_1/2$		Minimum Length of useful Thread on Pipe End Basic Gauge Length		Fitting Allowance		Wrenching Allowance		Tolerance on Position of Gauge Plane relative to Face of Internally Threaded Parts, $T_2/2$	
		mm	mm	mm	mm	mm	Turns	mm	Turns	mm	Turns	mm	Turns	mm	Turns	mm	Turns	mm
1/16	28	0.907	0.581	7.723	6.561	7.142	4 3/8	4.0	±1	±0.9	7 1/8	6.5	2 3/4	2.5	1 1/2	1.4	±1 1/4	±1.1
1/8	28	0.907	0.581	9.728	8.566	9.147	4 3/8	4.0	±1	±0.9	7 1/8	6.5	2 3/4	2.5	1 1/2	1.4	±1 1/4	±1.1
1/4	19	1.337	0.856	13.157	11.445	10.301	4 1/2	6.0	±1	±1.3	7 1/4	9.7	2 3/4	3.7	1 1/2	2.0	±1 1/4	±1.7
3/8	19	1.337	0.856	16.662	14.950	15.806	4 3/4	6.4	±1	±1.3	7 1/2	10.1	2 3/4	3.7	1 1/2	2.0	±1 1/4	±1.7
1/2	14	1.814	1.162	20.955	18.631	19.793	4 1/2	8.2	±1	±1.8	7 1/4	13.2	2 3/4	5.0	1 1/2	2.7	±1 1/4	±2.3
3/4	14	1.814	1.162	26.441	24.117	25.279	5 1/4	9.5	±1	±1.8	8	14.5	2 3/4	5.0	1 1/2	2.7	±1 1/4	±2.3
1	11	2.309	1.479	33.249	30.291	31.770	4 1/2	10.4	±1	±2.3	7 1/4	16.8	2 3/4	6.4	1 1/2	3.5	±1 1/4	±2.9
1 1/4	11	2.309	1.479	41.910	38.952	40.431	5 1/2	12.7	±1	±2.3	8 1/4	19.1	2 3/4	6.4	1 1/2	3.5	±1 1/4	±2.9
1 1/2	11	2.309	1.479	47.803	44.845	46.324	5 1/2	12.7	±1	±2.3	8 1/4	19.1	2 3/4	6.4	1 1/2	3.5	±1 1/4	±2.9
2	11	2.309	1.479	59.614	56.656	58.135	6 7/8	15.9	±1	±2.3	10 1/8	23.4	3 1/4	7.5	2	4.6	±1 1/4	±2.9
2 1/2	11	2.309	1.479	75.184	72.226	73.705	7 9/16	17.5	±1 1/2	±3.5	11 9/16	26.7	4	9.2	2 1/2	5.8	±1 1/2	±3.5
3	11	2.309	1.479	87.884	84.926	86.405	8 15/16	20.6	±1 1/2	±3.5	12 15/16	29.8	4	9.2	2 1/2	5.8	±1 1/2	±3.5
4	11	2.309	1.479	113.030	110.072	111.551	11	25.4	±1 1/2	±3.5	15 1/2	35.8	4 1/2	10.4	3	6.9	±1 1/2	±3.5
5	11	2.309	1.479	138.430	135.472	136.951	12 3/8	28.6	±1 1/2	±3.5	17 3/8	40.1	5	11.5	3 1/2	8.1	±1 1/2	±3.5
6	11	2.309	1.479	163.830	160.872	162.351	12 3/8	28.6	±1 1/2	±3.5	17 3/8	40.1	5	11.5	3 1/2	8.1	±1 1/2	±3.5

Pipe Threads - ANSI/ASME B1.20.1 (NPT/API)



Taper of Thread 1 in 16 measured on Diameter

E = Pitch Diameter at Hand-tight Plane. This is also the pitch diameter at the gauge plane.

L_1 = Length of Normal Hand-tight Engagement. This is also the L_1 gauge length. (Longer thread engagement may be used in special applications, such as flanges for high pressure use. In such cases the pitch diameter, E, remains as specified and the diameter at the end of the pipe is proportionally smaller.)

L_2 = Effective Length of Thread.

f = Truncation from point of thread triangle to flat (not shown in diagram). Minimum = 0.033P for all pitches. See table for maximum.

Example Designation:

$^3/_8$ -18 NPT

where

$^3/_8$ = Nominal pipe size

18 = Number of threads per inch

NPT= Symbol for the thread series and form (i.e. National (American) Standard Pipe, Taper)

Tolerances

When using L_1 gauges to check threads, the thread is within permissible tolerance if the ring gauge face, or plug gauge notch, is ±1 turn from being flush with the end of the thread.

Basic dimensions of American National Standard Taper Pipe Threads, NPT (ANSI/ASME B1.20.1)

NPS	Number of Threads per Inch	Pitch of Thread		Depth of Thread, max		Truncation, max		Pitch Diameter at Plane of Hand-tight Engagement		Length from End of Pipe to Plane of Hand-tight Engagement		Length of Useful Thread		Length of Vanish (or Washout)Thread	
		P		h		f		E		L_1		L_2		L_2	
		in	mm	in	mm	in	mm	in	mm	in	Threads	in	Threads	in	Threads
$^1/_8$	27	0.03704	0.941	0.02963	0.753	0.0036	0.091	0.37360	9.489	0.162	4.36	0.2639	7.12	0.1285	3.47
$^1/_4$	18	0.05556	1.411	0.04444	1.129	0.0049	0.124	0.49163	12.487	0.228	4.10	0.4018	7.23	0.1928	3.47
$^3/_8$	18	0.05556	1.411	0.04444	1.129	0.0049	0.124	0.62701	15.926	0.240	4.32	0.4078	7.34	0.1928	3.47
$^1/_2$	14	0.07143	1.814	0.05714	1.451	0.0056	0.142	0.77843	19.772	0.320	4.48	0.5337	7.47	0.2478	3.47
$^3/_4$	14	0.07143	1.814	0.05714	1.451	0.0056	0.142	0.98887	25.117	0.339	4.75	0.5457	7.64	0.2478	3.47
1	11.5	0.08696	2.209	0.06957	1.767	0.0063	0.160	1.23863	31.461	0.400	4.60	0.6828	7.85	0.3017	3.47
$1^1/_4$	11.5	0.08696	2.209	0.06957	1.767	0.0063	0.160	1.58338	40.218	0.420	4.83	0.7068	8.13	0.3017	3.47
$1^1/_2$	11.5	0.08696	2.209	0.06957	1.767	0.0063	0.160	1.82234	46.287	0.420	4.83	0.7235	8.32	0.3017	3.47
2	11.5	0.08696	2.209	0.06957	1.767	0.0063	0.160	2.29627	58.325	0.436	5.01	0.7565	8.70	0.3017	3.47
$2^1/_2$	8	0.12500	3.175	0.10000	2.540	0.0078	0.198	2.76216	70.159	0.682	5.46	1.1375	9.10	0.4337	3.47
3	8	0.12500	3.175	0.10000	2.540	0.0078	0.198	3.38850	86.068	0.766	6.13	1.2000	9.60	0.4337	3.47
$3^1/_2$	8	0.12500	3.175	0.10000	2.540	0.0078	0.198	3.88881	98.776	0.821	6.57	1.2500	10.00	0.4337	3.47
4	8	0.12500	3.175	0.10000	2.540	0.0078	0.198	4.38712	111.433	0.844	6.75	1.3000	10.40	0.4337	3.47
5	8	0.12500	3.175	0.10000	2.540	0.0078	0.198	5.44929	138.412	0.937	7.50	1.4063	11.25	0.4337	3.47
6	8	0.12500	3.175	0.10000	2.540	0.0078	0.198	6.50597	165.252	0.958	7.66	1.5125	12.10	0.4337	3.47
8	8	0.12500	3.175	0.10000	2.540	0.0078	0.198	8.50003	215.901	1.063	8.50	1.7125	13.70	0.4337	3.47
10	8	0.12500	3.175	0.10000	2.540	0.0078	0.198	10.62094	296.772	1.210	9.68	1.9250	15.40	0.4337	3.47
12	8	0.12500	3.175	0.10000	2.540	0.0078	0.198	12.61781	320.493	1.360	10.88	2.1250	17.00	0.4337	3.47
14	8	0.12500	3.175	0.10000	2.540	0.0078	0.198	13.87262	352.365	1.562	12.50	2.2500	18.00	0.4337	3.47
16	8	0.12500	3.175	0.10000	2.540	0.0078	0.198	15.87575	403.244	1.812	14.50	2.4500	19.60	0.4337	3.47
18	8	0.12500	3.175	0.10000	2.540	0.0078	0.198	17.87500	454.025	2.000	16.00	2.6500	21.20	0.4337	3.47
20	8	0.12500	3.175	0.10000	2.540	0.0078	0.198	19.87031	504.706	2.125	17.00	2.8500	22.80	0.4337	3.47
24	8	0.12500	3.175	0.10000	2.540	0.0078	0.198	23.86094	606.068	2.375	19.00	3.2500	26.00	0.4337	3.47

Note

- Basic dimensions are given to four or five decimal places to eliminate errors when calculating gauge dimensions, they do not imply a greater degree of precision than is normally obtainable.
- Metric dimensions, where shown, are calculated from the inch values and rounded.

Stainless Steel Finishes

This subsection considers surface finishing treatments applied to stainless steel tubular products. The main objectives of these treatments are to optimise corrosion resistance following thermal and mechanical processing and to enhance cosmetic appeal.

The passive (chromium oxide) film produced on the surface of stainless steel is superior to any protective coating that could be applied because it is self repairing (assuming contact with oxygen). However, the presence of defects or contamination on the surface can be unsightly, may degrade corrosion resistance and may cause hygiene problems in some applications.

Production Treatments

Various processes are applied to the surface of stainless steel products during manufacture. Manufacturing specifications, such as ASTM standards described in Sections 2, 3 and 4, define the processes that may be applied, with any limitations, and the quality of surface finish that should be obtained. These processes include the following:

- **Defect Removal**. The removal of surface defects by processes such as machining, grinding or welding.
- **Bead removal**. Removal of the external bead on welded tube is standard practice. The internal bead may also be removed by scarfing or cold working. Internal bead removal and surface quality are particularly important for hygienic tubes and fittings.
- **Descaling or Pickling**. Scale (high temperature oxides) produced in hot processing, heat treatment or welding can be removed by immersion in suitable acid solutions. Complete removal of oxide scale is essential for good corrosion performance. Paste type descaling solutions are available for use when immersion is not possible or where treatment needs to be localised, as on welds. Exposure time depends on scale thickness, type of acids and solution temperature.
  The descaling process is also known as 'Pickling' and the resulting surface can be described as having a pickled finish. Thorough washing with water should follow all acid treatments.
- **Removal of Contamination/Passivation**. Pick-up of carbon and alloy steel from contact with storage racks, machine beds and tooling can result in unsightly rust staining. Removal of this type of surface contamination is easily achieved using nitric acid. This treatment is sometimes referred to as passivation because of the ability of oxidising acids to accelerate the formation of the passive film. Cleaning acids, like nitric, will not remove high temperature scale.
- **Abrasive Blasting.** This process which can be carried out either wet or dry is an alternative to acid cleaning and descaling. It is important to use the correct iron-free abrasive in order to avoid surface contamination. Any abrasives which are recirculated should be cleaned to ensure they are free from contaminants. After treatment components are thoroughly washed in clean water and dried.
- **Bright Annealing**. Heating and slow cooling of steel in a carefully controlled inert atmosphere (e.g. hydrogen or cracked ammonia) ensures that oxidation of the surface is minimised and the metal surface retains its bright finish.

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Stainless Steel Finishes

Polishing and Specialised Surface Treatments

Summary of finishes and treatments

Finish	Treatment	Notes
No. 80	Abrasive belt finish using No. 80 Grit	As specified in ASTM A 270 for sanitary tubing
No. 120	Abrasive belt finish using No. 120 Grit	
No. 180	Abrasive belt finish using No. 180 Grit	
Nos. 80 - 600	Range of finishes produced using abrasive belt impregnated with Nos. 80 through to 600 Grit	Finishes described as 'Dull' through 'Bright' to 'Mirror' as grit number is increased
R	Rouge polishing to substantially remove all trace of grinding marks, pits, or other minor imperfections	As specified in ASTM A 270. Produces a mirror-like surface
T	Electropolishing free of grinding marks, pits, visible nonmetallic inclusions, or other minor imperfections	As specified in ASTM A 270

- **Grinding** applies to rough, often dry, operations where significant amounts of metal are removed, using loose abrasives or belts coarser than 100 grit.
- **Polishing** refers to finishes using abrasives finer than 100 grit suspended in lubricants.
- **Buffing** is a type of polishing done with high speed cloth wheels, charged with extremely fine abrasives.
- **Barrel and Vibratory Finishing**. Both these treatments can be carried out on stainless steel parts.
- **Electropolishing**. This method of polishing is essentially the reverse of electroplating, since the item to be polished has metal removed from it, rather than deposited on it. Dipped in various solutions, the item to be polished is the anode in an electrolytic bath. This process is ideal for producing a uniform highly reflective lustre with an extremely smooth finish on articles of intricate contour. The quality of this type of finish is largely governed by the original condition of the surface prior to the start of the treatment, since the amount of metal removed can be less than the depth of pits and scratches.

Hardness Conversions

Hardness conversion numbers for austenitic stainless steels (Rockwell C to other hardness numbers)

Rockwell C Scale, 150 kgf Load	Rockwell A Scale, 60 kgf Load	Rockwell Superficial Hardness		
		15N Scale, 15 kgf Load	30N Scale, 30 kgf Load	45N Scale, 45 kgf Load
Diamond Penetrator	Diamond Penetrator	Diamond Penetrator	Diamond Penetrator	Diamond Penetrator
48	74.4	84.1	66.2	52.1
47	73.9	83.6	65.3	50.9
46	73.4	83.1	64.5	49.8
45	72.9	82.6	63.6	48.7
44	72.4	82.1	62.7	47.5
43	71.9	81.6	61.8	46.4
42	71.4	81.0	61.0	45.2
41	70.9	80.5	60.1	44.1
40	70.4	80.0	59.2	43.0
39	69.9	79.5	58.4	41.8
38	69.3	79.0	57.5	40.7
37	68.8	78.5	56.6	39.6
36	68.3	78.0	55.7	38.4
35	67.8	77.5	54.9	37.3
34	67.3	77.0	54.0	36.1
33	66.8	76.5	53.1	35.0
32	66.3	75.9	52.3	33.9
31	65.8	75.4	51.4	32.7
30	65.3	74.9	50.5	31.6
29	64.8	74.4	49.6	30.4
28	64.3	73.9	48.8	29.3
27	63.8	73.4	47.9	28.2
26	63.3	72.9	47.0	27.0
25	62.8	72.4	46.2	25.9
24	62.3	71.9	45.3	24.8
23	61.8	71.3	44.4	23.6
22	61.3	70.8	43.5	22.5
21	60.8	70.3	42.7	21.3
20	60.3	69.8	41.8	20.2

Hardness conversion numbers for austenitic stainless steels (Rockwell B to other hardness numbers)

Rockwell B Scale, 100 kgf Load,	Brinnel Indentation Diameter, mm	Brinnel Hardness, 3000 kgf Load	Rockwell A Scale, 80 kgf Load	Rockwell Superficial Hardness		
				15N Scale, 15 kgf Load	30N Scale, 30 kgf Load	45N Scale, 45 kgf Load
1/16 in (1.588 mm) Ball		10 mm Ball	Diamond Penetrator	1/16 in (1.588 mm) Ball	1/16 in (1.588 mm) Ball	1/16 in (1.588 mm) Ball
100	3.79	256	61.5	91.5	80.4	70.2
99	3.85	248	60.9	91.2	79.7	69.2
98	3.91	240	60.3	90.8	79.0	68.2
97	3.96	233	59.7	90.4	78.3	67.2
96	4.02	226	59.1	90.1	77.7	66.1
95	4.08	219	58.5	89.7	77.0	65.1
94	4.14	213	58.0	89.3	76.3	64.1
93	4.20	207	57.4	88.9	75.6	63.1
92	4.24	202	56.8	88.6	74.9	62.1
91	4.30	197	56.2	88.2	74.2	61.1
90	4.35	192	55.6	87.8	73.5	60.1
89	4.40	187	55.0	87.5	72.8	59.0
88	4.45	183	54.5	87.1	72.1	58.0
87	4.51	178	53.9	86.7	71.4	57.0
86	4.55	174	53.3	86.4	70.7	56.0
85	4.60	170	52.7	86.0	70.0	55.0
84	4.65	167	52.1	85.6	69.3	54.0
83	4.70	163	51.5	85.2	68.6	52.9
82	4.74	160	50.9	84.9	67.9	51.9
81	4.79	156	50.4	84.5	67.2	50.9
80	4.84	153	49.8	84.1	66.5	49.9

Note
- The above hardness conversion number tables are approximate.

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General Conversions

Conversion factors

To convert	From Unit	To Units	Multiply by
Atmospheres (standard) to pounds per square inch	A	lbf/in^2 (psi)	14.70
Atmospheres (standard) to Pascal	A	Pa	101325
Bar to kilograms force per square centimetre	bar	kgf/cm^2	1.0197
Bar to pounds force per square inch	bar	lbf/in^2 (psi)	14.5038
Centigrade to Fahrenheit	°C	°F	multiply by 1.8 and add 32
Centimetres to feet	cm	ft	0.03280840
Centimetres to inches	cm	in	0.393701
Centimetres^3 to feet^3	cm^3	ft^3	0.0000353147
Centimetres^3 to inches^3	cm^3	in^3	0.06102376
Fahrenheit to Centigrade	°F	°C	subtract 32 and multiply by 0.5555
Feet per second to miles per hour	ft/s	mph	0.681818
Feet to centimetres	ft	cm	30.48
Feet to metres	ft	m	0.3048
Feet to millimetres	ft	mm	304.8
Feet^3 to metres^3	ft^3	m^3	0.02831685
Feet^3 to gallons	ft^3	gal	6.2288
Foot pounds to kilogram metres	ftlb	kgm	0.1382
Gallons (UK) to litres	gal	l	4.546092
Gallons (US) to litres	gal	l	3.785412
Grams per centimetres^3 to pounds per inch^3 (density)	gm/cm^3	lb/in^3	0.0361275
Grams to ounces	gm	oz	0.035274
Grams to pounds	gm	lb	0.00220462
Inches to centimetres	in	cm	2.540
Inches to metres	in	m	0.0254
Inches to millimetres	in	mm	25.4
Inches^3 to centimetres^3	in^3	cm^3	16.38706
Inches^3 to litres	in^3	l	0.01639
Kilogram metres to foot pounds	kgm	ftlb	7.233
Kilograms force to bar	kgf	B	0.9807
Kilograms force to Newtons	kgf	N	9.806650
Kilograms per metre to pounds per foot (assuming constant cross sectional area)	kg/m	lb/ft	0.671970
Kilograms per square centimetre to pounds per square inch	kg/cm^2	lb/in^2 (psi)	14.223
Kilograms per square metre to pounds per square foot	kg/m^2	lb/ft^2	0.2048
Kilograms per square metre to Newtons per square metre	kg/m^2	N/m^2	9.806650
Kilograms per square millimetre to pounds per square inch	kg/mm^2	lb/in^2 (psi)	1422.34
Kilograms per square millimetre to tons per square inch	kg/mm^2	ton/in^2	0.63497
Kilograms to pounds	kg	lb	2.205
Kilograms to tons (long)	kg	ton	0.0009842
Kilometres to miles	km	mile	0.62137
Litres of water at 62ºF to pounds	l	lb	2.205
Litres to inches^3	l	in^3	61.03
Litres to gallons (UK)	l	gal	0.2199692
Litres to gallons (US)l	l	gal	0.2641720
Metres to inches	m	in	39.37008
Metres to miles	m	miles	0.000621371
Metres to feet	m	ft	3.28084
Metres to yards	m	yd	1.093613

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General Conversions

Conversion factors (Continued)

To convert	From Unit	To Units	Multiply by
Metre^3 to inch^3	m^3	in^3	61023.76
Metre^3 to feet^3	m^3	ft^3	35.31466
Metre^3 to gallon (UK)	m^3	gallon	219.9692
Metre^3 to gallon (US)	m^3	gallon	264.1720
Metre^3 to litre	m^3	l	1000.0
Metre^3 to yard^3	m^3	yd^3	1.307951
Metric tons (or tonnes, 1000 kg) to long tons	tonne	ton	0.9842
Miles per hour to feet per second	mph	ft/s	1.46666
Miles to kilometres	m	km	1.60934
Millimetres to feet	mm	ft	0.003280840
Millimetres to inches	mm	in	0.03937008
Newtons per square metre (Pascal) to kilograms per square metre	N/m^2 (Pa)	kg/m^2	0.1019716
Newtons per square metre (Pascal) to pounds per square inch	N/m^2 (Pa)	lb/in^2 (psi)	0.000145
Newtons per square millimetre to pounds per square inch	N/mm^2	lb/in^2 (psi)	145.0377
Newtons per square millimetre to tons per square inch	N/mm^2	$tons/in^2$	0.06475
Newtons to kilograms force	N	kgf	0.1019716
Newtons to pounds force	N	lbf	0.2248089
Ounces to grams	oz	gm	28.3495
Pints imperial to litres	pt	l	0.5679
Pounds force to Newtons	lbf	N	4.448222
Pounds per inch^3 to grams per centimetre^3 (density)	lb/in^3	gm/cm^3	27.67990
Pounds per foot to kilograms per metre (assuming constant cross sectional area)	lb/ft	kg/m	1.4882
Pounds per square foot to kilograms per square metre	lb/ft^2	kg/m^2	4.882429
Pounds per square inch to atmospheres	lb/in^2 (psi)	A	0.06803
Pounds per square inch to bars	lb/in^2 (psi)	bar	0.06894757
Pounds per square inch to kilograms per square centimetre	lb/in^2 (psi)	kg/cm^2	0.07030697
Pounds per square inch to kilograms per square millimetre	lb/in^2 (psi)	kg/mm^2	0.0007030697
Pounds per square inch to Newtons per square millimetre	lb/in^2 (psi)	N/mm^2	0.006894757
Pounds to grams	lb	gm	453.60
Pounds to kilograms	lb	kg	0.453593
Square centimetres to square inches	cm^2	in^2	0.1550003
Square feet to square metres	ft^2	m^2	0.09290304
Square inches to square centimetres	in^2	cm^2	6.4516
Square inches to square millimetres	in^2	mm^2	645.16
Square kilometres to square miles	km^2	$miles^2$	0.386103
Square metres to square feet	m^2	ft^2	10.763910
Square metres to square yards	m^2	yd^2	1.195990
Square miles to square kilometres	$miles^2$	km^2	2.590
Square millimetres to square inches	mm^2	in^2	0.001550003
Square yards to square metres	yd^2	m^2	0.8361274
Tons per square inch to kilograms per square millimetre	ton/In^2	kg/mm^2	1.575
Tons per square inch to Newtons per square millimetre	ton/in^2	N/mm^2	15.4443
Tons (long) to kilograms	ton	kg	1016.047
Tons (long) to metric tons (or tonne, 1000 kg)	ton	tonne	1.016047
Yards to metres	yd	m	0.9144
Yards^3 to metres^3	yd^3	m^3	0.7645549

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Units of Measurement

Commonly used units of measurement

Quantity	SI / Metric		Imperial / US	
	Unit	Symbol	Unit	Symbol
Length	micrometre millimetre centimetre decimetres metre kilometre	$\mu m = 10^{-6}$ m $mm = 10^{-3}$ m $cm = 10^{-2}$ m $dm = 10^{-1}$ m m $km = 10^{3} m$	inch foot yard mile	in ft = 12 in yd = 3 ft ml = 1760 yd
Area	$(length)^2$ hectare	mm^2, cm^2, m^2 etc. 1 ha = 10^4 m^2	$(length)^2$	in^2, ft^2 etc.
Volume	$(length)^3$ litre	cm^3, dm^3, m^3 L = 10^{-3} m^3	$(length)^3$ pint gallon	in^3, ft^3 pt gal = 8 pt
Mass / Weight	gram kilogram metric ton (or tonne)	g kg = 10^3 g t = 10^3 kg	pound ton long ton (UK) short ton (US)	lb ton = 2240 lb = 2000 lb
Time	second	s	second hour	s h
Frequency	Hertz	Hz = 1/s	-	-
Force	Newton	N = kg.m/s^2	pounds force	lbf
Pressure, stress	Pascal bar	Pa = N/m^2 kPa = 10^3 Pa MPa = 10^6 Pa bar = 10^5 Pa	pounds force per square inch	lbf/in^2 psi ksi = 10^3 psi
Atmospheric pressure (standard)	Atmosphere	atm = 101325 Pa	Atmosphere	A = 14.7 lbf/in^2
Energy, work, quantity of heat	Joule kilowatt-hour	J = N.m kWh = 3.6 MJ	British thermal unit	Btu
Power	Watt	W = J/s	-	Btu/h

Abbreviations for Standards Organisations

Abbreviations for standards organisations and documents, referred to in this manual, are expanded below:

AFNOR	French Standards Association
AISI	American Iron and Steel Institute
ANSI	American National Standards Institute, Inc.
API	American Petroleum Institute
ASME	The American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
BS	British Standards issued by British Standards Institution (BSI)
DIN	German Standards
EN	European Norm (Standard) issued by European Committee for Standardisation (CEN)
ISO	International Organisation for Standardisation
JIS	Japanese Industrial Standards issued by Japanese Standards Authority (JSA)
MSS	Manufacturers Standardisation Society of the Valve and Fittings Industry, Inc.
SIS	Swedish Standards
SMS	Swedish Mechanical Standards
UNI	Italian Standards

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