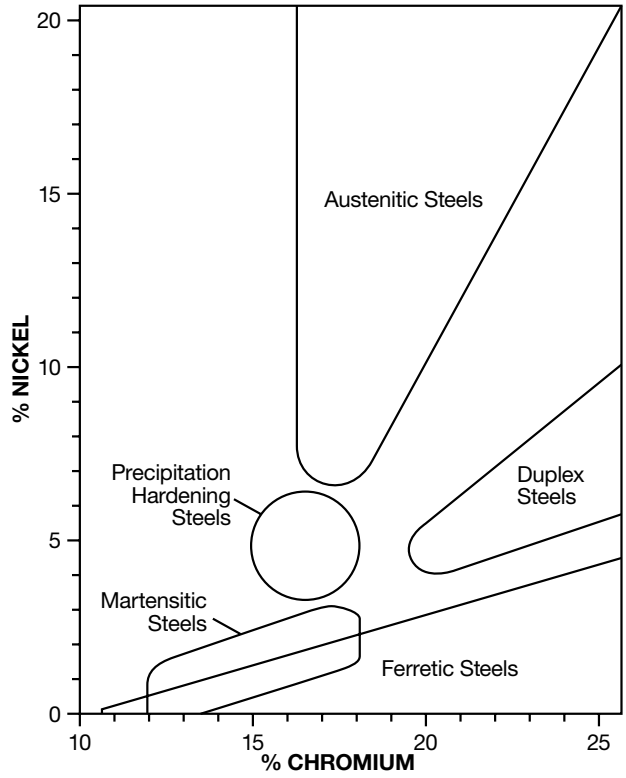
Categories of Stainless Steel

BASED ON NICKEL AND CHROMIUM CONTENT

FIGURE 1 **CATEGORIES OF STAINLESS STEEL**



Austenitic Stainless Steels

When nickel (Ni) is added to stainless steel in sufficient quantities, the crystal structure is changed from ferrite to austenite, hence the term austenitic stainless steels.

The basic composition of the austenitic stainless steels is 18% chromium (Cr) and 8% nickel (Ni). This is grade 304, sometimes loosely referred to as 18/8 or 18/10. If additional corrosion resistance is required, 2% molybdenum (Mo) is added, termed grade 316.

The carbon (C) content of almost all stainless steels is low (often 0.08% C max) compared with most other steels. There are also low carbon or L grades (0.03% C max) and stabilised grades alloyed with titanium (Ti) or niobium (Nb) to prevent a form of corrosion occurring in the region next to the weld in welded structures.

The common grade designations include 304, 304L, 321, 316, 316L, CF3M, CF8M, N08904 and S31254.

Basic properties of austenitic stainless steels include:

- Excellent corrosion resistance
- Excellent cleanability and hygiene factor
- Fabricated and formed with ease
- Excellent weldability
- Hardened by cold work, not by heat treatment
- Usually used in the fully annealed condition in which they are essentially non-magnetic
- The ability to handle both extremely low (cryogenic) temperatures and, depending on the load and permissable distortion, higher service temperatures of around 600ºC – or even higher if scaling resistance is the principal consideration.

Common uses and applications cover an extremely wide scope such as holloware, builders hardware, architectural applications, abattoir, beer and beverage production and food processing equipment (which require the cleanability and hygienic corrosion resistant properties).

They are used at very low (cryogenic) temperatures for the storage of liquefied gases and at high temperatures for heat exchangers, pollution control equipment and fume extraction.

Excellent wet (aqueous) corrosion resistance and weldability make them ideal for fabricated components such as pipework, tanks, process and pressure vessels in the chemical, petrochemical, petroleum, mineral extraction, pulp and paper, and food and beverage industries, railway carriages and goods wagons.

Austenitic stainless steels are available as plates, sheet and coil, tube and pipe (both seamless and welded), fittings, flanges, fasteners, bar, rod, wire, forgings and castings.

Common austenitic stainless grades are listed in Table 1 and their relationships in Figure 2 on page 5 and page 6 respectively.

Limitations

Austenitic stainless steels have some limitations:

They are only suitable for low concentrations of reducing acids or reducing acid mixtures at lower temperatures.

Reducing acids break down the oxide film and this leads to the general corrosion of these steels (see the Super Austenitic Stainless Steels paragraph in this section).

Halide ions, especially the chloride ion (Cl^-), have the ability to break down the passive film on stainless steels. This is often a highly localised form of attack and leads to pitting corrosion with very little overall metal loss.

Another form of chloride induced corrosion is stress corrosion cracking (SCC) which may occur above about 60ºC.

Due to these limitations, other austenitic stainless steels have been developed with greater resistance to the above corrosive conditions. Duplex grades can also offer improved resistance.

Heat resisting Austenitic Stainless Steels

High temperature alloys are largely based on alloys containing chromium because of the resistance the chromium oxide film provides. The basic high temperature alloys are simple iron-chromium alloys but the possibility of metallurgical changes giving undesirable structures requires the addition of other elements, particularly nickel, with some reaching up to 80% nickel.

This range of high nickel-chromium alloys can give oxidation resistant service under appreciable loading but at a relatively high cost.

Cost savings are introduced by replacing some of the nickel with iron – this group of alloys, at the lower limit of alloy content, includes the stainless steels.

The selection of which alloy to use – a stainless steel or a high nickel alloy – depends on the service requirement and is beyond the scope of this section.

The most common heat resisting stainless steels are the 310 group of alloys with around 25% chromium and 20% nickel, and S30815 with small additions of silicon, nitrogen and cerium. These resist scaling up to around 1100ºC and are frequently used for the less demanding zones of high temperature furnaces.

Basic properties include:

- Resistance to oxidation (scaling) at high temperatures
- Good high temperature strength
- S30815 has high resistance to sigma phase precipitation.

Austenitic stainless steels have maximum scaling limited temperatures between 840 to 1150°C with higher temperatures for continuous use and, usually, higher nickel. Strength limited temperatures are lower.

Super Austenitic Stainless Alloys

These are highly alloyed materials which may be considered as an extension to the austenitic stainless steels. They were developed for higher corrosion resistance, particularly to overcome the pitting and stress corrosion cracking limitations of standard austenitic stainless steels.

Their basic composition is such that the alloy content exceeds approximately 50%. The alloy additions typically include chromium in the range of 20 to 27%, nickel in the range of 25 to 31%, relatively high molybdenum content of 3 to 6%, and a low carbon content of less than 0.03%.

These higher contents give these alloys a markedly increased corrosion resistance to reducing acids at higher temperatures and concentrations and a high resistance to pitting corrosion and stress corrosion cracking in warm or hot chloride media.

Basic properties include:

- Same as standard austenitic stainless steels - non-magnetic, excellent cryogenic properties, high work hardening rate
- Readily fabricated
- Weldable even in thick material.

Common uses include applications in the chemical and petrochemical industries where more severe corrosive conditions of concentration, temperature and contaminant prevail, which make standard austenitic stainless steels unsuitable.

They are available in forms such as thicker sheet, plate, bar, tube, castings and pipe.

They are often available as proprietary alloys.

Martensitic Stainless Steels

These were the first stainless steels industrially developed (as stainless steel cutlery). They have a relatively high carbon (C) content and a chromium (Cr) content of 12 to 18%.

Basic properties of martensitic stainless steels include

- Moderate Corrosion Resistance
- Hardenable by heat treatment and therefore high strength and hardness levels can be developed
- Very limited weldability

The common specifications are wrought 410, 420, 431 and the cast CA-6NM with typical applications being knife blades, surgical instruments, fasteners, spindles, nozzles, shafts, impellers and springs.

Precipitation Hardening Stainless Steels

Precipitation hardening stainless steels have their compositions formulated so that they can be supplied in the solution treated condition, in which they are machinable.

Following fabrication operations, these steels can be hardening by a single ageing treatment. This is conducted at a relatively low temperature and can, therefore, be done without distorting the product.

These grades are consequently ideal for the production of long straight high strength shafts for pumps or valve spindles.

The most common grade is 17-4PH (S17400 or Type 630) which is a martensitic precipitation hardening grade. High strength wire can be produced in grade 17-7PH (S17700 or Type 631).

TABLE 1 **COMMON AUSTENITIC STAINLESS STEEL GRADES AND THEIR APPLICATIONS**

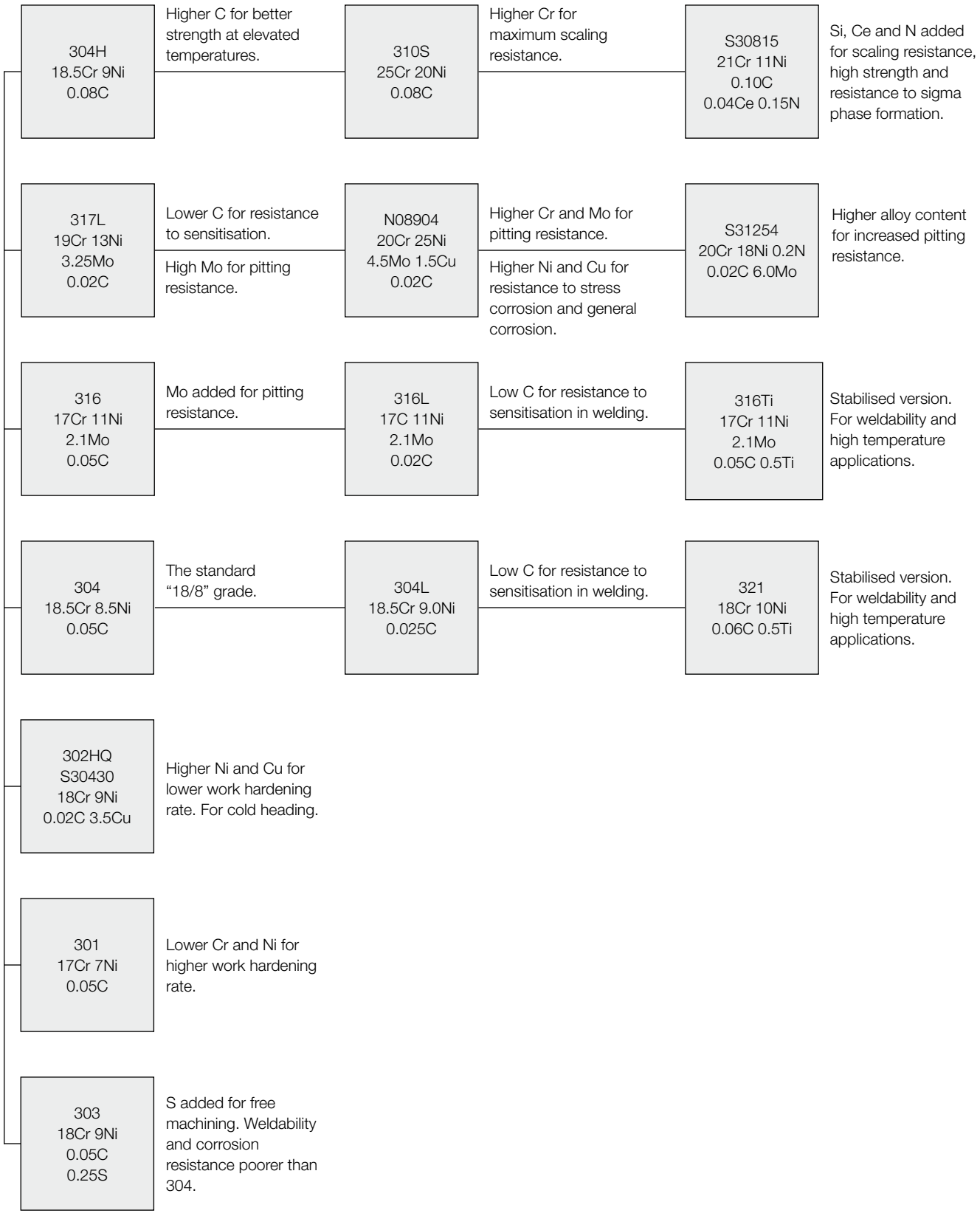
Common name	UNS number	Forms available*	Typical compositions (%)						Typical applications
			C	Cr	Ni	Mo	Ti	Other	
301	S30100	Sheet, Coil	0.05	17.0	7.0	-	-	-	General purpose stainless steel with good corrosion resistance for most applications. Used where the high work-hardening exponent is desirable. Can be supplied cold worked to give high strength. Used for structural applications suchs as rail carriages and wagons.
302HQ	S30430	Wire	0.02	18.0	9.0	-	-	3.5Cu	Wire for cold heading to produce fasteners etc.
303	S30300	Bar	0.05	18.0	9.0	-	-	0.25S	Free machining steel used where extensive machining is required. Corrosion resistance and weldability inferior to 304.
304	S30400	Sheet, Coil, Plate, Bar, Pipe, Tube	0.05	18.5	8.5	-	-	-	General purpose stainless steel with good corrosion resistance for most applications. Used for architecture, food processing, domestic sinks and tubs and deep drawing applications.
304L	S30403	Sheet, Coil, Plate, Pipe	0.025	18.5	9.0	-	-	-	Chemical plant and food processing equipment where freedom from sensitisation is required in plate thicknesses.
304H	S30409	Sheet, Coil, Plate, Pipe, Bar	0.06	18.5	9.0	-	-	-	Higher carbon content than 304L, for increased strength, particularly at elevated temperatures.
310	S31000	Sheet, Coil, Plate, Bar	0.12	25.0	20.0	-	-	-	Furnace parts and equipment. Resistant to temperatures 900 to 1100ºC.
310S	S31008	Sheet, Plate, Bar, Tube, Pipe	0.08	25.0	20.0	-	-	-	A low carbon version of 310 is used to resist nitric acid corrosion.
316	S31600	Sheet, Coil, Plate, Seamless and Welded Tube and Pipe	0.05	17.0	11.0	2.1	-	-	Used where higher corrosion resistance is required, eg. marine equipment. Can be welded up to 3mm without subsequent heat treatment.
316L	S31603	Sheet, Coil, Plate, Seamless and Welded Tube and Pipe	0.02	17.0	11.0	2.1	-	-	A low carbon modification of 316 where heavy section weldments are required without the risk of intergranular corrosion.
316Ti	S31635	Plate, Pipe, Tube	0.05	17.0	11.0	2.1	0.5	-	A titanium stabilised version of 316 is used where good resistance to intergranular corrosion and high temperature strength is required.
317L	S31703	Sheet, Coil, Plate	0.02	19.0	13.0	3.25	-	-	For chemical plant - has greater corrosion resistance than 316 in certain applications, notably in contact with brines and halogen salts. More usually available in the low carbon L grade.
321	S32100	Sheet, Coil, Plate, Bar	0.06	18.0	10.0	-	0.5	-	Heavy weldments in chemical and other industries. Suitable for heat resisting applications to 800ºC. Not suitable for bright polishing.
904L	N08904	Sheet, Plate, Bar, Pipe, Tube	0.02	20.0	25.0	4.5	-	1.5Cu	High resistance to general corrosion in: sulphuric and acetic acids, crevice corrosion, stress corrosion cracking, pitting in chloride bearing solutions etc. Good weldability.
+	S31254	Sheet, Plate, Tube, Pipe, Bar	0.02	20.0	18.0	6.0	-	0.2N	Used where high resistance to chloride pitting eg. seawater heat exhangers, bleach vats and washers in the pulp and paper industry.
+	S30815	Sheet, Plate, Bar, Tube, Pipe	0.10	21.0	11.0	-	-	0.15N	Used for furnace parts, radiant shields, fluidised beds. Resistant to temperatures up to 1150°C. Possesses high strength and resistance to sigma phase formation.

NOTE: Chemical compositions given in this and subsequent figures are typical values, which will vary for different steelmakers and products.

* Compatible or equivalent grades also available in castings.

+ Proprietary alloy names apply.

FIGURE 2 **FAMILY RELATIONSHIPS FOR STANDARD WROUGHT AUSTENITIC STAINLESS STEELS**



Ferritic Stainless Steels

These are nickel-free stainless steels. They have a varying chromium content of 10.5 to 18%, but a lower carbon (C) content than the martensitics (a special heat resistant grade contains 26% chromium). The common specifications are 430, 409 and weldable 12% chromium steels.

Basic properties of ferritic stainless steels:

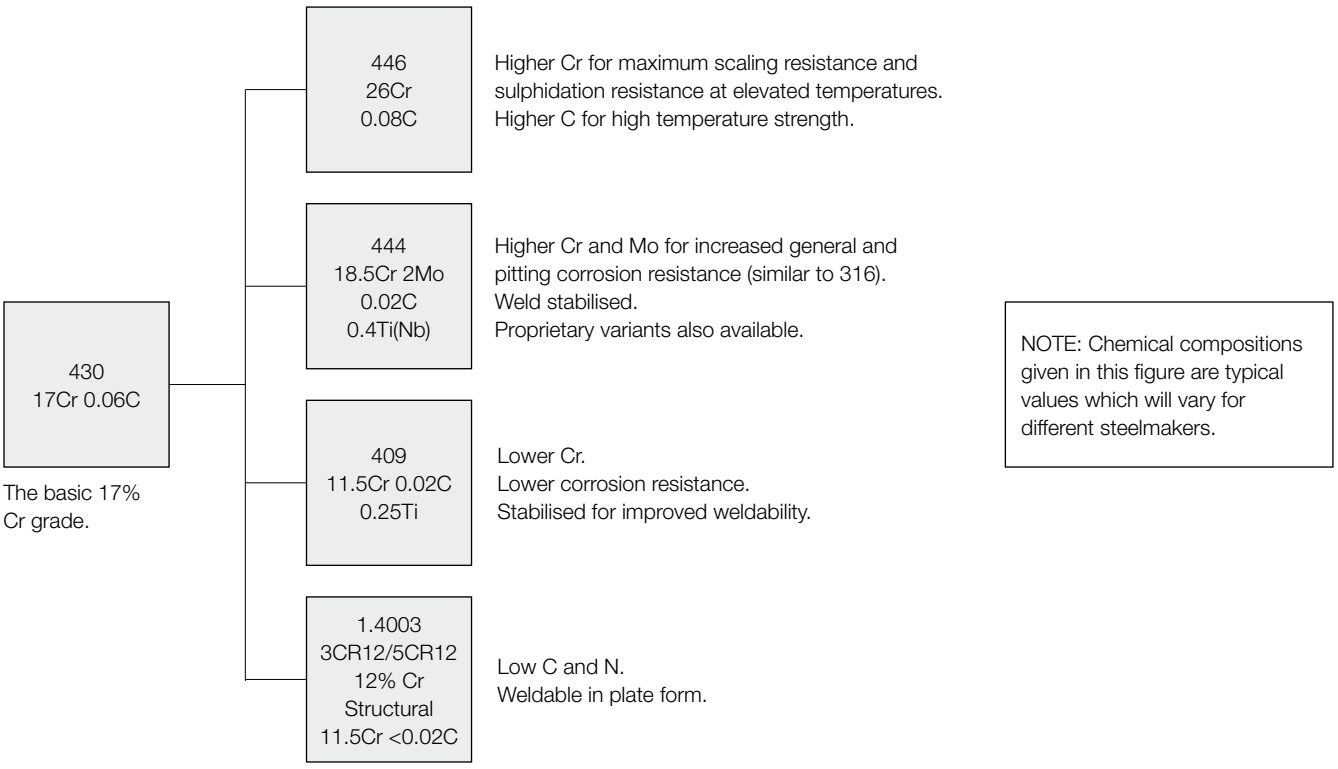
- Moderate to good corrosion resistance which increases with the chromium content
- Magnetic, non-hardenable and always used in the annealed condition
- Weldability is poor which generally limits their applications as welded components to thin gauge material
- Formability is closer to that of ferritic carbon steels than that of austenitic stainless steels.

Common uses include builders' hardware, domestic appliances (dishwashers, clothes dryers) and architectural and automotive trim. Thick gauge applications include liners, decking plates, spillways, chain conveyors, dust and fume extractors.

Due to their predominant use as thin gauge material they are readily available in the form of sheet and coil.

Common ferritic stainless grades and their relationships are listed below.

FIGURE 3 **FAMILY RELATIONSHIPS FOR STANDARD WROUGHT FERRITIC STAINLESS STEELS**



Duplex Stainless Steels

Duplex stainless steels have a structure of approximately equal amounts of ferrite and austenite and, therefore, may be referred to as ferritic-austenitic stainless steels.

The chromium content varies from 18 to 28%. The nickel content of 4.5 to 8% is insufficient to develop a fully austenitic crystal structure. “Lean” duplex grades substitute some of the nickel with other elements such as manganese.

Most grades contain molybdenum in the range 2.5 to 4% plus a small nitrogen addition which enhances both strength and pitting resistance.

Basic properties of the duplex stainless steels include:

- A mixed ferritic-austenitic, ie. duplex, crystal structure which results in high resistance to stress corrosion cracking
- An increased level of passivity due to higher Cr, Mo and N
- Good weldability and formability
- Higher tensile and yield strengths (compared with austenitic and ferritic stainless steels).

Common uses include applications such as heat exchanger panels and tubes, materials handling equipment, tanks and vessels where high chloride concentrations are present, eg. sea water cooling, desalination, food pickling plants and aggressive mine waters.

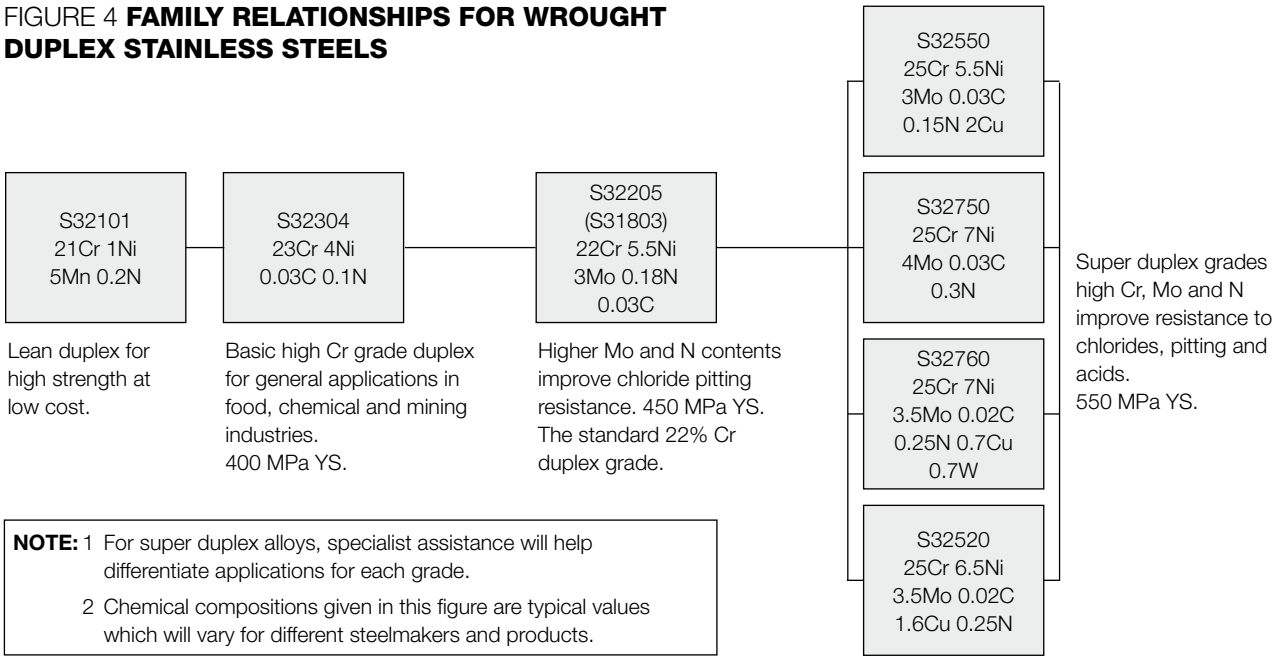
The forms available are sheet, plate, castings, bar, wire, tube and pipe. Duplex stainless steels are often available as proprietary alloys. Common duplex grades are listed below.

TABLE 2 **DUPLEX GRADES AND THEIR APPLICATIONS**

UNS number	Forms available*	Typical compositions (%)							Typical applications
		C	Cr	Ni	Mo	N	Cu	Other	
S32101	Sheet, Plate, Pipe, Fittings	0.03	21.5	1.5	0.5	0.22	0.5	5.0Mn	Corrosion resistance approaching that of 316, with higher strength and stress corrosion cracking resistance. Storage tanks and structural applications.
S32304	Sheet, Plate, Pipe, Fittings	0.03	23.0	4.0	-	0.1	-	-	Similar corrosion resistance to 316L. Higher yield strength and stress-corrosion cracking resistance. Used where high corrosion resistance is required in marine, mining, chemical, food and power industries. Particularly useful in nitric acid.
S31803	Plate, Pipe, Tube, Bar, Fittings	0.03	22.0	5.5	3.0	0.14	-	-	Superior corrosion resistance to 316L and 317L combined with high strength. Excellent stress corrosion and abrasion resistance. Typically used in heat exchangers, gas scrubbers, fans, chemical tanks, flowlines, marine and refinery applications.
S32205		0.03	22.5	5.5	3.2	0.18	-	-	
S32550	Plate, Sheet, Pipe, Bar, Fittings	0.03	25.0	5.5	3.0	0.15	2.0	-	Excellent resistance to corrosion by seawater, acids and salts combined with high strength, abrasion resistance and weldability.
S32750	Plate, Pipe, Tube, Bar, Fittings	0.03	25.0	7.0	4.0	0.3	-	-	Extremely high resistance to corrosion in severe marine, chloride and acid environments. Suitable for heat exchangers, reactors, pipework etc.
S32760		0.02	25.0	7.0	3.5	0.25	0.7	0.7 W	
S32520		0.02	25.0	6.5	3.5	0.25	1.6	-	

* Compatible or equivalent grades also available in castings. + Proprietary alloy names apply.

FIGURE 4 **FAMILY RELATIONSHIPS FOR WROUGHT DUPLEX STAINLESS STEELS**



NOTE: 1 For super duplex alloys, specialist assistance will help differentiate applications for each grade.

2 Chemical compositions given in this figure are typical values which will vary for different steelmakers and products.