aalco®

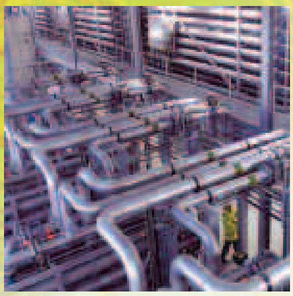
Company Profile

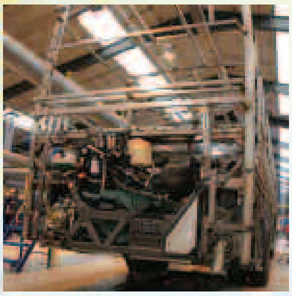
Stainless Steel

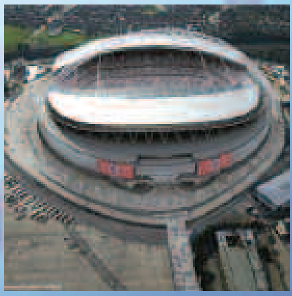
Aluminium

Copper, Brass & Bronze

General Data







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The information contained herein is based on our present knowledge and experience and is given in good faith. However, no liability will be accepted by the Company in respect of any action taken by any third party in reliance thereon.

As the products detailed herein may be used for a wide variety of purposes and as the Company has no control over their use, the Company specifically excludes all conditions or warranties expressed or implied by statute or otherwise as to dimensions, properties and/or their fitness for any particular purpose. Any advice given by the Company to any third party is given for that party's assistance only and without any liability on the part of the Company.

Any contract between the Company and a customer will be subject to the Company's Conditions of Sale. The extent of the Company's liabilities to any customer is clearly set out in those Conditions; a copy of which is available on request.

Weights

All weights shown in this publication are for guidance only. They are calculated using nominal dimensions and scientifically recognised densities. Please note that in practice, the actual weight can vary significantly from the theoretical weight due to variations in manufacturing tolerances and compositions.

Issue No. 3 – 02/2011

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General Data

Aalco is the UK's largest independent multi-metals stockholder. Customers from every sector of UK manufacturing and engineering industry, whether small local businesses or large multinational corporations, benefit from a cost-effective single source for all their metals requirements:

- An inventory that includes aluminium, stainless steel, copper, brass, bronze and nickel alloys in all semi-finished forms
- Comprehensive processing services providing items cut and/or finished to customer requirements
- Eighteen locations bringing local service to every corner of the UK
- Ongoing investment in technology and logistics to ensure on-time delivery

No order is too large or too small and Aalco offers a responsive and competitive service for supplying anything from single item orders to major JIT contracts, tailoring this service to the individual needs.

Whatever your requirement, in whatever quantity, your local Aalco service centre is ready and willing to satisfy your needs For a quotation, for further information, more extensive technical information, advice on product selection or to place an order, please contact your local Aalco service centre or refer to the web site

www.aalco.co.uk

Service

The most comprehensive stock range; the highest investment in processing equipment; local service centres nationwide; helpful, friendly, knowledgeable staff and the industry's biggest fleet of delivery vehicles – it all adds up to unbeatable service.

Aalco has maintained market leadership over many years through an absolute dedication to customer service – a service level that is continuously monitored and improved through key performance indicators.

That's why, for reliable, on-time delivery of exactly what you want, when and where you need it, whether it's a small one-off item or a complex JIT contract, Aalco is the essential first choice.

People

Exceptional customer service starts with people. Aalco develops and retains high quality personnel using a variety of 'in house' courses which cover both skills training, product knowledge and teamwork.

Every Aalco Service Centre has a dedicated team of people working together to provide an unbeatable service to customers in their region.

Customers can expect to receive a quick and informed response to any enquiries for material or for information.

Quality

Aalco takes great care when selecting manufacturing sources for its products and every mill we use is measured against a series of predetermined quality control requirements.

All products supplied by Aalco conform to the relevant BS or international standards certification can be supplied on request.

Aalco service centres operate a quality manual designed to ISO9000/2005 requirements. Many vendor approvals and bespoke quality control systems are operated through individual Aalco service centres, including aerospace approved materials from Southampton and Hull.

Standard Stock & "Specials"

In providing customers with a cost-effective single source for all their metals requirements, over 50% of Aalco sales are made up of non standard or customer-special items. Many such items are held in stock at the Service Centres for call-off by their local customers, whilst others are processed as required.

The Aalco multi-metal stock range comprises around 10,000 items of stainless steel, aluminium, copper, brass and bronze in all semi-finished forms. Full detail of the ranges is given on page 28 for stainless steel rolled products, page 33 for stainless steel bar, page 36 for stainless steel tubular products (tube, pipe, fittings & flanges), page 59 for rolled aluminium, page 62 for Aluminium Extrusions and page 70 for Copper-Based Alloys.

This combines with a comprehensive processing services offering items cut to customer's instructions as well as finishing and coating. In addition, Aalco regularly arranges sub-contract processing using a range of approved suppliers.

Aluminium Extrusions

As well as holding the UK's widest range of standard sections, Aalco has developed a particular expertise in the sourcing, stocking and processing of bespoke extrusions, bringing customers the benefit of Aalco's unrivalled purchasing power and sourcing expertise.

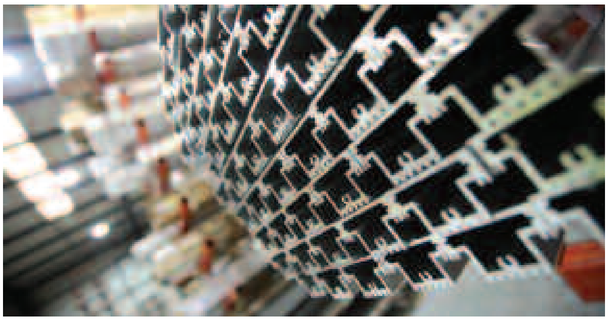
The standard stock range (detailed fully on page 60) covers round, flat & square bars in a choice of machinable alloys; tube, scaffold tube & box section; angle, tee & channel; a complete package of Road Transport sections plus a selection of shapes and sizes in various aerospace alloys.

The range of Road Transport sections includes bearers, runners, side raves, side guards, corner pillars, cant rails, tops hats, drop-sides, Zeds, mouldings, cappings and kick strips as well as a range of flooring options.

Processing Services

Processed material can save customers both time and money. Understanding this, Aalco has made a major investment in a wide range of modern processing equipment, particularly for cutting and finishing, at both its local and central service centres.

In addition, Aalco regularly arranges a wide array of processing services for customers on a sub-contract basis.



Logistics & Systems

Like all world-class distribution businesses, Aalco operates a hub and satellite system.

The satellites are 18 local Service Centres providing unrivalled service to customers in their local area.

The hub is The Metal Centre – a 270,000 square foot (25,000m^2) facility located in the West Midlands, bringing together 6,000 tonnes of stock and 130 employees. This state-of-the-art facility has a capacity to handle over 150,000 tonnes per year thanks to the largest automated handling system in Europe – this comprises a 5,500 cassette Kasto system in two 14 metre high units and one 8 metre high unit.

Linking The Metal Centre to the Service Centres is a 25-vehicle carrier fleet that travels overnight to ensure that an item in stock anywhere across the country can be delivered to any Aalco customer the next day, using the local truck fleet of well over 100 vehicles.

Keeping the whole system operating at maximum efficiency are highly sophisticated Information Systems, designed in-house and undergoing constant development to support the evolution of the Aalco business and maximise customer service.

Product Information

Aalco provides a wealth of product information to ensure that its customers are fully informed, not just about the choice of materials and sizes available but also on a range of technical topics including product selection, specifications, properties, fabrication & joining, finishing, installation and maintenance.

Shown inside the front cover of this brochure is a selection of the other publications that are all available free of charge from your local Service Centre - Everything from simple data-sheets to a CD-ROM with over 400 pages of technical information on stainless steel tubular products. What's more, all of these publications are available on-line and for down-load at any time of the day or night, every day of the year at **www.aalco.co.uk**

Road Transport Products

The range includes:

- **Rolled Products** – sheet & patterned sheet, plate & treadplate, shate
- **Standard Extrusions** – angle, channel, tee, tube & box section, flat/square/round bar
- **Special Sections** – Bearers/Runners, Floor Planks, Side Raves & Guards, Corner Pillars, Cant Rails, Top Hats, Zeds, Mouldings, Kick Strips
- **Dropside Sections & Systems**
- **Slip-resistant flooring** – Phenolic mesh-faced Birch wood plywood
- **Cappings** – ABS & Aluminium/ABS
- **Patterned aluminium flooring sheet**
- **GRP Panels**

Energy, Offshore & Process Industries

Aalco has established a Contract Services Division to meet the specialist project requirements of the energy, offshore and process industries.

Based at Aalco's Service Centre in Hull, the Contract Services team includes a number of staff with extensive experience in the sector. With the backing of Aalco's huge UK stock as well as access to the Amari stock held by Aalco's associated companies in Europe, the new Division provides the process industries with an outstanding service for all project requirements. Customers range from nuclear fuel reprocessing facilities to onshore/offshore oil, gas and petrochemical plants where Aalco has ongoing exclusive supply contracts.

Export

The wide Aalco stock range is of great interest to customers throughout the world seeking ready availability of semi-finished metal alloys.

Because export customers have specialist requirements in areas such as packaging and documentation, all exports from Aalco are handled by a dedicated team located at our Southampton service centre, which sources a full range of materials and:

- Provides the specialist knowledge and procedures required to service export markets together with the appropriate quality approvals
- Arranges special testing, inspection, documentation and releases as required
- Is ideally located to provide international deliveries to customers world-wide. Southampton is one of the UK's premier ports, with efficient and economic shipping routes for destinations across Europe and throughout the world. Equally, air-freight can be readily arranged for more urgent cargos.

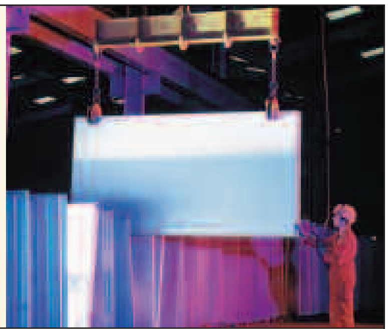
Aalco stock all of the commonly required forms of stainless steel including sheet, coil, strip, plate, bar and sections as well as a full range of tube, pipe fittings and flanges.

In addition to a comprehensive range of standard products, Aalco Service Centres stock industry specific items and customer specials with numerous specialist products and alloys satisfying the needs of a broad range of industries.

Aalco also provides a complete range of processing services that include bar, tube & pipe cutting; plate processing; coil processing and surface finishing.

The Core Product Ranges are:

Rolled Products
Quarto Plate
CPP Plate
Sheet
Polished Sheet
Type 1.4003 plate and sheet
Treadplate
Weld Mesh



Bar and Sections
Round and Hexagon Bar
Rolled Edge Flat Bar
Angle
Square

Tube
Seamless imperial sizes
Welded Metric Nominal Diameter (ND) sizes
Decorative – Round, Square, Rectangular
Structural – Square and Rectangular up to 250mm
Hygienics

Pipe
Seamless and welded from 1/4” to 12”

Fittings
Seamless and Welded Butt Weld Fittings
BSP Screwed
Hygienic Fittings
Welded Metric Nominal Diameter (ND)

Flanges
ASTM A182 / ANSI B16.5
BS 10 Flanges 316L Table E
BS 4504 / EN 1092 Raised Face, 16 Bar
Aluminium and Coated Mild Steel Backing Flanges

Full detail of all product ranges, alloys and sizes can be found in the Aalco Stocklist available **FREE** from your local Service Centre as well as on the website. The Aalco Tubular Products Data-Book provides a comprehensive 400-page guide to this extensive product range including all relevant specifications – this is available online or from your local Service Centre on CD-ROM.

Stainless steel is not a single material but the name for an extensive range of corrosion resistant alloy steels. These alloys were first developed early last century and by the 1920's several types had been established. In the UK Harry Brearley developed a 13% chromium steel, whilst working on a steel to improve the wear characteristics of rifle barrels. He observed that this steel only reacted slowly with his laboratory etching acids and when discarded sample pieces which were left outside in the rain did not rust, like lower chromium steel did. This "chromium/ carbon" steel was eventually used for cutlery as it could be hardened by heat treatment in a similar way to the non-chromium cutlery steels that were then being used. This reinforced the position of Harry Brearley's native Sheffield as a world centre for cutlery and blade production in the 20th century.

Around the same time metallurgists in France, Germany and the USA were also developing corrosion resistant steels. All these steels had the same basic ingredient, chromium at a minimum level of about 11%. These steels included what would later be classified as "ferritic", plain chromium steels with lower carbon levels than Harry Brearley's "martensitic" steel and "austenitic" steels with additional manganese or nickel.

So who invented stainless steel?
You have a choice; it depends where you come from or perhaps who you buy your steel from!

The current European standards for stainless steels contain in excess of 80 different steel grades, providing a wide range of properties to meet the demands of a very diverse range of applications to which these corrosion resistant steels can be put.

Worldwide demand for stainless steel is currently increasing at a rate of about 5% per annum. Annual consumption is now well over 20 million tonnes and continues to rise, particularly in application areas such as the building and construction industries and for household and kitchen appliance applications.

New uses continue to be found for stainless steels.
Their excellent corrosion resistance, attractive appearance, wide ranging mechanical properties and low maintenance costs offer competitive solutions when choosing modern materials for new applications. Stainless steels often provide better whole-life cycle cost benefits than alternative, lower initial cost material choices, such as painted or galvanized carbon steel.

Stainless steels are 100% recyclable and have been traditionally recycled for making new steel. About 80% of the newly made stainless steel produced in by western European steelmakers comes from recycled scrap, which requires very little processing before being remelted into new steel.

What is Stainless Steel?

Stainless steels are a group of corrosion resistant steels that contain a minimum of 10.5 % chromium. There are other steels, including some tool steels that also contain these levels of chromium. The difference between these steels and stainless steels is that in stainless steels the chromium is added principally to develop corrosion resistance. The European standard for stainless steels, EN 10088 (published in the UK as BS EN 10088) defines stainless steels as steels with a minimum of 10.5% for use in applications where their corrosion resistance is required.

Many commercially available stainless steels contain more than this minimum level of chromium and, in addition, contain varying amounts other alloying additions including nickel, molybdenum, titanium, niobium etc. These additions are made, not only to enhance the corrosion resistance of the steel but also develop other properties, such as mechanical strength, hardness, toughness, magnetic properties etc. or to change working characteristics including formability, machinability and weldability. Stainless steels can also be used in heat resisting and cryogenic applications as they also have excellent oxidation resistance. These particular steels generally have enhanced chromium levels to improve their heat resisting properties. They are covered by the BS EN 10095 standard.

The behaviour of the various stainless steels during manufacture, fabrication and in-service not only depends on their chemical compositions, but also on the design and surface finish of the manufactured items. Careful selection of the most appropriate steel grade, design and surface finish are vital to the successful application of stainless steels.

Types of Stainless Steel (Families)

Stainless steels have "family" names that reflect their metallurgical (atomic) structure.

These groupings, commonly referred to as families, are:

- Ferritic
- Austenitic
- Duplex (austenitic-ferritic)
- Martensitic and precipitation hardening.

More highly alloyed austenitic and duplex grades with better pitting corrosion resistance than the standard grades are known as "super-austenitic" and "super-duplex" stainless steels.

The properties of grades in these families can be quite different. This enables stainless steels as a group of materials to be used for such a wide range of applications.

The main features of each family are:

Ferritic

- Magnetic
- Low carbon
- Chromium main alloying element, typically 10.5-17%
- Not hardenable by heat treatment
- Typical grades 409 (1.4512), 430 (1.4016)

Austenitic

- Non-magnetic (when fully softened)
- Low carbon
- Chromium contents typically 16-20%
- Nickel contents typically 7-13%
- Not hardenable by heat treatment, but strengthen significantly during cold working
- Typical grades 304 (1.4301), 316 (1.4401)

Duplex

- Magnetic
- Low carbon
- Chromium contents typically 21-26%
- Nickel contents typically 3.5-6.5%
- Nitrogen added, typically 0.05-0.40%
- Not hardenable by heat treatment, but higher annealed strength levels than ferritic or austenitic stainless steels
- Typical grade 2205 (1.4462)

Martensitic and precipitation hardening

- Magnetic or non-magnetic
- Carbon can be up to 0.95%
- Chromium contents typically 12.0-17%
- Nickel contents typically 2-7%
- Precipitation hardening types also contain aluminium or copper
- Hardenable by heat treatment
- Typical grades 420 (1.4021), 17/4PH (1.4542)

Corrosion Resistance

All stainless steels are able to resist some level of corrosion. There is a wide range of service media and different forms that corrosion attack can take. This is one reason why there are the four main families of stainless steels and why each has its own range of grades. Stainless steels all rely on the chromium content to form a corrosion resisting, tightly adherent, chromium-rich passive layer. This invisible, very thin (about 5×10^{-9}m i.e. 0.000000005 metre thick) inert layer is the key to the durability of stainless steels.

If mechanically damaged or chemically attacked, the passive layer repairs itself, maintaining the protection of the underlying metal. This repair process is normally rapid but does require oxygen, which is present in most working environments. In this condition the surface is said to be "passive". If the passive layer is broken down or not allowed to reform if damaged, the surface is "active" and corrosion can take place.

The addition of more chromium and other alloying elements such as nickel and molybdenum improve the resilience of the passive film and so make the resulting steel more resistant to a wider range of corrosive conditions than the basic 10.5% chromium composition.

Other Properties of Stainless Steels

In addition to corrosion resistance, specific stainless steel grades have other properties that can be useful either in service or during manufacture and fabrication. These properties can differ widely between the families and various grades and include:

- **Mechanical Strength**

The mechanical strength of the ferritic (around 500 MPa) and austenitic (around 600 MPa) stainless steels is similar to low alloy steels. The austenitic steels maintain their strength better than the ferritic stainless steels or non-stainless structural steels with increases in temperature. This makes the austenitic stainless steels good choices for fire and heat resisting applications.

Duplex steels are about twice the strength of these others steels, with yield strengths of around 450 MPa and tensile strengths of 700 MPa. Their mixed structures of ferrite and austenite together with their nitrogen contents develop these higher strength levels. The strength of the martensitic and precipitation hardening steels can be altered over a wide range by heat treatment. The precipitation hardening types, in particular are capable of very high strength levels, up to 1100 MPa.

- **Hardness**

Hardness, the resistance to indentation or scratching, is similar for all the "softened" steels i.e. the ferritic, austenitic and duplex family grades. Only the martensitic grades with their enhanced carbon levels are capable of being hardened. Grades such as 440C (1.4125) can be hardened to around 60 HRC (Rockwell C). In contrast the precipitation hardening grades, despite their name, are mainly used for their heat treatable strength rather than hardness.

- **Toughness and ductility**

The properties of toughness and ductility usually go together, although they are different properties. Toughness is a measure of how much energy is absorbed by the metal during fracture. A brittle material has low toughness. Usually as temperatures get lower, the toughness of metals decreases. The austenitic stainless steels have excellent toughness, not only at ambient temperatures, but also at cryogenic temperatures (down to -196°C). The ferritic, duplex and precipitation hardening steels have good ambient temperature toughness and moderate toughness, down to about -40°C. Martensitic steels are however usually brittle, especially at most temperatures below ambient.

- **Work Hardening**

Work hardening is the progressive increase in strength and hardness as a material is "cold" worked. Most metals work-harden to some degree during operations like cold forming, bending or machining. The work hardening rate of the austenitic stainless steels is higher than most other metals. This is due to structural changes in the steel, as some of the austenite transforms to the stronger martensite constituent. Work hardening can be both a disadvantage and an advantage. It is undesirable during machining, but advantageous during some cold drawing operations, where it can delay premature failure during working. Inter-stage annealing operations are usually needed however when manufacturing severely drawn or complex shaped parts. The effects of cold working are reversible by annealing heat treatments at around 1050°C.

- **Magnetic Permeability**

Magnetic permeability is a measure of attraction to a permanent magnet. Most materials, including many metals are not attracted to a magnet. The common exception is iron and most steels, which can also be turned into magnets i.e. be magnetised and demagnetised by electrical fields. Softened austenitic steels do not behave in this way. They have very low magnetic permeability, with values of relative permeability around 1.005. Ferritic and martensitic stainless steels in contrast have relative permeability values around 15. With this very low relative permeability austenitic stainless steels can be used in equipment that very sensitive to magnetic field interference but also needs to be corrosion resistant. These applications include medical body scanner cases and naval mine sweeper vessel equipment. Grade 316LN (1.4406) with its additional nitrogen content is well suited to such applications. It should be noted that work-hardened austenitics can be slightly magnetic.

Recycling and the Environment

Stainless steels are 100% recyclable and have been traditionally recycled for making new steel.

Unlike carbon steels, which rely on paint or galvanized (zinc) coatings for their corrosion protection, stainless steels are not normally coated as they already have their own corrosion resistant surface. Reprocessing may only involve sorting the scrap material to optimize the use of expensive alloying additions such as nickel and molybdenum or removing surface oil and grease, left on from machining or forming processes.

This means that the costs of reprocessing scrap stainless steel can be kept lower than coated metals.

Some additional alloying is usually necessary in the steelmaking process however. About 80% of the newly made stainless steel produced in by western European steelmakers comes directly from the recycled scrap material.

Provided that appropriate grades of stainless steel are selected for their many applications, they should give long product service lives that require only a minimal level of maintenance. This means that whole life cycle cost benefits of using stainless steels can often be better than materials with lower initial costs, reducing unnecessary damage to the environment.

A particular example of the life cycle cost benefits of stainless steel is its use as reinforcing bar in high cost maintenance applications such as concrete tidal river or motorway bridges.

Selection of Stainless Steels

The main reason for considering stainless steels for any application is their corrosion resistance with other properties usually being secondary.

These include:

- Mechanical and physical properties
- Available forming, fabrication and joining techniques
- Environmental and material costs

The basic approach is to consider grades with as low a cost as possible, but the required corrosion resistance. After this other properties can be considered.

The lowest cost steels, subject to availability, should be those with the leanest compositions. This should initially encompass the straight chromium ferritic and martensitic grades, such as 410S (1.4000) or the 1.4003 type. Increasing the chromium (Cr) content will enhance the corrosion resistance, so a 17%Cr 430 (1.4016) grade can be expected to be a better choice, if needed. Similarly martensitic 431 (1.4057) grade with 15%Cr can be expected to have better corrosion resistance than the 12% Cr 420 (1.4021/1.4028) types.

In addition to this basic rule, nickel (Ni) additions support the corrosion resistance provided by the chromium and so widening the scope of service environments that these stainless steels can be used in.

The 2%Ni addition to the 431 (1.4057) martensitic improves corrosion resistance marginally. Normally to significantly improve corrosion resistance larger nickel additions are made, austenitic grades having between 7-13% Ni and the more exotic grades up to 30%Ni. These nickel additions are also responsible for the change in the steels structure from ferritic to austenitic. Structurally, between the ferritic and austenitic family grades are the duplex steels, with typically 3.5-6.5% Ni. Most of their corrosion resistance is derived from their chromium, molybdenum and nitrogen contents. The main function of the nickel is to "balance" the structure, which provides enhanced strength and resistance to stress corrosion cracking (SCC).

Some of the selection issues are summarised in the table, below:

Family	Example Grades	Advantages	Limitations
Ferritic	410S (1.4000) 430 (1.4016) 446 (1.4749)	Low cost, moderate corrosion resistance & good formability.	Nominal corrosion resistance, formability, weldability & elevated temperature strength.
Austenitic	304 (1.4301) 316 (1.4401)	Good corrosion resistance and cryogenic toughness. Excellent formability & weldability. Widely available.	Work hardening can limit formability & machinability. Limited resistance to stress corrosion cracking.
Duplex	2205 (1.4462)	Good mechanical strength. Very good pitting, crevice and stress corrosion cracking (scc) resistance.	Application temperature range more restricted than austenitics. More expensive, and less widely available than austenitics.
Martensitic	420 (1.4021) 431 (1.4057)	Low cost, hardenable by heat treatment with high hardness.	Nominal corrosion resistance. Limited formability & weldability.
Precipitation hardening	17/4PH (1.4542)	Strengthenable by heat treatment giving better toughness and corrosion resistance than martensitics.	Restricted availability, corrosion resistance & formability. Weldability better than martensitics.

Applications for Stainless Steels

The applications for stainless steels are extremely diverse. Typical applications can be illustrated for each of the family groups.

Ferritic Stainless Steels

- Vehicle exhausts
- Indoor architectural trim and panels
- Domestic appliances
- Low cost cooking utensils
- Food serving counters and furniture
- Bulk handling equipment

Austenitic Stainless Steels

- External architectural structures and cladding
- Building roofing, gutters and down-pipes
- External architectural metalwork (handrails, stairways, seating)
- External doors, fire doors and window frames
- Concrete reinforcing bar
- Fasteners (nuts and bolts)
- Food and drink manufacturing and processing equipment
- Domestic and retail catering equipment and sinks
- Water treatment, plumbing equipment and tubing
- Oven and furnace equipment
- Chemical processing and transport tanks

Martensitic Stainless Steels

- Cutlery
- Food preparation blades and kitchen knives
- Surgical instruments
- Pump and drive shafts
- Springs

Duplex Stainless Steels

- Pressure vessels
- Heat exchangers
- Lightweight bridge structures
- Off-shore oil and gas installations
- Ship's tanks and blast walls
- Chemical and petrochemical plant
- Brewery sparge tanks
- Food pickling plant and tanks

Precipitation Hardening Stainless Steels

- Aircraft and aerospace components
- Turbine blades
- Off-shore equipment & components
- Field gun frames and armaments
- Military and high performance vehicle components

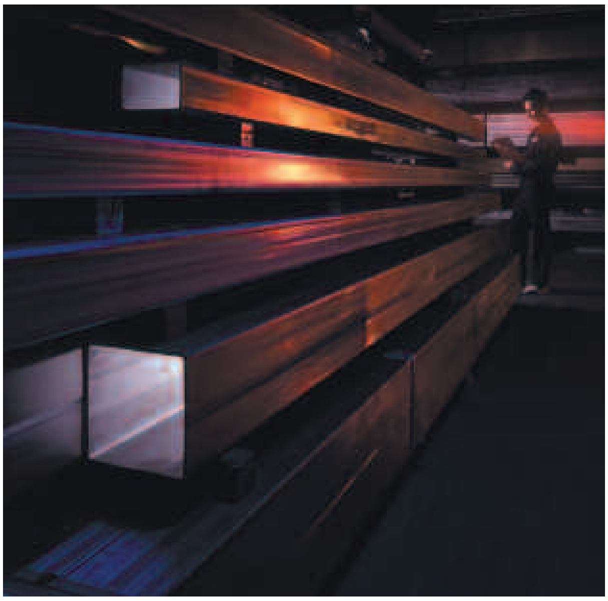
Stainless steels can be specified using well established standards that encompass a wide range of product forms and applications. Historically many countries of the world developed their own standards and grade number systems for metals and alloys, including stainless steels. The main standards that are used in the UK are European, British and American. Since 1995 Britain has been in the process of adopting European Standards, replacing the "BS" British Standards with "BS EN" standards for many stainless steel product forms. The American ASTM and ASME standards continue to be used for some products, in particular pipe, tube and fittings. Similarly the American (AISI) grade numbers e.g." 304" continue to be used by many people dealing with stainless steels in the UK on a daily basis. For specification purposes the European steel numbers e.g. "1.4301" should now be used unless, in special cases, the project or system design is specifically to the American ASME code or for export to the US or Far East.

Specifications for Stainless Steel Products

The main standards for stainless steel products in the UK are British Standard versions of European Standards. These standards are identical in all countries of the expanding EC and have to be adopted by all member states when they are introduced. Each country is allowed to publish translated versions through their own standardising agency. In Britain we use them as "BS EN" standards. The main standard that defines stainless grades is BS EN 10088-1. This was republished in 2005 and now includes corrosion resisting, heat resisting and creep resisting steels.

The main British Standards for stainless steels include:

- BS EN 10088-1 – List of Stainless Steels
- BS EN 10088-2 – Sheet, Plate and Strip
- BS EN 10088-3 – Bars, Rods, Wire, Sections and Bright Products
- BS EN 10296-2 – Welded Tubes
- BS EN 10297-2 – Seamless Tubes
- BS EN 10095 – Heat Resisting Steels



Most stainless steel product forms for general engineering and pressure purposes have now been incorporated into European Standards and the former British Standards withdrawn. Products like hollow bars (BS 6258) and concrete reinforcing bars (BS 6744) however are not yet specified in European Standards.

American ASTM (American Society for Testing and Materials) Standards use either the AISI (American Iron and Steel Institute) or UNS (Unified Numbering System) grade designations.

The AISI grades e.g. 304, 304L merely define the chemical composition ranges for these steels. They are not specifications for products like sheets, plates, bars, tubes etc. Products are specified in ASTM Standards, which usually cross-reference the UNS designations e.g. S30400, S30403. There is a wider range of ASTM Standards than European Standards for similar products. This is partly because the ASTM system has grown over the years whereas the European system was developed from scratch in 1995. The European standards system is no less comprehensive and should be easier to work with than the American standards.

The UNS system defines the grade compositions more precisely than the older AISI system. It is better for distinguishing between grade variants with different carbon or nitrogen contents. ASME (American Society of Mechanical Engineers) Standards are used for specifying coded pressure systems. The standard numbers are the same as the ASTM standards from which they are taken, but are prefixed with "SA" rather than the "A" of the ASTM for stainless steel products.

Examples of ASTM Standards include:

- ASTM A240 – Plate, Sheet and Strip
- ASTM A276 – Bars and Shapes
- ASTM A269 – Welded Austenitic Tubes for General Service
- ASTM A312 – Seamless and Welded Austenitic Pipes
- ASTM A789 – Seamless and Welded Duplex Tubes for General Service

Stainless Steel Grades

The grade numbers of the AISI system, which was adopted in British Standards during the 1960's, is an arbitrary 3 digit system, although the steel families are generally in the same groups i.e.

200 series – manganese/nickel austenitics e.g. 201
300 series – nickel austenitics e.g. 304, 316, 321
400 series – ferritics e.g. 409, 430 and martensitics e.g. 420, 431, 440C
600 series – precipitation hardening types e.g. 630 (17/4PH)

Duplex and super-austenitic stainless steel grades do not normally have AISI grade numbers, so are usually identified in ASTM Standards by either common names e.g. 2205, for the 1.4462 duplex steel or UNS numbers e.g. UNS S31254 for the 6% molybdenum "254SMO" super-austenitic.

The grade designation system used in European Standards was based on the German "Werkstoff-Nummers" e.g. 1.4301 for the AISI 304 type and 1.4307 for the AISI 304L type.

There is some logic to the way these numbers have been assigned to grades, but as with the AISI system it is largely a question of becoming familiar with the numbers. These "EN" steel numbers can be found in tables of related steel grades, showing the nearest AISI or old BS numbers.

The grade numbers used in the superseded British Standards are not however shown in the new BS EN standards, like BS EN 10088-1.

Throughout this brochure the grade numbers have been cross-referenced for brevity, e.g. 304 (1.4301).

What do the Standards Specify

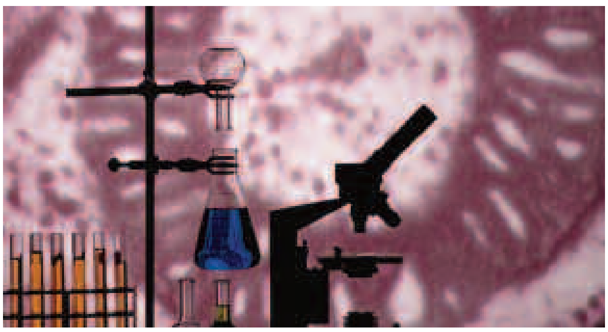
The scope of available standards for stainless steel products varies, depending on the publisher (standardising authority) and the age of the original standard.

All standards have a list of steel grades and most show the acceptable chemical (cast analysis) composition ranges for the grades. Many standards also include ambient temperature mechanical properties, including tensile proof strength, maximum tensile strength (UTS) and elongation. Other important parameters like surface finish and size tolerances are normally included in either the product standard or related and referenced standards.

Other property parameters such as grain size and micro-cleanness are rarely specified in standards. Physical properties like magnetic permeability, thermal expansion, density etc. are not included. If these are important to a purchaser, they have to be specified additionally at the time the steel is ordered.

The principal parameters included on stainless steel product standards include:

Chemical Composition



The ranges shown for each element e.g. carbon, chromium, etc. must be met from the steelmakers declared laboratory analysis of the cast from which the batch of product was made. Standards usually only require a range of elements that are important for the finished steel to meet the desired corrosion resistance and specified properties. For example molybdenum and titanium would not be shown on a mill certificate for a grade 304 (1.4301) product, but would be required for 316 (1.4401) i.e. the Mo, or 321 (1.4541) i.e. the Ti.

Product check analysis tests are not required by specifications and if needed must be ordered. Usually however standards give the acceptable deviation ranges from the cast analysis for any product check figures obtained. Only the specified elements for the particular grade need be checked by the product analysis.

Tensile Properties

Parameters measured in routine tensile tests that are normally included in standards are:

0.2% proof strength – Mpa (N/mm^2)
1.0% proof strength - Mpa (N/mm^2)
Tensile strength (UTS) - Mpa (N/mm^2)
Total Elongation (after failure) - %

Hardness

The requirements for separate hardness testing are not included in most modern stainless steel product standards. Older standards did tend to include hardness. There are no units of hardness, with the level of hardness being represented as an integer.

When specified the methods involved include:

Vickers – VPN (HV)
Brinell – HB
Rockwell B/C – HRB/HRC

Mill test certificates sometimes show hardness values from tests using the Rockwell B method, converted to the Vickers scale.

Impact Toughness

Charpy impact tests are specified for a limited number of grades and products. The standard test is done on a 10mm section and so thinner section products e.g. sheet, strip, tubes cannot normally be tested for impact strength. The test is sensitive to temperature and so the standards will generally specify an impact energy minimum for a specific temperature. The test units are normally Joules (J).

Corrosion Resistance

Rigorous corrosion testing is not required by stainless steel product standards.

The only corrosion test included in most product standards is for the susceptibility to intergranular (intercrystalline) corrosion, abbreviated to either IGC or ICC. Both European and ASTM standards have a testing standard for IGC / ICC (EN ISO 3651 in Europe or ASTM A262 in the US). Product standards will normally show if the test is required for each grade as a "yes/no" or "OK" criteria.

Other corrosion tests can be specified by order but are only normally requested if it is important to demonstrate that the product will meet some specific or exacting service requirement.

These tests include:

- Critical Pitting Temperature
- Salt Spray Atmosphere Resistance
- Huey Test (boiling nitric acid ICC susceptibility)

Other Tests for Stainless Steel Products

There are many other tests that may be relevant to the intended product application. Some are covered by separate testing standards, but tests not included in the product standard must be stipulated on the steel order.

These include:

- Physical Properties (Magnetic permeability)
- Mechanical Properties (Sub-zero or elevated temperature tests or to verify heat treatments)
- Steel Structure (Grain size, ferrite level, micro-cleanness)
- Corrosion Tests (CPT, salt spray)
- Surface & Internal Soundness (Eddy current, Dye-penetrant, Ultrasonic, X-Ray)
- Surface Finish (Normally Ra surface roughness CLA test)
- Surface Cleanness and Passive Condition (Generally on fabricated products only)

Certification of Stainless Steel Products

To meet ISO 9000 and related quality standard requirements most stainless steel mills now provide "Certificates with Goods", so that products being delivered can be verified at the point of receipt. European and hence British Standards define material certificate types in BS EN 10204. Material test certificates supplied by stainless steel manufacturers usually show this standard.

Normally the 3.1 Inspection (or batch) certificate type, previously known as 3.1B, is supplied.

Stainless steel products are often stocked with "dual" certificates so that their range of application standards is flexible. Dual certification is not covered by any standards and so if required, it must be ordered. Where the application standard and grade is specific however, receiving dual certificates does not disqualify the certificates, provided of course they covered the required standards and grades. Dual certificates can provide two distinct options, each having more than one set of:

- Standards (e.g. for sheet BS EN 10088-2 and ASTM A240 or ASME SA 240)
- Grades (e.g. 1.4301/1.4307 or 304/304L for standard and low carbon variants)

These can also be combined, for example:
BS EN 10088-2 1.4301/1.4307, ASTM A240 / ASME SA 240 304/304L

This means that the batch of sheets supplied has a chemical analysis and specified mechanical property values that meet BOTH grades in BOTH standards. It does not necessarily mean that ALL the specified parameters (e.g. dimensional tolerances, mechanical test methods etc.) meet both standards. If full compliance to a particular standard is required then a single standard certificate for the products should be requested.

European Directives and COSSH

In addition to European Standards there are restrictions on the supply of products stipulated in European Directives. Although these apply to stainless steels, they do not significantly affect the supply of commercially available products. The main directives of interest are:

Restriction of Hazardous Substances (RoHS)
Waste Electrical and Electronic Equipment (WEEE)
End of Life Vehicles (ELV)
"Nickel Directive"

These first three directives put restrictions on the amounts of lead, cadmium, mercury and hexavalent chromium that products are allowed to contain. A review done by some of the steelmakers has confirmed that the levels of lead, cadmium and mercury present in their stainless steel products is well below the maximum levels required by the directives. This should also be the case for commercially available stainless steels from reputable sources. The chromium in stainless steels is NOT in the hexavalent state and so the restrictions in the EU directives are not relevant.

The nickel directive, as it is known, only applies to products that are intended for use either in intimate, prolonged contact with human skin, or for products used during or immediately after body piercing operations.

Nickel contact dermatitis has only been connected with stainless steel in a very few isolated cases and then only in specific steel processing/ fabrication environments.

In addition to the European directives, UK health and safety law requires that a supplier of stainless steel products, that could be converted into articles (i.e. parts or fabrications), should provide a "MSDS" (Materials Safety Data Sheet) to demonstrate that there is adequate "COSSH" (Control of Substances Hazardous to Health). These MSDS data sheets should be available from the steelmakers.

In normal handling, storage and use stainless steels should not be a chemical hazard concern.

The corrosion resistance of stainless steels is the key to their successful use. To perform well in the wide range of environments that stainless steels are used in, the "enemy" corrosion must be understood by specifiers, designers, suppliers and end-users.

Corrosion is a mechanism of electro-chemical disintegration that most metals and some other materials can suffer from. It can occur at both ambient and elevated temperatures, where the mechanisms differ. At ambient temperatures the mechanisms are dependent on electrically conductive moisture and so are known as "aqueous corrosion". Elevated temperature attack mechanisms rely on the semi-conductive properties of the scales formed on the metal surfaces. Much of the stainless steel used operates around ambient temperatures, so aqueous corrosion mechanisms are of most interest.

The Stainless Steels Passive Layer

Stainless steels rely on their naturally forming passive surface layer for their corrosion resistance.

Although this layer forms rapidly under the right conditions, it cannot be regarded as permanent coating that is impermeable to all chemicals that might be present at the surface, like an indestructible invisible paint layer. The resistant properties of the passive layer depend on the chromium level and the presence of other alloying elements in the steel, but the layer can be broken down, and the steel become "active". The steel surface will then suffer corrosion if it continues to be exposed to these conditions.

General or Localised Corrosion

The passive layer, when intact, guards against overall attack, or general corrosion, to the surface. This is one of the features that distinguish stainless steels from low alloy and carbon steels, which form a general rust layer on their surfaces as they corrode in the presence of moisture and oxygen. The oxygen in the moisture is needed in the rusting process on these steels, but in stainless steels it actually helps promote their corrosion resistance by maintaining the passive layer. Although stainless steels can suffer from overall surface or general corrosion, local attack mechanisms are a much more common problem.

If for some reason the passive layer is weak at a particular spot or is mechanically broken in a small area, then corrosive attack can start. This is very often due to chloride "ions" in the surrounding aqueous media migrating to the metal surface through the defective area of the layer. Under these conditions the passive layer on the surrounding steel surface, whilst continuing to give protection here, promotes the localised corrosion mechanism that has started in the pit now being formed.

Forms of Aqueous Corrosion

The main forms of aqueous corrosion that can affect stainless steels are related to each other, but to help avoid them they can best be understood as separate mechanisms:

- Pitting Corrosion
- Crevice (Shielding) Corrosion
- Stress Corrosion Cracking (SCC)
- Bimetallic (Galvanic) Corrosion
- Intergranular (Intercrystalline) Corrosion (IGC)

Pitting Corrosion

Pitting corrosion can be initiated at surface defects already present in the steel, for example non-metallic inclusions, residual surface scale or large precipitates just under the surface. These defects can disturb the passive layer locally, providing potential corrosion sites.

For this reason, the steel used must always be:

- Properly descaled i.e. free of mill scale
- Sourced from reputable steelmakers who use good, clean steel making practices
- Heat treated to avoid unnecessarily large precipitates (including carbides)

Re-sulphurised "free-machining" stainless steels e.g. 303 (1.4305) can be more prone to pitting corrosion than non-treated grades of the same basic composition i.e. 304 (1.4301) in this case. The free-machining grades should only be used where absolutely necessary for very high unit production speeds as the service performance of the components can be compromised.

The pitting resistance of stainless steel grades can be compared from their compositions using Pitting Resistance Equivalent Numbers (PRENs). There are several formulae used to calculate PRENs, the most commonly used one for austenitic stainless steels is:

PREN = %Cr + (3.3 x %Mo) + (16 x %N)

The basic reliance on chromium for pitting resistance is shown, but more important, the higher potency of molybdenum and particularly nitrogen in the steel for conferring pitting resistance on the steel. Using this formula the PRENs of commonly used grades can be compared:

Grade	%Cr	%Mo	%N	PREN
304 (1.4301)	17/19.5	N.S.	0.11max.	17.0-20.8
304LN (1.4311)	17/19.5	N.S.	0.12/0.22	18.9-0.22
316 (1.4401)	16.5/18.5	2.0/2.5	0.11max	23.1-28.5
316LN (1.4406)	16.5/18.5	2.0/2.5	0.12/0.22	25.0/30.3

A similar formula can be used to compare duplex stainless steels, due to the higher potency of nitrogen in these steels:

PREN = %Cr + (3.3 x %Mo) + (30 x %N)

Grade	%Cr	%Mo	%N	PREN
2304 (1.4362)	22/24	0.1/0.6.	0.05/0.20	23.1-29.2
2205 (1.4462)	21/23	2.5/3.5	0.10/0.22	30.8-38.1
2507(1.4410)	24.0/26.0	3.0/4.0	0.24/0.35	37.7-46.5

Steels with a PREN of 40 or over are known as super-austenitic or super-duplex, depending on their family type.

Crevice (Shielding) Corrosion

Crevice corrosion is initiated in areas where the oxygen supply to the surface is restricted, compared to the surrounding, fully passive surfaces. This can happen at engineered or "designed-in" crevices, for example at bolted joints or beneath flanges or gaskets. Areas of the steel surface covered by dirt or debris deposits can also suffer from this form of attack, which is then sometimes called "shielding corrosion". Coarsely ground or machined surfaces can also act as crevices and more easily trap dirt and debris from their surroundings, which promotes crevice attack.

The mechanism is similar to that in pitting corrosion but is influenced more by the surroundings than the surface condition or internal structure of the steel.

Both pitting and crevice corrosion attack mechanisms involve using chloride ions made available in the environment and acidity, generated by the corrosion process. The more the environment provides chloride ions and the lower its pH (i.e. more acidic) the more likely these forms of corrosion are. Increasing temperatures also promote these localised forms of attack.

The main factors promoting crevice (and pitting) corrosion are:

- Presence of defects or crevices
- Coarse surface finishes (shown by high Ra values) or poorly finished surfaces
- Stagnant conditions (low oxygen levels & risk of deposits forming)
- High chloride content of solution
- Acid pH of solution (values less than 2 are hazardous)
- Increasing temperatures

Grades with increasing levels of chromium, molybdenum and nitrogen offer better resistance to crevice corrosion. The nickel content also reinforces the corrosion resistance, although it does not feature in the PREN formulae.

As a general rule stainless steels such as the 6% molybdenum austenitics can be expected to give the best resistance to crevice corrosion attack.

As a guide, some common stainless steels, rated in decreasing resistance to crevice corrosion are:

- 6% Mo austenitic (1.4547)
- 2205 (1.4462)
- 904L (1.4539)
- 316 (1.4401/1.4436)
- 304 (1.4301)
- 430 (1.4016)

Stress Corrosion Cracking (SCC)

Stress corrosion cracking requires three components for it to attack:

- Tensile stress
- Chlorides in the environment
- Temperature

All three of these components must be present for SCC to take place. Theoretically, removing any of these parameters eliminates the risk of SCC. Traditionally temperatures below 60°C were thought not to support SCC, but experience in very aggressive modern swimming pool building environments has shown that SCC can attack some stainless steels at lower temperatures.

Tensile stresses can be ether **applied** i.e. by loading a structure or component or **residual** from thermal contraction following heat treatment or welding or overheating during grinding or machining. Often SCC attack goes hand-in-hand with crevice or pitting, as the tips of the pits formed by these processes act as stress raising points in the metal.

Selecting grades to avoid pitting and crevice corrosion can help reduce the risk of SCC attack, but the common austenitic grades with nickel contents around 8% i.e. 304 (1.4301) are particularly susceptible to SCC, due mainly to their austenitic structure. For this reason the ferritic and duplex grades are much better choices for resisting SCC attack. Increasing the nickel content and/or improving the pitting resistance through molybdenum and nitrogen additions gives better resistance to SCC.

Stainless steels that can be considered where SCC is a particular hazard include:
444 (1.4521) ferritic (2%Mo)
2205 (1.4462) or any of the duplex grades
904L (1.4539) austenitic (24%Ni)
6% Mo (1.4547) super-austenitic (18%Ni, 6%Mo, 0.2%N)

Where feasible, stress relief heat treatments can also be used to help reduce the risk of SCC attack to the lower alloyed austenitic grades.

Bimetallic (Galvanic) Corrosion

Bimetallic or galvanic corrosion can occur when two different metals or alloys are joined and are in mutual contact with an electrolyte (liquid that can conduct electricity). The corrosion takes place on the least noble of the metals, whilst the more noble metal is effectively protected. Metals and alloys can be ranked in order of their nobility, depending on the electrolyte, in electrochemical or galvanic series tables. Stainless steels in their normally passive conditions are usually noble compared to most common metals that they come into contact with, including aluminium, copper, brasses, bronzes and zinc. As a result stainless steels do not normally suffer from this form of corrosion, but contact with galvanized steel can cause bimetallic corrosion to the zinc coating. This can occur in some external building applications where the two metal types come into contact.

To avoid bimetallic corrosion one or more of the following measures should be taken:

- Keep the junction dry
- Electrically insulate the metals (e.g. neoprene gaskets or washers)
- Apply a protective coating to the metal couple (e.g. paint or sealant)
- Use a design where the less noble metal has the larger surface area

Intergranular (Intercrystalline) Corrosion (IGC)

Austenitic and, to a lesser extent ferritic stainless steels can be susceptible to intergranular, or intercrystalline corrosion. This form of attack was originally associated with welding and was known as "weld decay". Heat from the welding process caused chromium carbides to form in the weld heat affected zone (HAZ), locally reducing the chromium level in the grain boundary regions, where the carbides could form most easily. Here the chromium level could be below the level needed to support the passive condition, locally so enabling localized grain boundary region attack.

This was avoided when the "stabilized" grades were introduced:

- 321 (1.4541)
- 347 (1.4550)
- 316Ti (1.4571)
- 430 Ti (1.4520)

The stabilising titanium or niobium additions tie up the available carbon as carbides that are more stable than chromium carbides thus preventing their formation when heated.

Alternatively, in practice the low carbon grades (i.e. below 0.030%) can be used, but unlike the stabilized grades they are not classed as being immune to this form of corrosion. Most duplex, super-duplex and super-austenitic grades have carbon contents specified low enough to avoid intergranular corrosion.

Selection of Stainless Steels to Avoid Corrosion

Corrosion tables for a wide range of service environments are published by the leading stainless steel producers and can be accessed via the BSSA web site, **www.bssa.org.uk**
These usually show steel grades that can be considered for combinations of chemical concentration and temperature and show if pitting or stress corrosion cracking are likely additional hazards.

To avoid corrosion in the application of stainless steels the following grade selection points should be considered:

- Select an appropriate grade, consistent with minimum cost
- Molybdenum and nitrogen in the steels improve pitting and crevice corrosion resistance
- Ferritic, duplex or high nickel grades are better choices if SCC attack is likely
- Super-austenitic grades should be considered for severe SCC risk areas, such as swimming pool building interiors
- Low carbon grades (except in the case of martensitic steels) are preferable to avoid IGC

Surface Finishes

Although the appearance of the surface is important in getting the desired aesthetic effect on stainless steel components, it is important to remember that stainless steels rely on their surface properties to give them their corrosion resistance.

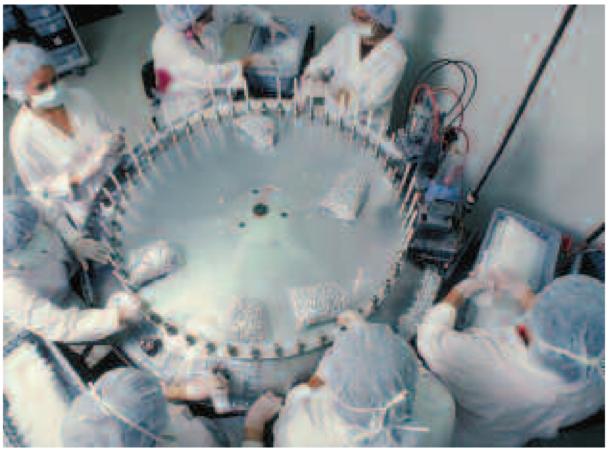
Specifying an appropriate surface finish on a stainless steel component is almost as important as selecting the right grade for the service environment.

As a general rule, to optimise corrosion resistance the smoothest, most crevice free surface possible should be specified.

The available standards help define surface finishes, but it is difficult to specify a surface finish precisely. Using just a grinding or polishing grit size e.g. "a 240 grit finish" is not adequate. There are a large number of surface parameters that can be used when trying to accurately and fully specify a surface finish. These do not usually make it possible to fully specify measure and reproduce the desired finish.

In practice comparative reference samples should always be used to help specify surface finishes on stainless steel products.

Appearance, Corrosion Resistance and Cleanability



The attributes of appearance, corrosion resistance and cleanability of stainless steel surfaces are bound together. The metal surface is normally intended to be exposed and not dependent on additional surface protection (e.g. paint or plating) for its corrosion resistance. This usually means that it is expected to have good visual appeal as well as the required corrosion resistance. In food industry and medical applications the surfaces must also be readily cleansable, be well suited to automated cleaning systems (i.e. CIP or Clean in Place technology) and not trap or retain dirt, soil or bacteria at any time in their operating or cleaning cycles. Architectural applications also depend on the ability of surfaces not to trap dirt and to have a certain amount of "self-cleaning". With careful design detailing and ensuring that the "grain" direction of mechanically finished surfaces is vertical, rainwater can be used to help keep the surfaces clean, corrosion free and extend the times between routine cleaning operations.

Surfaces of food and pharmaceutical manufacturing equipment, in particular, must not contaminate the products being processed or handled. Coated surfaces can degrade and shed foreign material, the unprotected surfaces then exposed, corrode allowing corrosion products to get into the system.

For these reason stainless steels, correctly specified, designed, fabricated, surface finished and operated are the material of choice for not only for food and drink manufacturing, but a wide range of architectural and process industries.

Mill Finishes

Mill finishes are the starting point for specifying finishes on stainless steel products. Often ex-mill finishes, without any further finishing, can be suitable and appropriate for stainless steel products, particularly where the aesthetics of appearance are not important considerations. This can save cost without compromising product performance.

Mill finishes are categorised by their manufacturing routes and are broadly divided into:

- Hot Rolled (1)
- Cold Rolled (2)

These finishes are defined in stainless steel product standards for flat products (BS EN 10088-2) and long products (BS EN 10088-3) and are summarized below:

HOT ROLLED FINISHES			
BS EN Code	**Finishing Process**	**Characteristics**	**Typical (Ra) micro-metres**
1C	Hot rolled, heat treated, not descaled	Surface covered with mill scale suitable for heat resisting applications as supplied. Must be descaled to optimise aqueous corrosion resistance	-
1E	Hot rolled, heat treated, mechanically descaled	Freed of mill scale by shot blasting or grinding. Surface can have limited crevice corrosion resistance	_
1D	Hot rolled, heat treated, pickled	Most common 'hot rolled' finish available. Most corrosion resistant hot rolled finish	4-7
1U	Hot rolled, not heat treated, not descaled	Surface is left covered with rolling (mill) scale. Surface only suitable for products intended for further working.	-

COLD ROLLED FINISHES			
BS EN Code	**Finishing Process**	**Characteristics**	**Typical (Ra) micro-metres**
2B	Cold rolled, heat treated, pickled, skin passed	Most common 'cold rolled' finish available. Non-reflective, smooth finish, good flatness control. Thickness range limited by manufactures' skin passing rolling capacity.	0.1-0.5
2C	Cold rolled, heat treated, not descaled	Smooth but with scale from heat treatment. Suitable for parts to be machined or descaled in subsequent production, or for heat resisting applications.	-
2D	Cold rolled, heat treated, pickled	Similar to 2B in thicker sheet size ranges. Not as smooth as 2B.	0.4-1.0
2E	Cold rolled, heat treated, mechanically descaled	Rough and dull. Appropriate on steel types that are difficult to descale using pickling solutions.	-
2H	Cold rolled, work hardened	"Temper" rolled. On austenitic types improves mechanical strength. Smoothness similar to 2B.	-
2R (Formerly 2A/BA)	Cold rolled, bright annealed	Highly reflective "mirror" finish, very smooth. Manufactured items can be put into service without further finishing.	0.05-0.1
2Q	Cold rolled, hardened and tempered, scale free	Only available on martensitic types e.g. 420 (1.4021). Scaling avoided by protective atmosphere heat treatment. Can also be descaled after heat treatment.	-

Special Finishes

Special finishes are also defined in the BS EN 10088 standards. These can be produced either at the manufacturing mills or by specialist stainless steel processors.

These finishes can be applied to material produced as either:

- Hot Rolled (1)
- Cold Rolled (2)

Some of these special finishes are only available on cold rolled material i.e. code 2.

Codes 1 or 2 indicate that the starting material can be either hot or cold rolled.

BS EN Code	Finishing Process	Characteristics	Typical Grit	Typical (Ra) micro-metres
1G or 2G	Ground	A unidirectional texture, not very reflective.	120	-
1J or 2J	Brushed or dull polished	Smoother than "G" with a unidirectional texture, not very reflective.	180 240	0.2-1.0
1K or 2K	Satin polished	Smoothest of the special non-reflective finishes with corrosion resistance suitable for most external applications.	320	less than 0.5
1P or 2P	Bright polished	Mechanically polished reflective finish. Can be a mirror finish.	600 800	less than 0.1
2F	Cold rolled, heat treated, skin passed on roughened rolls	Uniform non-reflective matt surface, can be based on either 2B or 2R mill finishes.		-
1M or 2M	Patterned	One side patterned only. Includes "chequer" plates ("1" ex-mill finish) & fine textures finishes ("2" ex-mill finish).		-
2W	Corrugated	Profile rolled (e.g. trapezoidal or sinusoidal shapes).		-
2L	Coloured	Applied to flat (2R, 2P or 2K type fishes) or patterned (2M) sheet base finishes in a range of colours.		-
1S or 2S	Surface coated	Normally coated on one side only with a metallic coating, such as tin, aluminium or titanium.		-

Comparison of Mill Finishes

The table shows how the BS EN 10088-2 flat product codes compare with the superseded BS 1449-2 and DIN (German) codes and the current ASTM A480 codes, for flat products.

BS EN Code	Description	BS 1449-2	DIN	ASTM
1D	Hot rolled, heat treated, pickled	1	IIa (c2)	1
2B	Cold rolled, heat treated, pickled, skin passed	2B	IIIc (n)	2B
2D	Cold rolled, heat treated, pickled	2D	IIIb (h)	2D
2R	Cold rolled, bright annealed	2A	IIId (m)	BA
2G	Cold rolled, ground	3A	-	No.3
2J	Cold rolled, brushed or dull polished	3B (or 4)	-	No.4
2K	Cold rolled, satin polished	5	-	No.6
2P	Cold rolled, bright polished	8	-	No.8

Mechanically Abraded Finishes

Mechanical finishes for stainless steels are defined as finish codes G, J, K and P in BS EN 10088-2. Terms grinding, polishing, brushing and buffing even when used along with these codes, are not sufficient to accurately define the finish. There can often be confusion about what these terms mean.

Grinding and Polishing

Both grinding and polishing involve the deliberate removal of metal from the surface using an abrasive. The resulting surface will have some directional marks, partially dependent on the grit size of abrasive used. In the case of the very fine abrasives used in polishing it should only be possible to see any 'directional marks' under a microscope. Viewed normally 1P/2P finishes should appear non-directional.

There is no accepted definition of an abrasive grain or grit size that differentiates grinding from polishing. As a guide however, grit sizes of 80 and coarser are normally associated with grinding.

Grit sizes of 120 and finer are used in preparing polished finishes. Like polishing, which always involves using successively finer abrasive grit sizes to obtain the desired final finish, grinding can also involve more than one abrasive grit stage.

The final grit size used in both grinding and polishing does not fully define the finish and must not be used in an attempt to specify a ground or polished finish on stainless steel. Other parameters such as abrasive pressure, contact time, material feed rate and whether the operations are done dry or wet all affect the character of the finish produced.

Mechanical finishes merely described as 'satin' or 'polished' can vary quite significantly between mechanical finishing contractors.

OTISHEEN® is an example of proprietary fine satin finish with an attractive lustre and smooth finish. Its unique “clean-cut” surface is produced using fine abrasives and a special cutting compound.

The correct choice of steel grade is also important when a bright polished finish is required. The 321 (1.4541) and 316Ti (1.4571) grades which contain small amounts of titanium, should not be used if a

completely defect-free mirror polished finish is required. "Flaky" surface defects are likely to be left after polishing as the hard titanium carbide particles are dislodged from the softer surrounding steel surface. When 2P finishes are required the alternative 304L (1.4307) and 316L (1.4404) should be selected.

Brushing

Brushing normally involves the use of a fine abrasive action on the surface of the metal. In contrast to grinding and polishing there is no deliberate attempt to remove part of the surface. The surface is modified by the action of bristles or a nylon fabric medium (e.g. Scotch-Brite®) that may have some fine abrasive or lubricant added.

Although it can be a single stage process, following a suitable polishing preparation stage, brushing can be done in several stages to obtain a particular finish. Brushed finishes have the same special finish code, 2J in BS EN 10088-2 as dull polished.

Buffing

In buffing no attempt is made to remove metal from the surface. Buffing is only intended to smooth and brighten the existing surface. Traditionally buffing uses cotton or felt based media, often with the addition of lubricants applied to the buffing wheel.

Whenever buffing is being considered as the final finishing operation, it is important that the pre-treated (or existing) surface is defined and controlled. Buffing cannot be used as a substitute for polishing to obtain finishes such as 1P/2P on 'intermediate' abraded ground or polished surfaces. It will only smooth down the surface and will not impart the same characteristics as if the surface has been abraded with successively finer grit sizes (i.e. as in polishing).

Buffing cannot be used as shortcut to obtaining a polished finish. If the surface that is going to be finished by buffing is too coarse, there is risk that traces of the underlying surface finish will be visible on the finally buffed surface.

There is currently no provision for specifying buffed finishes on stainless steel flat products in BS EN 10088-2.

BS 1449-2 (1983) in contrast defined two buffed finishes:

- No.3B - dull buffed
- No.7 - bright buffed.

The ASTM A480 standard also includes a No 7 bright buffed finish.

Applications for mechanically abraded stainless steel finishes

Mechanically finished stainless steel is widely used, including both internal and external building applications. The surface appearance, corrosion resistance and dirt retention of mechanically finished stainless steel surfaces can vary widely, depending, in part, upon the nature of the abrasive medium used and the polishing practice. The1K/2K finishes are fine and clean cut, with minimal surface micro-crevices. This helps optimize the corrosion resistance and minimise dirt retention. These finishes are more suitable than the 1J/2J finishes for external applications, especially where service environments may be aggressive. The coarser 1J/2J and 1G/2G finishes, where required for their aesthetic appearance, are more suitable for indoor applications.

Brushed finishes are susceptible to damage, but scratches can be readily abraded out by competent surface restoring contractors. These surfaces do not fingerprint easily and so can be used in applications such as internal panels, doors and windows.

Atmospheric deposits and other forms of surface soiling can be washed away better on any uni-directionally polished or ground surface, if the abrasion direction is vertical.

Polished reflective surfaces are also susceptible to damage. Remedial polishing is possible but it is more difficult to get satisfactory results than on non-reflective finished surfaces.

Non-Directional Mechanical Finishes

Bead and shot-blasted finishes are produced by the impact of a hard, inert medium onto the steel surface. This gives a uniform, non-directional matt surfaces with low reflectivity. Bead blasting or peening gives a finish with a soft satin texture. Peening can also improve the stress corrosion cracking resistance of the steel surface as any small residual surface tensile stresses are replaced by compressive stress pattern.

The textures of the blasted surfaces vary with the blast media. These include glass, ceramic or lead bead, silicon carbide, aluminium oxide, stainless steel shot or ground quartz. For architectural applications steel shot or glass bead peening methods are used for getting finishes with a non-directional surface sheen and the best corrosion resistance possible.

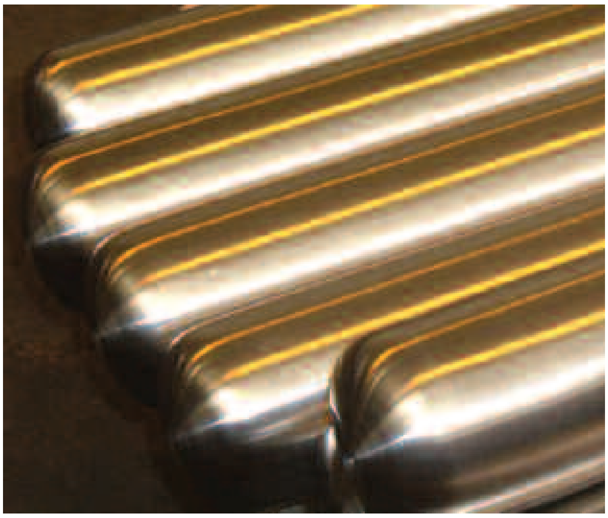
Surface blasting methods use an impacting medium that cuts the steel surface, removing small amounts of metal. The resulting surface finish and hence surface corrosion resistance of the treated stainless steel is partly dependant on the blasting medium. In contrast surface peening does not remove metal. The impact of the rounded bead peening medium produces small craters in the surface, giving a dimpled appearance.

Bead blasted finishes for stainless steels are not covered in BS EN 10088-2. The quality of the finish depends on the blast media, blast intensity and the coverage of the surface, but these alone cannot be used to specify the finish.

The specification should be agreed with a specialist surface contractor.

Applications for blasted stainless steel finishes include:

- Structural support members (e.g. external walkway support arms)
- Cast glazing fixing and connections
- Architectural external and internal cladding, facades and columns
- Sculptures and street furniture



Patterned Finishes

Stainless steel sheets can be given patterned rolled finishes. BS EN 10088-2 covers the specification of both hot and cold rolled products with a one side patterned only as special finish "M". This includes "chequer" plates ("1" ex-mill finish) and fine textures finishes ("2" ex-mill finish). The specific design of the patterns is not defined in the standard and has to be agreed.

These three-dimensional relief effect patterns can be produced by either texture rolling or pressing (embossing). BS EN 10088-2 only covers single sided patterns with a plain, flat surface on the reverse side. Products are also available with a reversed relief effect pattern on both sides. These are formed by rolling sheets through pairs of mating, matched male-female patterned rolls.

Matt rolled surfaces are defined as special finish "2F" by BS EN 10088-2. These finishes are produced by 'skin pass' rolling flat cold rolled stainless steel coil on roughened rolls, rather than on the polished rolls that are used to produce the smooth 2B finish. The 2F finish produced is a uniform non-reflective matt surface.

These patterned finishes are only produced at the manufacturing mill or at specialist processors, using patterned or textured rolls to form the surface features by cold rolling.

Patterned rolled sheets are more rigid than flat sheets, particularly in the austenitic stainless steels, where the work hardening characteristics of the steel are used to advantage. These relief patterned surfaces do not show finger-marks as readily as flat sheets. The finer texture patterns can also be used to reduce sliding friction and improve heat dissipation, compared to flat sheet products.

Applications for patterned rolled stainless steel sheets include:

- High traffic contact products (lift doors and panels, column cladding, ticket machines)
- Food and drink machinery
- Supermarket check-out desks
- Domestic appliance casings

Chemical Finishes

Stainless steel can be finished chemically or electro-chemically.

The main processes used include:

- Electropolishing
- Colouring
- Etching

Electropolishing

Electropolishing involves the anodic dissolution of a thin layer of the surface. It can be done on most metals including stainless steels. Approximately 20 to 40 micro-metres of the surface is removed leaving a smoothed surface that optimises the corrosion resistance and cleansibility of the component and reduces surface stresses left over from mechanical polishing pre-treatments. Any contamination and debris left on the surface by the mechanical surface pre-treatments are also removed during the electropolishing process. Electropolished surfaces should be fully passive after treatment. The polished surfaces show lower rates of bacterial growth, which is useful in food industry applications.

Scratches and other visible surface irregularities are unlikely to be removed by electropolishing.

Non-metallic inclusions at the surface of the steel may also be more visible after electropolishing, compared to the finish after mechanical polishing methods. Electropolishing can be used on castings as a check on the surface soundness.

Electropolished finishes cannot be specified using the BS EN 10088-2 or BS EN 10088-3 stainless steel standards.

The process is covered by:

- BS ISO 15730:2000-Metallic and other inorganic coatings. Electropolishing as a means of smoothing and passivating stainless steel

Colouring

Stainless steel can be coloured either by the application of paint or by chemical treatments. Paint systems rely upon introducing a second layer of material onto the surface whereas chemical systems rely upon altering the thickness and nature of the passive film on the stainless steel item. A particular attraction of chemically coloured stainless steel is that it appears to change colour under different shades and angles of artificial and natural light.

The process is normally restricted to cold rolled sheet products, and although it is possible to colour fabricated components. Chemical colouring of stainless steel sheet uses a mixture of chromic and sulphuric acids that develop the thickness of the naturally occurring passive film on the steel surface, depending on the immersion time.

The sequence of colours formed as the film grows in thickness produces a range that includes bronze, blue, black, charcoal, gold, red-violet and green. A wide range of pre-finished surfaces can be coloured. These include flat mechanically ground, polished (satin) or blasted finishes or roll-patterned surfaces. A charcoal colour effect can be produced by treating a satin polished sheet to the same conditions that normally produce a blue on non-polished sheet surfaces. Colouring can also be combined with acid etched patterns to provide an even wider range of textures, lustre's and reflective effects.

Only the best quality stainless steel sheet can be successfully chemically coloured.

A far less frequently produced 'blackened' finish can be produced by immersion in a fused sodium dichromate salt bath at around 400°C.

Coloured finishes can be specified through BS EN 10088-2 as special finish 2L (cold rolled material only)

Applications for coloured stainless steel sheet products include:

- Architectural external cladding (facades, columns, roofing etc.)
- Internal cladding in low traffic areas
- Signs and shop display panels
- Sculptures

Coloured stainless steel is difficult to repair if scratched which is why it is best suited to these applications where scratches and abrasion are unlikely.

Stainless steels are selected for applications where their inherent corrosion resistance, strength and aesthetic appeal are required. However, dependent on the service conditions, stainless steels will stain and discolour due to surface deposits and so cannot be assumed to be completely maintenance-free. In order to achieve maximum corrosion resistance and aesthetic appeal, the surface of the stainless steel must be kept clean. Aalco's OPTISHEEN® is a high quality satin finish which is easy to keep clean.

Preparation for the Service Environment

Pickling & Passivation

The terms pickling, passivation and descaling when applied to the maintenance of stainless steels are sometimes misunderstood.

Stainless steels are intended to naturally self-passivate whenever a clean surface is exposed to an environment that can provide enough oxygen to form the chromium rich passive surface layer. Passivation treatments are however sometimes specified for machined parts.

Stainless steels cannot be passivated unless the steel surface is clean and free from contamination and scale from operations such as welding. Scale may need to be removed first before the metal surface can be pickled (removal of metal surface by chemical dissolution).

Although the surface of freshly pickled stainless steel will normally be immediately passivated by the pickling acid, these two treatments are not the same. Pickling usually involves nitric/hydrofluoric acid mixtures. Passivation normally involves only nitric acid. Nitric acid will however remove light surface iron contamination.

There are 3 standards that deal with the passivation of stainless steel surfaces:

- ASTM A380 - Practice for Cleaning, Descaling and Passivating of Stainless Steel Parts, Equipment and Systems
- ASTM A967 - Specification for Chemical Passivation Treatments for Stainless Steel Parts (based on US Defense Department standard QQ-P-35C)
- BS EN 2516 - Passivation of Corrosion Resisting Steels and Decontamination of Nickel Base Alloys

Removing Heat Tint after Welding

Heat tinting is a thickening of the naturally occurring oxide layer on the surface of the stainless steel. The colours formed are similar to 'temper colours' seen after heat treatment of carbon steels, but occur at slightly higher temperatures. As the steel surface oxidizes chromium is drawn from below the surface of the metal to form more chromium rich oxide.

This leaves the metal just below the surface with a lower than normal chromium level and hence reduced corrosion resistance.

If the service application is at an elevated temperature then removal of heat tint is not important as some oxidation heat tinting is likely on the surface during service and will blend into any localised weld tinting.

Where the application requires the steel to have ambient temperature "aqueous" corrosion resistance then visible heat tint should be removed. This will restore the surface corrosion resistance that the steel grade used is capable of providing.

The removal of heat tint from stainless steel fabrications can be done mechanically. Chemical methods should be used to finish the process or used as a single stage process.

These methods include:

- Brush-on pastes or gels
- Spray or immersion acid pickling
- Electrolytic methods

It is also important that hidden inside faces of welded fabrications are free of heat tint. Although these areas may be out of sight, they are likely to be in direct contact with the service environment for which the particular stainless steel grade was selected and so are just as important as the steel on the outside faces.

Weld backing gas systems should virtually eliminate inside weld tint but pickling these areas should still be part of good finishing practice and properly prepare the fabricated items for their service environment.

Iron Contamination and Rust Staining

Stainless steel supplied by reputable manufacturers, stockholders or fabricators will normally be clean and contamination free. These items should not show rust staining, unless contamination is introduced.

Using non-stainless steel processing and handling equipment when working with stainless steel can be a source of contamination. Work table bearers, lifting 'dogs' and chains can be some of the causes of rust staining. Non-metallic contact materials and vacuum lifting equipment should be used to avoid contamination during handling and fabrication. Cutting or grinding debris from working with non-stainless steels should not be allowed to settle on any stainless steel surfaces. As soon as any of this contamination becomes wet, rust staining is likely to develop.

Tests can be done if contamination is suspected. Some of the tests simply look for rust staining if the surface is wetted or exposed to high humidity environments. To detect the cause of rust staining i.e. free iron on the surface, rather than the effect, then the ferroxyl test should be used. This will detect either free iron or iron oxide directly and is sensitive enough, used correctly, to detect even small levels of contamination.

The test is outlined in the ASTM A380 standard, which also deals with methods for removing the contamination.

In practice phosphoric acid cleaners can be used to remove moderate iron contamination. These are usually effective if sufficient time and care is taken. Phosphoric acid will not usually change the appearance i.e. etch the surface.

Alternatively, dilute nitric acid will remove small amounts of embedded iron and make sure the cleaned surface is fully passive. Nitric acid will fully dissolve the contamination but can etch and so change the appearance of the stainless steel surface if not used carefully. This may not be acceptable in cases where the surface is intended for its aesthetic appeal.

Cleaning and Maintenance in Service

Stainless steels are selected for applications where their inherent corrosion resistance, strength and aesthetic appeal are required. However, dependent on the service conditions, stainless steels will stain and discolour due to surface deposits and so cannot be assumed to be completely maintenance-free. In order to achieve maximum corrosion resistance and aesthetic appeal, the surface of the stainless steel must be kept clean. Provided the grade of stainless steel and the surface finish are correctly selected, and cleaning schedules carried out on a regular basis, good performance and long service life will result.

Factors Affecting Routine Maintenance

Surface contamination and the formation of deposits on the surface of the stainless steel must be prevented. These deposits may be minute particles of iron or rust generated during construction.

The surface should not be allowed to become contaminated with non-stainless steel or iron particles. The surface finish and orientation (if it is a directional finish) selected and the design of the components must minimise the risk of dirt entrapment and build up. OPTISHEEN® is a good choice of surface finish for avoiding dirt build up and so extending the times between routine cleaning. Coarser finishes will require more frequent cleaning. The particular application will also affect the maintenance requirements.

Industrial and even naturally occurring atmospheric conditions can produce deposits which can be equally corrosive, e.g. salt deposits from marine conditions. Working environments such as the heat and humidity in swimming pool buildings can also be very aggressive. These conditions can result in surface discolouration of stainless steels, requiring more frequent maintenance.

Architectural metalwork, cladding, catering equipment etc. that is touched and finger-marked will need more frequent routine cleaning to keep its intended look. The accessibility of the stainless steel surfaces will also affect the approach to maintenance and cleaning. Where items like external building cladding is going to be difficult and expensive to maintain, particular attention should be paid at the design stage to surface finish and design detail to help avoid, or at least delay the accumulation of dirt.

Specialist application equipment including food and drink manufacturing and processing and pharmaceutical manufacture usually involves special cleaning and sanitisation systems. These often involve clean-in-place (CIP) technology. Expert advice on design, selection, fabrication and surface finishing should be obtained so that the in-service maintenance regimes do not compromise the service performance of any stainless steel used in equipment for these applications.

Maintenance Programme

The frequency of cleaning is dependent on the application. A simple guideline is:

Clean the metal when it is dirty in order to restore its original appearance.

This may vary from once to four times a year for external applications, but may be daily for items in 'hygienic' applications. Recommendations on cleaning frequencies in architectural applications are shown below.

Location	430 (1.4016)	304 (1.4301)	316 (1.4401)
Internal	As required to maintain appearance or design		
Suburban or rural	6-12 month intervals (as appropriate to location and design)		
Industrial or urban	Grade not recommended	3-6 months	6-12 months
Coastal or marine	Grade not recommended	Grade not recommended	6-12 months

Routine Cleaning Methods

Stainless steel is easy to clean. Washing with soap or mild detergent and warm water followed by a clear water rinse is usually quite adequate for routine domestic and architectural equipment cleaning.

Where stainless steel has become extremely dirty with signs of surface discolouration (perhaps following periods of neglect, or misuse) alternative methods of cleaning may be needed.

Suggested cleaning methods are shown below.

Problem	Suggested Method	Comments
Routine cleaning of light soiling	Soap, detergent or dilute (1%) ammonia solution in warm clean water. Apply with a clean sponge, soft cloth or soft fibre brush then rinse in clean water and dry.	Satisfactory on most surfaces.
Fingerprints	Detergent and warm water, alternatively, hydrocarbon solvent.	Proprietary spray-applied polishes available to clean and minimise re-marking.
Oil and grease marks	Hydrocarbon solvents e.g. methylated spirit, isopropyl alcohol, and acetone.	Alkaline formulations are also available with surfactant additions.
Stubborn spots, stains and light discolouration. Water marking. Light rust staining	Mild, non-scratching creams or polishes. Apply with soft cloth or soft sponge, rinse off residues with clean water and dry.	Avoid cleaning pastes with abrasive additions. Suitable cream cleansers are available with soft calcium carbonate additions or with the addition of citric acid. Do not use chloride solutions.
Localised rust stains caused by carbon steel contamination	Proprietary gels, or 10% phosphoric acid solution (followed by ammonia and water rinses), or oxalic acid solution (followed by water rinse).	Small areas may be treated with a rubbing block comprising fine abrasive in a hard rubber or plastic filler. A test should be carried out to ensure that the original surface finish is not damaged. Carbon steel wool, or pads previously used on carbon steel should not be used.
Burnt on food or carbon deposits	Pre-soak in hot water with detergent or ammonia solution. Remove deposits with nylon brush and fine scouring powder if necessary. Repeat if necessary. Finish with using "routine cleaning".	Abrasive souring powder can leave scratch marks on polished surfaces.
Tannin (tea) stains and oily deposits in coffee urns	Tannin stains – soak in a hot solution of washing soda (sodium carbonate). Coffee deposits - soak in a hot solution of baking soda (sodium bicarbonate).	These solutions can also be applied with a soft cloth or sponge. Rinse with clean water. Satisfactory on most surfaces.
Adherent hard water scales and mortar/cement splashes	10-15 volume % solution of phosphoric acid. Use warm, neutralise afterwards with dilute ammonia solution. Rinse with clean water and dry. Alternatively soak in a 25% vinegar solution and use a nylon brush to remove deposits.	Proprietary formulations available with surfactant additions. Take special care when using hydrochloric acid based mortar removers near stainless steel.
Heating or heavy discolouration	a) Non-scratching cream or metal polish b) Nylon-type pad, e.g. Scotchbrite® c) Nitric acid-hydrofluoric acid pickling pastes or a nitric acid passivation solution.	a) Creams are suitable for most finishes. b) Use on brushed and polished finishes along the grain. c) Changes in surface appearance usually result when cleaning with these acids.
Badly neglected surfaces with accumulated grime deposits	A fine, abrasive car body refinishing paste. Rinse clean afterwards to remove all paste material and dry.	May brighten dull finishes. To avoid a patchy appearance, the whole surface may need to be treated.
Paint, graffiti	Proprietary alkaline or solvent paint strippers, depending upon paint type. Use soft nylon or bristle brush on patterned surfaces.	Apply as directed by manufacturer.

Routine Cleaning Notes

Abrasives

- Non-scratch nylon abrasive pads can usually be used safely on most stainless steel surfaces. They may however scratch highly reflective surfaces.
- If wire brushes are used, these should be made from stainless steel.
- With directional brushed and polished finishes, align and blend the new "scratch pattern" with the original finish, checking that the resulting finish is aesthetically acceptable.
- Avoid using hard objects such as knife blades and certain abrasive/souring agents as it is possible to introduce surface scuffs and scratches.
- Ensure that all abrasive media used are free from sources of contamination, especially iron and chlorides.
- Before using an abrasive on a very prominent surface, try it out on a small, unobtrusive, hidden or non-critical area first to make sure that the resulting finish will match the original.

Cleaning Chemicals

- Chloride-containing solutions, including hydrochloric acid-based cleaning agents and hypochlorite bleaches can cause unacceptable surface staining and pitting on stainless steel surfaces.
- When bleaches are used for sanitising stainless steel surfaces they must be diluted and contact times kept to a minimum.
- Hydrochloric acid based solutions, such as silver cleaners, or building mortar removal solutions must not be used in contact with stainless steels.
- Superficial scratching can sometimes be removed with proprietary stainless steel cleaners or with a car paint restorer.
- Any proprietary cleaning agents used should be prepared and used in accordance with the manufacturers or suppliers' health and safety instructions.
- Solvents should not be used in enclosed areas.

Rinsing

- Use clean rinsing water to avoid water marks.
- Tap water is usually adequate.
- De-ionised water can be used to avoid drying streaks in hard water area.

Stainless steels can be formed, cut, machined and joined using a wide range of methods. Many of these methods are similar to those used on low alloy or carbon steels, but the properties of stainless steels mean that some of the process controls need to be adjusted. The most important issue however is that the inherent corrosion resistance of the stainless steel is not compromised by the fabrication method, tooling, handling or storage facilities used in the fabrication shop. Contamination must not be carried over form any processing of carbon steels on the same equipment.

Machines, tooling and handling equipment dedicated to use on stainless steels is preferable to avoid cross-contamination.

Stainless Steel Properties

Most standard stainless steels can be fabricated using suitable methods. The most significant phenomena that affects their fabrication, compared to low alloy steel, is there higher work hardening rates. This applies mainly to the austenitic family of stainless steels. The other families, particularly the duplex, martensitic and precipitation hardening steels have higher initial hardness and strength and so must be worked in their softened conditions.

To reduce tool wear and maintain machining cutting speeds, machinability enhanced or "free-machining" grades, as they are commonly know, can be used. Traditionally these grades have sulphur additions to help with chip-breaking and supply some solid lubrication to the surfaces being machined. Alternative compositions with calcium or copper additions are now available for improved machinability.

Sheet austenitic steels for deep-draw forming have been developed with enhanced nickel contents to delay the onset of work-hardening in the cold forming operation. Bar products for severe cold forming operations such as cold heading for the manufacture of fasteners are available. These have copper additions, which have a similar effect as nickel on the work hardening characteristics of the steel.

Cold Forming

Cold forming is the changing of the shape of a piece of metal without applying any heat to soften it, or removing any metal from the surface. Flat products (sheet and strip), long products (bar, rod and wire) and hollow products (tube and pipe) are widely cold worked in ferritic, austenitic and duplex stainless steels.

These methods include:

- Deep Drawing (sheet)
- Stretch Forming (sheet)
- Folding (sheet) and Bending (tube and bar)
- Cold Forging (fasteners)
- Drawing (wire)
- Cold Sizing (Rod, wire and tube)

Deep Drawing

The austenitic steels have the best deep drawing characteristics of the stainless steels, in-spite of their tendency to work-harden. Ferritic steels draw well, but have lower ductility, limiting the depth of drawing and are more "anisotropic" i.e. their ductility in different directions of the sheet varies more than austenitic steels, resulting in wasteful "earring" at the edges of drawn parts. The superseded BS 1449:2 British standard for stainless sheet products had a grade 304S16, with a higher nickel range than the standard 304S15, specifically to enhance deep draw-ability. The BS EN 10088-2 standard does not cater for this compositional difference and only has grade 1.4301 to cover all "304" variants. Steelmakers and suppliers however recognise the on-going need for this steel and if requested supply steel within the 1.4301 range, but with nickel towards the top of the range.

Stretch Forming

Stretch forming works by reducing the thickness of the walls of the drawn product. This mechanism is well suited to the strong work-hardening characteristics of austenitic stainless steels. Although extra power is needed to continue the drawing process, longer draw strokes are possible because of the work-hardening effect, without risking fractures in the stretched wall of the drawn component. Steel grades like 301 (1.4310) with a 6.0% minimum nickel have been developed specifically for making stretch formed panels. The manufacturing mill heat treatment can also be adjusted to optimise "stretch-formability", if this forming method is specified by the customer before purchase.

Folding and Bending

The ductility and work hardening of the austenitic stainless steels makes these steels a good choice for folding and bending. Bend radii of around twice the diameter for softened bar, rod and tube are possible. These steels "spring-back" more than other steels after bending and so a greater over-bend allowance is needed to achieve the final angle of bend required. Higher initial forces are needed for bending ferritic and particularly duplex stainless steels than austenitic steels, due to their higher yield strengths. As they do not exhibit the same levels of work- hardening as the austenitic steels however, the pressing forces do not increase to the same extent.

Cold Forging

Cold forging is a very severe cold forming process and requires very good ductility and low work-hardening to avoid cracking in the forged component. Grade 1.4567 with a 3.0% copper addition to an 18%Cr, 8.5%Ni composition, is intended for these applications.

Cutting

Stainless steels can be cut by both cold methods including:

- Shearing (slitting)
- Sawing
- Water-jet Cutting
- Laser Cutting and thermal methods, such as Plasma arc

The cutting methods do not rely on specific stainless steel properties and most grades can be cut with these methods.

The high work hardening rates of the austenitic stainless steels requires more powerful and sturdier equipment for shearing operations. High quality blades that keep their sharp cutting edges are also needed for shearing and sawing. Deep, slow cuts with flood cooling to avoid overheating are the best way to deal with the work-hardening issue during sawing. Band-sawing is a better choice than hack-sawing. When hack-sawing, the blade must not be dragged back over the steel surface being cut, or the teeth will be dulled making the next cut more difficult due to the work-hardening effect on the cut surface.

Cold cutting methods are less prone to work piece distortion than thermal methods. This is particularly important when cutting austenitic stainless steels as they have thermal expansion rates 50% higher than ferritic steels. The low heat input of laser cutting makes it ideal for cutting stainless steel.

Thermal cutting stainless steels requires more heat than the cutting of low alloys steels. The cut surfaces must be protected from excessive scale formation and after cutting any scale on the edges should be removed to ensure that the corrosion resistance of the cut surface is restored. Oxy-acetylene "torch" cutting is not suitable for stainless steels.

Machining

The austenitic stainless steels are regarded by some fabricators as difficult to machine.

With sufficiently robust and powerful machine tools, high quality cutting tools with appropriate cutting angles and chip breakers, appropriate feed and speed cutting parameters and adequate work-piece cooling, most stainless steels can be machined without undue difficulty. Only where very high production rates and volumes are required should the enhanced machinability grades such as 303 (1.4305) be needed. The weldability and pitting corrosion resistance of this sulphurised steel is inferior to that of 304 (1.4301) grade, which should be used instead whenever possible.

Work-hardening austenitic grades during machining must be avoided by using a deep-cut, high feed, low speed approach, compared to low alloy steel machining.

The other families of stainless steel have good machinability if machined in their softened condition. They do require more cutting force than low alloy steels however due to their higher mechanical strengths.

Joining

Stainless steels can be joined by using a wide range of cold or "thermal" i.e. requiring heat, methods.

The main cold joining methods are:

- Riveting
- Bolting
- Adhesive Bonding

Thermal joining methods include:

- Soldering
- Brazing
- Welding

Cold joining is often less expensive and less prone to distort the finished components than the alternative thermal processes and can be used on all the families of stainless steels without disturbing their heat treated properties. The joint strengths, particularly riveted and adhesively bonded, are usually well below the strength of the surrounding metal. With careful design the strength of bolted joints can be significantly better, but to match the strength of the surrounding "parent" metal, full penetration seam welding is the only option.

Riveted and bolted joints can create crevices that can be sites for corrosion if the environment is severe. The correct grade of rivets, nuts, bolts and washers must be selected for the environment. If in doubt, use a more corrosion resistant grade than the steel being joined to avoid bimetallic (galvanic) attack on the fasteners.

Adhesive bonding tends to seal the joints, making them less prone to crevice corrosion attack than mechanical joining methods.

Soldering stainless steels is usually done at temperatures below 450°C, using either silver or copper alloy solders. Thorough surface preparation is essential. Any oil or grease must be removed and the surface abraded to remove any iron contamination and provide a key for the solder. Conventional hydrochloric acid based fluxes should not be used. Instead Phosphoric acid based fluxes should be used when soldering stainless steel.

Brazing is similar to soldering in that a dissimilar, lower melting point alloy is used to make the joint. The melting ranges are higher than in soldering and the joints produced are stronger.

To protect the joint during the joining process, brazing stainless steels can be done using either:

- Flux protection
- Controlled furnace atmospheres
- Vacuum furnace protection

Both soldered and brazed joints can suffer from bimetallic (galvanic) corrosion. These methods should not be used in service environments that approach the full corrosion resistance potential of the steel being joined.

Welded joints are capable of having strengths comparable with those of the parent metal parts. Properly executed and cleaned welded joints should also have matching corrosion resistance to the parent metal and should not normally suffer from crevice, pitting or bimetallic corrosion.

Most stainless steels can be welded. Austenitic and duplex grades are particularly suitable for welding. Ferritic stainless steels should only be welded in thin sections. Precipitation hardening grades are weldable but welding martensitic stainless steels is only feasible with the lower carbon content grades.

The austenitic and duplex stainless steels can be welded using a wide range of techniques.

This normally involves protecting the joint area from oxidation using either an inert gas (e.g. argon) cover or a molten flux. The exceptions are spot and stud welding, which can be done surrounded by air.

The methods used for welding stainless steels include:

Gas Protected

- TIG (GTAW) – Tungsten Inert Gas
- MIG (GMAW) – Metal Inert Gas
- MAG – Metal Active Gas
- AW – Plasma Arc Welding
- Laser Welding
- Electron Beam Welding

Flux Protected

- MMA (SMAW) – Shielded Manual Metal Arc
- SAW – Submerged Arc Welding
- FCW (FCAW) – Flux Cored Welding

No Protection

- ERW – Electrical Resistance Welding (seam and spot joints)
- Friction Welding (stud welding)

For general fabrication work the TIG, MIG and MAG are the most widely used methods.

Welding is usually best done with filler (essential with MIG, MMA and FCW), but in some situations can be done "autogenously" i.e. without a filler metal. Fillers, when used must be selected to match the corrosion resistance of the parent metal. Austenitic stainless steels are also frequently welded to low alloy steels, particularly in construction work. Careful selection of "over-alloyed" filler metals is important when dissimilar metal welding to avoid the finished weld being brittle or it cracking during cooling.

The Core Product Ranges are:

Plate

CPP Plate to BS EN 10088-2, ASTM A240 & ASME SA240.

Quarto Plate to BS EN 10088-2, ASTM A240 & ASME SA240.
Cold Rolled & Descaled Plate to ASTM A240 & ASME SA240 in grades 304L & 316L thicknesses 2mm to 6mm thick.1.4003 Plate 2mm to 6mm thick.

Sheet

1.4016 (430) & 1.4301 (304) Bright Annealed Sheet 0.5 to 2mm thick.

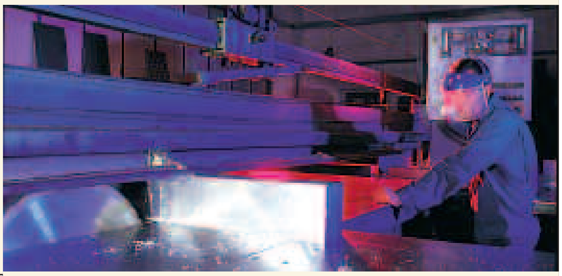
2B Sheet 0.5 to 3mm thick in grades 1.4016 (430), 1.4301 (304) & 1.4401 (316).

1.4003 Sheet 1mm to 2.5mm thick, 2B finish.

240 Grit Polished & White Poly-Coated Sheet in grades 1.4016 (430),
1.4301 (304) & 1.4401 (316) thicknesses 0.7mm to 3mm.

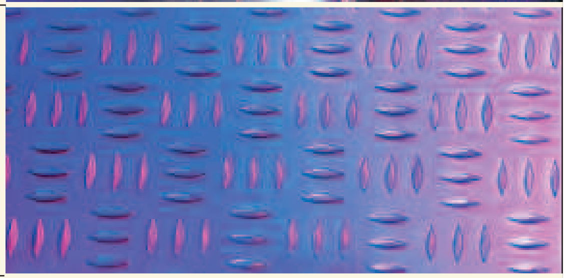
Plate & Sheet Cutting

Aalco, together with sister companies and approved sub-contractors, provides a full range of cutting services including guillotine, water-jet, laser and plasma as well as coil processing.



Treadplate

Stainless Treadplate, dual certified to DIN59220 (T) & ASTM A793 Pattern 1.



Coil, Strip & Blanks

Using sister companies and approved sub-contractors Aalco provides full range of coil processing services.

Polishing

Aalco stocks a range of polished & protectively-coated sheet in grades
1.4016 (430), 1.4301 (304) & 1.4401 (316).

As well as this stock Aalco provides the full range of polished finishes and coatings on sheet and plate using sister companies and approved sub-contractors.

Full detail of all product ranges, alloys and sizes can be found in the Aalco Stocklist available **FREE** from your local Service Centre as well as on the website.

The superceded BS 1449 & BS 1501 standards have been replaced by BS EN Standards:

Standard	Scope
BS EN 10088-2	Replaces BS 1449-Part 2: 1983
BS EN 10028-7	Replaces BS 1501-Part 3: 1990
BS EN 10095	Covers Heat Resisting Grades
BS EN 10029	Tolerances for Quarto Hot Rolled Plate
BS EN 10051	Tolerances for Coil Produced (CPP) Hot Rolled Plate

It is useful to highlight where the new BS EN standards differ from the superceded BS standards:

- Mechanical Properties have been changed
- Tensile strengths are now higher and a maximum is stipulated
- Chemical Compositions vary slightly with Nickel contents on some grades being slightly lower
- 304S15, 304S16 & 304S31 have all been replaced by 1.4301
- BS EN 10088-2 states that Class B thickness tolerances shall normally be produced
- BS EN 10028-7 states that the normal thickness tolerance is Class B
- Surface Finish Standards have been extended and some changed

Flatness – Quarto Plate

Thickness (mm)	Tolerance in mm over given length in mm	
	1000	2000
≥ 3 to < 5	9	14
≥ 5 to < 8	8	12
≥ 8 to < 15	7	11
≥ 15 to < 25	7	10
≥ 25 to < 40	6	9
≥ 40 to ≤ 250	5	8

Flatness – CPP

Width	Tolerance* for given category		
	B	C	D**
Up to 1200	18	23	**
> 1200 to 1500	23	30	**
Over 1500	28	38	**

For CPP there are 3 categories of tolerances according to the grade where:

- *B = Ferritic & Martensitic Grades*
- *C = Austenitic Grades without Mo*
- *D = Austenitic Grades with Mo*

**These flatness tolerances only apply for thicknesses up to 25mm*

***To be agreed at time of enquiry & order*

Length – Quarto Plate

Length (mm)	Tolerance in mm	
Under 4000	– 0	+ 20
4000 to 5999	– 0	+ 30
6000 to 7999	– 0	+ 40

Length – CPP

Length (mm)	Tolerance in mm	
Under 2000	– 0	+ 10
≥ 2000 to < 8000	– 0	0.005 x Length

Width – Quarto Plate

Length (mm)	Tolerance in mm	
≥ 2000 to < 3000	– 0	+ 25
> 3000	– 0	+ 30

Width – CPP

Length	Plus tolerance in mm (- 0)	
	Mill edges	Trimmed
≤1200	+ 20	+ 3
> 1200 to ≤ 1500	+ 20	+ 5
Over 1500	+ 20	+ 6

Thickness – Quarto Plate to BS EN 10029 Class B

Thickness (mm)	Tolerance in mm		Max variation in mm within a plate for given width in mm	
	Minus	Plus	1000/1250/1500	2000
3 to 4.9	0.3	0.9	0.8	0.9
5 to 7.9	0.3	1.2	0.9	0.9
8 to 14.9	0.3	1.4	0.9	1.0
15 to 24.9	0.3	1.6	1.0	1.1
25 to 39.9	0.3	1.9	1.1	1.2
40 to 79.9	0.3	2.5	1.2	1.3
80 to 149	0.3	2.9	1.3	1.4
150 to 250	0.3	3.3	1.4	1.5

Thickness – CPP to BS EN 10051 Category A Materials*

Thickness (mm)	Tolerance in mm (plus or minus) for given width in mm			
	Up to 1200	1201 to 1500	1501 to 1800	Over 1800
Up to 2.0	0.17	0.19	0.21	-
> 2 to ≤ 2.50	0.18	0.21	0.23	0.25
> 2.5 to ≤ 3.0	0.20	0.22	0.24	0.26
> 3 to ≤ 4.0	0.22	0.24	0.26	0.27
> 4 to ≤ 5.0	0.24	0.26	0.28	0.29
> 5 to ≤ 6.0	0.26	0.28	0.29	0.31
> 6 to ≤ 8.0	0.29	0.30	0.31	0.35
> 8 to ≤ 10.0	0.32	0.33	0.34	0.40
> 10 to ≤ 12.50	0.35	0.36	0.37	0.43
> 12.5 to ≤ 15.0	0.37	0.38	0.40	0.46
> 15 to ≤ 25.0	0.40	0.42	0.45	0.50

Duplex grade thickness tolerances are not covered in BS EN 10051

** Category A Materials covers Ferritic and Martensitic Grades only. For non-Mo austentics add 30% and for Mo austentics add 40%.*

Comparative Grades

AUSTENITIC				FERRITIC/MARTENSITIC	
BS 1449-2	BS EN 10088-2	BS 1449-2	BS EN 10088-2	BS 1449-2	BS EN 10088-2
284S16	-	316S13	1.4432	403S17	1.4000
301S21	1.4310	316S31	1.4401	405S17	1.4002
304S11	1.4307	316S33	1.4436	409S19	1.4512
304S15	1.4301	317S12	1.4438	430S17	1.4016
304S16	1.4301	317S16	-	434S17	1.4113
304S31	1.4301	320S31	1.4571	410S21	1.4006
305S19	1.4303	320S33	-	420S45	1.4028
315S16	-	321S31	1.4541		
316S11	1.4404	347S31	1.4550		

N.B. The grades stated are the nearest comparisons and not direct equivalents.

Main Grade Differences

Grade	Carbon (%)		Chrome (%)		Nickel (%)		UTS (N/mm_)	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
304S15	-	0.06	17.5	19.0	8.0	11.0	500	-
304S16	-	0.06	17.5	19.0	9.0	11.0	500	-
304S31	-	0.07	17.0	19.0	8.0	11.0	490	690
1.4301	**-**	**0.07**	**17.0**	**19.5**	**8.0**	**10.5**	**540***	**750***
304S11	-	0.03	17.0	19.0	9.0	12.0	480	-
1.4307	**-**	**0.03**	**17.5**	**19.5**	**8.0**	**10.0**	**520***	**670***
316S31	-	0.07	16.5	18.5	10.5	13.5	510	-
1.4401	**-**	**0.07**	**16.5**	**18.5**	**10.0**	**13.0**	**530***	**680***
316S11	-	0.03	16.5	18.5	11.0	14.0	490	-
1.4404	**-**	**0.03**	**16.5**	**18.5**	**10.0**	**13.0**	**530***	**680***

* Tensile properties stated apply to steels in the solution annealed condition.

Finishes according to BS EN 10088-2/10028-7: *See page 16*

The superceded BS 1449 standard has been replaced by two BS EN Standards:

Standard	Scope
BS EN 10088-2	Replaces BS 1449-Part 2: 1983
BS EN 10059	Cover Heat Resisting Grades
BS EN 10259	Tolerances for Cold Rolled material

It is useful to highlight where the new BS EN standards differ from the superceded BS standards:

- 27 grades in BS have been replaced by 83 grades in EN and thus many EN grades do not have an old BS equivalent
- Mechanical Properties have been changed
- Tensile strengths are now higher and a maximum is stipulated
- Chemical Compositions vary slightly with Nickel contents on some grades being slightly lower
- 304S15, 304S16 & 304S31 have all been replaced by 1.4301
- Surface Finish Standards have been extended and some changed

Flatness Tolerances

Nominal Length (L) (mm)	Normal Tolerance (mm)
Up to 3000	10
Over 3000	12

Length Tolerances

Nominal Length (L) (mm)	Normal Tolerance (mm)
Up to 2000	+5 / –0
Over 2000	+0.0025 X L / –0

Thickness Tolerances

	Tolerance in mm (+ or –) for given width in mm		
Thickness	1000	1250	1500
Under 0.30	0.03	-	-
≥ 0.30 to < 0.50	0.04	0.04	-
≥ 0.50 to < 0.60	0.045	0.05	-
≥ 0.60 to < 0.80	0.05	0.05	-
≥ 0.80 to < 1.00	0.055	0.06	0.06
≥ 1.00 to < 1.20	0.06	0.07	0.07
≥ 1.20 to < 1.50	0.07	0.08	0.08
≥ 1.50 to < 2.00	0.08	0.09	0.10
≥ 2.00 to < 2.50	0.09	0.10	0.11
≥ 2.50 to < 3.00	0.11	0.12	0.12
≥ 3.00 to < 4.00	0.13	0.14	0.14

Width Tolerances

Thickness	All Plus Tolerance in mm for given width in mm (i.e. – 0) 1000	1250 & 1500
Under 1.5	+ 1.5	+ 2.0
≥ 1.50 to < 2.50	+ 2.0	+ 2.5
≥ 2.50 to < 3.50	+ 3.0	+ 3.0
≥ 3.50 to ≤ 6.50	+ 4.0	+ 4.0

Comparative Grades

AUSTENITIC				FERRITIC/MARTENSITIC	
BS 1449-2	BS EN 10088-2	BS 1449-2	BS EN 10088-2	BS 1449-2	BS EN 10088-2
284S16	-	316S13	**1.4432**	403S17	**1.4000**
301S21	**1.4310**	316S31	**1.4401**	405S17	**1.4002**
304S11	**1.4307**	316S33	**1.4436**	409S19	**1.4512**
304S15	**1.4301**	317S12	**1.4438**	430S17	**1.4016**
304S16	**1.4301**	317S16	-	434S17	**1.4113**
304S31	**1.4301**	320S31	**1.4571**	410S21	**1.4006**
305S19	**1.4303**	320S33	-	420S45	**1.4028**
315S16	-	321S31	**1.4541**		
316S11	**1.4404**	347S31	**1.4550**		

N.B. The grades stated are the nearest comparisons and not direct equivalents.

Main Grade Differences

Grade	Carbon (%)		Chrome (%)		Nickel (%)		UTS (N/mm_)	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
304S15	-	0.06	17.5	19.0	8.0	11.0	500	-
304S16	-	0.06	17.5	19.0	9.0	11.0	500	-
304S31	-	0.07	17.0	19.0	8.0	11.0	490	690
1.4301	**-**	**0.07**	**17.0**	**19.5**	**8.0**	**10.5**	**540***	**750***
304S11	-	0.03	17.0	19.0	9.0	12.0	480	-
1.4307	**-**	**0.03**	**17.5**	**19.5**	**8.0**	**10.0**	**520***	**670***
316S31	-	0.07	16.5	18.5	10.5	13.5	510	-
1.4401	**-**	**0.07**	**16.5**	**18.5**	**10.0**	**13.0**	**530***	**680***
316S11	-	0.03	16.5	18.5	11.0	14.0	490	-
1.4404	**-**	**0.03**	**16.5**	**18.5**	**10.0**	**13.0**	**530***	**680***

* Tensile properties stated apply to steels in the solution annealed condition.

The Core Product Ranges are:

Round Bar

1.4305 (303)

Bright Drawn in metric and imperial diameters from 3mm & 1/8" to 25mm & 1"

Smooth Turned or Bright Ground in metric and imperial diameters from 25mm & 1" to 60mm & 3"

Rough Turned in imperial diameters from 3" to 7"

1.4301 (304)

Bright Drawn in metric and imperial diameters from 3mm & 1/8" to 25mm & 1"

Smooth Turned in metric and imperial diameters from 25mm & 1" to 60mm & 3"

Rough Turned in imperial diameters from 3" to 16"

1.4404 (316)

Bright Drawn in metric and imperial diameters from 3mm & 1/8" to 25mm & 1"

Smooth Turned or Bright Ground in metric and imperial diameters from 7/8" & 25mm to 60mm & 3"

Rough Turned in imperial diameters from 3" to 16"

Flat Bar

Metric sizes from 20mm x 10mm to 100mm x 25mm in grades 1.4307 (304) & 1.4404 (316L)

Rolled Edge Flat Bar

From 12mm x 3mm to 100 x 12mm in grades 1.4301 (304) & 1.4404 (316L)

Non-standard widths and other grades available to order on short lead time

Hexagon Bar

From 0.3125" to 2.5" in grades 1.4305 (303) & 1.4404 (316L)

Square Bar

Metric sizes from 12mm x 12mm to 50mm x 50mm in grades 1.4301 (304) & 1.4404 (316L)

Angle

Metric sizes from 20 x 20 x 3mm to 100 x 100 x 10mm in grades 1.4301 (304) & 1.4404 (316L)

Other sizes can be fabricated on short lead times

Bar Sawing

Aalco Service Centres have bar sawing capacity on-site to provide anything from single cut lengths to high volume repetition cuts

Full detail of all product ranges, alloys and sizes can be found in the Aalco Stocklist available **FREE** from your local Service Centre as well as on the website.

The superceded BS 970 Parts 1 & 3: 1991 standards have been replaced by a number of BS EN Standards, the most important of which are shown below.

Standard	Scope
BS EN 10088-3	Replaces BS 970 Part 1: 1991 & BS 970 Part 3: 1991 covering chemical composition & mechanical properties
BS EN 10058	Tolerances for Hot Rolled Flat Bars
BS EN 10059	Tolerances for Hot Rolled Square Bars
BS EN 10060	Tolerances for Hot Rolled Round Bars
BS EN 10061	Tolerances for Hot Rolled Hexagonal Bars
BS EN 10278	Tolerances for Bright Bars (Drawn, Turned or Ground)
ISO 286-2	Tolerance Classifications (see page 4)

Diameter Tolerances – Smooth Turned

Diameter (mm)	Tolerance (mm)
> 18 to ≤ 30	+ 0 / – 0.084
> 30 to < 50	+ 0 / – 0.100
> 50 to < 80	+ 0 / – 0.120

Diameter Tolerances – Bright Drawn

Diameter (mm)	Tolerance (mm)
> 6 to ≤ 10	+ 0 / – 0.036
> 10 to ≤ 18	+ 0 / – 0.043
> 18 to ≤ 30	+ 0 / – 0.052

Diameter Tolerances – Rough Turned

Diameter (mm)	Tolerance (mm)
75 to 150	– 0 / +1.5
151 to 225	– 0 / +2.0
226 to 410	– 0 /+3.0

Thickness Tolerances – Hot Rolled Flat

Size (mm)	Tolerance (mm)
Up to 20	+ / – 0.5
20 to 40	+ / – 1.0
> 40 to 80	+ / – 1.5

Width Tolerances – Hot Rolled Flat

Size (mm)	Tolerance (mm)
10 to 40	+ / – 0.75
> 40 to 80	+ / – 1.0
> 80 to 100	+ / – 1.5
> 100 to 120	+ / – 2.0
> 120 to 150	+ / – 2.5

Tolerances – Rolled Edge Flat Bars

Width	+ / – 1.0mm
Thickness	+ / – 0.5 mm
Flatness across width	1mm Max Variation
Flatness across length	12-40mm: 25mm Max Variation 41-100mm: 20mm Max Variation
Edge Bow	12-40mm: 15mm Max Variation 41-100mm: 10mm Max Variation

Tolerances – Hot Rolled Square Bars

Diameter (mm)	Tolerance (mm)
75 to 150	– 0 / + 1.5
151 to 225	– 0 / + 2.0
226 to 410	– 0 /+ 3.0

Tolerances – Angle Bars

Leg Size	Leg Tolerance	Thickness Tolerance	Max Internal Radius
	+ / – mm	+ / – mm	mm
20 x 20	1.5	0.4	4
25 x 25	1.5	0.5	4
30 x 30	2.0	0.5	4
40 x 40	2.0	0.6	5
50 x 50	2.0	0.6	7
60 x 60	3.0	0.75	7
65 x 65	3.0	0.75	9
70 x 70	3.0	0.75	9
75 x 75	3.0	0.75	9
80 x 80	3.0	0.75	9
90 x 90	3.0	0.75	10
100 x 100	3.0	0.75	10

Comparative Grades

AUSTENITIC				FERRITIC/MARTENSITIC	
BS 970	BS EN 10088-3	BS 970	BS EN 10088-3	BS 970	BS EN 10088-3
303S31	**1.4305**	321S31	**1.4541**	410S21	**1.4006**
304S11	**1.4307**	316S11	**1.4404**	416S21	**1.4005**
304S15/S31	**1.4301**	316S31	**1.4401**	431S29	**1.4057**

N.B. The grades stated are the nearest comparisons and not direct equivalents.

Main Grade Differences

Grade	Carbon (%)		Chrome (%)		Nickel (%)		UTS (N/mm_)	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
303S31	-	0.12	17.0	19.0	8.0	10.0	510	-
1.4305	**-**	**0.10**	**17.0**	**19.0**	**8.0**	**10.0**	**500***	**750***
304S31	-	0.07	17.0	19.0	8.0	11.0	490	-
1.4301	**-**	**0.07**	**17.0**	**19.5**	**8.0**	**10.5**	**500***	**700***
304S11	-	0.03	17.0	19.0	9.0	12.0	480	-
1.4307	**-**	**0.03**	**17.5**	**19.5**	**8.0**	**10.0**	**500***	**700***
316S31	-	0.07	16.5	18.5	10.5	13.5	510	-
1.4401	**-**	**0.07**	**16.5**	**18.5**	**10.0**	**13.0**	**500***	**700***
316S11	-	0.03	16.5	18.5	11.0	14.0	490	-
1.4404	**-**	**0.03**	**16.5**	**18.5**	**10.0**	**13.0**	**500***	**700***

* Tensile properties stated apply to steels in the solution annealed condition.

ISO 286 Tolerances in mm

Diameters (mm)	Tolerance in mm for given Tolerance Number							
	6	7	8	9	10	11	12	13
> 1 – 3 inc.	0.007	0.009	0.014	0.025	0.040	0.060	0.090	0.140
> 3 – 6 inc.	0.008	0.012	0.018	0.030	0.048	0.075	0.120	0.180
> 6 – 10 inc.	0.009	0.015	0.022	0.036	0.058	0.090	0.150	0.220
> 10 – 18 inc.	0.011	0.018	0.027	0.043	0.070	0.110	0.180	0.270
> 18 – 30 inc.	0.013	0.021	0.033	0.052	0.084	0.130	0.210	0.330
> 30 – 50 inc.	0.016	0.025	0.039	0.062	0.100	0.160	0.250	0.390
> 50 – 80 inc.	0.019		0.046	0.074	0.120	0.190	0.300	0.460
> 80 – 120 inc.	0.022			0.087	0.140	0.220	0.350	0.540
> 120 – 180 inc.	0.025			0.100	0.160	0.250	0.400	0.630
> 180 – 250 inc.				0.115	0.185	0.290	0.460	0.720
> 250 – 315 inc.						0.320	0.520	0.810
> 315 – 400 inc.						0.360	0.570	0.890
> 400 – 500 inc..						0.400	0.630	0.970
> 500						0.440	0.700	1.100

EXAMPLES:

H	=	Minus tolerance	e.g. 45 mm dia **H9**	=	+ 0 / - 0.062
J	=	Tolerance divided	e.g. 45 mm dia **J9**	=	+ / - 0.031
K	=	Plus tolerance	e.g. 45 mm dia **K9**	=	+ 0.062 / - 0

The Core Product Ranges are:

Tube

Seamless to ASTM A269, imperial sizes from 1/8″ O/D x 24swg to 4″ O/D x 1/4″ wall in grade 316L

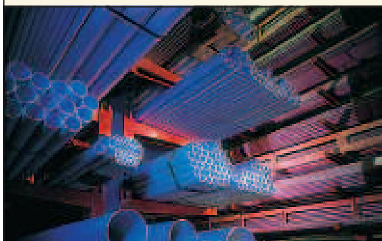
Seamless to ASTM A269, grades 304L & 316L, in metric sizes 6mm O/D x 0.5mm wall to 38mm O/D x 4mm wall

Decorative – Round, Square, Rectangular

Structural – Square and Rectangular up to 250mm

Hygienic – See below

Welded Metric Nominal Internal Diameter - See below



Pipe

Seamless and welded to ASTM A312 from 1/4″ to 12″ in grades 304L & 316L

Flanges

ASTM A182 / ANSI B16.5

BS 10 Table E, Grade 316L

BS 4504 / EN 1092 Raised Face, 16 Bar

Backing Flanges in Aluminium and Coated Mild Steel

Fittings

Butt Weld Fittings, Seamless and Welded, to ASTM A403 in grades 304L & 316L including elbows, tees & reducers

BSP Screwed Fittings, grade 316 from 1/8″ to 3″

Hygienic fittings (see below)

Welded Metric Nominal Internal Diameter (see below)

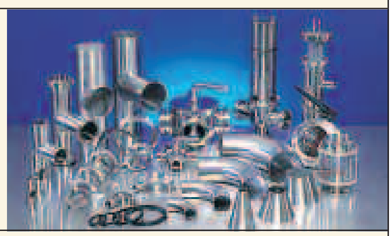
Hygienic Tube and Fittings

Grades 304L & 316L 3/4″ O/D to 4″ O/D:

Tube – As welded & Descaled, Annealed & polished or Bright Annealed

Bends, Fitted Bends, Tees, Reducers, Clamps & Tube Hangers

Unions – RJT, IDF & DIN



Metric – Welded Nominal Internal Diameter (ND)

From 18mm O/D x 1.5mm wall to 910mm O/D x 5mm wall

Grades 1.4432 (316L High Molybdenum), 1.4307 (304L) & 1.4571 (316 Ti)

Tube, Elbows, Tees, Reducers, Collars, End Caps, Tube Clamps & Clips

Backing Flanges in Aluminium & Coated Mild Steel

Full detail of this range is available in a separate publication as well as on the web site

Aalco Stainless Steel Tube Databook & CD-ROM

Aalco has produced a 400 page guide to tubular product specifications for stainless steel
It is available on CD-ROM and can be down-loaded from the web site

Full detail of all product ranges, alloys and sizes can be found in the Aalco Stocklist available **FREE** from your local Service Centre as well as on the website. The Aalco Tubular Products Data-Book provides a comprehensive 400-page guide to this extensive product range including all relevant specifications – This is available online or from your local Service Centre on CD-ROM.

The term pipe covers a specific range of sizes laid down by ANSI specifications. Any sizes not covered by these specifications are tube. Stainless Steel Pipe dimensions determined by ASME B36.19 covering the outside diameter and the Schedule wall thickness. Note that stainless wall thicknesses to ANSI B36.19 all have an 'S' suffix. Sizes without an 'S' suffix are to ANSI B36.10 which is intended for carbon steel pipes.

Seamless and Welded

ASTM A312: Seamless and straight-seam welded austenitic pipe intended for high temperature and general corrosive service. Filler metal not permitted during welding.

ASTM A358: Electric fusion welded austenitic pipe for corrosive and/or high temperature service. Typically only pipe up to 8 inch is produced to this specification. Addition of filler metal is permitted during welding.

ASTM A790: Seamless and straight-seam welded ferritic/austenitic (duplex) pipe intended for general corrosive service, with a particular emphasis on resistance to stress corrosion cracking.

ASTM A409: Straight-seam or spiral-seam electric fusion welded large diameter austenitic light-wall pipe in sizes 14" to 30" with walls Sch5S and Sch 10S for corrosive and/or high temperature service.

ASTM A376: Seamless austenitic pipe for high temperature applications.

ASTM A813: Single-seam, single- or double- welded austenitic pipe for high temperature and general corrosive applications.

ASTM A814: Cold-worked welded austenitic pipe for high temperature and general corrosive service.

Note: Welded pipes manufactured to ASTM A312, A790 and A813 must be produced by an automatic process with NO addition of filler metal during the welding operation.

Welded Pipe Specifications

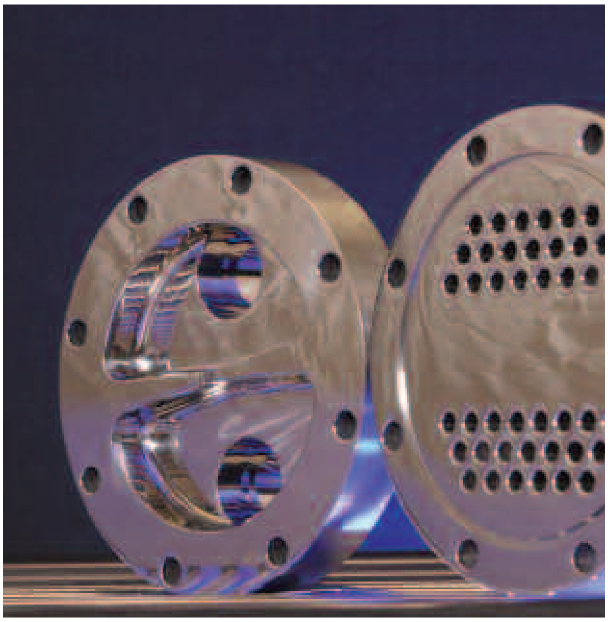
Usually it will be to ASTM A312. If it is to ASTM A358 then there are various Classes available as shown below. The Class Number dictates how the pipe is welded and what non-destructive tests:

- **Class 1:** Pipe shall be double welded by processes employing filler metal in all passes and shall be completely radiographed.
- **Class 2:** Pipe shall be double welded by processes employing filler metal in all passes. No radiography is required.
- **Class 3:** Pipe shall be welded in one pass by processes employing filler metal and shall be completely radiographed.
- **Class 4:** Same as Class 3 except that the welding process exposed to the inside pipe surface may be made without the addition of filler metal.
- **Class 5:** Pipe shall be double welded by processes employing filler metal in all passes and shall be spot radiographed.

Markings on pipe

The full identification of the pipe should be continuously marked down its whole length, including:

- Nominal Pipe Size (Nominal Bore)
- Schedule (Wall Thickness)
- Specification
- Grade
- Method of Manufacture (Seamless or Welded)
- Heat Number
- Manufacturer's Name or Symbol



Pipe Sizes

Pipe dimensions and weights per metre ANSI/ASME B36.19M-1985

Nominal Pipe Size	OD		Schedule 5S[1]			Schedule 10S[1]			Schedule 40S			Schedule 80S		
	in	mm	in	mm	kg/m	in	mm	kg/m	in	mm	kg/m	in	mm	kg/m
1/8	0.405	10.3	–	–	–	0.049	1.24	0.28	0.068	1.73	0.37	0.095	2.41	0.47
1/4	0.540	13.7	–	–	–	0.065	1.65	0.49	0.088	2.24	0.63	0.119	3.02	0.80
3/8	0.675	17.1	–	–	–	0.065	1.65	0.63	0.091	2.31	0.84	0.126	3.20	1.10
1/2	0.840	21.3	0.065	1.65	0.80	0.083	2.11	1.00	0.109	2.77	1.27	0.147	3.73	1.62
3/4	1.050	26.7	0.065	1.65	1.03	0.083	2.11	1.28	0.113	2.87	1.69	0.154	3.91	2.20
1	1.315	33.4	0.065	1.65	1.30	0.109	2.77	2.09	0.133	3.38	2.50	0.179	4.55	3.24
1 1/4	1.660	42.2	0.065	1.65	1.65	0.109	2.77	2.70	0.140	3.56	3.39	0.191	4.85	4.47
1 1/2	1.900	48.3	0.065	1.65	1.91	0.109	2.77	3.11	0.145	3.68	4.05	0.200	5.08	5.41
2	2.375	60.3	0.065	1.65	2.40	0.109	2.77	3.93	0.154	3.91	5.44	0.218	5.54	7.48
2 1/2	2.875	73.0	0.083	2.11	3.69	0.120	3.05	5.26	0.203	5.16	8.63	0.276	7.01	11.41
3	3.500	88.9	0.083	2.11	4.51	0.120	3.05	6.45	0.216	5.49	11.29	0.300	7.62	15.27
3 1/2	4.000	101.6	0.083	2.11	5.18	0.120	3.05	7.40	0.226	5.74	13.57	0.318	8.08	18.63
4	4.500	114.3	0.083	2.11	5.84	0.120	3.05	8.36	0.237	6.02	16.07	0.337	8.56	22.32
5	5.563	141.3	0.109	2.77	9.47	0.134	3.40	11.57	0.258	6.55	21.77	0.375	9.53	30.97
6	6.625	168.3	0.109	2.77	11.32	0.134	3.40	13.84	0.280	7.11	28.26	0.432	10.97	42.56
8	8.625	219.1	0.109	2.77	14.79	0.148	3.76	19.96	0.322	8.18	42.55	0.500	12.70	64.64
10	10.750	273.1	0.134	3.40	22.63	0.165	4.19	27.78	0.365	9.27	60.31	0.500[2]	12.70[2]	96.01[2]
12	12.750	323.9	0.156	3.96	31.25	0.180	4.57	36.00	0.375[2]	9.53[2]	73.88[2]	0.500[2]	12.70[2]	132.08[2]
14	14.000	355.6	0.156	3.96	34.36	0.188[2]	4.78[2]	41.30[2]	–	–	–	–	–	–
16	16.000	406.4	0.165	4.19	41.56	0.188[2]	4.78[2]	47.29[2]	–	–	–	–	–	–
18	18.000	457	0.165	4.19	46.81	0.188[2]	4.78[2]	53.26[2]	–	–	–	–	–	–
20	20.000	508	0.188	4.78	59.25	0.218[2]	5.54[2]	68.61[2]	–	–	–	–	–	–
22	22.000	559	0.188	4.78	65.24	0.218[2]	5.54[2]	75.53[2]	–	–	–	–	–	–
24	24.000	610	0.218	5.54	82.47	0.250	6.35	94.45	–	–	–	–	–	–
30	30.000	762	0.250	6.35	118.31	0.312	7.92	147.36	–	–	–	–	–	–

Notes

1 Schedules 5S and 10S wall thicknesses do not permit threading in accordance with ANSI/ASME B1.20.1.

2 These dimensions and weights do not conform to ANSI/ASME B36.10M.

– The suffix 'S' after the schedule number indicates that the pipe dimensions and weight are in compliance with this stainless steel pipe specification, ANSI/ASME B36.19M-1985, and not the more general ANSI/ASME B36.10M-1995 specification.

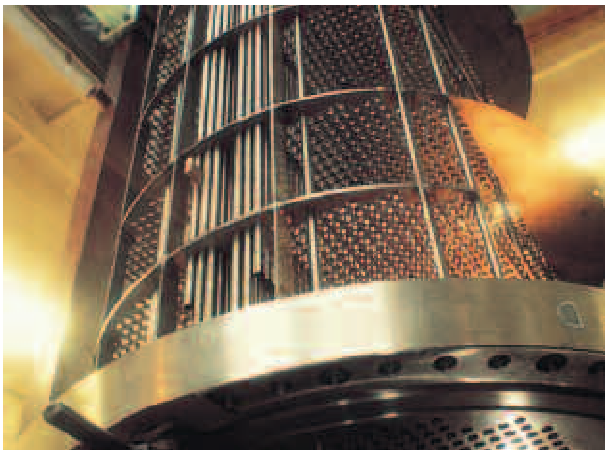
– Although this specification is applicable to stainless steel, quoted weights are for carbon steel pipe and should be multiplied by 1.014 for austenitic and duplex steels, or by 0.985 for ferritic and martensitic steels.

Tube Specifications

ASTM Standards covered in this section	
	ASTM Tube – General Requirements
A450/A450M	General Requirements for Carbon, Ferritic Alloy, and Austenitc Alloy Steel Tubes (Incorporated within the ASTM Tube General Requirements subsection)
A370	Mechanical Testing of Steel Products, (Incorporated within the ASTM Tube General Requirements subsection)
A213/A213M	Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater and Heat Exchanger and Condenser Tubes
A249/A249M	Welded Austenitic Steel Boiler, Superheater, Heat Exchanger and Condenser Tubes
A268/A268M	Seamless and Welded Ferritic and Martensitic Stainless Steel Tubing for General Service
A269	Seamless and Welded Austenitic Stainless Steel Tubing for General Service
A270	Seamless and Welded Austenitic Stainless Steel Sanitary Tubing
A511	Seamless Stainless Steel Mechanical Tubing
A554	Welded Stainless Steel Mechanical Tubing
A632	Welded, Unnealed Austenitic Stainless Steel Tubular Products
A778	Welded, Unnealed Austenitic Stainless Steel Tubular Products
A789/A789M	Seamless and Welded Ferritic/Austenitic (Duplex) Stainless Seel Tubing for General Service
A791/A791M	Welded, Unnealed Ferritic Stainless Steel Tubing
A803/A803M	WeldedFerritic Stainless Steel Feedwater Heater Tubes

Grades Available

Types 304L and 316L are the most readily available from stock in a large range of metric and imperial tube sizes and wall thicknesses. A wide range of other sizes and grades including duplex types and nickel alloys are manufactured to order.



Markings on the tube

The full identification should be continuously marked down the whole length, including:

- Size – Outside Diameter (O/D) and Wall Thickness
- Specification
- Grade
- Method of Manufacture (Seamless or Welded)
- Heat Number
- Manufacturer's Name or Symbol

Tube Size Ranges

An extensive size range is available. Non-standard tube sizes may be subject to mill quantity restrictions and extended delivery times.

Below is a guide to the sizes readily available on an ex-stock basis:

- Hypodermic tube from 0.4mm to 5mm O/D with wall thickness 0.05mm to 0.4mm
- Instrumentation tube in straight lengths or continuous coils of up to 1,000 metres long: O/Ds 6mm, 8mm, 10mm and 12mm with heavy wall thicknesses, typically 0.5mm, 1mm, 1.5mm or 2mm
- Metric sizes from 6mm O/D to 610mm O/D with wall thickness 1mm to 6mm
- Imperial sizes from 1/8" O/D to 6" O/D with wall thickness from 24swg to 10swg
- Hygienic/Sanitary Tube
  - Imperial sizes to ASTM A270: 1/2", 1", 11/2", 2", 21/2", 3" & 4" O/D with 16swg wall and 4" O/D with 14swg wall
  - Metric sizes to DIN 11850: 1", 11/2", 2", 21/2" & 3" O/D with 1.5mm wall and 4" O/D with 2mm wall
- Welded Tubes for the water industry from 18mm O/D x 1.5mm wall to 910mm O/D x 5mm wall
- Welded Tube for automotive exhaust systems, mostly in grade 409 – A limited size range from 35 to 63mm O/D with wall thickness 1.2mm to 2mm
- Decorative and structural tubes (welded)
  - Round in metric and imperial O/D sizes from 6mm O/D x 1.0mm wall to 100mm O/D x 3mm wall and 1/8"O/D x 24swg to 4" O/D x 1/4" wall
  - Square in metric and imperial O/D sizes from 12.7mm O/D x 1.5mm wall to 250mm x 250 x 10mm wall
  - Rectangular in metric sizes from 20mm x 10mm x 1.2mm wall to 300mm x 200 x 10mm wall
  - Other items include Oval, Handrail and Textured Finish – Most common oval size is 60mm x 33mm x 2.0mm wall
  - Note that most decorative tubes are supplied with a polished finish

Tube

Standard Tolerances for welded and seamless cold finished tube (ASTM A 450/A 450M)

(OD)		Variations in OD[1]				Variation in t_{min}[2]		(Thin wall tube only)	
		Under		Over		Under	Over		
in	mm	in	mm	in	mm	%	%	in	m
< 1	< 25.4	0.004	0.1	0.004	0.1	0	20	0.020	0.5
1	25.4	0.006	0.15	0.006	0.1	0	20	0.020[4]	0.5[4]
>1 to 1 1/2	>25.4 to 38.1	0.006	0.15	0.006	0.15	0	20	0.020[4]	0.5[4]
>1 1/2 to < 2	>38.1 to < 50.8	0.008	0.2	0.008	0.2	0	22	0.020[4]	0.5[4]
2	50.8	0.008	0.2	0.008	0.2	0	22	2.0% of OD	
>2 to 2 1/2	>50.8 to 63.5	0.010	0.25	0.010	0.25	0	22	2.0% of OD	
>2 1/2 to 3	>63.5 to 76.2	0.012	0.3	0.012	0.3	0	22	2.0% of OD	
>3 to 4	>76.2 to 101.6	0.015	0.38	0.015	0.38	0	22	2.0% of OD	

Notes

1 Includes ovality tolerance except for thin wall tube
2 t_{min} = minimum wall thickness
3 Ovality = Difference between maximum and minimum OD
Thin wall tube is defined as that with a wall thickness t≤0.020 in (0.5 mm) for any OD, or t≤2% of OD if OD ≤2 in (50.8mm), or t≤3% of OD if OD >2 in (50.8mm)
4 Or 2.0% of OD, if this gives a larger tolerance value.

For more information plus a complete table of sizes and dimensions as well as full specifications, please visit the Down-Loads page of the Aalco web site and select the Tubular Products Databook. www.aalco.co.uk/literature

Hygienics

Stainless Steel Hygienics is the name given to a range of tube and fittings used in applications requiring a clean and sanitary flow of liquids and where it is essential to avoid contamination of the products being carried.
These applications cover the food processing, beverage, biotech and pharmaceutical industries including breweries and dairies.

- The applications are low pressure with a maximum of 150lbs.
- The products are available in grades 304L and 316L.
- The size range is from 1/2 inch to 4 inch O/D.
- The tube and fittings are of welded construction with the internal bead rolled to flatten it and eliminate crevices, thus preventing interruptions to the flow and eliminating the risk of contamination or bug traps as well as facilitate easy cleaning.
- The tube and fittings are offered with a choice of external finishes:
  – Descaled
  – Bright Annealed
  – Dull Polished
  – Semi-Bright or Bright Polished.

Manufacturing Standards

- Hygienic tubes are manufactured to ASTM A270, DIN 11850 and BS 4825 Part 1.
- Hygienic fittings are manufactured to BS 4825 Parts 2 to 5.

Markings on tube and fittings

Tube and fittings with a bright annealed or polished finish will be unmarked.

Size Range

Sizes to ASTM A270

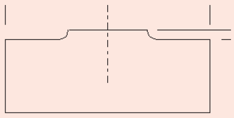
O/D in	Wall swg/mm
1/2	16 /1.63
1	16 /1.63
1 1/2	16 /1.63
2	16 /1.63
2 1/2	16 /1.63
3	16 /1.63
4	16 /1.63
4	14 /2.03

Sizes to DIN 11850

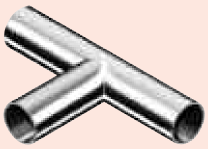
O/D in	Wall mm
1	1.5
1 1/2	1.5
2	1.5
2 1/2	1.5
3	1.5
4	2.0

Bends – 45 and 90 degree bends & 180 degree return bends

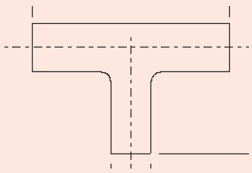
Pulled Tees



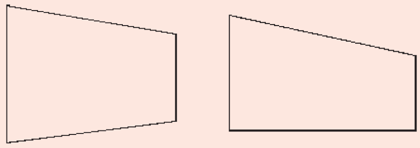
Full Tees



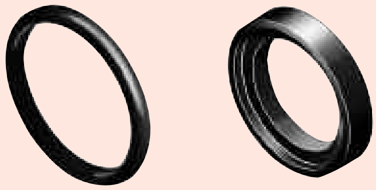
Reducing Tees



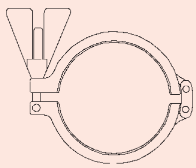
Reducers – Concentric & Eccentric



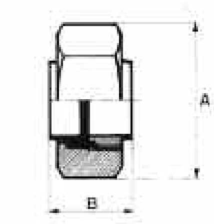
Seals – Nitrile Rubber, EPDM

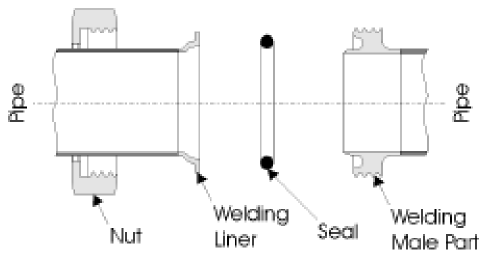


Pipe Clips and Hangers



RJT Union



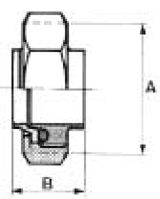


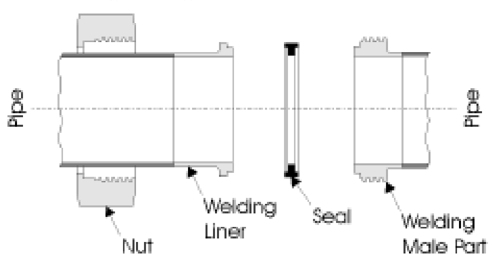
The Ring Joint Type (RJT) Union, manufactured to BS 4825 Part 5, comprises four parts: Nut - Liner - Seal - Male Part.

Primarily used where tubes are frequently disassembled for cleaning.

The seal is of an 'O Ring' type and is made of Nitrile:

IDF Union





The International Dairy Federation (IDF) Union manufactured to ISO 2853 and BS 4825 Part 4, comprises four parts: Nut - Liner - Seal - Male Part. Here the liner is machined and the seal is a square section. It has a thicker nut than the RJT and a more substantial liner. It is machined rather than pressed. It is considered easier to use.

The IDF has a smoother and cleaner flow line that is free of crevices and bug traps. Its principle use is in CIP (Clean In Place) systems involving infrequent access and joint disassembly.

The IDF seal has a square section and is more substantial than the RJT. It is made of Nitrile or EPDM.

Butt Weld Fittings are a family of fittings used for forming circumferential butt weld joints in pipe-work systems.

They are used only in conjunction with ANSI Pipe and are available in the same size range.
They are used in areas where pipe-work is permanent and are designed to provide good flow characteristics.

Manufacturing Standards

Wrought pipe fittings are manufactured to dimensions and tolerances in ANSI B16.9 with the exception of short radius elbows and return bends which are made to ANSI B16.28. Light-weight corrosion resistant fittings are made to MSS SP43.

Butt Weld Fittings are available to ASTM A403, ASTM A815 and MSS SP43. These standards require the fittings to be manufactured as follows:

- Seamless austenitic fittings are made from seamless pipe to ASTM A312.
- Welded fittings in austenitic grades are manufactured from welded pipe to ASTM A312 or plate to ASTM A240. Note that welded fittings manufactured from plate may have two welds.
- Duplex (ferritic/austenitic) grades are manufactured from pipe to ASTM A790 or plate to ASTM A240.

ASTM A403/A815 Butt Weld Fittings are sub-divided into four classes:

- **WP-S:** Made from seamless pipe to ASTM A312 (Austenitic) or ASTM A790 (Duplex).
- **WP-W:** Manufactured from welded pipe to ASTM A312 (Austenitic) or ASTM A790 (Duplex). There is no requirement for radiography unless a manufacturer's weld has been introduced or there are welds made with the addition of filler metal.
- **WP-WX:** Of welded construction. All welds must be 100% radiographed in accordance with Paragraph UW-51 of Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code.
- **WP-WU:** Of welded construction. All welds must be 100% examined ultrasonically in accordance with Paragraph UW-51 of Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code. Note that this Class only applies to austenitic fittings made to ASTM A403.

CR Fittings are manufactured to the requirements of MSS SP43. These are light-weight fittings and do not require radiography.

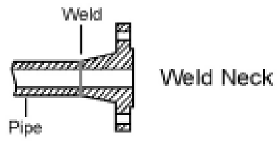
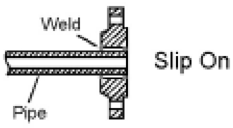
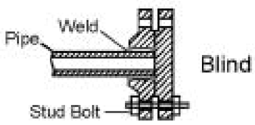
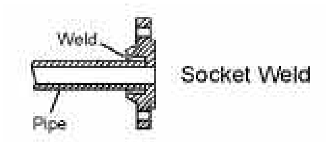
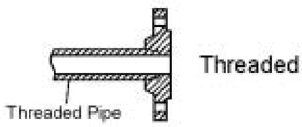
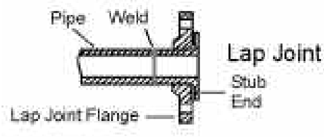
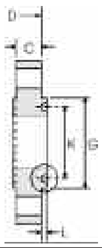
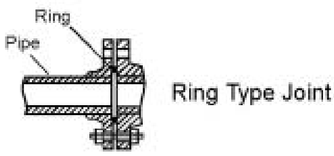
Notes:

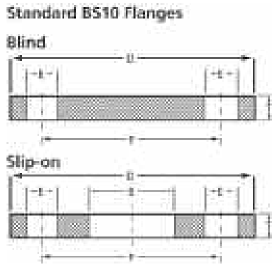
- WP: Means Wrought Pipe
- CR: Means Corrosion Resistant

Markings on tube and fittings

The full identification of the fitting should be marked on it including:

- Nominal Pipe Size (Nominal Bore)
- Schedule (Wall Thickness)
- Specification
- Grade
- Method of Manufacture (Seamless or Welded)
- Heat Number
- Manufacturer's Name or Symbol

Type	Jointing Method	General Description
Weld Neck 		Used in critical applications. These are circumferentially welded onto the system at their necks which means that the integrity of the butt-welded area can easily be examined by X-ray radiography. The bores of both pipe and flange match thus reducing turbulence and erosion.
Slip On 		This is slipped over the pipe and then fillet welded. Easy to use in fabricated applications.
Blind 		Sometimes called a blanking flange, this is used for blanking off pipelines, valves and pumps and as an inspection cover.
Socket Weld 		This is counter-bored to accept the pipe, which is then fillet welded. The bore of both the pipe and the flange are the same to ensure good flows.
Screwed/Threaded 		This requires no welding and is used to connect other threaded components in low pressure non-critical applications.
Lap Joint 		These are always used with either a stub end or a taft which is butt-welded to the pipe with the flange loose behind it. Thus the stub end or the taft always provides the sealing face. Easily assembled and aligned, it is favoured in low pressure applications. To reduce cost these 'backing' flanges can be supplied without a hub and/or made from coated carbon steel.
Ring Type Joint 		This can be employed on Weld Neck, Slip On or Blind Flanges for leak-proof connection at high pressures. The seal is made by a metal ring being compressed into a hexagonal groove on the flange face.

Type	General Description
Weld Neck 	**Plate or Table (BS 10:1962)** These are produced to suit Nominal Bore/NPS Pipe Sizes. They are produced from bar or plate rather than forgings and are not pressure rated. Blind and Slip-On, flat-faced, types are readily available in grades 304L and 316L in sizes from 1/2" to 6" as Table D and Table E, with larger sizes and other Tables (thicknesses) made to order. These economical flanges are used for light-duty applications where corrosion resistance is the primary consideration rather than high pressure or temperature.
BS EN 1092 Part 1 Also referred to as PN Flanges (Formerly BS 4504)	These are not interchangeable with ANSI Flanges. They are available readily available in types 304L and 316L with various pressure ratings of which 10 Bar & 16 Bar are the most commonly used.
Metric Tru-Bore	Please visit the Down-Loads page of the Aalco web site **www.aalco.co.uk/literature** and select the brochure on this product range.
Hygienic	Please refer to information about the Hygienics product range on pages 40 & 41.

Flange Faces

Of the four choices available the most common configurations are:

- For ANSI and BS EN 1092 – Raised Face
- BS 10 – Flat Face.

Note that this does not apply to Screwed or Lap Joint Flanges.

Type	General Description
Raised Face	To facilitate welding
Flat Face	
Ring Type Joint (RJT)	For leak-proof connection at high pressures
Tongue & Groove – Small or Large	

Finish

The finish is given as a surface roughness measured as Arithmetic Average Roundness Height (AARH). The finish requirements are stipulated by the standards, such as ANSI B16.5 and are within the range 125AARH to 500AARH, which is equivalent to 3.2 to 12.5 Ra.

Pressure Ratings

(The pressure rating will also determine the dimensions of the flange – Full details can be found in the relevant specification.)

Flange Type	ANSI B16.5	ANSI B16.47 Series A MSS SP-44	ASME B16.47 Series B API 605	BS EN 1092/ (BS 4504)
	lbs	lbs**	lbs**	Bar
Weld Neck	150-2500	150-900	150-300	2.5-40
Weld Neck Ring Type Joint	300-2500	300-900	150-300	N/A
Slip On	150-1500	-	-	2.5-40
Slip On				
Ring Type Joint	300-1500	-	-	N/A
Threaded	150-2500	-	-	6-40
Lap Joint	150-2500	-	-	6-40
Blind	150-2500	-	-	2.5-40
Socket Weld	150-1500	-	-	N/A

Note: **Flange sizes 26" and above

What semi-finished product are flanges made from?

	Forging A182	Plate ASTM A240	Bar	Casting
ANSI B16.5	✓	✓	-	-
BS 3293	✓	-	-	-
MSS SP-44	✓	-	-	-
API 605	✓	-	-	-
BS EN 1092/(BS 4504)	✓	✓	-	✓
BS 10	✓	✓	✓	✓

Notes:

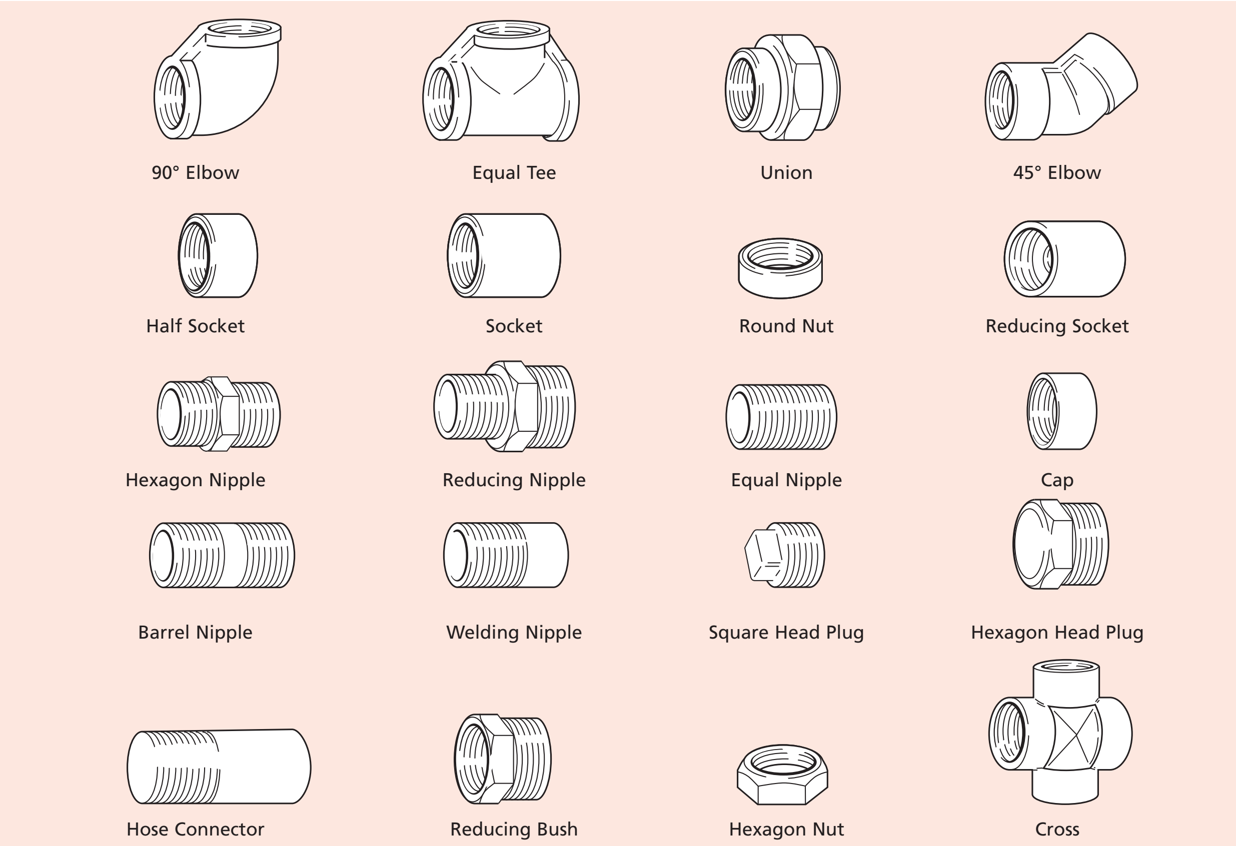
- ASTM A240 plate can be used to manufacture ANSI B16.5 blind flanges, but this is not generally accepted in the UK.
- Most small BS 10 flanges are normally made from bar as this is the most economical manufacturing process.

Markings on a flange

All flanges should be permanently marked on the external diameter of the base with:

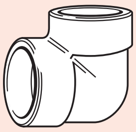
- Pipe Size (NPS/NB)
- Pipe Wall Thickness (Schedule) if appropriate
- Specification
- Grade
- Heat Number
- Manufacturer's Name or Symbol

Whitworth Threads/British Standard Pipe Thread

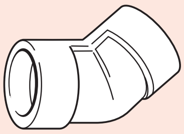


- BSP fittings are a family of fittings used to connect up threaded pipe and equipment.
- They are manufactured from pipe, bar, hollow bar, castings or forgings.
- The pipe to be threaded must have a wall thickness of Schedule 40S minimum.
- The fittings are used in non-critical, low pressure applications where welding is not possible or required. They therefore provide a relatively low cost method of connection.
- BSP fittings are usually fitted with a sealant (paste or tape such as PTFE) and are considered to be permanent pipe-work.
- Low Pressure BSP Fittings are rated at 150lb and are made to wrought iron specification BS 1740.
- BSP fittings are made only in type 316.
- They are provided with a Certificate of Conformity only, and not a full Test Certificate.
- Sizes 1/8 to 3 inch are the most commonly used and thus the most readily available.
- External MALE threads are tapered and Internal FEMALE threads are parallel. The threads are cut to BS21: Part 1: 1985 and are called Whitworth Threads – See below.

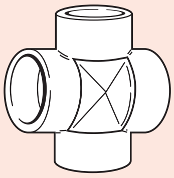
Nominal size of outlet		Min O/D	Min O/D of body behind external thread	Min I/D of body behind internal thread	No. of threads per inch
in	mm	mm	mm	mm	
1/8	6	15.0	9.8	8.6	28
_	8	18.5	13.3	11.4	19
3/8	10	22.0	16.8	15.0	19
_	15	27.0	21.1	18.6	14
_	20	32.5	26.6	24.1	14
1	25	39.5	33.4	30.3	11
1	32	49.0	42.1	39.0	11
1	40	56.0	48.0	44.8	11
2	50	68.0	59.8	56.7	11
2	65	84.0	75.4	72.2	11
3	80	98.0	88.1	84.9	11
4	100	124.0	113.3	110.1	11
5	125	151.0	138.7	135.5	11
6	150	178.0	164.1	160.9	11



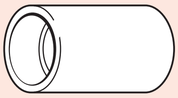
90° Elbow



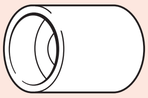
45° Elbow



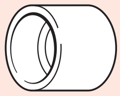
Cross



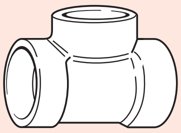
Full Coupling



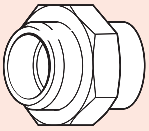
Reduced Coupling



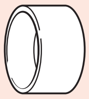
Half Coupling



Equal Tee



Union



Cap

- Socket Weld Fittings are a family of fittings used in joints for high pressure pipe-work systems. Circumferential socket welds are used to incorporate these fitting into the joints.
- They are used only in conjunction with ANSI Pipe and are available in the same size range.
- They are used in areas where pipe-work is permanent and is designed to provide good flow characteristics.

- Socket Weld Fittings are produced to BS 3799, ASTM A182 & ANSI B16.11 as applicable.
- They are available in four pressure ratings: 2000lb, 3000lb, 6000lb & 9000lb.
- The same range of high pressure fittings is also available with screwed ends with NPT threads.

Corrosion Susceptibility of Metals

Most susceptible to corrosive attack (less noble)	Magnesium and its alloys
	Zinc and its alloys
	Aluminium and its alloys
	Cadmium
	Mild steel
	Cast iron
	Stainless steel, 13% Cr, type 410 (active)
	Lead-tin solder, 50/50
	Stainless steel, 18/18 type 304 (active)
	Stainless steel, 18/18/3% Mo, type 316 (active)
	Lead
	Tin
	BRASSES
	Gunmetals
	Aluminium Bronzes
	Copper
	Copper-nickel alloys
	Monel
	Titanium and its alloys
	Stainless steel, 18/8, type 304 (passive)
	Stainless steel, 18/8/3 Mo, type 316 (passive)
	Silver
	Gold
Least susceptible to corrosive attack (more noble)	Platinium

Imperial Wire and Sheet Metal Gauge

No.	Imperial Standard (swg) ins	mm
0	0.324	8.23
1	0.300	7.62
2	0.276	7.01
3	0.252	6.40
4	0.232	5.89
5	0.212	5.38
6	0.192	4.48
7	0.176	4.47
8	0.160	4.06
9	0.144	3.66

No.	Imperial Standard (swg) ins	mm
10	0.128	3.25
11	0.116	2.95
12	0.104	2.64
13	0.092	2.34
14	0.080	2.03
15	0.072	1.83
16	0.064	1.63
17	0.056	1.42
18	0.048	1.22
19	0.040	1.02

No.	Imperial Standard (swg) ins	mm
20	0.036	0.914
21	0.032	0.813
22	0.028	0.711
23	0.024	0.610
24	0.0220	0.559
25	0.0200	0.508
26	0.0180	0.457
27	0.0164	0.417
28	0.0148	0.376

Conversion Factors

Description	From Unit	To Units	Multiply by
Angstrom units to microns			0.001
Atmospheres (standard) to pounds per square inch	A	lbfin^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	multply 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	substract 32 and multiply 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/cm^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 62°F 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	gal	0.2641720
Metres to inches	m	in	39.37008
Metres to microns			1 million
Metres to miles	m	miles	0.000621371
Metres to feet	m	ft	3.28084
Metres to yards	m	yd	1.093613
Metre^3 to inch^3	m^3	in^3	61023.76
Metre^3 to feet^3	m^3	ft^3	35.31466

Description	From Unit	To Units	Multiply by
Metre³ to gallon (UK)	m^3	gallon	219.9692
Metre³ to gallon (US)	m^3	gallon	264.1720
Metre³ to litre	m^3	l	1000.0
Metre³ to yard³	m^3	yd^3	1.307951
Metric tons (or tonnes, 1000kg) to long tons	tonne	ton	0.9842
Microns to Angstrom units			1000
Microns to metres			0.000001
Microns to millimetres			0.001
Microns to thousands of an inch			0.03937008
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
Millimetres to microns			1000
Millimetres to thousands of an inch			39.37008
Newtons per square metre (Pascal) to kilograms per square metre	N/m^2 (Pa)	kg/m^2	0.1019716
Newtons per square millimetre to pounds per square inch	N/mm^2	lb/in^2 (psi)	145.0377
Newtons per square millimetre to to tons per square inch	N/mm^2	$tons/in^2$	0.06475
Newtons to kilograms force	N	kgf	0.1019716
Newtons to pound force	N	lbf	0.2248089
Ounces to grams	oz	gm	28.3495
Pints imperial litres	pt	l	0.5679
Pounds force to Newtons	lbf	N	4.448222
Pounds per inch³ to grams per centimetre³ 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 squarefoot 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/cm^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 kiilograms	ton	kg	1016.047
Tons (long) to metric tons (or tonne, 1000kg)	ton	tonne	1.016047
Yards to metres	yd	m	0.9144
Yards³ to metres³	yd^3	m^3	0.7645549

Formulae for Calculation

All weights shown in this publication are theoretical weights for guidance only. They are calculated using nominal dimensions and scientifically recognised densities. The formulae used are shown below together with the densities of the alloys. Please note that in practice, the actual weight can vary significantly from the theoretical weight due to variations in manufacturing tolerances and compositions.

Form	Dimensions in mm	Weight for Alloys of Density p Kg/dm³	
Round	Diameter = d	0.00078540 d^2p	Kg/m
Hexagon	Width across flats = f	0.00086603 f^2p	Kg/m
Square	Side = a	0.00100 a^2p	Kg/m
Flat	Width = w Thickness = t	0.00100 wtp	Kg/m
Angle/Tee	Leg lengths = L_1, l_2 Thickness = t	0.00100 (L_1 + L_2-t)tp	Kg/m
Channel	Leg lengths = L_1, l_2 Base = B Thickness = t	0.00100 (B + L_1 + L_2-2t)tp	Kg/m
Plate/ Sheet	Thickness = t Length = L Width = w	tp 0.000001 Lwtp	Kg/m Kg/Sheet
Strip	Width = w Thickness = t	0.100 wtp	Kg/100m
Pipe/Tube (Round)	Outside diameter = D Inside diameter = d Wall thickness = t	0.0031416 (D-t)tp, or 0.0031416 (d+t)tp	Kg/m
Square/ Rectangular Tube	Sides = a_1, a_2, Wall thickness = t	0.001 (2a_1 + 2a_2-4t)tp	Kg/m
Wire	Diameter = d	0.78540 d^2p	Kg/Km

Comparative Properties

Metal	Density	Melting Temp °C	Thermal Conductivity	Electrical Resistivity	UTS	Proof Stress	Elongation %	Typical Young's Modulus GPa
Aluminium pure	2.7	660	201	2.65	105	85	4	68
Aluminium alloy	2.7	660	184	3.7	310	260	7	68 to 89
Brass CZ121	8.5	954	110	6.33	400	190	20	103 to 120
Copper C101	8.9	1083	385	1.67	360	280	15	128 to 131
Iron	7.8	1537	80	9.71	210	120	40	152 to 183
Lead	11.3	327	35	20.65	20	0	60	16 to 18
Nickel alloy (Nimonic 105)	7.9	1327	12	132.0	990	800	5	180 to 234
Stainless Steel (18CR/8Ni)	7.9	1527	150	70	570	215	30	205 to 215
Mild Steel	7.8	1427	63	12	690	350	20	196 to 211
Tin	7.3	232	65	12.8	25	20	60	44 to 53

Chemical Elements

Aluminium – **Al**
Arsenic – **As**
Boron – **B**
Cadmium – **Cd**
Carbon – **C**
Chromium – **Cr**
Cobalt – **Co**
Columbium – **Cb***
Copper – **Cu**
Hydrogen – **H**
Iron – **Fe**
Lead – **Pb**
Lithium – **Li**
Manganese – **Mn**
Molybdenum – **Mo**
Nickel – **Ni**
Niobium – **Nb**
Nitrogen – **N**
Oxygen – **O**
Phosphorus – **P**
Selenium – **Se**
Silicon – **Si**
Sulphur – **S**
Tellurium – **Te**
Tin – **Sn**
Titanium – **Ti**
Zinc – **Zn**
Zirconium – **Zr**

* The American designation for Niobium

Densities

Material	Density Kg/dm³
Aluminium	2.70
Stainless Steel	
– Ferritic/Martensitic	7.75
– Austenitic	7.92
Copper	8.90
Brass	8.47
Bronze	8.89
INCOLOY® Alloy 800	7.95
INCOLOY® Alloy 800H	7.95
INCOLOY® Alloy 825	8.14
INCOLOY® Alloy 903	8.14
INCOLOY® Alloy DS	7.92
INCONEL® Alloy 600	8.42

Material	Density Kg/dm³
INCONEL® Alloy 601	8.06
INCONEL® Alloy 617	8.36
INCONEL® Alloy 625	8.44
INCONEL® Alloy 690	8.19
INCONEL® Alloy 718	8.19
INCONEL® Alloy X-750	8.25
MONEL® Alloy 400	8.83
MONEL® Alloy K-500	8.46
Nickel 200	8.89
Nickel 201	8.89
UNS 31803	7.80
17-4 PH	7.75

Comparative Densities

Material	Density Kg/dm³
Stainless Steel	1.000
Stainless Steel – Ferritic and Martensitic	0.977
Mild and Carbon Steel	0.994
Low Alloy Steel	0.987
Aluminium	0.341
Copper	1.134
Brass	1.066
Aluminium Bronze	0.970
Titanium	0.571
Lead	1.440

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AALCO SERVICE CENTRES

ABERDEEN
Unit 9B, Peterseat Drive
Peterseat Park, Altens
Aberdeen AB12 3HT
Tel: 01224 854810
Fax: 01224 871982
e-mail: aberdeen@aalco.co.uk

AYLESBURY
Unit 1, Premus
Coldharbour Way, Aylesbury
Buckinghamshire HP19 8AP
Tel: 01296 461700
Fax: 01296 339923
e-mail: aylesbury@aalco.co.uk

BELFAST
The Belfast Metal Centre
20 McKinney Road
Newtownabbey
County Antrim BT36 4PE
Tel: 02890 838838
Fax: 02890 837837
e-mail: belfast@aalco.co.uk

BIRMINGHAM
Shelah Road
Halesowen
West Midlands B63 3PH
Tel: 0121 585 3600
Fax: 0121 585 6864
e-mail: birmingham@aalco.co.uk

CHEPSTOW
Avenue West
Newhouse Park Estate
Chepstow
Monmouthshire NP16 6UD
Tel: 01291 638 638
Fax: 01291 638 600
e-mail: chepstow@aalco.co.uk

DYFED
Units 3-4
Capel Hendre Industrial Estate
Ammanford
Carmarthenshire SA18 3SJ
Tel: 01269 842044
Fax: 01269 845276
e-mail: dyfed@aalco.co.uk

GLASGOW
117 Clydesmill Place
Cambuslang Investment Park
Glasgow G32 8RF
Tel: 0141 646 3200
Fax: 0141 646 3260
e-mail: glasgow@aalco.co.uk

HULL
Saxon Way
Priory Park West
Hessle
Hull HU13 9PB
Tel: 01482 626262
Fax: 01482 626263
e-mail: hull@aalco.co.uk

LEEDS
Unit 1
Revie Road off Elland Road
Leeds LS11 8JG
Tel: 0113 276 3300
Fax: 0113 276 0382
e-mail: leeds@aalco.co.uk

LIVERPOOL
207 Great Howard Street
Liverpool L5 9ZH
Tel: 0151 207 3551
Fax: 0151 207 2657
e-mail: liverpool@aalco.co.uk

MANCHESTER
Express Trading Estate
Stone Hill Road
Farnworth
Bolton BL4 9NN
Tel: 01204 863456
Fax: 01204 863430
e-mail: manchester@aalco.co.uk

NEWCASTLE
First Avenue
Team Valley Trading Estate
Gateshead, Tyne & Wear
NE11 0NU
Tel: 0191 491 1133
Fax: 0191 491 1177
e-mail: newcastle@aalco.co.uk

NORWICH
Roundtree Way
Mousehold Lane
Norwich NR7 8SR
Tel: 01603 787878
Fax: 01603 789999
e-mail: norwich@aalco.co.uk

NOTTINGHAM
Harrimans Lane
Dunkirk
Nottingham NG7 2SD
Tel: 0115 988 2600
Fax: 0115 988 2636
e-mail: nottingham@aalco.co.uk

PLYMOUTH
Unit B Armada Point
Estover Industrial Estate
Plymouth PL6 7PY
Tel: 01752 770877
Fax: 01752 770844
Email: plymouth@aalco.co.uk

SOUTHAMPTON
Test Lane, Nursling
Southampton SO16 9TA
Tel: 02380 875200
Fax: 02380 875275
e-mail: southampton@aalco.co.uk

STOKE
Unit F, Forge Way
Brown Lees Industrial Est
Biddulph
Stoke-on-Trent ST8 7DN
Tel: 01782 375700
Fax: 01782 375701
e-mail: stoke@aalco.co.uk

SWANLEY
Units 6 & 7
Pedham Place Industrial Estate
Wested Lane,
Swanley
Kent BR8 8TE
Tel: 01322 610900
Fax: 01322 610910
e-mail: swanley@aalco.co.uk

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