Special Stainless Steels

Carpenter 20-Cb3 - A Stainless Steel having 20% chromium, 34% nickel, 2.5% copper and columbium and tantalum equal to 8 times the carbon content for carbide stabilization. This alloy has excellent resistance to corrosive conditions, and especially to sulfuric acid.

Nickel based Alloys

Incoloys, Inconels, Monel:

A very important group of alloys are the nickel-based Inconels and Incoloys. These alloys have excellent resistance to corrosive attack by many aggressive chemicals. They also have excellent resistance to oxidation at high temperatures and have good high temperature strength. They typically contain 15-23% chromium to provide a protective oxide film. The inconels contain 30-73 % nickel, while the incoloys have from 32-42% and 30-36% iron. Some grades contain a small amount of titanium or tantalum for improved high temperature strength; and aluminum to improve the protective characteristics of the oxide film at elevated temperatures (a mixed chromium oxide/aluminum film).

Inconel 600 - High nickel, 76%, high chromium, 15.5% for resistance to oxidizing and reducing atmospheres. I600 is used for severely corrosive environments at high temperature.

Inconel 601 - High nickel, 60.5%, high chromium, 23.0% plus 1.5% aluminum. Good high temperature properties. I601 provides outstanding resistance to oxidation, and good resistance to carburizing and sulfur containing atmospheres.

Incoloy 800 - 32.5% nickel, 46.0% iron, 21% chromium. Resistance to oxidation and carburization at high temperatures. Resists sulfur attack and corrosion in many environments.

Incoloy 800H - A special version of the above alloy with a small controlled amount of carbon for improved high temperature strength.

Monel 400 - High nickel, 66% high copper, 31%. Monel provides good resistance to corrosion in salt water. Not subject to chloride stress cracking. Monel is used for heat exchangers and for sulfuric acid applications.

Hastelloys:

These nickel-based alloys are used for their excellent corrosion resistance under many severe conditions due to their high molybdenum content.

Hastelloy B - 61% nickel, 28% molybdenum. Excellent corrosion resistance to hydrochloric acid and to sulfuric, phosphoric and acetic acids and hydrogen chloride gas.

Hastelloy C - 54% nickel, 16% molybdenum, 15.5% chromium, 4% tungsten. Excellent corrosion resistance to many chemical environments, including ferric acid and cupric chlorides, contaminated mineral acids, and wet chlorine gas. Oxidation resistant to 1900°F

Hastelloy X - 47% nickel, 9% molybdenum, 22% chromium, 0.5% tungsten. Good high temperature strength and resistance to oxidation to 2200°F. Also good for reducing conditions.

HAYNES® Alloys:

HAYNES® HR-160® alloy - HAYNES HR-160 alloy with outstanding resistance to most forms of high temperature corrosion. Its high levels of chromium and silicon provide for the formation of a highly protective surface oxide scale which resists attack from sulfur, chloride, vanadium and other salt deposits.

HAYNES® 214® alloy - HAYNES 214 alloy is a nickel-base superalloy with outstanding oxidation resistance at temperatures up to about 2300°F(1260°C). Although it can be age-hardened by thermal treatment at temperatures below about 1700°F (925°C), 214 alloy is principally intended or use in the solution-treated condition at temperatures of about 1800°F (980°C) or above.

HAYNES® 230® alloy - HAYNES 230 alloy is a nickel-chromium-tungsten-molybdenum alloy that combines excellent high-temperature strength, outstanding resistance to oxidizing environments up to 2100°F(1149°C) for prolonged exposures, premier resistance to nitriding environments, and excellent long-term thermal stability.

HAYNES® 556® alloy - HAYNES 556 alloy is a solid-solution-strengthened superalloy that combines excellent resistance to sulfidizing carburizing and most other high-temperature corrosive environments with good oxidation resistance, excellent fabricability and high elevated temperature strength up to 2000°F (1095°C).

Haynes: Trademark of Haynes International Inc.

Thermo Electric ceramic protecting tubes are used in many different industries including iron and steel, glass, cement and lime processing. Their principal advantages include resistance to high temperatures and thermal shock, chemical inertness, good abrasion resistance and high dielectric strength. Our high purity alumina tubes are primarily used to protect noble metal thermocouples such as the platinum - rhodium types. Alumina and mullite protecting tubes are the most widely used, and are available in a wide variety of sizes. They are supplied with stainless steel bushings so that you can order them as part of a thermocouple assembly, and without bushings for replacement purposes. A cermet (metal - ceramic) tube is also offered for high temperature applications where extra high tube strength and abrasion resistance is required.

Mullite

Viltreous refractory mullite (silica - alumina) protection tubes can be used to 3000°F. They are impervious to air to 3000°F, to dry hydrogen and carbon monoxide to 2550°F, and will maintain 10 - 5 millimeters of mercury to 2600°F. Low rate of thermal expansion imparts good thermal shock resistance. Acid slag resistance is good, basic slag resistance is fair. Low sag. Recommended for use with J, K, and T thermocouples.

Fired Properties

Water absorption: impervious
Flexural Strength: 20,000 PSI
Coefficient of Linear Thermal Expansion: 2.8 x 10 - 6/°F
Hardness (Moh's scale): 7.5 - 8

High Purity Alumina

Sintered alumina oxide (over 99.5% Alumina Oxide) tubes have a maximum working temperature of 3450°F. They have the highest bending and breaking strength of any of our ceramic tubes above 2200°F. The high thermal conductivity of 99.5% alumina oxide guarantees quick temperature response. It is highly resistant to reducing, oxidizing, and high vacuum atmospheres, corrosive alkaline vapors and aluminum chloride vapors. Stable to acids, alkalis, metal melts, most glass fluxes, salt melts and slags. Dense structure prevents penetration of melts providing longer life in enviroments which normally react within 96% alumina. These tubes are impermeable to most gases under the conditions found in industrial furnaces. They are highly recommended for use with thermocouples containing platinum, iridium, and rhodium because of their relative freedom from Silicon dioxide and Iron oxide contaminants which can affect the thermocouple calibration and lifespan at high temperatures. Especially recommended for the glass industry where 99.5% alumina tubes are used in the furnace roof as well as in the melt.

Properties

Water Absorption: impervious
Flexural Strength: 55,000 PSI
Thermal Expansion: 32 to 1832°F: 4.5 x 10 - 6/°F (approx)
Hardness (Moh's scale): 9

Cermet

Cermet metal - ceramic is a combination of chromium and aluminum oxide stable in oxidizing atmospheres to 2500°F. Cermet tubes are stronger and more resistant to repeated thermal and mechanical shock than ceramic materials, but are relatively brittle as compared to metals. Abrasive conditions at temperatures to 2300°F have little effect on cermet tubes, and chemicals such as sulphur dioxide, sulphur trioxide and concentrated sulphuric acid have a low rate of attack on the material. Ferrous alloys, copper, brass, zinc, lead and many other metals do not wet cermet. Thermal conductivity approximates that of cast iron for fast temperature response. Typical applications include open hearth furnace checkers, copper and brass melting pots, and abrasive conditions where gas - borne particles rapidly erode metal tubes operating near their softening point. Not recommended for use in molten aluminum, acid or carbide slags, nitriding carburizing atmospheres.

Properties

Flexural Strength at 68°F: 45,000 PSI
Coefficient of Thermal Expansion: 75 to 1830°F: 5 x 10 - 6/°F
Hardness (Rockwell): C - 34

Silicon Carbide

Silicon carbide protection tubes can be used in temperatures up to 3000°F where an extremely hard and chemically inert material is required. It resists most acids, molten salts and acid slags making it ideal for use with molton metals such as aluminum, copper, brass, cadmium, lead and zinc. This resistance to corrosive attack and abrasion are maintained at temperatures above the range of commonly used nickel-chromium alloys such as INCONELS, INCOLOYS, HASTELLOYS etc. Other useful properties include a high heat-shock resistance and thermal conductivity. Silicon carbide protection tubes are often used in conjunction with alumina inner tubes.

Thermowells are critical accessories for the successful operation of temperature sensors in industrial processes. They protect the sensing element and insure that the temperature of the process is passed to the sensor. Unfortunately, many users look at thermowells as a commodity product and do not realize the wide range of performance they supply. An improperly specified thermowell could result in:

1. A catastrophic failure due to poor welding practices that compromises the process.
2. Poor compatibility with the temperature and media of the process leading to premature failure.
3. Inadequate temperature transfer to the sensor, thus providing an inaccurate signal.
4. Incompatibility with the process velocity leading to catastrophic failure due to vibration.

The specifying engineer can eliminate the possibility of these problems by working with a quality manufacturer who can ensure that the thermowell is the right selection for the application.

Heat Transfer

A very important role of the thermowell is to transfer heat from the process to the sensor. For this reason, quality manufacturers follow a number of guidelines to improve the heat transfer qualities of the well. First is the bore diameter, which is the drilled out portion of the well where the sensor is inserted. For thermocouples, it is recommended to use a .385 inch diameter bore. This allows ample room for the sensing element to be inserted into the well and makes removal easy. Because thermocouples are tip sensitive, the sensor to well contact is critical in the tip of the thermowell. For this reason, most industrial thermocouple sensors are spring loaded to insure contact with the thermowell. For RTD's the recommended bore is .260 inches of diameter. This provides a closer relationship with the normally .250 inches diameter element. Because RTD's are stem sensitive, it is important that the well be close to the side of the sensing element. This improves the transfer of heat directly to the RTD element within the probe. Improved heat transfer provides better accuracy and better response time, which are normally weaknesses of RTD's. Thermowell profile is another means of insuring that the thermowell is capable of transferring the process temperature. Most thermowells have a tapered construction where the tip is of a smaller diameter than the base of the stem. This aids in the transfer of heat. A variation on the tapered well is the stepped down well, where the tip is significantly reduced in diameter for a specified length. This improves the heat transfer to the sensing element even more. It will help make the sensor more sensitive to changes in the process temperature. This is more commonly used for RTD's where stem sensitivity is important for accurate temperature measurement.

Process Connection

Generally, thermowells are either threaded into the process connection or attached using a flanged connection. The guidelines are rather simple. For smaller diameters where the well will not be required to be removed on a regular basis and corrosion is not a serious problem, threaded process connections are preferred. By threading into a welded in fitting, the well is attached directly to the vessel or pipe. To make installation easier, a 1 - 1/8 inch hex is left at the top of the well. This provides a strong place for the installer to grip the well with a wrench. The hex portion can be extended up to 3 inches for easier installation for use under insulation. For installations where the well needs to be removed more frequently due to corrosion or other requirements, a flanged connection is used. The flanged connection will bolt to a mating flange mounted to the process. Flanged connections are more appropriate for high pressure applications and larger pipe sizes. They are normally used up to 3 inches in diameter. For some applications where the process is not corrosive and access is not required, a welded connection for the thermowell may be used. These provide a high quality connection, but obviously cannot be removed without significant effort. Welded connections are also preferred for very high temperature and pressure applications, especially steam lines.

Flanged Well Construction

When a flanged thermowell is made, a blind (blank) flange is machined to provide a hole to pass the thermowell stem through. This stem must then be adequately attached to the flange to insure that it can withstand the pressure, temperature, shock and corrosion of the process. The normal method used to attach the flange to the stem is a seal weld at both the top and bottom of the flange. The seal weld requires good welding procedures to insure that the welds are strong and void free. If a seal weld should fail, it is possible for the stem to travel downstream in the process and damage any equipment in the line, such as pumps or compressors. Some users will use a lower quality material for the flange and a higher quality material for the stem. This is based on the fact that most of the flange is not normally in contact with the process. While this saves money on the initial purchase, if the welds of dissimilar metals are not done with certified welding procedures, the weld between the flange and stem may lack integrity. When high alloy wells are used on some processes, the flange may be of a lower alloy with a built up surface of the high alloy on the raised face. For example, a hastelloy well may have a hastelloy stem and a stainless flange with a hasteloy overlay on the raised face, which can be considered part of the wetted surface of the well. This again is a cost saver, but could lead to weld and well failures if not done by certified procedures. Another option is to have a flange stem connection that is both threaded and welded. This provides an additional security for the connection should the seal weld fail. One major process licenser specifies this connection for all thermowells. The most secure method of connecting the flange to the well is with a full penetration weld. In this, the flange is overbored to allow the well material to make full contact for the entire length of the connection. With a full penetration welded connection, the integrity of the connection is excellent. While this is much more costly in initial procurement cost, it can save significant long term cost in the life and performance of the thermowell. Again, proper welding procedures are critical.

The weakest part of most metal components is the surface. It is here that corrosion and wear takes place, and where most metals fail. One of the most effective methods of preventing metal failure is to protect the surface with an industrial strength coating. Metal impregnation was developed to help the chemical and process industries run smoother with lower production and replacement costs. Thermo Electric can supply any number of coatings on thermowells or directly on the sensor probe itself to protect for problems arising from erosion, corrosion, abrasion, release and various problems resulting from intense temperatures.

Epoxy Coatings

Air dry epoxy coatings are self-priming, high gloss, corrosion resistant coating that are recommended for use where a high performance, chemically resistant coating is desired. These coatings offer single coat corrosion protection at 4-6 mils thickness, as well as very good abrasion resistance. It may also be used as a 2 or 3 coat system for use in industrial environments including offshore oil and gas.

PTFE (polytetrafluoro ethylene) nonstick coatings are two-coat (primer/topcoat) systems. The chemical inertness of PTFE is outstanding because of the chemical structure. These products have the highest operating temperature of any fluoropolymer, extremely low coefficient of friction, good abrasion resistance, and good chemical resistance. PTFE coatings can withstand a maximum use temperature of 600°F. This coating is typically applied to a thickness of 1-3 mils.

Tefzel coating is a melt processable fluoropolymer coating. It's a copolymer of TFE and ethylene also known by its chemical name. Tefzel coatings provide maximum continuous service temperature is 300°F, excellent chemical resistance to a wide range of chemicals, exceptionally Tough and abrasion resistant.

Metco 16C is one of several self-fluxing alloys which was designed to be remelted in a normal atmosphere after being sprayed. They then coalesce into a dense, essentially pore-free coating. Metco 16C produces coatings which resist wear by abrasive grains, hard surfaces, particle erosion, fretting, and cavitation. It is useful for nearly all hard-facing applications, especially on irregular shapes, and where heavy coatings are required. Coatings up to 1/8" (3 mm) or more in thickness may be fused without difficulty. Coatings of Metco 16C are similar in wear resistance to coatings of Metco 15E Self-Fluxing Nickel-Chromium Alloy Powder. They are easier to fuse than coatings of Metco 15E and have less tendency to crack. The fused surface of Metco 16C is not quite as smooth as that of Metco 15E. Where a very smooth as-fused surface is required, a few mils of Metco 15E can be applied over the Metco 16C before fusing.
Of all of the Metco self-fluxing alloys, Metco 16C and Metco 19E are generally the most resistant to corrosion. The Metco self-fluxing alloys were designed to be sprayed with Metco ThermoSpray equipment, and subsequently fused. Metco 16C is certifiable as meeting U.S. Navy Specifications OS 12358, MPR 1031 and MPR 1032.

Stellite 6 is a cobalt based alloy coating powder designed to produce hard, dense coatings. Coatings of Stellite 6 are recommended for resistance to wear by abrasive grains and hard surfaces. They are resistant to wear, galling and corrosion and retain these properties at high temperatures, Their exceptional wear resistance is due mainly to the unique inherent characteristics of the hard carbide phase dispersed in a CoCe alloy matrix. Stellite 6 has excellent resistance to many forms of mechanical and chemical degradation over a wide temperature range, and retains an acceptable level of hardness up to 930°F(500°C).

TECHNICAL REFERENCE

Process Fluid	Concentration	Temperature	Well Material
Acetate Solvents	Pure		Monel 400 or Nickel 200
Acetic Acid	to 50%	212°F	316 Stn. Stl.
Acetic Acid	to 99%	212°F	Hastelloy C276
Acetic Anhydride	All Conc.		Hastelloy C276
Acetone	All Conc.	212°F	Hastelloy C276 or Monel 400
Acetylene			304 Stn. Stl.
Alcohol, Ethyl	All Conc.	70°F to 212°F	316 Stn. Stl.
Aluminum		Molten	Cast Iron
Aluminum Acetate	Saturated		304 Stn. Stl.
Aluminum Sulphate	to 25%	212°F	304 Stn. Stl.
Aluminum Sulphate	to 50%	212°F	Hastelloy C276
Ammonia	All Conc.	70°F	304 Stn. Stl.
Ammonium Chloride	All Conc.	70°F	316 Stn. Stl.
Ammonium Fluoride	to 25%	150°F	Hastelloy C276
Ammonium Nitrate	All Conc.	212°F	304 Stn. Stl.
Ammonium Phosphate	to 25%	212°F	304 Stn. Stl.
Ammonium Sulphate	All Conc.	212°F	Hastelloy C276
Amyl Acetate	All Conc.	300°F	Monel 400
Aniline	All Conc.	400°F	304 Stn. Stl.
Asphalt		250°F	C1018 Steel
Barium Carbonate		70°F	304 Stn. Stl.
Barium Chloride	to 25%	212°F	Hastelloy C276
Barium Hydroxide	to 50%	212°F	316 Stn. Stl.
Barium Sulphide			304 Stn. Stl.
Baroacic Acid	5%		304 Stn. Stl.
Beer		70°F	304 Stn. Stl.
Benzaldehyde			304 Stn. Stl.
Benzene, Benzol		212°F	304 Stn. Stl.
Benzoic Acid	All Conc.	212°F	316 Stn. Stl.
Black Liquor			Hastelloy C276
Bleaching Powder	15%	70°F	Monel 400
Bordeaux Mixture	All Conc.	212°F	304 Stn. Stl.
Boric Acid	All Conc.	400°F	316 Stn. Stl.
Bromine	Wet	70°F	Tantalum
Bromine	Dry	70°F	Tantalum
Butane		400°F	Carbon Steel
Butyl Alcohol			Copper
Butylacetate			Monel 400
Butylenes			Carbon Steel
Butyric Acid		70°F	304 Stn. Stl.
Butyric Acid		212°F	Hastelloy C276
Calcium Bicarbonate			304 Stn. Stl.
Calcium Chlorate	30%	212°F	304 Stn. Stl.
Calcium Fluoride			304 Stn. Stl.
Calcium Hydroxide	20%	212°F	304 Stn. Stl.
Calcium Hydroxide	50%	212°F	Hastelloy C276
Calcium Hypochlorite	15%	70°F	Monel 400
Carbolic Acid	All Conc.	212°F	316 Stn. Stl.
Carbon Dioxide	Dry		Carbon Steel
Carbon Dioxide	Wet		Carbon Steel
Carbon Tetrachloride	All Conc.	70°F	Monel 400
Carbonic Acid		212°F	304 Stn. Stl.

Process Fluid	Concentration	Temperature	Well Material
Chloracetic Acid	All Conc.	300°F	Hastelloy C276
Chlorex Caustic			316 Stn. Stl.
Chlorine Gas	Dry	70°F	C.Stl.
Chlorine Gas	Moist	70°F	Hastelloy C276
Chloroform	Dry	212°F	Monel 400
Chromic Acid	5%	70°F	304 Stn. Stl.
Chromic Acid	50%	212°F	Hastelloy C276
Cider	All Conc.	300°F	304 Stn. Stl.
Citric Acid	15%	70°F	304 Stn. Stl.
Citric Acid	All Conc.	212°F	Hastelloy C276
Coal Tar		Hot	304 Stn. Stl.
Coke Oven Gas		70°F	Aluminum
Copper Nitrate	All Conc.	300°F	316 Stn. Stl.
Copper Sulphate	All Conc.	300°F	316 Stn. Stl.
Corn Oils		212°F	316 Stn. Stl.
Cottenseed Oil			Carbon Steel
Creosols		212°F	304 Stn. Stl.
Cyanogen Gas			304 Stn. Stl.
Dowtherm			Carbon Steel
Epson Salt			304 Stn. Stl.
Ether		70°F	304 Stn. Stl.
Ethyl Acetate			Monel 400
Ethyl Chloride		70°F	304 Stn. Stl.
Ethyl Sulphate		70°F	Monel 400
Ethylene Glycol	All Conc.	212°F	304 Stn. Stl.
Ethylene Oxide		70°F	Carbon Steel
Ferric Chloride	1%	70°F	316 Stn. Stl.
Ferric Chloride		212°F	Tantalum
Ferric Nitrate		212°F	Tantalum
Ferric Sulphate	All Conc.	300°F	Tantalum
Fluorine		212°F	Hastelloy C276
Fluosilicic Acid		70°F	Carp. 20
Formaldehyde	40%	212°F	316 Stn. Stl.
Formic Acid	All Conc.	300°F	316 Stn. Stl.
Furfural		400°F	316 Stn. Stl.
Galic Acid	5%	150°F	Monel 400
Gasoline		70°F	304 Stn. Stl.
Glucose		70°F	304 Stn. Stl.
Glycerine		212°F	304 Stn. Stl.
Glycerol		70°F	304 Stn. Stl.
Hydrobromic Acid	All Conc.	212°F	Hastelloy B
Hydrochloric Acid	All Conc.	212°F	Tantalum
Hydrocyanic Acid	All Conc.	212°F	304 Stn. Stl.
Hydrofluoric Acid	60%	212°F	Hastelloy C276
Hydrogen Chloride	Dry	500°F	304 Stn. Stl.
Hydrogen Peroxide		212°F	304 Stn. Stl.
Hydrogen Sulphide	Dry	212°F	316 Stn. Stl.
Iodine		70°F	Hastelloy C276
Kerosene		300°F	304 Stn. Stl.
Lacquer		212°F	316 Stn. Stl.
Lactic Acid	5%	150°F	316 Stn. Stl.
Lactic Acid	10%	212°F	Tantalum

TECHNICAL REFERENCE

Process Fluid	Concentration	Temperature	Well Material
Latex		212°F	Carbon Steel
Lime Sulphur			PVC
Linseed Oil		70°F	304 Stn. Stl.
Magnesium Carbonate		150°F	304 Stn. Stl.
Magnesium Chloride	5%	70°F	Monel 400
Magnesium Chloride	5%	212°F	Nickel 200
Magnesium Hydroxide	All Conc.	70°F	304 Stn. Stl.
Magnesium Nitrate		150°F	304 Stn. Stl.
Magnesium Oxide	All Conc.	70°F	304 Stn. Stl.
Magnesium Sulphate	40%	212°F	304 Stn. Stl.
Mailic Acid		212°F	316 Stn. Stl.
Mercuric Chloride	10%	70°F	Hastelloy C276
Mercury	100%	660°F	Carbon Steel
Methane		70°F	Carbon Steel
Methyl Chloride	Dry	70°F	Carbon Steel
Methylene Chloride	All Conc.	212°F	304 Stn. Stl.
Milk		175°F	304 Stn. Stl.
Molasses		300°F	304 Stn. Stl.
Muriatic Acid		70°F	Tantalum
Naphta		70°F	304 Stn. Stl.
Natural Gas		70°F	304 Stn. Stl.
Neon		70°F	304 Stn. Stl.
Nickel Chloride		70°F	304 Stn. Stl.
Nickel Sulphate		212°F	304 Stn. Stl.
Nitric Acid	40%	180°F	347 Stn. Stl.
Nitric Acid	All Conc.	370°F	Tantalum
Nitrobenzene		70°F	304 Stn. Stl.
Nitrous Acid		70°F	304 Stn. Stl.
Oleic Acid	All Conc.	400°F	316 Stn. Stl.
Oleum		70°F	316 Stn. Stl.
Oxalic Acid	5%	70°F	304 Stn. Stl.
Oxalic Acid	10%	212°F	Monel 400
Oxygen	Liquid		304 Stn. Stl.
Oxygen		70°F	Carbon Steel
Palmitic Acid	All Conc.	400°F	316 Stn. Stl.
Pentane			304 Stn. Stl.
Petroleum Ether			304 Stn. Stl.
Phenol	All Conc.	212°F	316 Stn. Stl.
Phosphoric Acid	10%	70°F	316 Stn. Stl.
Phosphoric Acid	85%	212°F	Hastelloy C276
Picric Acid		70°F	304 Stn. Stl.
Pot.Permanganate	5%	70°F	304 Stn. Stl.
Potassium Bromide		70°F	316 Stn. Stl.
Potassium Carbonate	20%	212°F	316 Stn. Stl.
Potassium Chlorate		70°F	304 Stn. Stl.
Potassium Chloride	20%	70°F	316 Stn. Stl.
Potassium Chloride	20%	212°F	Monel 400
Potassium Hydroxide	30%	212°F	316 Stn. Stl.
Potassium Nitrate	40%	212°F	316 Stn. Stl.
Potassium Nitrite	20%	70°F	316 Stn. Stl.
Potassium Sulphate	30%	212°F	316 Stn. Stl.
Potassium Sulphide	10%	212°F	304 Stn. Stl.

Process Fluid	Concentration	Temperature	Well Material
Potassium Sulphite	30%	212°F	304 Stn. Stl.
Propane		300°F	Carbon Steel
Pyrogallic Acid			304 Stn. Stl.
Quinine Bisulphate	Dry		316 Stn. Stl.
Quinine Sulphate	Dry		304 Stn. Stl.
Salommoniac		70°F	Monel 400
Sea Water		70°F	Monel 400
Shellac			304 Stn. Stl.
Silver Chloride		70°F	Carp. 20
Silver Nitrate		212°F	304 Stn. Stl.
Sodium Bicarbonate	All Conc.	150°F	316 Stn. Stl.
Sodium Bisulphate	20%	212°F	Hastelloy B
Sodium Bisulphite	20%	212°F	Hastelloy C276
Sodium Carbonate	20%	212°F	316 Stn. Stl.
Sodium Chloride	30%	70°F	316 Stn. Stl.
Sodium Chloride	30%	212°F	Monel 400
Sodium Chromate	All Conc.	212°F	316 Stn. Stl.
Sodium Fluoride	5%	70°F	Hastelloy B
Sodium Hydroxide	30%	212°F	316 Stn. Stl.
Sodium Hypochlorite			Tantalum
Sodium Nitrate	40%	212°F	304 Stn. Stl.
Sodium Nitrate	20%	70°F	304 Stn. Stl.
Sodium Peroxide	Fused		304 Stn. Stl.
Sodium Phosphate	10%	212°F	Carbon Steel
Sodium Silicate	10%	212°F	Carbon Steel
Sodium Sulphate	30%	212°F	316 Stn. Stl.
Sodium Sulphide	10%	212°F	316 Stn. Stl.
Sodium Sulphite	30%	212°F	304 Stn. Stl.
Stearic Acid			316 Stn. Stl.
Sulphur		Molten	304 Stn. Stl.
Sulphur	Wet		316 Stn. Stl.
Sulphur Dioxide		500°F	316 Stn. Stl.
Sulphur Trioxide	Dry	500°F	316 Stn. Stl.
Sulphuric Acid	Fuming	365°F	Carp. 20
Sulphuric Acid	All Conc.	212°F	Hastelloy B
Sulphurous Acid	20%	70°F	316 Stn. Stl.
Tar			Carbon Steel
Tartaric Acid		70°F	304 Stn. Stl.
Tartaric Acid		150°F	316 Stn. Stl.
Tin		Molten	Cast Iron
Tinan. Tetrachloride	All Conc.	70°F	316 Stn. Stl.
Toluene			304 Stn. Stl.
Trichloracetic Acid	All Conc.	70°F	HastelloyB
Trichlorethylene	Dry	300°F	Monel 400
Turpentine		70°F	316 Stn. Stl.
Vegetable Oils			304 Stn. Stl.
Vinegar			304 Stn. Stl.
Whiskey, Wine			304 Stn. Stl.
Xylene			Copper
Zinc		Molten	Cast Iron
Zinc Chloride	All Conc.	212°F	Hastelloy B
Zinc Sulphate	All Conc.	212°F	316 Stn. Stl.

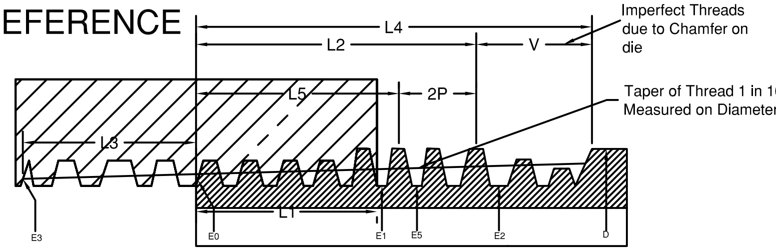
Pipe Size	O.D.	Sched. 40	Sched. 60	Sched. 80	Sched. 100	Sched. 120	Sched. 140	Sched. 160	XS	XXS
		Wall Thick.	Wall Thick.	Wall Thick.	Wall Thick.	Wall Thick.	Wall Thick.	Wall Thick.	Wall Thick.	Wall Thick.
1/8"	0.405	0.068	0.095	0.095	0.000	0.000	0.000	0.124	0.000	0.190
1/4"	0.540	0.088	0.119	0.119	0.000	0.000	0.000	0.145	0.000	0.238
3/8"	0.675	0.091	0.126	0.126	0.000	0.000	0.000	0.158	0.000	0.252
1/2"	0.840	0.109	0.147	0.147	0.000	0.000	0.000	0.188	0.000	0.294
3/4"	1.050	0.113	0.154	0.154	0.000	0.000	0.000	0.219	0.000	0.308
1"	1.315	0.133	0.179	0.179	0.000	0.000	0.000	0.250	0.000	0.358
1-1/4"	1.660	0.140	0.191	0.191	0.000	0.000	0.000	0.281	0.000	0.382
1-1/2"	1.900	0.145	0.200	0.200	0.000	0.000	0.000	0.344	0.000	0.400
2"	2.375	0.154	0.218	0.218	0.000	0.000	0.000	0.375	0.000	0.436
2-1/2"	2.875	0.203	0.276	0.276	0.000	0.000	0.000	0.438	0.000	0.552
3"	3.500	0.216	0.300	0.300	0.000	0.000	0.000	0.000	0.000	0.600
3-1/2"	4.000	0.226	0.318	0.318	0.000	0.000	0.000	0.531	0.000	0.636
4"	4.500	0.237	0.337	0.337	0.000	0.438	0.000	0.625	0.000	0.674
5"	5.563	0.258	0.375	0.375	0.000	0.500	0.000	0.719	0.000	0.750
6"	6.625	0.280	0.432	0.432	0.000	0.562	0.000	0.906	0.000	0.864
8"	8.625	0.322	0.500	0.500	0.594	0.719	0.812	1.125	0.406	0.875
10"	10.750	0.365	0.500	0.594	0.719	0.844	1.000	1.312	0.500	1.000
12"	12.750	0.406	0.500	0.688	0.844	1.000	1.125	1.406	0.562	1.000
14"	14.000	0.438	0.500	0.750	0.938	1.094	1.250	1.594	0.594	0.000
16"	16.000	0.500	0.500	0.844	1.031	1.219	1.438	1.781	0.656	0.000
18"	18.000	0.562	0.500	0.938	1.156	1.375	1.562	1.969	0.750	0.000
20"	20.000	0.594	0.500	1.031	1.281	1.500	1.750	2.125	0.812	0.000
24"	24.000	0.688	0.500	1.125	1.375	1.625	1.875	2.344	0.875	0.000
30"	30.000	0.000	0.500	1.219	1.531	1.812	2.062	0.000	0.969	0.000

All Dimensions are given in inches and are in accordance with ASME B36.10 or ANSI/ASME B36.19 as applicable.
The decimal thickness listed for the pipe sizes represent their nominal or average wall dimensions.
For nominal sizes through 10", Standard weight thickness is identical to schedule 40 thickness.
For nominal sized through 8", Extra strong thickness is identical to schedule 80 thickness.
These do not conform to ANSI/ASME B36.19.

Pipe Size	O.D.	Sched. 40	Sched. 60	Sched. 80	Sched. 100	Sched. 120	Sched. 140	Sched. 160	XS	XXS
		I.D.	I.D.	I.D.	I.D.	I.D.	I.D.	I.D.	I.D.	I.D.
1/8"	0.405	0.269	0.000	0.215	0.000	0.000	0.000	0.157	0.215	0.025
1/4"	0.540	0.364	0.000	0.302	0.000	0.000	0.000	0.250	0.302	0.064
3/8"	0.675	0.493	0.000	0.423	0.000	0.000	0.000	0.359	0.423	0.171
1/2"	0.840	0.622	0.000	0.546	0.000	0.000	0.000	0.464	0.546	0.252
3/4"	1.050	0.824	0.000	0.742	0.000	0.000	0.000	0.612	0.742	0.434
1"	1.315	1.049	0.000	0.957	0.000	0.000	0.000	0.815	0.957	0.599
1-1/4"	1.660	1.380	0.000	1.278	0.000	0.000	0.000	1.160	1.278	0.896
1-1/2"	1.900	1.610	0.000	1.500	0.000	0.000	0.000	1.338	1.500	1.100
2"	2.375	2.067	0.000	1.939	0.000	0.000	0.000	1.687	1.939	1.503
2-1/2"	2.875	2.469	0.000	2.323	0.000	0.000	0.000	2.125	2.323	1.771
3"	3.500	3.068	0.000	2.900	0.000	0.000	0.000	2.624	2.900	2.300
3-1/2"	4.000	3.548	0.000	3.364	0.000	0.000	0.000	0.000	3.364	2.728
4"	4.500	4.026	0.000	3.826	0.000	3.624	0.000	3.438	3.826	3.152
5"	5.563	5.047	0.000	4.813	0.000	4.563	0.000	4.313	4.813	4.063
6"	6.625	6.065	0.000	5.761	0.000	5.501	0.000	5.187	5.761	4.897
8"	8.625	7.981	7.813	7.625	7.437	7.187	7.001	6.813	7.625	6.875
10"	10.750	10.020	9.750	9.562	9.312	9.062	8.750	8.500	9.750	8.750
12"	12.750	11.938	11.626	11.374	11.062	10.750	10.500	10.126	11.750	10.750
14"	14.000	13.124	12.812	12.500	12.124	11.812	11.500	11.188	13.000	0.000
16"	16.000	15.000	14.688	14.312	13.938	13.562	13.124	12.812	15.000	0.000
18"	18.000	16.876	16.500	16.124	15.688	15.250	14.876	14.438	17.000	0.000
20"	20.000	18.812	18.376	17.938	17.438	17.000	16.500	16.062	19.000	0.000
24"	24.000	22.624	22.062	21.562	20.938	20.376	19.876	19.312	23.000	0.000
30"	30.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	29.000	0.000

All Dimensions are given in inches and are in accordance with ASME B36.10 or ANSI/ASME B36.19 as applicable.
The decimal thickness listed for the pipe sizes represent their nominal or average wall dimensions.
For nominal sizes through 10", Standard weight thickness is identical to schedule 40 thickness.
For nominal sized through 8", Extra strong thickness is identical to schedule 80 thickness.
These do not conform to ANSI/ASME B36.19.

Basic NPT Dimensions



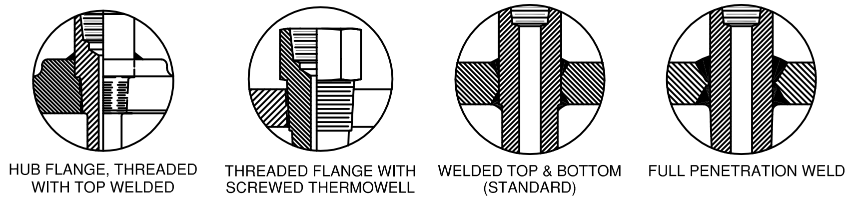
For all dimensions, see corresponding reference letter in table.
Angle between sides of thread is 60 degrees. Taper of thread, on diameter, is 3/4 inch per foot. Angle of taper with center line is 1°47'.
The basic maximum thread height, h, of the truncated thread is 0.8 x pitch of thread. The crest and root are truncated a minumum of 0.033 x pitch for all pitches.

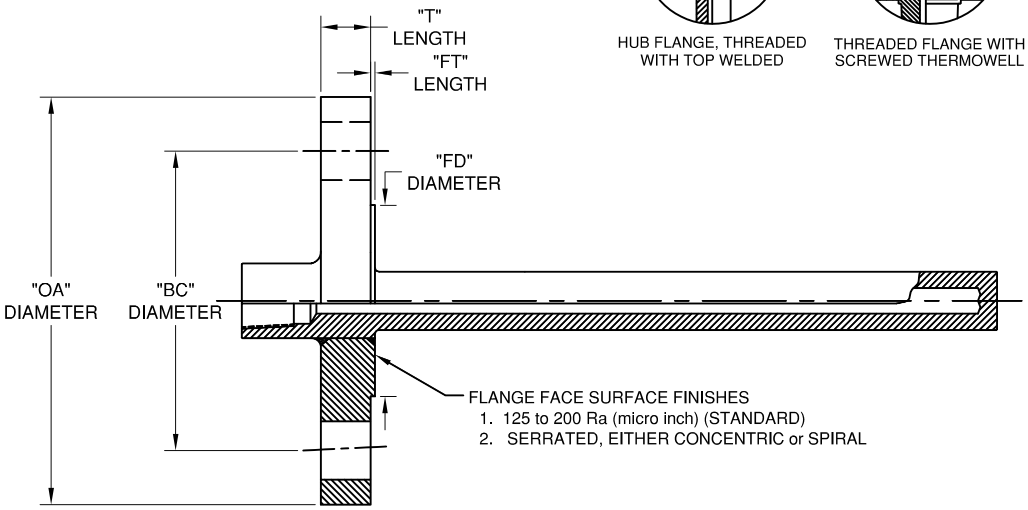
Nominal Pipe Size	Outside Dia. of Pipe, D	Threads per Inch, n	Pitch of Thread, P	Pitch Diameter at Beginning of External Thread, E0	Handtight Engagement		Effective Thread, External	
					Length, L1 In.	Dia., E1	Length, L2 In.	Dia., E2
1/16	0.3125	27	0.03704	0.27118	0.160	0.28118	0.2611	0.28750
1/8	0.405	27	0.03704	0.36351	0.1615	0.37360	0.2639	0.38000
1/4	0.540	18	0.05556	0.47739	0.2278	0.49163	0.4018	0.50250
3/8	0.675	18	0.05556	0.61201	0.240	0.62701	0.4078	0.63750
1/2	0.840	14	0.07143	0.75843	0.320	0.77843	0.5337	0.79179
3/4	1.050	14	0.07143	0.96768	0.339	0.98887	0.5457	1.00179
1	1.315	11 1/2	0.08696	1.21363	0.400	1.23863	0.6828	1.25630
1 1/4	1.660	11 1/2	0.08696	1.55713	0.420	1.58338	0.7068	1.60130
1 1/2	1.900	11 1/2	0.08696	1.79609	0.420	1.82234	0.7235	1.84130
2	2.375	11 1/2	0.08696	2.26902	0.436	2.29627	0.7565	2.31630
2 1/2	2.875	8	0.12500	2.71953	0.682	2.76216	1.1375	2.79062
3	3.500	8	0.12500	3.34062	0.766	3.38850	1.2000	3.41562
3 1/2	4.000	8	0.12500	3.83750	0.821	3.88881	1.2500	3.91562
4	4.500	8	0.12500	4.33438	0.844	4.38712	1.3000	4.41562

Nominal Pipe Size	Wrench Makeup Length for Internal Thread		Vanish Thread, (3.47 thds.), V	Overall Length External Thread, L4	Nominal Perfect External Threads		Height of Thread, I1	Basic Minor Dia. at Small End of Pipe, K0
	Length, L3	Dia., E3			Length, L5	Dia., E5		
1/16	0.1111	0.26424	0.1285	0.3896	0.1870	0.28287	0.02963	0.2416
1/8	0.1111	0.35656	0.1285	0.3924	0.1898	0.37537	0.02963	0.3339
1/4	0.1667	0.46697	0.1928	0.5946	0.2907	0.49556	0.04444	0.4329
3/8	0.1667	0.60160	0.1928	0.6006	0.2967	0.63056	0.04444	0.5676
1/2	0.2143	0.74504	0.2478	0.7815	0.3909	0.78286	0.05714	0.7013
3/4	0.2143	0.95429	0.2478	0.7935	0.4029	0.99286	0.05714	0.9105
1	0.2609	1.19733	0.3017	0.9845	0.5089	1.24543	0.06957	1.1441
1 1/4	0.2609	1.54083	0.3017	1.0085	0.5329	1.59043	0.06957	1.4876
1 1/2	0.2609	1.77978	0.3017	1.0252	0.5496	1.83043	0.06957	1.7265
2	0.2609	2.25272	0.3017	1.0582	0.5826	2.30543	0.06957	2.1995
2 1/2	0.2500	2.70391	0.4337	1.5712	0.8875	2.77500	0.10000	2.6195
3	0.2500	3.32500	0.4337	1.6337	0.9500	3.40000	0.10000	3.2406
3 1/2	0.2500	3.82188	0.4337	1.6837	1.0000	3.90000	0.10000	3.7375
4	0.2500	4.31875	0.4337	1.7337	1.0500	4.40000	0.10000	4.2344

All dimensions given in inches. Increase in diameter per thread is equal to 0.0625/n.
The basic dimensions of the ANSI standard taper pipe thread are given in inches to four or five decimal places. While this implies a greater degree of precision than is ordinarily attained, these dimensions are the basis of gage dimensions and are so expressed for the purpose of eliminating errors in computations.

TECHNICAL REFERENCE





Class 150 Forged Flanges

Nom. Pipe Size	No./Dia. of Holes (1)	BC	OA	FD	T
1/2	4-0.62	2.38	3.5	1.38	.38
3/4	4-0.62	2.75	3.88	1.69	.44
1	4-0.62	3.12	4.25	2	.50
1 1/4	4-0.62	3.5	4.62	2.5	.56
1 1/2	4-0.62	3.88	5	2.88	.62
2	4-0.75	4.75	6	3.62	.69
2 1/2	4-0.75	5.5	7	4.12	.82
3	4-0.75	6	7.5	5	.88
3 1/2	8-0.75	7	8.5	5.5	.88
4	8-0.75	7.5	9	6.19	.88

1. Bolt hole diameter 1/8 in. larger than bolt diameter
2. "FT" length equal to 1/16 in.
3. Exracted from ANSI B16.5, see complete standard for critical applications.

Class 300 Forged Flanges

Nom. Pipe Size	No./Dia. of Holes (1)	BC	OA	FD	T
1/2	4-0.62	2.62	3.75	1.38	.50
3/4	4-0.75	3.25	4.62	1.69	.56
1	4-0.75	3.5	4.88	2	.63
1 1/4	4-0.75	3.88	5.25	2.5	.69
1 1/2	4-0.88	4.5	6.12	2.88	.75
2	8-0.75	5	6.5	3.62	.82
2 1/2	8-0.88	5.88	7.5	4.12	.94
3	8-0.88	6.62	8.25	5	1.06
3 1/2	8-0.88	7.25	9	5.5	1.13
4	8-0.88	7.88	10	6.19	1.19

1. Bolt hole diameter 1/8 in. larger than bolt diameter
2. "FT" length equal to 1/16 in.
3. Exracted from ANSI B16.5, see complete standard for critical applications.

TECHNICAL REFERENCE

Class 600 Forged Flanges

Nom. Pipe Size	No./Dia. of Holes (1)	BC	OA	FD	T
1/2	4-0.62	2.62	3.75	1.38	0.56
3/4	4-0.75	3.25	4.62	1.69	0.62
1	4-0.75	3.5	4.88	2	0.69
1 1/4	4-0.75	3.88	5.25	2.5	0.81
1 1/2	4-0.88	4.5	6.12	2.88	0.88
2	8-0.75	5	6.5	3.62	1
2 1/2	8-0.88	5.88	7.5	4.12	1.12
3	8-0.88	6.62	8.25	5	1.25
3 1/2	8-1.00	7.25	9	5.5	1.38
4	8-1.00	8.5	10.75	6.19	1.5

1. Bolt hole diameter 1/8 in. larger than bolt diameter
2. "FT" length equal to 1/4 in.
3. Exracted from ANSI B16.5, see complete standard for critical applications.

Class 900 Forged Flanges

Nom. Pipe Size	No./Dia. of Holes (1)	BC	OA	FD	T
1/2	4-0.88	3.25	4.75	1.38	0.88
3/4	4-0.88	3.50	5.13	1.69	1.00
1	4-1.00	4.00	5.88	2.00	1.13
1 1/4	4-1.00	4.38	6.25	2.50	1.13
1 1/2	4-1.13	4.88	7.00	2.88	1.25
2	8-1.00	6.50	8.50	3.63	1.50
2 1/2	8-1.13	7.50	9.63	4.13	1.63
3	8-1.00	7.50	9.50	5.00	1.50
4	8-1.25	9.25	11.50	6.19	1.75

1. Bolt hole diameter 1/8 in. larger than bolt diameter
2. "FT" length equal to 1/4 in.
3. Exracted from ANSI B16.5, see complete standard for critical applications.

Class 1500 Forged Flanges

Nom. Pipe Size	No./Dia. of Holes (1)	BC	OA	FD	T
1/2	4-.088	3.25	4.75	1.38	0.88
3/4	4-0.88	3.50	5.13	1.69	1.00
1	4-1.00	4.00	5.88	2.00	1.13
1 1/4	4-1.00	4.38	6.25	2.50	1.13
1 1/2	4-1.13	4.88	7.00	2.88	1.25
2	8-1.00	6.50	8.50	3.63	1.50
2 1/2	8-1.13	7.50	9.63	4.13	1.63
3	8-1.25	8.00	10.50	5.00	1.88
4	8-1.38	9.50	12.25	6.19	2.13

1. Bolt hole diameter 1/8 in. larger than bolt diameter
2. "FT" length equal to 1/4 in.
3. Exracted from ANSI B16.5, see complete standard for critical applications.

Class 2500 Forged Flanges

Nom. Pipe Size	No./Dia. of Holes (1)	BC	OA	FD	T
1/2	4-0.88	3.50	5.25	1.38	1.19
3/4	4-0.88	3.75	5.50	1.69	1.25
1	4-1.00	4.25	6.25	2.00	1.38
1 1/4	4-1.13	5.13	7.25	2.50	1.50
1 1/2	4-1.25	5.75	8.00	2.88	1.75
2	8-1.13	6.75	9.25	3.63	2.00
2 1/2	8-1.25	7.75	10.50	4.13	2.25
3	8-1.38	9.00	12.00	5.00	2.63
4	8-1.63	10.75	14.00	6.19	3.00

1. Bolt hole diameter 1/8 in. larger than bolt diameter
2. "FT" length equal to 1/4 in.
3. Exracted from ANSI B16.5, see complete standard for critical applications.