Second edition

Ferritic Stainless Steels

worldstainless

Foreword

Dear reader,

We are proud to release the second edition of our Ferritic Stainless Steels brochure. We were immensely encouraged by the fact that our first edition of this brochure, released in 2007, was exceptionally well received and reached a very broad audience.

Stainless steels are stainless because their high Chromium content (>10.5% Cr) which gives them remarkable resistance to different corrosion types. Ferritic stainless steel grades, which are primarily Iron-Chromium alloys with some other elements added are no exception. The well-known standard ferritic grades (eg; 409, 410 and 430) are readily available all over the world. These grades are very successfully used in important applications, such as washing-machine drums and within other domestic appliances. More recently developed ferritic grades (eg; 439 and 441) meet an even broader range of requirements and can be formed to more complex shapes and joined using conventional jointing methods, including welding.

The strong support of the worldstainless members and the Team Stainless partners has allowed us to present an update of this important reference document. Special thanks you to the International Chromium Development Association for their input in the original version of this brochure. The worldstainless team is very grateful for all these contributions from our stakeholders. Our sincere thanks go to Thomas Pauly for reshaping the main text and to Dr. Clara Herrera from Swiss Steel Group for reviewing the draft of the brochure and her additional suggestions. Furthermore, a heartfelt thank you is extended to those worldstainless members who have provided images and applications for inclusion within the brochure. Without their contributions, this brochure would not be as enlightening!

We trust that this brochure will serve as a useful learning and reference resource for producers, material specifiers, architects, OEMs, stockists, and the wider community interested in stainless steels. We hope it will serve as a practical tool in your decision-making.

Tim Collins
Secretary-General
world stainless association

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1. Fabulous Ferritics

In the face of rising, fluctuating raw-material costs, ferritic stainless steels have proved a useful solution in many applications in which cost-saving material substitution has become imperative.

In recent years, prices of raw materials such as aluminium, copper, zinc and nickel have exploded. Stainless steel producers and users are affected specifically by the price volatility of nickel − a key constituent of the widely used austenitic stainless steels also known as the 300 series.

In strategic material selection, expected price stability is an important criterion, whether it be for price-sensitive volume products or projects with long lead times. In these areas, fabricators may want to consider alternatives to nickel-containing stainless steels.

While, in specific fabrication processes and operating conditions, nickel can be a useful or even indispensable ingredient of stainless steel, it is not always a must. It is the purpose of the present publication to describe the circumstances in which non-nickel alloyed ferritic stainless steels of the so-called 400 series can be suitable alternatives, both technically and economically.

Lower cost, more stable price

Stainless steels are defined as steels that

a. have a maximum carbon content of 1.2 % and

b. contain at least 10.5 % of chromium.

Ferritic grades basically consist of iron and chromium. The price of chromium – the ingredient that provides the high level of corrosion resistance to stainless steel – has historically been relatively stable. Certain ferritic grades contain additional alloying elements, such as molybdenum, to enhance specific properties.

Professional griddle, in grade 430.
Picture courtesy of Lincat Limited, Lincoln, UK

Ferritic stainless steels share most of the mechanical and corrosion resistance properties of their more expensive cousins, the austenitics, and even exceed them in certain characteristics.

Canopy, in grade 446M, S. Korea.
Picture courtesy of the Korea Iron & Steel Association (KOSA), Seoul, S. Korea;

For users of copper, aluminium or austenitic stainless steels, ferritic grades can often be a way of benefiting fully from the unique qualities of stainless steel while keeping material and fabrication cost at a reasonable level.

Five groups of ferritics

Ferritic grades fall into five categories – three groups of standard grades and two of "special" grades.

Group 1 (type 409/1.4512, 410/1.4003) has the lowest chromium content of all stainless steels and is also the least expensive. This group can be ideal for non- or lightly corrosive environments or applications where slight localised corrosion is acceptable. Type 409 was originally designed for automotive exhaust system silencers (exterior parts in non-severe corrosive environments). Type 410L is often used for containers, buses and coaches or LCD monitor frames.

Group 2 (type 430/1.4016) is the most widely used category of ferritic alloys. Having a higher chromium content, group 2 grades show greater resistance

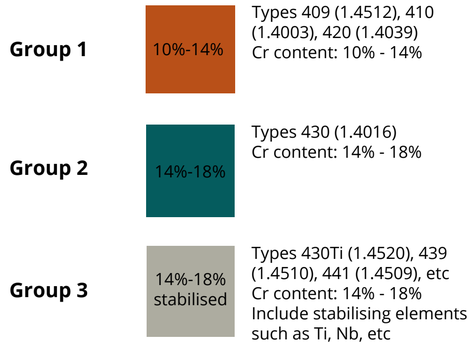


Figure 1 *Standard ferritic grades*

to corrosion and are often used as an alternative to the austenitic grade 304, mainly in indoor applications. Typical uses include washing machine drums, indoor panels, household utensils, dishwashers, pots and pans. For information on its welding characteristics, see p. 19

Group 3 includes types 430Ti/1.4520, 439/1.4510, 441/1.4509, etc. These grades have the same Cr content as group 2 and

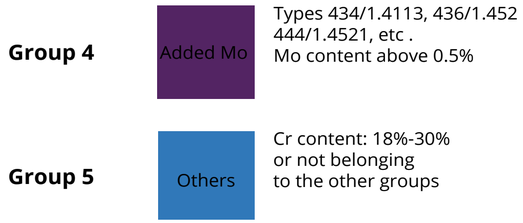


Figure 2 *Special ferritic grades*

the addition of stabilizing elements such as Ti, Nb, etc. and show better weldability and formability. Typical applications include sinks, heat exchanger tubes (for instance in the sugar industry or in energy generation), exhaust systems (with extended service life compared to their counterparts in type 409) and the welded parts of washing machines. Group 3 ferritic grades can often replace austenitic type 304 in applications in which the latter would be over-specified.

Group 4 includes types 434/1.4113, 436/1.4526, 444/1.4521, etc. These grades have added molybdenum, to improve corrosion resistance. Typical applications include hot water tanks, solar water heaters, visible parts of exhaust systems, electric kettle and microwave oven elements, automotive trim and outdoor panels, etc. The corrosion resistance level of type 4 can be similar to that of type 316.

Group 5 (types 446/1.4749, 445/1.4621 etc.) has additional chromium and contains molybdenum, for extra corrosion and scaling (oxidation) resistance. They are denominated as super-ferritic stainless steels and are superior to type 316 in respect of these properties. Typical uses include applications in coastal and other highly corrosive environments. The corrosion resistance of JIS 447 is equal to that of titanium metal.

Impressive references

Among the success stories of ferritic stainless steels, two typical applications stand out: automotive exhaust systems and washing machine drums.

Exhaust systems are exposed to high temperatures and corrosive conditions. The substitution of aluminised carbon steel for ferritic stainless steels means that today, the useful life of an exhaust system can be that of the car.

Washing machine drums must withstand detergents and a virtually constantly humid environment. Even slight corrosion would be unacceptable as it might stain or damage the textiles. Ferritic stainless steel ensures that the drum remains in pristine condition to the very end of the service life of a washing machine.

For manufacturers of these products, ease of fabrication and reasonable material cost make ferritic stainless steel an obvious choice.

Other current uses of ferritic grades range from kitchenware, barbecue grills and catering equipment to indoor furniture and decorative items, automotive trim, superheater and reheater tubes, burners, air-conditioning ducts, etc. Many new applications are waiting to emerge.

Today's high-quality ferritics

In the early days of ferritic stainless steels, the number of grades was limited. Today, stainless steel producers offer a large portfolio of alloying compositions tailored to specific and demanding applications.

Picture courtesy of Aperam, France

Progress in steel making and refining technology has added to the general performance level of these grades.

When ferritics became more widely available in the 1970s, they were sometimes naively substituted for general purpose austenitic grades like 304 without their specific in properties and fabrication requirements being taken into account. At that time, disappointing initial experience resulted in subdued acceptance of ferritics in demanding applications.

Solar Water Heater, Taiwan, China
Picture courtesy of Suncue Company Ltd. and Yieh United Steel Corp. (YUSCO), Taiwan, China

However, when historic peaks in raw material prices urged specifiers to reduce material cost, ferritic stainless steels met with renewed interest. Stainless steel producers invested in the development

of new ferritic grades with enhanced corrosion resistance and fabrication properties so they qualified for a wider range of applications. At the same time, accessible technical information and customer support led to ferritics becoming a fully accepted option within the spectrum of stainless steels. Bearing in mind that the various families of grades (austenitic, ferritic, duplex, martensitic, precipitation hardening) cover defined – and sometimes overlapping – ranges of applications, it is important to find out where ferritics perform best, and to adapt fabrication parameters to their intrinsic properties.

Fine for forming

In terms of formability, ferritic stainless steel is comparable to carbon steel. While it is less malleable than austenitic stainless steel, it is in many cases fully adequate. It is important to match the grade and the tooling according to the specific requirements.

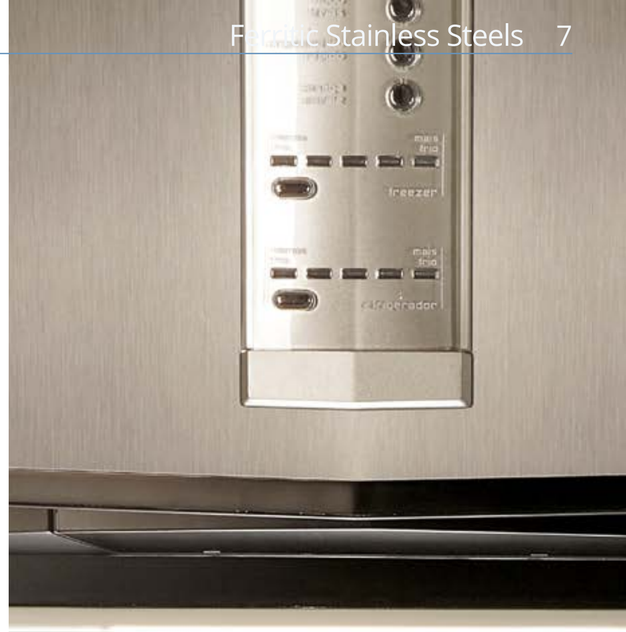
Proud to be magnetic

A widely held misconception is that because ferritics are magnetic they are not "real" stainless steels and will corrode like carbon steels. This is incorrect. Corrosion resistance is primarily a matter of chemical composition – in particular chromium content. It is totally unrelated to the magnetic properties, which depend on the atomic structure of the material.

Being both stainless and magnetic can be an asset: induction cooking only works with ferromagnetic materials. Clinging notes to a stainless steel fridge door or attaching stainless kitchen utensils to a magnet count among the many cases, in which magnetic properties are useful.

Specific technical advantages

Ferritic grades share the overall advantages of all stainless steels: corrosion resistance, aesthetic appeal, heat resistance, low Life Cycle Cost, full recyclability, biological neutrality and ease of fabrication. Compared to austenitic grades, they are lower in cost and they can even exceed their cousins in specific characteristics.



Ferritic Characteristics

- Ferritic stainless steels are magnetic.
- They provide excellent high-temperature oxidation resistance, which means that they are less prone to scaling than austenitics when heated.
- Niobium-stabilised ferritics are more creep resistant than austenitics and deform less under the long-term influence of mechanical stress.

These characteristics can be advantageous in design and fabrication. Independently of cost considerations, they can make ferritic grades the best choice for technical reasons.

Ferritics have higher thermal conductivity than austenitics, i.e. they transfer heat more quickly.

Their expansion is lower, i.e. they expand/ shrink less with temperature changes.

Springback is less marked in ferritics than in austenitics.

The yield strength of ferritics is higher than the popular austenitic grade 304 and similar to carbon steels.

Unlike most austenitics, ferritics are not prone to stress corrosion cracking under the combined influence of stress and chlorides.

2. Corrosion Resistance Properties

Stainless steels are “stainless” primarily because of their chromium content.

A comparison of the corrosion resistance properties of the five ferritic “groups” with those of austenitic type 304 shows that the corrosion resistance of nickel-containing (austenitic) types can often be matched by ferritic grades.

The Pitting Resistance Equivalent Number (PREN) makes it possible to rank grades in respect of their resistance to localised corrosion. It is calculated from the alloying content.

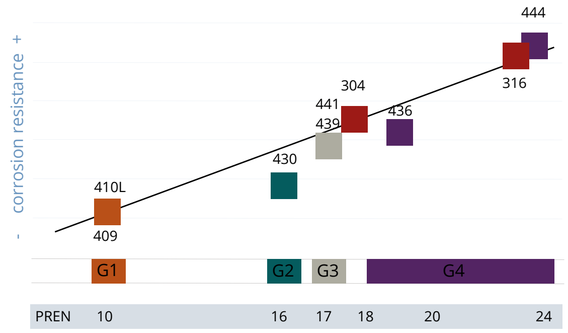


Figure 3 *Corrosion resistance of ferritic and austenitic grades*

Resistance to localised corrosion

Stainless steel applications are mostly maintenance-free but, in some cases, occasional maintenance (removal of deposits, for example) may be necessary, to ensure corrosion-free service. The corrosion resistance of stainless steels is determined by chemical composition rather than crystal structure (ferritic or austenitic). Indeed, in terms of resistance to corrosion, there is a broad area of overlap between ferritics and austenitics.

Figure 3 shows the relation between the PREN and the pitting corrosion resistance of austenitic and ferritic stainless steels.

Group 1 ferritics are best suited to non-severe conditions, such as indoor atmosphere (where the material is either not exposed to water or regularly dries). Outdoors, they are used in applications in which some superficial corrosion is acceptable and ferritic stainless steel is selected to ensure a longer service life than carbon steel.

Group 2 grades are effective in contexts involving intermittent contact with water, in non-severe conditions.

Group 3 grades are suitable for similar contexts to those appropriate for Group 2 grades but are easier to weld.

Partially 444 building cladding, Brazil
Picture courtesy of Aperam South America, Brazil

Group 4 ferritics are more corrosion resistant than austenitic type 304 and are suitable for a wide variety of uses.

Group 5 includes, for example, grades with a very high chromium content of around 29 % Cr plus 4 % Mo, which makes them as corrosion resistant in seawater as titanium.

The Pitting Resistance Equivalent Number

The pitting resistance equivalent number (PREN) is a measure of the relative pitting corrosion resistance of a stainless steel grade in a chloride-containing environment. The higher the PREN value of a grade, the more corrosion resistant it will be. The most common formula is

PREN = %Cr+3.3%Mo+16%N

Chromium (Cr) is an indispensable ingredient of stainless steel. While molybdenum (Mo) cannot replace chromium, it significantly boosts its effect: one extra percent of molybdenum increases pitting corrosion resistance as much as 3.3 percent of extra chromium. Even small alloying additions of Mo strongly enhance the corrosions resistance of a grade.

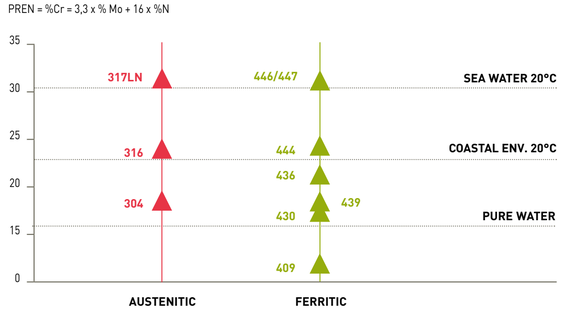


Figure 4 *PREN values of austenitic and ferritic grades*

It should be noted that nickel is absent from the PREN equation. Nickel serves as a process facilitator in certain fabrication techniques and is beneficial in specific corrosive environments; however, it does not per se determine the resistance of a stainless steel to localised corrosion.

Although PREN values are mainly used to rank grades within the same stainless steel family, figure 4 provides a broad idea of the relative corrosion resistance of austenitic and ferritic grades. It shows that for the most common austenitic grades 304 and 316, there are near-equivalent ferritic alternatives in terms of pitting corrosion resistance.

Avoiding corrosion

The passive layer of stainless steel depends on oxygen to remain intact. An accumulation of deposits can deprive the steel of oxygen at critical points and initiate corrosion. Further propagation of corrosion may lead to eventual failure of the part.

Corrosion sets in when pH reaches a critically low value (low pH = high acidity). The “pH” level is a unit of measure describing the degree of acidity or alkalinity of a solution. This is measured on a scale of 0 (acid) to 14 (based).

Atmospheric corrosion

This type of corrosion occurs on a steel surface, in the thin, wet film created by a combination of humidity in the air and pollutants such as chlorides in, e.g., coastal atmosphere or sulphur compounds in industrial environments.

Grade selection

Ferritic grades can be used in atmospheric environments of widely varied corrosive severity. All parameters concerning in-service conditions should be closely considered in selecting the appropriate

grade.

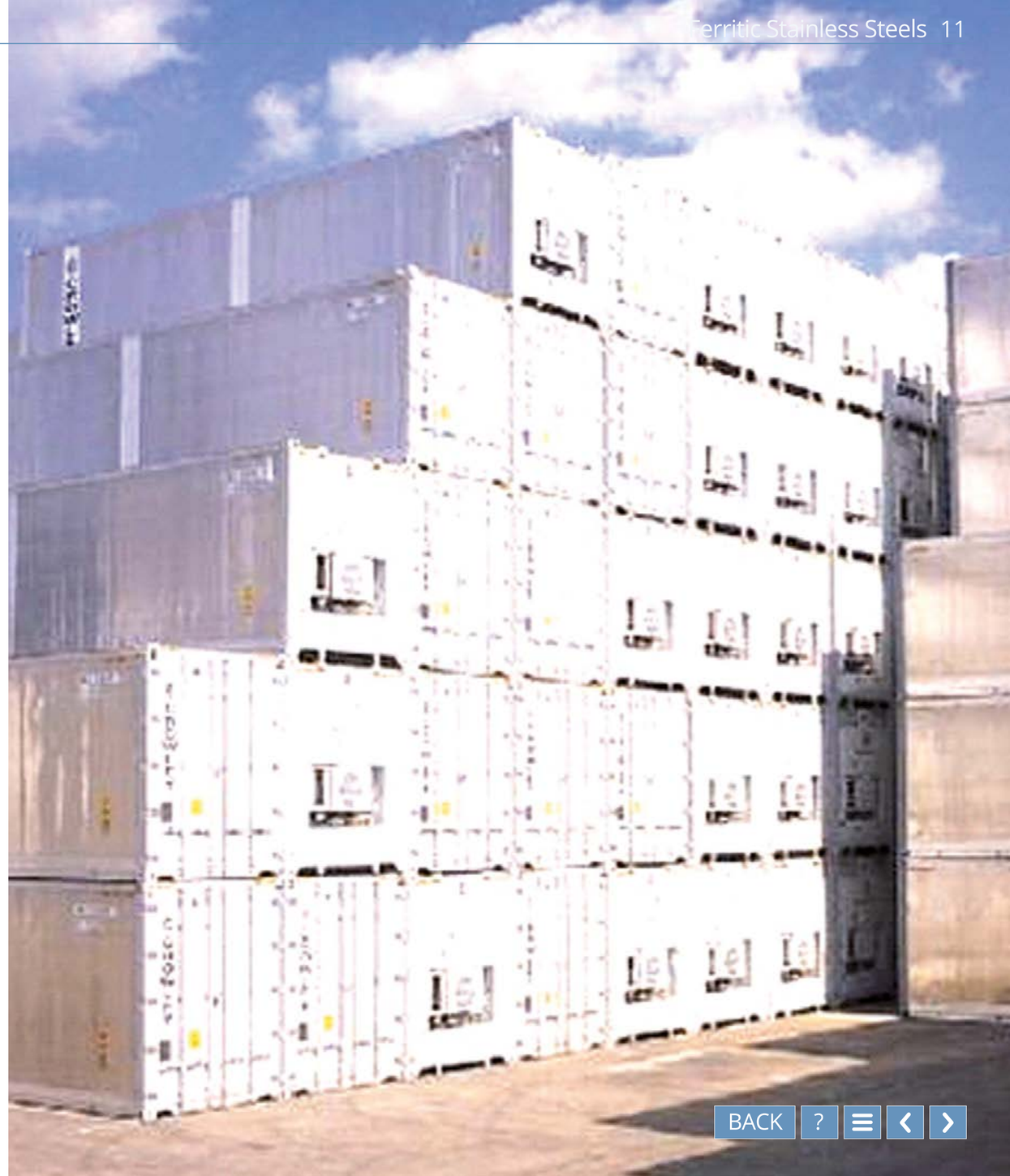
If slight localised surface rust (pitting corrosion), for example, is of no importance in a certain application or environment, a lower-cost grade might well be a fully appropriate material choice.

Oxidation resistance

Unlike the two above types of corrosion, which require the presence of humidity, high-temperature cyclic oxidation is “dry corrosion”. It occurs at high temperatures (> 500 °C) and in oxidising atmospheres, with or without thermal cycles.

When stainless steels are heated to such levels, a surface oxide, scale, will form. Although it is not comparable to the thin, invisible passive layer, it also has a protective effect insofar as it delays further oxidation. However, the scale having a significantly lower coefficient of thermal expansion than the bulk metal, it is prone to cracking and spalling when the metal cools and contracts.

Because of their lower coefficient of thermal expansion, ferritic grades will spall less than austenitic alloys. No spalling means no loss of substance and no further oxidation. This is why ferritic stainless steels are common materials for components of heating systems such as burners or automotive exhaust systems including manifolds.



3. Mechanical and physical properties

Ferritics have higher yield strength than austenitics, while their elongation and forming properties are similar to those of carbon steels. Their physical properties include two characteristics in which they excel austenitic grades: lower thermal expansion and higher thermal conductivity.

Mechanical properties

The mechanical properties of a metallic material determine how it compresses, stretches, bends, scratches, dents or breaks. The most commonly used criteria for evaluating mechanical characteristics include:

- **strength**: the degree of resistance of a material to deformation. Two critical values are generally considered:
  - yield strength, i.e. the stress that a material can be subjected to before permanent plastic deformation occurs
  - tensile strength, i.e. the stress it can be subjected to before failing
- **hardness:** the degree of resistance to indentation by an applied load
- **toughness**: the capacity to absorb deformation energy before breaking
- **ductility** (or plasticity): the ability to deform plastically without fracturing

Some of these properties can be measured by tensile tests. The resulting stress-strain curve maps the response of a material to various loads. Specifically, it provides information on yield strength (YS), ultimate tensile strength (UTS) and total elongation at failure (E).

ASTM A 240				JIS G 4305				EN 10088-2				
	R_m min	R_{p02} min	A_5 min		R_m min	R_{p02} min	A_5 min			R_m	R_{p02} min	A_{80} min
409	380	170	20	--	--	--	--	X2CrTi2	1.4512	380-560	220	25
410S	415	205	22	SUS 410	440	205	20	X2CrNi12	1.4003	450-650	320	20
430	450	205	22	SUS 430	420	205	22	X6Cr17	1.4016	450-600	280	18
434	450	240	22	SUS 434	450	205	22	X6CrMo17-1	1.4113	450-630	280	18
436	450	240	22	SUS 436	410	245	20	X6CrMoNb17-1	1.4526	480-560	300	25
439	415	205	22	--	--	--	--	X2CrTi17	1.4520	380-530	200	24
439	415	205	22	--	--	--	--	X2CrTi17	1.4510	420-600	240	23
441	415	205	22	--	--	--	--	X2CrMoNb18	1.4509	430-630	250	18
S44400 (444)	415	275	20	SUS 444	410	245	20	X2CrMoTi18-2	1.4521	420-640	320	20
304	515	205	40	SUS 304	520	205	40	X5CrNi1-80	1.4301	540-750	230	45

Table 1 *Mechanical properties (cold rolled flat products).*
This table expresses properties in terms of U.S., Japanese and European standards, comparing ferritic grades with standard austenitic 304. Rm = ultimate tensile strength, Rp02 = yield strength and A5/A80 = elongation to fracture.

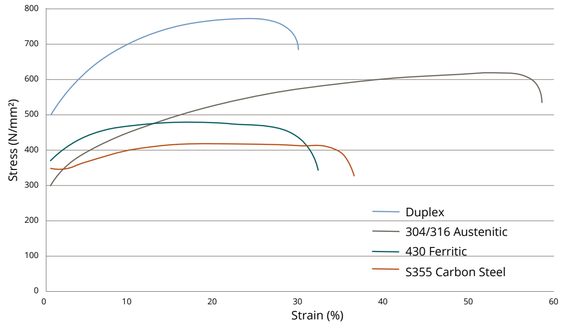


Figure 5 *Typical stress strain curves of stainless steels*

The stress-strain curves in figure 5 show that while ferritic grade 430 has its limits, it clearly performs exceptionally well within these limits.

Ferritic stainless steels have stress-strain curves fairly similar to those of plain carbon steels. With moderately high yield strength (generally higher than that of austenitics), moderately high ultimate tensile strength and good total elongation performance, they offer good ductility.

Physical properties

The physical properties of a metallic alloy concern the ability of the material to conduct heat, conduct electricity, expand or shrink, etc. Unlike austenitics, ferritics are magnetic. Also, the thermal conductivity of ferritics is much higher than that of austenitics. Depending on the application, both these properties can be useful. For instance, cookware from ferritic stainless steel does not require complex multi-layer bottoms to be suitable for induction cooking; in heat exchangers, ferritic grades can optimise efficiency.

The thermal expansion coefficient of ferritic stainless steels is similar to that of carbon steel and much lower than that of austenitic stainless steel. As a result, ferritics distort less when heated.

Type of stainless steel	Density	Electric resistance	Specific heat	Thermal conductivity	Thermal expansion coefficient		Young's modulus x10³
	g/cm³	Ω mm²/m	0 ~ 100°C J/kg • °C	100°C W/m • °C	0~200°C 0~600°C	10-6/°C	N/mm²
409/410 10%-14% Cr	7.7	0.58	460	28	11	12	220
430 14%-17% Cr	7.7	0.60	460	26	10.5	11.5	220
Stabilised 430Ti, 439, 441	7.7	0.60	460	26	10.5	11.5	220
Mo > 0.5% 434, 436, 444	7.7	0.60	460	26	10.5	11.5	220
Others 17%-30% Cr	7.7	0.62	460	25	10.0	11.0	220
304	7.9	0.72	500	15	16	18	200
Carbon steel	7.7	0.22	460	50	12	14	215

Table 2 *Physical properties*
The modulus of elasticity of ferritic grades (at 20°C) is superior to that of 304 austenitic.
IS units: g/cm3 = kg/dm3 – J/kg • °C = J/kg • °K – W/m • C = W/m • K –10-6/°C = 10-6/°K – N/mm3 = MPa.

4. Forming ferritic grades

Cold forming operations change the shape of strip or sheet products by subjecting them to plastic strain. The forming operation involves complex combinations of tensile and compressive loading, using both stretching and deep drawing deformation.

Although ferritic stainless steels do not reach the drawability of their austenitic counterparts, some ferritic grades, notably titanium-stabilised 17 % chromium grades, show excellent drawing performance, which is fully adequate for the intended end-use.

Stamped top and bottom of boilers, in grade 441, S. Africa.
Picture courtesy of SunTank, Pretoria, S. Africa

Sink, in grade 430, Japan.
Picture courtesy of Japan Stainless Steel Association (JSSA), Tokyo, Japan;

Drawing ferritic grades

Drawing is the process most commonly used for forming hollow objects from a flat sheet or "blank". The good drawing behaviour of ferritic stainless steels, coupled with their considerable price advantage, can make ferritics the optimum choice.

In the drawing process, shaping of the part is achieved by pressing a flat sheet blank into a die cavity, by means of a punch. The metal is drawn inwards, slipping between the die and the blank holder to form the walls or "skirt" of the part.

SUCCESSFUL DRAWING MEANS

- the absence of fracture
- excellent surface appearance
- minimum material consumption
- high fabrication productivity
- low tool wear

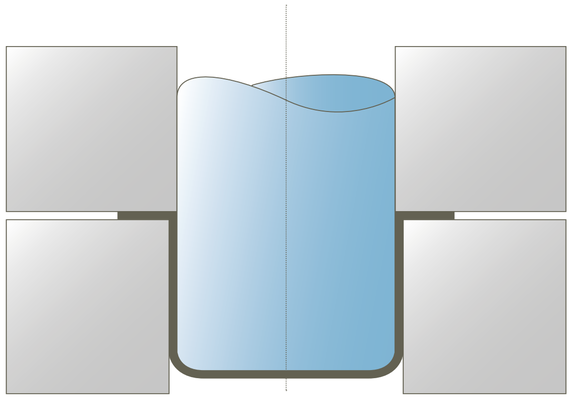


Figure 6 *Deep drawing*
The slipping effect differentiates "drawing" from the "stretch-forming" method, in which the blank is constrained by the blankholder.

The LDR factor

The limit drawing ratio (LDR) is an important deep-drawability parameter. It refers to the quotient of the maximum blank diameter (D) that can be deep drawn into a cylinder in one step and the diameter of that cylinder. LDR = D/d

Ferritics have higher LDR values than austenitics, which makes them particularly suitable for drawing.

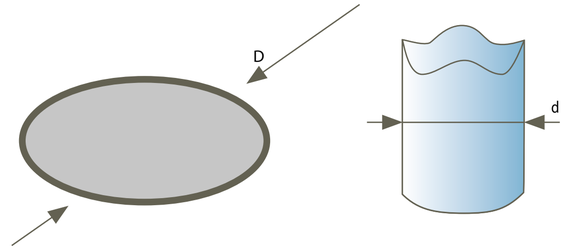


Figure 7 *Limit drawing ratio*

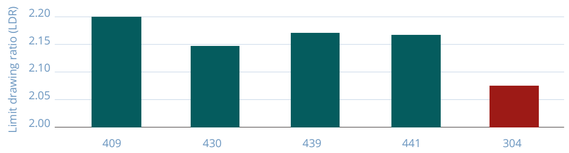


Figure 8 *Limit Drawing Ratio grade comparison*

Stretch-forming ferritic grades

Ferritic grades are inferior to austenitics in pure stretch-forming.

Figure 10 compares the stretching performance of various grades. “Dome height” refers to the maximum degree of deformation before “necking” (the phase just before failure) of a blank undergoing stretching.

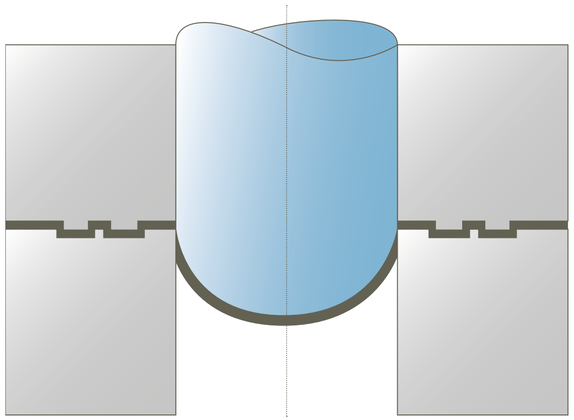


Figure 9 *In stretch-forming, the drawn area becomes thinner*

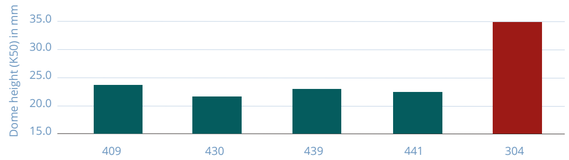


Figure 10 *Stretch-forming performance*
Dome height (K50) for different stainless steels

Forming limit curves

In practice, industrial forming operations involve a combination of both drawing and stretch-forming deformation, in a series of “passes”.

Forming limit curves are a useful guide to maximum deformation before failure, in both deep drawing and stretching processes. Established for the principal stainless steel grades, they can be used to

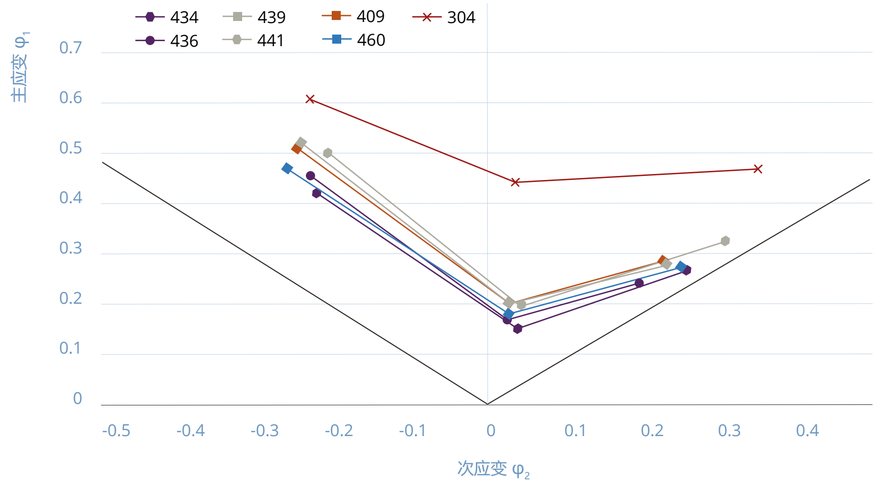


Figure 11 *Major and minor strain curves.*

With and without surface defect.
Pictures courtesy of Aperam, France

analyse a forming operation.

These curves define local deformations during and after forming in terms of two principal "true strains": longitudinal ("major strain") and transverse ("minor strain"). The curves plot the effects of the various combinations of these two strains, up to the point of fracture. The higher the position of its curve the better the formability of a grade.

Forming behaviour of ferritics

Generally, the work hardening and elongation characteristics of ferritic stainless steels are comparable to those of high-strength carbon steels. They are not the same as those of austenitic grades.

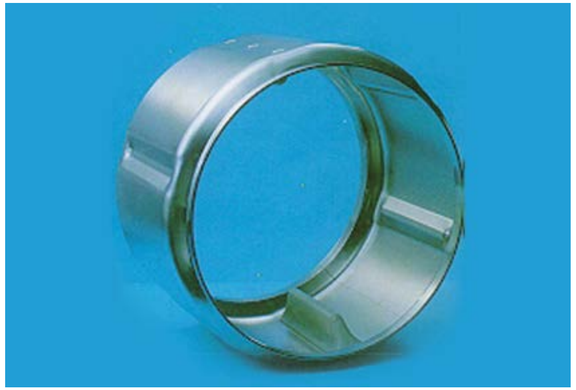
Design, construction and fabrication parameters and the material properties of the ferritic grade concerned must be considered together, in order to get the best out of the drawing process.

Stamped manifold, in grade 441.
Picture courtesy of Aperam, France

"Ridging"

After certain forming operations, ferritic grades may be prone to surface phenomena known as "ridging" and "roping".

These defects take the form of a series



Dryer drum: 409 welded sheet, formed by expansion.
Picture courtesy of Aperam, France

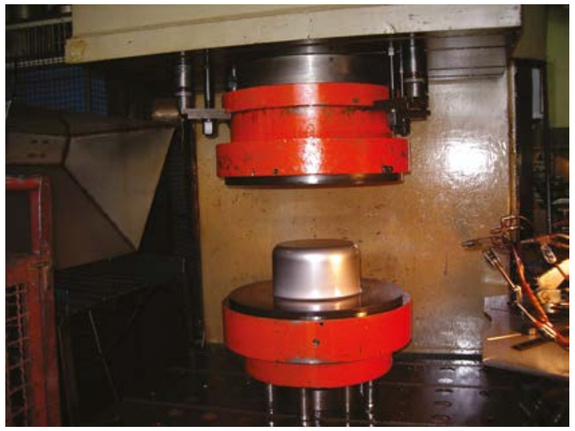
of lines or ridges, parallel to the sheet rolling direction. “Ridging” describes the overall profile of the deformed surface and includes both the microgeometry modifications and the “roping” undulations caused by the deformation.

The addition of a stabilising element, such as titanium, will bring improvement here. Titanium-stabilised grade 430 Ti produces remarkable results in this regard and is thus often chosen to replace an austenitic grade in applications involving deep drawing.

Lubrication

Good lubrication of the blank and the tooling is essential for successful drawing. It avoids altering the surface appearance and prevents sticking phenomena detrimental to tool life.

If ferritic stainless steels are delivered with a bright, smooth surface, a high viscosity drawing lubricant may be used. Dedicated lubricants for stainless steels are special oils that are pressure-resistant and only have a minimal chlorine content if any. Uniformly applied on the blank, they are easily removable from a stainless steel component after drawing.



Tooling

Using the right tooling is vital since it has a decisive influence on friction conditions and thus on metal flow during the forming operation. In special cases, tools (mould and die) can be made of copper, iron or aluminium bronze.

Surface treatments, such as a TiCN coating, may be applied, to increase the life of the tooling. The blank holder and die tools have to be carefully polished. The punch can remain rough.

Forming properties of the main steel groups

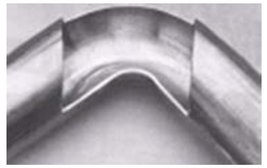
Table 3 compares the forming properties of ferritic stainless steels (which have a specific metallurgical structure and hence specific behaviour) to those of carbon steel and austenitic stainless grades. It uses standard criteria applied in defining deformation characteristics.

“Bcc” (body-centred cubic) and “fcc” (face-centred cubic) refer to the particular atomic structure of each type of steel.

	Carbon steels	Ferritic stainless steels	Austenitic stainless steels
structure	bcc	bcc	fcc
work hardening	low	low	high
springback	low	low	high
deep drawing	excellent	good	good
stretch forming	good	good	excellent
ridging	no	can occur	no

Table 3 *Comparison of the forming properties of different steels.*
"Bcc" (body-centred cubic) and "fcc" (face-centred cubic) refer to the particular atomic structure of each type of steel.

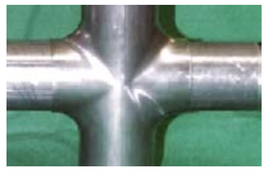
Pictures courtesy of Aperam, France; unless stated otherwise



Bending of 430Ti welded tube.

Deformation of the weld (1.4003).

Corrugated and finned heat exchanger welded tubes, in grade 439.



1.4003 hydroformed welded tube.

Welded bended tubes of a manifold, in grade 441.
Picture courtesy of Faurecia, Nanterre, France;

The case for ferritics

While the tables and curves show the overall superiority of austenitic stainless steels in terms of formability, the cost advantage of ferritic grades are such that they are often an alternative. Specifically, careful selection of the drawing method allows a remarkably wide use of ferritic grades. Indeed, in specific criteria – such as deep drawing or springback – ferritics behave better than austenitics.

Users should thoroughly discuss technical questions regarding the use of ferritic grades with a reputable material supplier. Stainless steel industry expertise is always available, to help users find ways to use ferritic grades successfully and to ensure that the most appropriate grade is chosen for any given application.

5. Joining ferritic grades

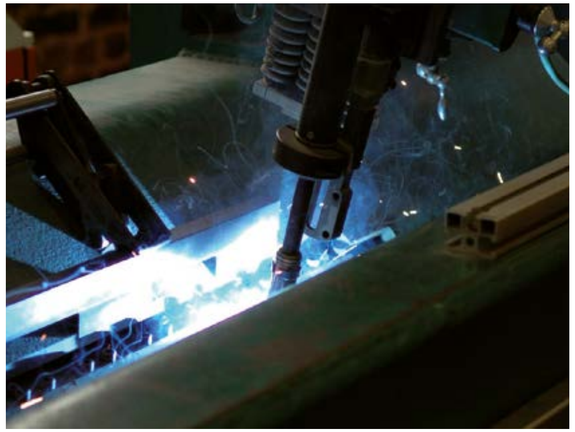
Ferritic grades are well suited to the common methods of joining stainless steels:

- **Welding**: the joining of two or more materials through melting and re-solidification of the base and filler metals
- **Soldering**: the joining of materials by heating them to soldering temperature (below the solidus temperature of the base metal) in the presence of filler metals with a liquid temperature lower than 450°C
- **Brazing**: the same as soldering; however, coalescence occurs at temperatures higher than 450°C
- **Mechanical joining**: includes clinching, seaming, riveting and mechanical fasteners
- **Adhesive bonding**: achieved by pressing clean, activated surfaces together after applying an adhesive that bonds under the influence of oxygen, water or through chemical reaction.

Welding

Many welding processes developed for carbon steels can be used with stainless steels. However, only a few of them are fully appropriate for stainless steels and have become standard: arc, resistance, electron, laser-beam and friction welding.

Welding is the most efficient and least costly way to join metals. The process is the basis for lightweight structures (through the optimal use of materials), is suitable for virtually all commercial metals and provides design flexibility.



Welding
Picture courtesy of Aperam, France;

The welding characteristics of stainless steels are determined by chemical composition, metallurgical structure and physical properties. Ferritic grades have some useful advantages over austenitics when it comes to welding, since they feature lower thermal expansion, lower electrical resistivity and higher thermal conductivity.

Stabilised and unstabilised ferritic grades

On average, ferritic stainless steels tend to be less prone than austenitic grades to the intergranular corrosion that can result from welding.

This is especially true of “stabilised” ferritic grades, which contain strong carbide formers, such as titanium (Ti) and niobium (Nb). These tie up the carbon in the steel, during the welding process, preventing it combining with chromium to form chromium carbide. With consequent chromium depletion at grain boundaries prevented, stabilised ferritic grades are virtually immune to intergranular corrosion.

To ensure complete stabilisation, Ti content must be five times greater than carbon content, or Nb plus Ti must be three times greater than carbon content.

Sometimes, the introduction of nitrogen into this formula can be advisable, to refine the grain in the melted zone.

Unstabilised ferritic grades contain no Ti or Nb and can therefore be susceptible to intergranular corrosion in the heat affected zone, due to chromium carbide formation. This effect is called “sensitisation”. Its extent depends mainly on the carbon level.

The corrosion resistance of sensitised steels can, however, be restored by annealing, at a temperature range of 600-800 °C.

Picture courtesy of Faurecia, Nanterre, France;

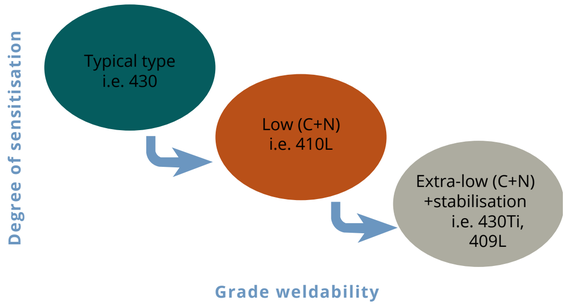


Figure 12 *Degree of sensitisation and grade weldability*

Overmatching filler metals

To ensure that a weld will be corrosion resistant, any ferritic filler metal used should slightly overmatch the composition of the base metal in terms of Cr, Mo, Ti and/or Nb alloying elements. This is because heating will tend to cause a loss of chromium in the weld zone. Alternatively, austenitic filler metal can be used, with an overmatch of Cr and Mo alloying elements.

Protective gases

Being high in chromium, stainless steels are highly oxidisable in the molten state. If they are not protected from air during the welding process, chromium will be lost and oxides will form, resulting in lack of soundness and decreased corrosion resistance in the weld. Protection of the

Exhaust system welding, grade 439, S. Korea.
Picture courtesy of Faurecia, Nanterre, France

weld surface and neighbouring area is usually ensured by the provision of an inert gaseous shield. This shielding gas can either be an inert gas of pure argon (Ar) or helium (He) or a mixture of Ar and He.

For the welding of ferritics, these shielding gases should be pure argon or argon-helium mixtures. Argon-hydrogen mixtures, often used for austenitic grades, bring a risk of hydrogen embrittlement in the weld joint, in the case of ferritic grades. Argon is the most commonly employed backing gas (protecting the rear of the workpiece). Nitrogen must not be used with ferritic grades.

Welded tank, grade 444, Europe.
Picture courtesy of Aperam, France;

Troubleshooting ferritic welding problems

As well as the risks referred to above, there can also be risks of embrittlement by “phase formation” and “grain coarsening” at high temperatures. Their solutions are listed in the following “remedies” table.

Stainless steel group	Special feature	Phenomenon	Cause	How to avoid
unstabilised grades	sensitisation	poor corrosion resistance in welded zone	Cr-carbide precipitation in grain boundary	annealing in temperature range 600-800°C
stabilised grades	grain coarsening	poor toughness in welded zone	excessive grain growth due to high temperature	minimising the heat input of welding
Cr from 15 %	475°C embrittlement	embrittlement occurs in the range from 400-540°C	decomposition of the matrix into 2 phases, one rich in iron, one rich in chromium	reheating at 600°C and cooling rapidly
high Cr-Mo grades	sigma (σ) phase embrittlement	embrittlement occurs at 500-800°C	sigma (σ) phase formation due to decomposition of delta (δ) ferrite	reheating above 800°C and cooling rapidly
unstabilised grades	martensitic phase embrittlement	embrittlement occurs in lower Cr and higher-C types	martensitic phase formation due to faster cooling	removing the martensitic phase by long annealing in the 600 - 700°C range

Table 4 *Welding ferritic steels: remedies*

Arc welding

Arc welding is the form of welding most commonly employed with ferritic grades.

Gas tungsten arc welding (GTAW or TIG welding)

In this process also known as the Tungsten Inert Gas (TIG) process the energy needed to melt the metal is provided by an electric arc between the tungsten electrode and the workpiece.

Stainless steels are always welded in the straight polarity DC mode (the electrode being the negative pole), under an inert atmosphere. If a filler metal is used, this will be in the form of uncoated rods (manual welding) or coiled wire (automatic welding).

Welded tank, grade 441, S. Africa.
Picture courtesy of SunTank, Pretoria, S. Africa

Gas Metal Arc welding (GMAW or MIG)

Unlike the GTAW process, in GMAW – also known as the Metal Inert Gas (MIG) process – the electrode is consumable. The arc is struck between the molten filler wire and the workpiece. The shielding gas, injected through the torch, around the wire, is usually argon with an addition of

Ferritic tube mill, Brazil.
Picture courtesy of Aperam South America

2 % to 3 % oxygen, though more complex mixtures may be used for certain welding modes.

Since the weld is essentially composed of filler metal, it is vital that the filler metal composition should promote penetration and perfect wetting of the base metal.

This high-productivity process is more difficult to perform than GTAW welding but results can be excellent when the process is well controlled.

Resistance welding

In resistance welding, an electric current is passed through the parts to be joined and welding is caused by resistance heating.

Several resistance welding techniques exist, the most common being spot welding and seam welding. In both cases, the major advantages of resistance welding are:

- the limited modification of the microstructure in the heat affected zones (HAZ)
- the virtual absence of surface oxidation if the sheets are correctly cooled

- the very low level of distortion of the sheets after welding and
- "forging" deformation during welding, which is particularly useful for the joining of ferritic steels.

Compared to the requirements of mild steel, the main differences in process parameters for stainless steel are in the lower and more precisely adjusted welding powers (due to low electrical and thermal conductivities) and higher electrode forces.

Welded structural frame in grade 1.4003.
Picture courtesy of Solaris Bus & Coach Co., Poland

Soldering a gutter, tin-coated grade 430Ti.
Picture courtesy of Brandt Edelstahldach GmbH, Cologne, Germany

Other processes

Other welding processes applicable to ferritic stainless steels include electron and laser beam welding and friction welding.

Soldering and brazing

Soldering and brazing are processes for joining metallic components in the solid state by means of a fusible filler metal that has a melting point well below those of the base metals. Soldering employs soft filler alloys with melting points below 450 °C, whereas brazing alloys are harder and melt at higher temperatures.

The advantages of these joining techniques include the following convenient features:

- They require only a low-temperature heat source.

Pickling, passivation and decontamination

The slight discolouration resulting from welding should be eliminated by either mechanical descaling or a chemical treatment called pickling.

Pickling is carried out in a fluonitric solution (10 % HNO_3 + 2 % HF) or using pickling pastes formulated especially for welds.

It can be followed by a passivation and decontamination treatment – to help the passive layer (see p. 64) reform quickly and remove organic metallic residues (iron-rich particles). The process involves immersion in a cold 20 % to 25 % nitric acid bath.

Local passivation of weld zones can also be carried out by means of special passivating pastes.

- Joints can be permanent or temporary.
- Dissimilar materials can be joined.
- The rate of heating and cooling is slow.
- Parts of varying thicknesses can be joined.
- Realignment is easy.
- They require less heat than welding.

In deciding on the suitability of soldering or brazing for a specific structural joint, care should be taken to evaluate carefully the strength or performance required of the joint. In all cases, while carrying out the joining, it is essential to ensure perfect wetting of the two solid parts by the molten filler material.

Before and after pickling.

Brazing welded tubes, grade 441.

Pictures courtesy of Aperam, France;

Sensitisation will occur more readily in the case of unstabilised grades.

Mechanical joining

Mechanical joining techniques used for carbon steels can be equally successfully used with stainless steels.

Mechanical joining has certain advantages:

- Dissimilar materials can easily be joined
- There is no heat-affected zone (HAZ).
- Parts of varying thicknesses can be joined

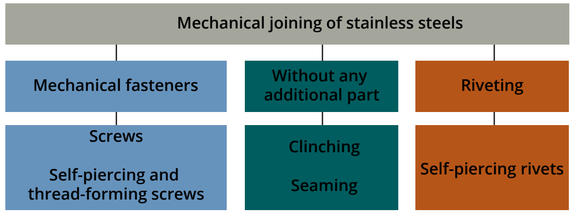


Figure 13 *Mechanical joining of stainless steels*

- There is no thermal expansion.

Consideration should, however, be given to the fact that the mechanical properties of mechanical joints may have certain weaknesses, since there is no complete coalescence of the joining partners. The joining operation method may also require two-side access.

It is vital to prevent intermetallic corrosion, which can result from galvanic coupling. To avoid this risk, parts to be joined should preferably be made from the same stainless steel or equivalent grades. It is important to ensure that any screws, bolts, fasteners or rivets are also stainless steel.

Screwing and bolting

Stainless steel screws and bolts are available in all the principal grades. While 17 % Cr ferritic grades are best suited for use in only mildly aggressive environments, their corrosion resistance in chloride-containing media is enhanced by the addition of 1 % to 1.5 % molybdenum.

Riveting

This technique is always carried out at ambient temperature, using rivets of a maximum diameter of about 5 mm. It is strongly recommended that joints be designed in such a way that the rivets are loaded in shear rather than in tension.

Clinching

This relatively recent joining technique can be readily applied to stainless steels, thanks to their high ductility. Involving a cold forming process, it causes no structural modification or surface oxidation.

Since the sheets to be joined must overlap, clinching is usually combined with adhesive bonding. The process produces a hermetically sealed joint that avoids the risk of crevice corrosion and can also absorb vibrations.

Seaming

Exploded display of washing-machine interior. Picture courtesy of ThyssenKrupp Nirosta GmbH, Krefeld, Germany;

In this mechanical sheet-joining technique, the edges of one or both of the sheets concerned are bent through an angle of 180° to produce a tight seam. As with clinching, different materials can be joined – for example, an austenitic and a ferritic grade.

Perfectly leak-proof joints can be achieved with this technique, which is widely used in the manufacture of domestic appliances.

Adhesive bonding

As mentioned above, adhesive bonding can be employed to reinforce mechanical joints. However, it is in itself an appropriate joining technique for thin sheet metal, providing a number of advantages:

- There is no modification of the surface appearance, geometry or microstructure of the assembled areas.
- Dissimilar materials can be joined easily, also in aesthetically demanding applications.
- Correctly designed, joints can have excellent fatigue strength. The method can provide thermal, electrical or acoustic insulation.
- Parts of varying thickness can be joined.

Bonding of guttering, tin-coated 430Ti. Picture courtesy of Willem de Roover, Ghent, Belgium;

Picture from Inossidabile Magazine, courtesy of Centro Inox, Milan, Italy

Products and applications

Ferritics are often associated with decorative trim, sinks and car exhausts. Their actual and potential usefulness extends far beyond these confines.

Ferritic stainless steels are straight chromium steels, without alloying additions of nickel. They resist corrosion and oxidation, are highly resistant to stress corrosion cracking, are usefully magnetic and offer a host of other technical, aesthetic and practical advantages. They often prove better value in the long run than carbon steel and are significantly less costly than their nickel-containing, austenitic cousins.

Ferritic stainless steels have the potential for further market penetration. The following pages show something of the range of possible uses of these materials. The chapter covers applications from many sectors of the market and many parts of the world.

Wynyard Walk, Sydney Australia. 445M2 ferritic stainless steel. Picture courtesy of ASSDA.

Transportation

Automobile exhaust systems
Motorcycle exhaust
Automobile decorative trim or bright strip
Automotive fuel union component
Automobile fuel tank
Traffic sign
Turbine Housing (CK-SMiTH)
Exhaust Gas Recirculation Cooler for Gasoline Engine Vehicle
Bipolar plate for hydrogen fuel cell vehicle
Truck trailer body
Railway wagons
Biomass wagons
Core for Automobile fuel pumps
Cladding of a refurbished tunnel

Picture courtesy of Columbus Stainless

Automobile exhaust systems

Grade:	AISI 441, 439, 436 B444LM B425NT/B432

Grade 441, 439, 436
Picture courtesy of the Stainless Steel Council of China Iron and Steel Association

Grade: B425NT/B432
Picture courtesy of the Stainless Steel Council of China Iron and Steel Association

Grade B444LM
Picture courtesy of the Stainless Steel Council of China Iron and Steel Association

Ferritic stainless steels are extensively used for the exhaust systems of gasolin cars. Characteristics and applications of steel grades: Cr18-NbTi, Cr18-Ti, Cr18-Mo-Ti, with good high temperature resistance, corrosion resistance, forming and other properties, used in automotive exhaust systems and other fields.

Source: Stainless Steel Council of China Iron and Steel Association

Motorcycle exhaust

Grade:	AISI 441

Solfer Srl is one of the most important Italian producers of exhaust silencers, which are supplied to the major motorcycle manufacturers. The need to cut costs while keeping the technical performance of materials unchanged, has led the manufacturers of exhaust systems to use ferritic stainless steels in place of traditional austenitic steels. Ferritic steels do not contain nickel, and consequently, they are not subject to the problems related to price volatility, but obviously contain chrome, an essential element which ensures their corrosion resistance properties. Among the alternative ferritic steels available in the market, grade 441 is a material in a position to guarantee high level performance, both in terms of corrosion resistance and in terms of mechanical characteristics, and represents one of the most effective replacements of EN 1.4301 (AISI 304) stainless steel in the automotive industry. Lately, the company started a project aimed at completely replacing AISI 304 with ferritic 441 grade stainless steel, which could be successfully completed in a 6-month time span, and provided for a number of tests, which confirmed the perfect suitability of this new ferritic grade to the production of exhaust systems.

Picture from Inossidabile Magazine, courtesy of Centro Inox

Source: Centro Inox

Automobile decorative trim or bright strip

Grades:	436D
	J442D, J346D
	B442M/B436M

Car decoration strip refers to the application in high-end fuel car or electric car body appearance decoration and interior decoration strip materials, including the side of the car body and the windows, handlebars and inlet around the outer water cut decoration strip, exposed to the outside of the vehicle is called exterior trim, used for the interior decoration is called interior trim. The stainless steel bright surface material used represents the highest surface quality level of stainless steel, which is called “zero-defect product”.

The steel has excellent atmospheric corrosion resistance (industrial atmosphere, coastal atmosphere, volcanic atmosphere, etc.), good halogen ion point corrosion resistance, excellent intergranular corrosion resistance, excellent cold forming and cold forming wrinkle resistance, fine and smooth surface, and has great potential for deep surface processing.

The typical use is in water cut decorative strips inside and outside the windows of high-grade cars.

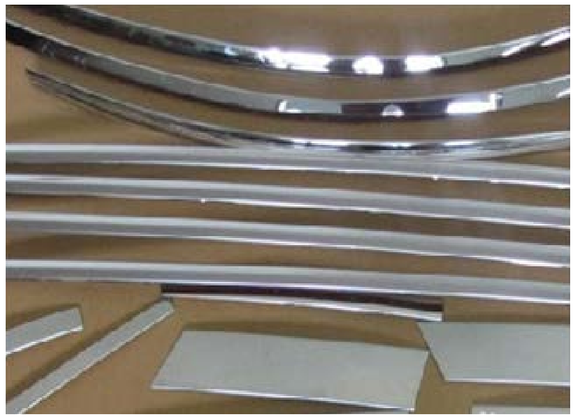
Source: Stainless Steel Council of China Iron and Steel Association

Grade 436D
Picture courtesy of the Stainless Steel Council of China Iron and Steel Association

Grade: J442D, J346D
Picture courtesy of the Stainless Steel Council of China Iron and Steel Association

Grade B442M/B436M
Picture courtesy of the Stainless Steel Council of China Iron and Steel Association

Grade 436D
Picture courtesy of the Stainless Steel Council of China Iron and Steel Association



Automotive fuel union component

Picture courtesy of the Japan Stainless Steel Association

Grade: equivalent to SUS410J1L

Automobile fuel tank

Grade: B425FT

B425FT is Nb-bearing ultrapure ferritic stainless steel. The product has high corrosion resistance and formability. It is suitable for automobile fuel tank parts without coating treatment.

Source: Stainless Steel Council of China Iron and Steel Association

Picture courtesy of the Stainless Steel Council of China Iron and Steel Association

Traffic sign

Grade: SUS430

In Japan, the material of choice for traffic light fittings has been aluminum. With the introduction of LED lights, there has been a need to consider a replacement for existing fixtures. Kyosan Electric Manufacturing Company noted the price stability of ferritic stainless steels and researched the technology development of this material, leading it to specify ferritic grade 430 for its new generation traffic lights. Using deep-drawing technologies, coupled with the improved formability of ferritic stainless steels, the developer has succeeded in forming complex sharply-bent sections, enabling him to produce

Picture courtesy of the Japan Stainless Steel Association

similar fixtures while using stainless steel. The material change created new demand for stainless steel and it is anticipated that this application will increase to 10,000 units per year in the future and continuous use of stainless steel for this application can be expected over the coming years.

Source: Japan Stainless Steel Association

Turbine Housing (CK-SMiTH)

Grade:	heat-resistant ferritic stainless steel

A conventional turbine housing has a comparatively high heat capacity, because it is made of a solid layer of high heat resistant cast iron. Therefore, when the system starts at a cold temperature, it takes a long time until the temperature of the exhaust gas rises to the activation temperature of the purification catalyst system.

Calsonic Kansei Corporation has focused on this issue and has developed a new turbine housing system for diesel engines - “CK-SMiTH”, which has replaced conventional cast iron with stainless steel sheet material. The CK-SMiTH has a dual

Picture courtesy of the Japan Stainless Steel Association

layer structure, of thinner press-formed stainless steel sheet materials, to reduce its weight and heat capacity. The reduced heat capacity leads to shorter activation time for the exhaust purification catalyst system from a cold start. In addition, an air layer within this dual structure improves its heat retention, and this high heat retention can extend idling stop time, because heat loss is reduced during engine stoppage. Furthermore, thanks to the reduction in heat loss to external systems, there is an efficiency of the turbine, even after warm up.

Picture courtesy of the Japan Stainless Steel Association

Thus, thanks to these advanced characteristics, the CK-SMiTH results in reduced fuel consumption and a higher performance in exhaust efficiency. Given the stringent requirement against with environment pollution, turbocharger systems have been, and will continue to be used, to ensure the high performance of diesel engines while reducing their environmental impacts. In addition, the requirement to have high durability at higher exhaust gas temperatures is expected to increase in the future, particularly in the field of gasoline engine systems, and the technology of the CK-SMiTH also can be adopted in high-performance system for gasoline engines.

Finally, using thinner press-formed sheet materials in turbocharger systems contribute to the expansion of the stainless steel market, and is also expected to encourage improvements in fabrication technology.

Exhaust Gas Recirculation Cooler for Gasoline Engine Vehicle

Grade: SUS430J1L, SUS444, j444e, EN 1.4521 (K44X) /2D

Pictures courtesy of the Japan Stainless Steel Association

An EGR cooler reduces the generation of NOx in the combustion process by reducing the instantaneous high temperature during combustion in the engine, so as to reduce emission pollution. EGR cooling technology can reduce the fuel consumption of gasoline engine by 2 ~ 6%. An EGR cooler is composed of metal parts called heat sink in the outer cylinder, diaphragm, vent pipe or further vent pipe. These parts are joined by brazing. Its service environment is relatively harsh, and the materials are required to have good high-temperature performance, low coefficient of thermal expansion, excellent molding performance, excellent corrosion resistance and welding (brazing) performance in the service process.

Source: Stainless Steel Council of China Iron and Steel Association

Picture courtesy of Aperam

Pictures courtesy of the Stainless Steel Council of China Iron and Steel Association

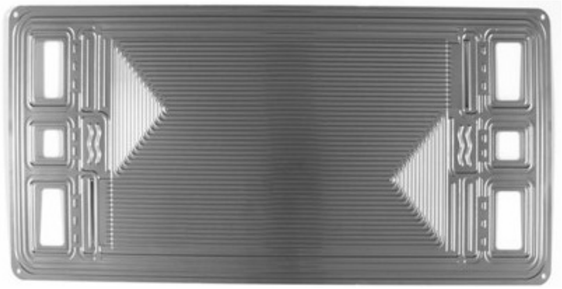
Bipolar plate for hydrogen fuel cell vehicle

Grade: Poss470FC

Fuel-cell vehicles are attracting attention as the ultimate eco-friendly car as they solve the problem of mileage and charging time, which are the shortcomings of electric cars. Through joint development with Hyundai Motor (2013~2017), POSCO has created a new market for stainless steel in the fuel cell vehicle sector by developing a non-coated super-ferritic stainless steel, Poss470FC, for the bipolar plates of fuel cell stack. Poss470FC has been commercially applied in Hyundai Motor's fuel cell vehicle, NEXO, which comes on the market in March, 2018, with world top performance of mileage per charging, 609Km and charging time of 5 min.

Fuel cell converts the chemical energy of electrochemical reaction of hydrogen and oxygen into electricity. A bipolar plate is a multi-functional component in the fuel cell stack, which connects and separates unit cells, aids uniform distribution of reaction gases and collects electrical current from each unit cells. Bipolar plates comprises 60~80% of the whole weight and 30~40% of the total production cost of the fuel cell stack.

The material used for bipolar plates should be excellent in corrosion resistance and electrical conductivity. The developed Poss470FC stainless steel has an alloy design that ensures excellent corrosion resistance and world-top electrical conductivity without any additional coating process. As to the superior conductivity, instead of complex and expensive coating process, relatively simplified chemical reforming procedure could remarkably enhance the surface conductivity of Poss470FC that it is equal to or better performance than that of C-coated Ti.



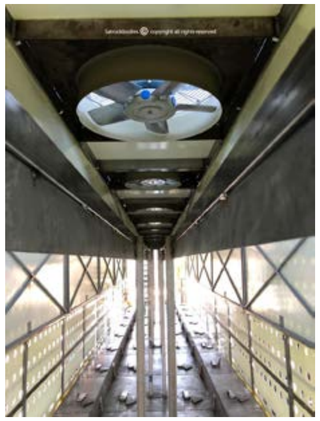
Picture courtesy of POSCO

With the advent of this competitive bipolar plate, the cost of stack manufacturing has been reduced, contributing to the potential expansion of fuel cell vehicles. The innovation of uncoated fuel cell separators not only eliminates the threat of scaling down the stainless steel exhaust system due to the reduction of internal combustion engines, but also provides new market opportunities. For example, whereas the consumption of stainless steel on exhaust system in internal combustion engines is 20~25kg per vehicle, the amount of material requirement for bipolar plates might up to 80kg per vehicle.

Source: POSCO

Truck trailer body

Grade: 3Cr12



3Cr12 is successfully used in wet sliding abrasion conditions and materials handling applications in the agricultural, mining and power generation industries. It is widely used in the transport industry, finding applications in passenger vehicles, rail freight wagons and coaches, trailers, trucks and cars. In industrial structural applications, 3Cr12 is used for walkway

Picture courtesy of Columbus Stainless

systems, cladding and roofing, piping, cable racking, electrical enclosures and utility bridges. It is also used in water and sewage treatment applications.

By using 3Cr12 in the body of the truck trailer, Byrne Trailers has reduced the tare weight of their vehicles; they are 250 times more corrosion resistant than carbon steel, they need less maintenance, and finally their products are cost effective.

Railway wagons

Grade: T4003

The typical composition of the grade used is Cr12.0%-Ti0.15%-Ni0.8%, with excellent toughness, welding performance and corrosion resistance; it is mainly used in the field of railway freight cars.

Source: Stainless Steel Council of China Iron and Steel Association

Picture courtesy of the Stainless Steel Council of China Iron and Steel Association

Biomass wagons

Grade: 3Cr12

For transporting pelletized biomass from the ports of Tyne, Hull and Immingham to the Drax power station in North Yorkshire, ferritic stainless steel wagons are used.

3Cr12 Stainless steel was chosen for the wagons due to its higher corrosion resistance and reduced friction to mild steel.

Picture courtesy of Columbus Stainless

Core for Automobile fuel pumps

Grade:	DIN 1.4512 - UNS S40920/2D

Ferritic grade 1.4512 (equivalent to 409) stainless steel is now being used to manufacture the core of fuel pumps which have historically been made from tin plated steel. The advantage of using stainless steel is that the fuel pump cores no longer need the extra surface treatment that was necessary when using tin plated steel, resulting in a saving of time, logistics and cost. Being a ferritic stainless steel, the cost structure is relatively stable.

Picture courtesy of Aperam South America

Building and construction

Cladding of a refurbished tunnel
Masts of the Moreland Bridge
Kelso Station Pedestrian bridge
Basic packing for wooden houses
E-houses
Salt-tolerant pole transformer
Roofing:

- International terminal at Tokyo Haneda Airport
- Qingdao Jiaodong International Airport
- Ritz-Carlton Hotel, Kyoto
- Japan National Stadium

Solar panels
Solar system with stainless steel mounts
Metal Attachments for Solar Panels
Solar water heaters
Primary Heat Exchanger Pipes for Water Heater

Façade cladding:

- Nagoya Science Museum
- Fukuoka Bar Association Hall
- Senzoku Gakuen
- GINZA Six Building
- Incheon Songdo Convention Center
- Allianz Park Palmeiras Stadium
- Clad Family Apartments
- Raw Material Yard
- Elevator Panels
- Nakameguro Ventilation Plant
- Railway Bridge in Tokyo
- Nou Bridge
- Wynyard Walk
- Water tank panels in Shanghai Tower
- Metal fixings for wire systems
- Fractal - stainless steel tiles

Toriide Naruto (metal roof)
Picture courtesy of the Japan Stainless Steel Association

Cladding of a refurbished tunnel

Picture from Inossidabile Magazine, courtesy of Centro Inox

Grade: 430 (EN 1.4016)

The refurbishment of a 283 meter-long road tunnel in the mountainous area of the Aosta Valley involved the installation of a new cladding. As a material, colour-coated stainless steel was specified. The stainless steel substrate served to ensure long-term corrosion resistance, especially in view of the inevitable exposure of the rear side of the sheet to humidity. On the front side, reflective metallic surfaces had to be avoided to prevent glare. In-line colour coated stainless steel fulfilled both these critical requirements. The proven ferritic 17 % chromium grade 430 (EN 1.4016) was a cost-effective solution. The selected colour, white, spread the light evenly without causing glare. The chemical composition of both the primer and the coating ensured that no toxic gases could develop even in the case of fire. Installation was fast and efficient, making it possible to complete the refurbishment within two months.

Masts of the Moreland Bridge

Picture courtesy of Columbus Stainless

Grade: 3Cr12

The Moreland Millennium Bridge is an iconic bridge which was commissioned in 1999 by the Durban Roads Department to be built over the M41 highway in Umhlanga Rocks. It is located in Durban, South Africa, approximately 1 km from the coastline. To ensure its longevity, the architects decided to build the structural components in stainless steel. Grade 304 was specified for the structural tubing and 3CR12 for the vertical masts.

Due to budgetary constraints at the time of construction; the hand rails at street level were specified in galvanized steel. All the metal work was painted white, not only to enhance the desired aesthetics but also for corrosion considerations due to the applications proximity to the shoreline.

Over the years, regular flaking of the paint on the galvanized railings, due to paint damage and under-film creep, has resulted in significant corrosion, necessitating repainting on numerous occasions. The painted stainless steel, including 3CR12 structures, have shown no evidence of corrosion, even where damage to the paint has occurred. This application has highlighted the superior paint adhesion of stainless steel compared to galvanized steel in coastal applications.

Kelso Station Pedestrian bridge

Picture courtesy of Columbus Stainless

Picture courtesy of Columbus Stainless

Grade: 3Cr12 rebar

In South Africa, the failures attributed mainly to the corrosion of the rebar are prevalent along the coast and are mainly attributed to wind-borne salt carried inland due to strong prevailing winds. A classic example is of a series of pedestrian bridges installed on the KwaZulu Natal south coast. The location of the bridges span rivers at their outflow into the sea, therefore the bridges are exposed throughout their existence to regular heavy spray from breaking waves during onshore and alongshore winds. These bridges were constructed in the 1950s using concrete reinforced with uncoated mild steel rebar.

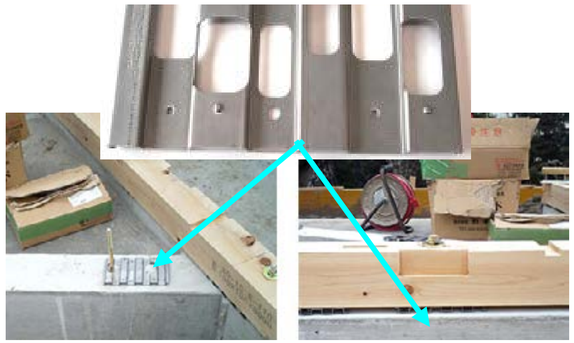
Over the course of the years, severe spalling and falling concrete was experienced. During the course of the mid 1990's, after 40 years in service, an extensive and expensive rehabilitation process was embarked on to repairs the structural integrity and safety of these bridges. Due to extensive catastrophic failure of the existing bridges, 3Cr12 reinforcing bar was proposed.

A series of bridges were installed along the coast, following the success 5 years of research in accelerated corrosion conditions. Examination of these bridges after 20 years in service reveals that 3Cr12 rebar has demonstrated itself to be economically viable in this application, even in this harsh marine environment.

3Cr12's self-repairing characteristics of the chrome oxide layer means the corrosion protection integrity is maintained even if mechanically damaged during handling. The advantages received are high strength, less maintenance and lower life cycle cost compared to the conventional carbon steel reinforced structure.

Basic packing for wooden houses

Grade: 12% Cr steel



Picture courtesy of the Japan Stainless Steel Association

E-houses

Picture courtesy of Columbus Stainless

Turnkey Modular have developed a fabrication technique that exploits the infinite flexibility and exceptional accuracy of building components that are laser cut and CNC bent from sheet metal. This technique has completely displaced the requirement for any structural steel in any of their structures. The structures rely on the inherent strength within individual components to form an exceptionally strong exoskeleton structure.

Grade: 3Cr12 HRA

This has made the product extremely scalable without the need for skilled artisans. The intelligence now resides within each component – making the fabrication process a simple assembly process. Reliability, accuracy and repeatability in this method are unprecedented when compared to traditional large structure fabrication. 3D design and finite element analysis have allowed for optimal structural elements originated from flat sheet metal. The technique has allowed for the building fully compliant blast rated structures in the oil and gas field with surprisingly reduced amounts of steel reinforcing.

Salt-tolerant pole transformer

Grade: SUH409L, SUS410L

Picture courtesy of the Japan Stainless Steel Association

Roofing

Grades:	SUS445J2, B445J2, hot-dip galvanized SUS430 (toughten Z), SUS443J1

Ferritic stainless steels have an excellent corrosion resistance for roofing, in combination with the low thermal coefficient and the good weldability, they are ideal for this application, even in marine environments.

Grade SUS445J2 was used for the roofing of the **International Terminal at Tokyo Haneda Airport**. In addition to its excellent properties, stainless steel was also chosen because the roof is visible to all airport users and it was therefore important to specify a material which would retain an attractive appearance throughout the useful life of the building.

Also for the **Qingdao Jiaodong International Airport** a welded stainless steel roof was chosen. The grade used was B445J2. The stainless steel plates are 0.5 mm thick.

Roofing of the International Terminal at Tokyo Haneda Airport
Picture courtesy of the Japan Stainless Steel Association

Roof of The Ritz-Carlton Hotel Kyoto
Picture courtesy of the Japan Stainless Steel Association

Toriide Naruto (metal roof)
Picture courtesy of the Japan Stainless Steel Association

Qingdao Jiaodong International Airport welded stainless steel roof (stainless steel thickness 0.5mm)
Picture courtesy of the Stainless Steel Council of China Iron and Steel Association

"Perfect Roof" of High-purity Ferritic Stainless Steel (SUS443J1)
Picture courtesy of the Japan Stainless Steel Association

The roof of the **Ritz-Carlton Hotel** in Kyoto, was patterned according to Japan's traditional building technique of Sukiya-construction and the ferritic SUS445J2 sand-blasted stainless steel provides a "mattlooking finish". The parties concerned worked and succeeded in sandblasting the ferritic roofing stainless steel of 0.4 mm in thickness, which had been previously deemed difficult.

The **Japan National Stadium** was designed as a high quality, long-life facility to last 100 years. In order to realize this designing concept, coated ferritic stainless steel has been adopted by the companies involved for finishing material of the stadium roof. The substrate grade is SUS445J2 with small thermal expansion and strong corrosion resistance, which is finish- coated with fluorine resin.

For suppressing the temperature increase caused by solar radiation, fluorine resin has been selected as it offers the highest level of whiteness and durability in the pre-coating materials. At the time of construction, the welding process of "stainless steel water-proofing method" was optimized to reduce the material loss and shorten the work period.

Japan National Stadium (roof)
Picture courtesy of Japan Stainless Steel Association

The adoption of stainless steel at the National Stadium, a model structure to last long and harmonize with nature, is expected to be a significant contributor for boosting stainless steel demand in the future.
Stainless steel type used: SUS445J2 (Finish-coated with fluorine resin)
Consumption: Approx.120,000 kg

Source: Japan Stainless Steel Association

Solar panels

Grade:	NSSC FWR Series (equivalent to SUS430LX)

For the Steel-Container-Type Solar Panel Stands, steel containers containing heavy materials such as stones, earth and sand are installed on the ground as the panel mounting base. Therefore, it is possible to install a solar power generation system regardless of the ground environment and conditions.

Since the site where the container was installed is located a few hundred meters from the Pacific coast, stainless steel containers made of NIPPON STEEL Stainless' resource-saving stainless steel (SUS430LX class NSSC FW series) have been used for the first time in consideration of corrosion resistance and durability. In the construction method using steel containers where stainless steel suitable for the environment can be freely chosen, it is possible to install a solar power generation system in an environment or area where it was previously difficult to install by the conventional method. Demand for such a method using stainless steel is expected to increase.

Foundations for Solar Panel Mounts
Picture courtesy of the Japan Stainless Steel Association

By applying resource-saving stainless steel together with a solar power generation system, which is a renewable energy source, this method has greatly contributed to reducing the social environmental impact.

Solar system with stainless steel mounts

Grade:	SUS443J1 2B

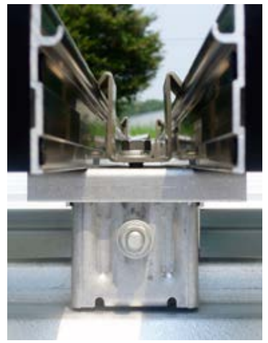
The Premium SUS Solar System, is a solar panel installation that does not require holes to be made in the roof, thus avoiding problems associated with leaks. It can be quickly and easily installed using stainless steel mounts. The principle behind this system is supporting the weight of the solar panels not on particular points but on the entire face of the mount so as to spread the load burden across the surface of the roof. Furthermore, the system allows for power generation even from the underside of the panels, using the reflection of scattering light. With a number of features which optimise the advantages of stainless steel as a construction material, significant cost

Premium SUS Solar System with Stainless Steel Mounts
Pictures courtesy of the Japan Stainless Steel Association

reductions have been achieved. To extend the life of the system, the mounts are made entirely from stainless steel, thus eliminating deterioration associated with corrosion, particularly in aggressive coastal environments. A ferritic grade was selected in order to manage the distortion problems commonly linked to long spans and a 2B finish was specified to raise the reflection efficiency of the underside of the panels. Enhanced strength at lighter weights was achieved through corrugating the stainless sheets and welding was omitted in favour of the use of stainless steel fasteners. With the increasing demand for solar power generation, this stainless steel unit brings advantages in the form of sustainable resources and a longer, maintenance-free service life.

Metal Attachments for Solar Panels

Grade: SUH409L, SUS410L



Metal Attachments for Solar Panels
Picture courtesy of the Japan Stainless Steel Association

Metal attachments were developed to fix solar panels onto metal roofs. Because the panels have a usable life span of more than 20 years, it became imperative to develop attachments which are made from materials with a similar durability to avoid additional maintenance or replacement due to corrosion. Against this background, Caname Company and Nippon Teppan, together with Alstar Stainless, developed metal attachments made from ferritic stainless steel grades 409L and 410L (containing 11% chrome) for industrial solar panels. Tests conducted onsite in the Okinawa Prefecture have demonstrated the durability of this product. The stainless steel is aluminized. This grade of stainless steel has the required strength and corrosion resistance, but displays a certain level of surface discolouration over time and the aluminium coating maintains an attractive finish. These attachments have been patented and have gained in popularity. With the current surge demand for solar power systems, these attachments are expected to contribute to further growth in the future.

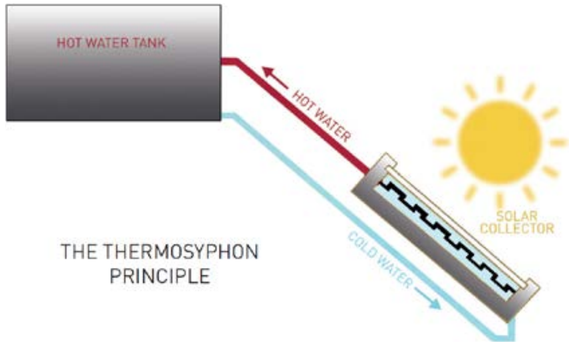
Solar water heaters

Grade:	TTS445J1 441, 410, 444, 431 a.o.

A solar water heating system consists essentially of a collector system (flat plate or evacuated tubes) and a water storage tank. Various metals are currently used in the construction of these two elements.

Ferritic stainless steels are a highly suitable material for use throughout such systems. From a technical point of view, they have various advantages, not least of which is their resistance to corrosion. They are also relatively low in initial cost and, being highly durable and trouble-free, offer significant Life Cycle Cost advantages.

More details here.



Picture courtesy of the Stainless Steel Council of China Iron and Steel Association

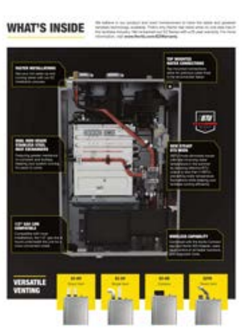
Primary Heat Exchanger Pipes for Water Heater

Grade:	SUS444 (JFE434LN2)

Heat exchangers for water heaters shipped to the North American market are required to have higher efficiency and longer durability (corrosion resistance) than those for the Japanese market because the heaters are subjected to severer thermal efficiency, more stringent environmental standards and harder water quality.

Instead of copper commonly used for the products sold in Japan, NORITZ has decided to adopt stainless steel due to its durability and price stability, and started commercial production.

Since the heaters were released to the large North American market, they have been well accepted to boost the maker's sales and have served as the flagship product there.



Pictures courtesy of Japan Stainless Steel Association

In line with demand expansion for the heaters, stainless steel consumption is expected to increase as well in the future.

Consumption: 45 g/piece or 495 g/product

Source: Japan Stainless Steel Association

Façade cladding

Grades:	SUS445J1, SUS445J2 (NSSC220M), 16Cr-Sn-LC, N(NSSCFW2), SUS445J2, STS 446M (26Cr-LCN), 444 2B, Grade EN 1.4526 (K36) /BA

A ferritic stainless steel grade with high strength and excellent resistance to

Outer Wall of the Planetarium at the Nagoya City Science Museum
Picture courtesy of the Japan Stainless Steel Association

Fukuoka Prefecture Bar Association Building
Picture courtesy of the Japan Stainless Steel Association

corrosion, type SUS 445J1 was specified for the symbolic spherical outer wall of the world's largest planetarium, at **Nagoya City Science Museum**. The size and surface area of the sphere required a material which is capable of withstanding seismic shocks while maintaining a pleasing aesthetic appearance over the planned design life of the building.

The **Fukuoka Bar Association Hall** is the first building to be constructed in the redevelopment project of the Tenjin Area of Fukuoka City, the largest city in Kyushu. The cladding of the façade was done with ferritic stainless steels. The surface of the stainless steel sheet is polished to express the design derived from the traditional textile pattern "Hakataori Kenjo-gara".

Senzoku Gakuen is a private institution in Kawasaki, Japan, which operates a school of music, a junior college, primary and secondary schools, and a kindergarten. The rehearsal studios, a bulbous, free-form structure, built with a concrete base, covered with ferritic grade SUS445J2 stainless steel. The designers, K /o Design Studio and Kajima Design used the latest 3D programming technologies which

Senzoku Gakuen College of Music Silver Mountain
Picture courtesy of the Japan Stainless Steel Association

made it possible to construct the free-form structure, utilizing the optimal fit for the 8,000 pieces of stainless steel cut to irregular sized sheets. A characteristic of the structure, known as the "Silver Mountain" is the moderate luster of transparent-coated ferritic stainless steel and the beautiful scale-like twisted patterns on the surface.

GINZA SIX (Outer Panels)
Picture courtesy of the Japan Stainless Steel Association

The **GINZA SIX Building** has 13 floors above ground and 6 floors underground and has a total area of 148,000 square meters. For the trademark eaves, which can be seen from a distance, Mitsubishi Chemical Corporation's stainless steel composite material "ALPOLIC/fr®SCM" which uses NSSC®220M was applied. This ferritic stainless steel has excellent rust-resistance and a lower thermal expansion coefficient.

Incheon Songdo Convention Center
Picture courtesy of POSCO

The **Incheon Songdo Convention Center** is considered a major building in the international business district, and is a landmark. The entire exterior, including the roof and walls, is made of stainless steel materials, so that it boasts a refined, splendid appearance. In consideration of the characteristics of the coastal area, the exterior walls were designed with stainless steel materials, which are excellent in corrosion resistance. In addition, welded honeycomb panels were used to secure flatness.

The **Allianz Park Palmeiras Stadium** is a multi-functional arena that specifically serves the needs of a wellknown São Paulo soccer team. Stainless steel tube and strip are combined into a proprietary facade system called "Stripweave". It provides an optimal balance between transparency and reflectivity for the hot and sunny climate of the region. As a material, higher alloyed ferritic grade 444 was identified as the best choice for the project.

Allianz Parque Palmeiras Stadium
Picture courtesy of Aperam South America

The **Clad Family Apartments** in Montreuil, France beautifully showcases how stainless steel, most often used in public buildings, can also be a versatile material of choice for private buildings.

Clad Family Apartments
Picture courtesy of Aperam Stainless Europe

KARA (ferritic 1.4526 grade) stainless steel was archi5's choice of material to achieve the building's façade – lightly fluted with shallow waves adapted to suit the scale of the building – reflecting sunlight to surrounding buildings during the day and reflecting street lights at night. The Uginox® Bright covering, with its brilliant finish, takes on all the colours of the seasons. The result is a dynamic façade with a genuine sense of motion.

Raw Material Yard - Grade 443
Picture courtesy of the Stainless Steel Council of China Iron and Steel Association

This **Raw Material Yard** has a roof in 443 (Cr21-NbTi) which has excellent corrosion resistance, formability and weldability properties. The roof thickness is 0.5 mm.

Grade B443Nb is also used in **elevator panels**.

Elevator Panels - Grade B443Nb
Picture courtesy of the Stainless Steel Council of China Iron and Steel Association

The **Nakameguro Ventilation Plant** of the Tokyo Metropolitan Highway is installed over the tunnel running under the Meguro River and the Yamanote Street – a chic section of the City. Since the material for the Plant was required to be aesthetic and durable, a weather-resistant ferritic stainless steel grade was selected. Particularly for louvers and fixtures which are placed at lower parts of the Plant and visible to the public, sand blast-finished SUS445J1 with excellent designability is used and satisfies local residents' request that "the Plant should be harmonious with the surrounding buildings" and "the Plant should also be harmonious with the strolling path along the Meguro River".

In addition, SUS445J1 is adopted for the shutters for the Plant's emergency exits. Nakameguro Ventilation Plant is located close to Tokyo Bay and therefore exposed to a severely corrosive environment. The shutters need to be reliable and fully operative all the time, and cannot fail due to rust or other causes in case of emergency.

Nakameguro Ventilation Plant - Grade SUS445J1
Picture and text courtesy of the Japan Stainless Steel Association

For this **Railway Bridge in Tokyo**, a high-performance exterior material for bridges that uses coated stainless steel with excellent durability for the exterior was used. By using stainless

Railway Bridge - Grade SUS430J1L
Picture courtesy of the Japan Stainless Steel Association

steel, durability of 100 years is expected. By using ferritic SUS430J1L, 3 major outcomes were achieved; (1) sufficient corrosion resistance, (2) a linear expansion coefficient close to carbon steel, and (3) cost stability. In addition to being able to expect longer-term durability by applying fluorine resin coating, it is also possible to deal with situations where harmony with the surrounding landscape is required as the coating can be different colours.

For the refurbishment of the **Nou Bridge** in Niigata prefecture, Japan, the selective use of ferritic stainless steel was a rational and cost-saving choice. Out of the four spans of the bridge structure, the exposed outer two needed to be replaced. The new concrete spans were cast on site and reinforced with type SUS410 17% chromium stainless steel, which ideally fulfilled both the corrosion resistance and cost reduction requirements. While the use of stainless steel reinforcement in new

Nou Bridge - Grade SUS410 rebar
Picture courtesy of the Japan Stainless Steel Association

roads and bridges is not uncommon, this case shows that the stainless steel option is also technically and economically viable in repair and renovation.

Wynyard Walk is a major pedestrian walkway connecting Wynyard Train Station to the bustling Barangaroo waterfront precinct and Sydney CBD. Completed in 2017, the new infrastructure forms one of several solutions to break pedestrian

Wynyard Walk - Grade 445M2, 2B
Picture courtesy of the Australian Stainless Steel Development Association

congestion, with an estimated 75,000 commuters using the hub every day. It features over 1600 m² of perforated and solid stainless steel sheeting into ceiling and fascia panelling installed at the Clarence Street entry façade and the tunnel lining. The panels twist and curve with the bends of the tunnel, creating a sense of flow and motion.

Unique to this stunning architectural application is the use of ferritic stainless steel, 445M2, rather than the conventional specification of 304 or 316. The key factors of formability, cost and corrosion resistance, as well as stainless steel's aesthetic appeal were the driving factors around the specification of this grade for this project.

China Baowu Steel Group Corporation supplied a ferritic grade B444Ti with 18% Chrome and 2% Molybdenum, with good corrosion resistance and good weldability, for the manufacture of a **water tank panel in Shanghai Tower**. This grade is also suitable for other applications in the water industry, including water treatment plants, water circulation pipes, effluent treatment and general plumbing operations.

Water tank in Shanghai Tower - Grade B444Ti /2B
Picture courtesy of China Baowu Steel Group Corporation

Since mid-2015, wiring systems in escape routes in the UK must be supported by **metal fixings** or held by metal containment instead of plastic because the latter can melt and fail. UK suppliers, Source Engineering and Manufacturing, selected stainless steel for their new metallic fastening system. As cables are often found in enclosed or permanently humid locations, stainless steel eliminates

Metal fixings for wire systems - Grade 430 (EN 1.4016)
Picture courtesy of Source Engineering and Manufacturing, Plympton, Devon, UK

the corrosion risks. Ferritic stainless steel was found to have the most suitable profile in terms of cost-effectiveness and technical performance.

Fractal is the trade name for a new range of ferritic **stainless steel tiles**. The Fractal design provides designers, builders and home decorators with an easy to use and efficient method of installing stainless steel wall decorations through its modular system. Fractal can easily be applied to

Fractal tiles - Grade AISI 430 or 441 /polished P4/
4x4 inch/0.7 mm thick
Picture courtesy of IMINOX

smooth walls in any building structure, including homes, offices, hotels, hospitals, restaurants, sports centers, gardens, walls, kitchens, bathrooms, elevators, laboratories, spas, schools, fireplaces, etc. achieving a contemporary and sophisticated effect.

Commercial food equipment

Miscellaneous:

- Ecodyger
- Bread mould

Refrigerator
Oil Filters and Oil Net Components
Impeller and Wind Wheel System
Smoke Collection Chamber and Flow Guide Plate

Grades:	EN 1.4016 (AISI 430), AISI 439

"**Ecodyger**" is an innovative and sustainable system that, thanks to a regeneration process, reduces the volume of organic waste up to 90 percent in just a few hours. A machine cycle, which lasts 5-7 hours, regenerates organic waste and releases liquid and solid residues.

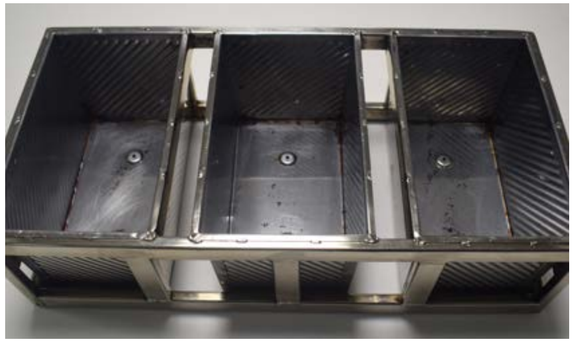
Ecodyger - for organic waste - Grade EN 1.4016 (AISI 430)
Picture from Inossidabile Magazine, courtesy of Centro Inox

"Ecodyger" is made of EN 1.4016 (AISI 430) stainless steel with a satin finish. It offers several advantages: it is easy to install, eliminates usage costs and the need to clean and sanitise storage areas. It cuts personnel costs of handling waste and reduces or eliminates the need for biodegradable bags. "Ecodyger" is compliant with waste prevention regulations. More information: ecodyger.com

Stainless steel food trucks - Grade 439 /Polished
Picture courtesy of Aperam South America

Stainless steel has become the material of choice for the interiors of food trucks. In these examples we show the use of ferritic grade 439 with highly polished surfaces in industrial and professional fittings for mobile street kitchens. Stainless steel has been used to manufacture the plates, ovens, fryers, hoods and refrigerator units. These specialty fittings use very precise design specifications, to prevent units or appliances moving or opening when the vehicle is in motion. As food trucks require very demanding standards of hygiene, the relative ease with which stainless steel may be cleaned and sterilized provides one if its prime advantages for this application. Another important point of differentiation is that stainless steel has been independently proved to be safe for use in food applications and does not taint or in any way interfere with the taste of the food. Stainless steel is also used for manufacturing the structural accessories such as awnings and doors for the trucks because its high mechanical strength and durability contributes to a longer design life and a reduction of maintenance costs. The trucks look good, they look clean, they are hygienic and they will last a long time - an imaginative use of stainless steel to serve our daily lives. One often sees photographs of gleaming stainless steel kitchens in up-market restaurants and hotels - and you can get the same effect from a street vendor.

Contrary to the belief of baking professionals, we established baking in stainless steel. **Bread Mould** is made in Mild steel & Aluminium now and bread



Bread moulds - Grade 439 /Polished
Picture courtesy of the Indian Stainless Steel Development Association

is baked at a temperature of 210-240°C. The moulds are in continuously in the oven baking and are exposed to these temperatures on continuous basis.
There is a thick coating of white flour and oil which gets stuck to the mould and becomes black in colour.
Ferritic Grade 430 was used in 0.6 mm thickness and the bread mould was developed in stainless steel. Continuous trials were done on a set of 50 moulds with the leading manufacturer in India and results were fantastic. Baking was achieved with the same parameters and moreover moulds could be cleaned well, making it more hygienic and safe in comparison to the moulds used at present. This will open a good potential for usage of stainless steel in the Baking Industry.

Refrigerator

Grades:	Cr13, Cr17, EN 1.4016, AISI 430, SUS 430

Ferritic stainless steels are widely used in the door panels, linings of refrigerators and the linings of freezers. The material selection is closely related to performance requirements. The edges of the door panels need to fit tightly with the magnetic sealing strips of the cabinet body to ensure airtightness. Therefore, ferritic stainless steels with strong magnetism such as Cr13 or Cr17 are selected. These steels have a high magnetic permeability (μ≥200), which can form a stable adsorption with the magnetic sealing strips to avoid cold air leakage. For example, the iQ300 series refrigerators of Siemens (Germany) use Cr17 ferritic stainless steel for the door

edges. After testing, the magnetic sealing contact pressure remains stable above 8N/cm during the temperature cycle from -20°C to 40°C.

The outer door panels of refrigerators mostly use 0.6 - 0.8mm thick AISI 430 cold-rolled stainless steel plates. Due to their chromium content of 16% - 18%, after being sanded with a 180 - grit particle size (No.4 surface finish), they not only present a uniform and delicate metallic luster

(with a reflectivity of 65%), but also form a micron - scale rough structure (Ra≤1.6μm), which can effectively hide fingerprints and scratches and is convenient for daily cleaning. For example, the outer door of the BCD - 549WSEKU1 refrigerator of Haier (China) adopts this process. After 100,000 wiping tests, the surface glossiness only decreases by 5%, and the resistance time to neutral salt spray corrosion exceeds 1,000 hours.

If the refrigerator linings do not require welding processes, SUS 430 stainless steel is usually directly used. Because it has excellent cold - forming properties (elongation ≥22%), it can form complex inner cavity structures through a single stamping process. For example, the cold storage inner liner of the BCD - 655WKPZM (E) refrigerator of Midea (China) is integrally formed by SUS 430 stainless steel, avoiding the risk of rust at the welding points. Ferritic stainless steel still maintains good toughness (impact energy ≥27J) in low - temperature environments (as low as - 40°C), and it does not contain nickel elements. Its cost is 30% - 40% lower than that of austenitic stainless steel, which meets the economic requirements of large - scale home appliance production.

In addition, the surface passivation film of SUS 430 stainless steel can effectively resist the organic acids in food residues (such as lemon juice with a pH of 3), ensuring food storage safety. The lining of the RF28R7551SR/SC freezer of Samsung (South Korea) also uses SUS 430 stainless steel. Through the electrochemical polishing process, the surface smoothness is further improved (Ra≤0.8μm), reducing the frost formation by 40% compared with traditional galvanized plates and extending the cleaning cycle to more than 3 months. These characteristics make ferritic stainless steel the preferred material for the core components of refrigerators, taking into account functionality, durability and economy.

Oil Filters and Oil Net Components

Grades: SUS 430

For oil filters and oil net components, AISI 430 stainless steel nets with a thickness of 0.3-0.5mm are mostly selected, which are treated by electrolytic polishing or passivation, and the mesh density is 50-60 meshes. The smooth surface reduces the adhesion force of grease by 40%, and the measured grease interception rate can reach over 91%. The cleaning cycle is doubled compared with that of traditional carbon steel nets. In the 1000-hour edible oil immersion test, the mass loss rate ≤ 0.03g/m², which can effectively resist the erosion of fatty acids. It not only ensures efficient oil filtration and anti-blocking performance but also significantly improves the service life and reduces the maintenance cost.

Impeller and Wind Wheel System

Grades: SUS 439

The impeller and wind wheel system often uses SUS 439 ferritic stainless steel with Ti stabilization elements, and the blades are formed by laser cutting. Its yield strength ≥ 245MPa, and it can still maintain the stability of the blade angle under a high-speed rotation of 1800rpm. After a 500-hour continuous operation test, the dynamic balance deviation < 3g·cm, ensuring the stability of the smoke exhaust efficiency. The low roughness surface reduces the adhesion amount of grease particles by 28%. Combined with the self-cleaning function of the impeller, it can reduce the disassembly and cleaning frequency by 40%, having the dual advantages of anti-deformation and anti-grease accumulation under high-intensity operation.

Smoke Collection Chamber and Flow Guide Plate

Grades: SUS 430

The smoke collection chamber and flow guide plate use SUS 430 stainless steel plates with a thickness of 1.0-1.5mm, and an integrated structure is formed by bending. The material can withstand the local high temperature of 120°C during the peak cooking period, and it has a low coefficient of thermal expansion, making it not easy to deform after long-term use, effectively reducing the escape of lampblack. The seamless design eliminates the welding seams, reducing the grease residue by more than 45% compared with the welded structure. For daily cleaning, simply wiping can remove more than 90% of the stains. While improving the smoke exhaust effect, it greatly simplifies the cleaning and maintenance work.

Home and office

Home and office

- Toasters and pizza ovens
- Kitchen hood
- Range hoods
- Tableware
- Kitchenware
- Electrical Socket Covers
- Educational tool
- Furniture
- Floor heating system
- Residential energy storing system
- Home Delivery Boxes
- Ecocute Piping for Cold and Hot Water Supply
- Washing Machine Drums
- Dishwashers
- Stove
- Salt and pepper pots
- Amalooloo - sanitation system
- Condensing Gas Boiler Exchangers
- Kitchen Cabinets
- Heat Exchangers for Domestic Gas Water Heaters
- Inner Liners and Exteriors of Appliances such as Microwaves, Ovens, Air Fryers, and Rice Cookers

Picture from Inossidabile Magazine, courtesy of Centro Inox

Toasters and pizza ovens

Grades: EN 1.4016 (AISI 430)

Picture from Inossidabile Magazine, courtesy of Centro Inox

Toasted bread is a key element of breakfast. However, a special product is needed for the classic browning of our slices of bread, namely a toaster.

In this sense, a company in the Brianza area is very popular for making and selling grilling plates, bread toasters, traditional sliced bread toasters or belt toasters and brioche or pizza ovens. All products are made using EN 1.4016 (AISI 430) ferritic stainless steel, with a thickness ranging from 0.8 to 1.5 mm. The surfaces feature a 2R or 2B finish, depending on whether they are visible or not. During the design stage, the designers turned to stainless steel for its well-known properties of corrosion resistance, hygiene and ease of cleaning, combined with a high aesthetic value. All glass ceramic grilling plates and stainless steel elements are suitable for contact with food. More information: milantoast.com

Picture from Inossidabile Magazine, courtesy of Centro Inox

Kitchen hood

Grades: EN 1.4016 (AISI 430), scotch-brite finish

The 35CC kitchen hood distinguishes itself by its technology, its small size, and its compact shape. All the charm of a line that draws from the past and reinterprets it with an eye to high-tech, is concentrated on a cube that measures only 35 cm on each side. To guarantee long durability and correct performance over time, it is necessary to use for the hood particularly strong and resistant materials, such as stainless steel. The 35CC kitchen hood is made of Scotch-Brite finish EN 1.4016 (AISI 430) stainless steel. Due to its excellent corrosion resistance properties, stainless steel effectively protects against the corrosion attacks produced by the smoke and the steam that form in the kitchen during cooking operations. These characteristics result in long durability over time, since they keep the hood healthy and efficient, and allow the filtering system to correctly operate. The technical functionality of stainless steel thus perfectly combines with a strong aesthetical appeal.
More information: elica.com

Picture from Inossidabile Magazine, courtesy of Centro Inox

Range hoods

Grades: AISI 430

The outer shells and decorative panels of range hoods often use AISI 430 cold-rolled stainless steel plates with a thickness of 0.6-1.0mm, containing 16%-18% chromium. After wire drawing treatment, a rough structure with Ra≤1.6μm is formed. The surface texture effectively reduces the adhesion of fingerprints and oil stains. Its resistance to neutral salt spray exceeds 800 hours, and it can maintain its metallic luster even after being used for many years in the high-humidity and high-grease environment of the kitchen. Meanwhile, the characteristic of cold forming elongation rate ≥ 22% enables it to be stamped into complex shapes in one go, avoiding the accumulation

of dirt in welding seams. Moreover, the material cost is 25%-35% lower than that of aluminum alloy, combining aesthetics, durability and economic efficiency.

Tableware

Grades:	12Cr13, 20Cr13, 30Cr13, 40Cr13, 50Cr15MoV, 60Cr13

Picture courtesy of the Stainless Steel Council of China Iron and Steel Association

Picture courtesy of the Stainless Steel Council of China Iron and Steel Association

This steel with high hardness and good corrosion resistance, is used in table knives, forks, scissors and other fields.

Kitchenware

Grades:	430LDT, TTS443

This steel has high deep drawing and anti-wrinkle properties and is mainly used in pots, soymilk machine liners, rice cooker liners, etc.

Picture courtesy of the Stainless Steel Council of China Iron and Steel Association

Electrical Socket Covers

Grades:	441 /No. 4 finish

For electrical socket covers in South Africa ferritic grade 441 stainless steel was used. This grade is perfectly suitable for Indoor applications. The polished, No. 4 finish surface provides an attractive finish which is easy to keep clean and the cover will last a life time.

Picture courtesy of Columbus Stainless

Educational tool

Grades: EN 1.4512 (AISI 409)

A publishing house specializing in the creation of educational tools has recently put on the market a game aimed at speech therapists. This game is used as an evaluation tool in investigations of children with specific language and learning disorders. The board, on which magnetic cards can be attached, must be light and thin, as well as ferromagnetic. Centro Inox directed the publishing house towards the choice of EN 1.4512 (AISI 409) ferritic stainless steel. To add value to the game in terms of recyclability and sustainability, the company requested that the base material for the board should come from processing scraps.

Picture from Inossidabile Magazine, courtesy of Centro Inox

Manufacturer: Fabbrica dei Segni Cooperativa Sociale; fabbrica-dei-segni.it

Furniture

Grades: EN 1.4016 (AISI 430), BA finish

"Tempesta" (Tempest) is a line of EN 1.4016 (AISI 430), BA finish, furnishing elements. These pieces of furniture are light and easily stackable, and have a perfectly ergonomic and a stylistically elegant structure.

The name of this line derives from the optical effect given by the stainless steel plate, which is punched and scattered with countersunk holes simulating the presence of water drops. The collection includes: a stackable chair, a stackable armchair, an armchair coupled with a small table, a stool, a stackable deck chair, and finally, a set of tables with a tubular stainless steel structure.

Picture from Inossidabile Magazine, courtesy of Centro Inox

Manufacturing Company: Graepel Italiana S.p.A.; lamiereforate.it

Floor heating system

Grades: EN 1.4521 (AISI 444)

Tecnofar, a leading company in the production of austenitic and ferritic stainless steel tubes, on the occasion of the construction of one of its new production plant, has successfully tested the use of its tubes for the underfloor heating system. As a result of the studies carried out in cooperation with qualified external laboratories, the decision fell on tubes made of EN 1.4521 (AISI 444) ferritic stainless steel, having an outer diameter of 22 mm and a thickness of 0.8 mm.
The choice to use the tubes produced by the company itself turned out to be very interesting for two main reasons: simple and fast installation, and considerable savings in terms of costs in comparison with the plastic tubes that are commonly used for this purpose. With this new and versatile product, which ensures high quality and durability over time, the company celebrated at that time its 40th anniversary.

Picture from Inossidabile Magazine, courtesy of Centro Inox

Pictures from Inossidabile Magazine, courtesy of Centro Inox

Stainless steel tubes produced by:
Tecnofar S.p.A., tecnofar.it

Residential energy storing system

Grades: SUS443J1

Since the Great East Japan Earthquake of 2011, Japan's power situations have entered a period of drastic changes.

The residential energy storage system offered by NEC has attracted attention as a smart system to store electricity without waste and use it when needed. For example, if consumers store electricity of lower rates offered in midnight and use it when needed, they can reduce their electricity charges. In addition, such electricity storage/usage contributes to decreasing the peak demand in their communities. Also they can use the system as a backup for emergency in case blackout occurs.

Picture courtesy of the Japan Stainless Steel Association

To promote the use of the Residential Energy Storage System, low price and high quality are essential conditions. SUS443J1 used in the System is a superb material, which does not contain nickel, a rare metal, and is not only low and stable in terms of price but also has corrosion resistance at least equal to or better than the conventionally used SUS304.

The System made with SUS443J1, a

resource-saving and environment-friendly material, will continue to maximize energy resources in the future. In the future, construction of common ditches extending approximately 240 km is planned nationwide and demand for SUS443J1 products is likely to rise, enabling the parties to make further social contribution.

Home Delivery Boxes

Grades: SUS443J1

Rising popularity of shopping on the Net is making a drastic change in Japan's distribution industry. In addition to the increasing number of goods to be delivered, additional burdens on drivers due to the necessity of redelivery have received considerable attention. What is coming under the spot light as one possible solution to such redelivery problem is the use of home delivery boxes.

"SUS 443J1", a highly corrosion-resistant ferritic stainless steel type, has recently been adopted as a material for home delivery boxes for single-family houses. "SUS 443J1" does not contain nickel, a rare metal, but has corrosion resistance equal or superior to that of SUS304.

Picture courtesy of the Japan Stainless Steel Association

This type not only helps reduce and stabilize material costs borne by customers but also helps make delivery boxes of higher quality. Furthermore, adopting dull finish suited for coating has facilitated shorter production time and smaller inventories. These factors have led to enhancing a flexible production system capable of dealing with abrupt changes in order entries.

Home delivery boxes for single-family houses developed in order to solve a social problem and "SUS443J1" a resource-saving and environment-friendly steel type. The combination of the two will continue to make contributions to a wide spectrum of Japanese society.

Ecocute Piping for Cold and Hot Water Supply

Grades: SUS445J1

The EcoCute is an energy efficient electric heat pump, water heating and distribution system that uses heat extracted from the air to heat water for domestic, industrial and commercial use. Instead of the more conventional ammonia or haloalkane gases, EcoCute uses carbon dioxide as a refrigerant. The technology offers a means of energy conservation and reduces the emission of greenhouse gas. The Ecocute Systems have introduced ferritic grade SUS 445J1 Stainless steel for their water pipes because of its combination of strength and resistance to corrosion. The system has been designed to clean the pipes automatically after use. Keeping the inside of the pipes clean enhances the immaculate image of the energy-saving and environment-friendly Ecocute System.

Picture courtesy of the Japan Stainless Steel Association

Washing Machine Drums

Grades: SUS430, SUS430LX

The typical composition of this steel is Cr16.5 %, Cr17.5 %-Ti0.1 %-Nb0.2 %, with excellent corrosion resistance, forming properties, used in washing machines, dishwashers, microwave ovens, smokers stoves and other fields.

Picture courtesy of the Stainless Steel Council of China Iron and Steel Association

Dishwashers

Grades: SUS 430, SUS 430LX

The application of ferritic stainless steel in the field of dishwashers is highly consistent with the requirements of the equipment for corrosion resistance, structural strength, and cleanliness, mainly reflected in the core components such as the inner liners, cutlery racks, and spray arms. The inner liners of dishwashers are long-term exposed to a high-temperature washing environment of 60°C - 70°C and come into contact with detergents containing chloride ions (such as bleach) and weak acids and alkalis (pH = 9 - 12). Therefore, ferritic stainless steel SUS 430 with a chromium content of 16.5% and SUS 430LX ferritic stainless steel with chromium contents of 16.5%, 17.5% and containing Ti 0.1% - Nb 0.2% are mostly selected. Both of them have excellent corrosion resistance and forming properties. The inner liner of

Picture courtesy of the Stainless Steel Council of China Iron and Steel Association

the SJ23HI88MC dishwasher of Siemens (Germany) is made of 0.8mm thick SUS 430 stainless steel. After 100,000 washing cycle tests, there is no pitting corrosion on the surface or rust at the weld seams. Moreover, it has a high cold forming elongation rate, and the arc-shaped inner cavity can be formed by a single stamping process, avoiding the welding points from becoming the weak areas for corrosion.

The cutlery racks in dishwashers need to have a certain strength to bear the weight

of the tableware and be able to withstand frequent stretching and friction. The strength and toughness of ferritic stainless steel enable it to meet these requirements, and it is not easy to deform or be damaged during the use process. In addition, its surface is smooth, not easy to be stained, and convenient for cleaning, which can prevent food residues and dirt from adhering to the cutlery racks and affecting the cleaning effect of the dishwasher. Some high-end dishwashers also use ferritic stainless steel for accessories such as spray arms and filters. By taking advantage of its corrosion resistance and wear resistance, these key components can maintain good performance during long-term use, reducing the frequency of maintenance and replacement.

In terms of appearance components, ferritic stainless steel has a metallic luster, with a beautiful and generous appearance. It can be used for the outer shell or front panel of the dishwasher, etc., enhancing the overall texture and visual effect of the dishwasher, enabling it to better integrate into different kitchen decoration styles. Moreover, it is not easy to fade or change color, and can still maintain a bright appearance after long-term use. At the same time, the surface of ferritic stainless steel is easy to process and handle. Through processes such as wire drawing and polishing, different surface effects can be created to meet consumers' needs for personalization and high quality.

Stove

Grades: 430SB, B444LM

430SB board is a special grinding surface with fine grain and warm luster. It is used to make high-grade kitchenware.

Picture courtesy of the Stainless Steel Council of China Iron and Steel Association

Salt and pepper pots

Grades: 430LDT, TTS443

Picture courtesy of the Stainless Steel Council of China Iron and Steel Association

Amalooloo - sanitation system

Grade: 3Cr12

The Amalooloo Sanitation System is specifically designed to function without any water and is only dependent on natural environmental conditions. It improves the dignity, health and hygiene of the community and reduces or eliminates sanitation related diseases with on-site treatment. The dry human organic waste can be removed on an annual basis by a service provider at a very affordable rate, or by the household themselves at no cost. The dry human organic waste can be used as a fertiliser as a method of nutrient recovery.

Picture courtesy of Columbus Stainless

Condensing Gas Boiler Exchangers

Grades:	EN 1.4509 (K41) /2B-2R

Picture courtesy of Aperam

1.4509 (K41) is a Niobium & Titanium stabilised ferritic grade of stainless steel, containing 18% chromium, which has been approved for use in the automotive exhaust industry for many years. Aperam has capitalised on this experience for a new application for heat exchangers in condensing gas boilers that makes them more resistant to corrosion and easier to maintain. Stainless steel is a green material par excellence: it is infinitely recyclable, environmentally neutral , and, when in contact with water, there is no leaching of its constituent metals which could alter their composition. There are many advantages from using of this grade of stainless steel for the manufacture of gas boiler exchangers. The addition of Niobium enables continued high temperature oxidation resistance, thermal fatigue resistance and creep resistance. Stainless steel oxidises lower than other commonly used materials, resulting in a longer life for the exchanger. The material also allows thinner gauges to be specified, which provides a reduction in weight for the exchanger, and, by extension, for the boiler. Its resistance to aggressive boiler condensates is better than other commonly used materials and as with all ferritic grades, it is not susceptible to stress corrosion. The dual stabilisation with titanium and niobium affords it excellent resistance to intergranular corrosion.

Kitchen Cabinets

Grades: NSSC FW1®

Picture courtesy of Cleanup

Cleanup is a well - known Japanese kitchenware manufacturer. It became famous in 1973 by launching the first modular kitchen in Japan. In 1975, the company introduced the industry's first stainless - steel cabinet kitchen, "Sakura DX". The frame, side panels, bottom, and drawer base of the cabinet are all made of stainless steel, which triggered a trend of stainless - steel cabinets in Japan.

Japan is a country with high temperatures and humidity. In kitchens, where there is higher humidity and sufficient nutrients, it inevitably provides ideal conditions for the growth of mold. Wooden or iron cabinets will be oxidized when exposed to a humid environment for a long time, leading to mildew, rust, and unpleasant odors. Therefore, a kitchen that is resistant to mold and odor has become a common need for people. NSSC FW1® Ferritic stainless steel, which is lightweight, moisture - resistant, mold - resistant, and cost - effective, is the ideal material. Chromium in stainless steel combines with oxygen in the air to form a barrier called a "passivation film". This "passivation film" prevents stainless steel from rusting due to oxidation by the air. Moreover, even if the surface is damaged, the "passivation film" will regenerate naturally. A "Sakura DX" cabinet used in an ordinary household for more than 30 years fully demonstrates the strength and beauty of stainless steel. After inspection, there are no problems with mold or rust in this cabinet. Its frame structure is in good condition and can still be used continuously. Moreover, the luster of the stainless - steel components has remained for more than 30 years.

At the same time, due to the recyclability of stainless steel, in 2011, Cleanup decided to use stainless steel instead of wood in its major cabinet products. The cabinet structure is designed for easy disassembly and recycling. Cleanup has launched a "Cabinet Recycling Program" in cooperation with approximately 4,000 member organizations, including building contractors, renovation companies, and fuel suppliers. When customers purchase a new kitchen equipped with a "Stainless - Steel Eco Cabinet" through a member company, their old stainless - steel cabinets will be evaluated and recycled. Customers can choose to receive stainless - steel tools provided by Cleanup as a reward or donate to support reforestation.

Picture courtesy of Cleanup

Heat Exchangers for Domestic Gas Water Heaters

Grades: SUS444

Picture courtesy of A.O. Smith

As the “heart” of a domestic gas water heater, the heat exchanger is the core component for achieving the energy conversion of “gas heat energy → hot water”. Therefore, the performance of the materials used in it directly determines the hot water efficiency, safety in use, lifespan, and environmental protection level. In the early days, heat exchangers were basically made of copper. Copper has advantages such as good heat conduction, good ductility, and easy processing. However, it often suffers from perforation and leakage due to poor corrosion resistance.

As a global leader in the gas water heater field, the American company A.O. Smith innovatively uses SUS 444 ultra - pure ferritic stainless steel as the material for gas water heater heat exchangers. SUS 444 ultra - pure ferritic stainless steel contains approximately 18% chromium and about 2% molybdenum. It can form an extremely dense and stable “passivation film” on the metal surface. Therefore, it has excellent corrosion resistance and can effectively resist the corrosion of condensate water and acidic water quality (such as chloride ions and sulfate ions). Its lifespan is 3 to 4 times longer than that of traditional copper heat exchangers.Secondly, it also has excellent thermal stability. Its coefficient of thermal expansion is only half that of copper (about 10.4×10^{-6}/°C). In a high-temperature environment with frequent start-ups and shut-downs, the risk of component deformation is reduced by 50%, making it suitable for complex working conditions. A.O. Smith’s domestic-grade stainless steel heat exchanger can operate continuously for 100,000 times without structural damage in a temperature difference cycle test of 60°C - 80°C. Moreover, the material cost is much lower than that of austenitic stainless steel and copper, and it is 100% recyclable, which is in line with the global green manufacturing trend. At the same time, A.O. Smith optimizes the structure of the heat exchanger through the “Full-Dimension Energy-Gathering Heat Exchange Pipeline” technology, increasing the heat exchange area by 2.5 times and equipped with patented spoiler technology, making the heat efficiency close to that of copper heat exchangers.

Inner Liners and Exteriors of Appliances such as Microwaves, Ovens, Air Fryers, and Rice Cookers

Grades: SUS 430, SUS 430LX

Ferritic stainless steel has multiple advantages in the field of heating appliances like microwaves, ovens, air fryers, and rice cookers. Galanz (China) uses SUS 430 for the inner liners, exteriors, and turntable brackets of microwaves. SUS 430 contains 12% - 18% chromium. In the high - temperature environment of 150°C - 250°C generated during microwave heating, a “passivation film” forms on its surface. This film can effectively resist oxidation by high - temperature steam and avoid metal fatigue deformation.

The service life of components made of SUS 430 is 2 - 3 times longer than that of ordinary carbon steel. Moreover, it can replace traditional sprayed inner liners (such as epoxy resin coatings), preventing the coating from peeling off and contaminating food.

The surface of SUS 430 ferritic stainless steel is smooth and dense (Ra≤1.6μm). It can resist organic acids in food residues (such as ketchup and lemon juice), reduce the adhesion of food residues, and withstand the erosion of water vapor, thus avoiding rust and unpleasant odors. The cleaning cycle can be extended by more than 30%. The cold - forming elongation of SUS 430 ferritic stainless steel is ≥22%, which allows it to form complex cavities through a single stamping process. Its cost is 30% - 40% lower than that of austenitic stainless steel, showing processing economy. It is an ideal material for the inner liners, exteriors, and key components of mid - to high - end microwaves, achieving a balance in high - temperature resistance, corrosion resistance, easy cleaning, cost control, and environmental friendliness.

Industry

Filing cabinets
Use at vineyards
Retainers
Heat exchanger
Coal conveyer belt
Lining for flue duct
Cane carrier slats
Tubes for power plant condensor
Expanded metal mesh
Heat exchanger fin tubes for chillers
Shoe Sole Catcher

Picture courtesy of the Stainless Steel Council of China Iron and Steel Association

Filing cabinets

Grades: EN 1.4509 (441)

Filing cabinets are an extremely functional piece of furniture, important for companies and workplaces. The filing cabinets presented in this article are made from 0.8 mm thick sheets of austenitic stainless steel EN 1.4307 (AISI 304L) or ferritic stainless steel EN 1.4509 (commercially known as “441”).

Picture from Inossidabile Magazine, courtesy of Centro Inox

In the first cutting phase, the sheets are mechanically processed by means of a punching machine and, then, bent. The main structure of the cabinet is obtained by means of punching operations. Finally, the hinges are assembled by punching, followed by the various doors and their locks.

As well as being completely fireproof, these filing cabinets comply with Italian FCMs (Food Contact Materials) requirements and are therefore also suitable for companies in the food chain.

Realization: Facilitas Srl; facilitas.it

Use at vineyards

Grades: EN 1.4510 (AISI 439), EN 1.4512 (AISI 409) and EN 1.4509 (441)

Stainless steel has kept the traditional “flavour” of this particular sector intact with an emphasis on technology, sustainability and quality. The products used to make a vineyard include trellis posts with a diameter of 60 to 76.1 mm and a 1.00 to 2 mm thickness, vine posts of 50 to 60 mm in diameter and a 1.00 to 2.00 thickness and lastly the stakes of 25 to 38 mm diameter and a 0.70 to 1 mm thickness. The full range of vineyard posts, presented here, are made of EN 1.4510 (AISI 439), EN 1.4512 (AISI 409) and EN 1.4509 (441) stainless steel.

Picture from Inossidabile Magazine, courtesy of Centro Inox

Picture from Inossidabile Magazine, courtesy of Centro Inox

Stainless steel is a long-lasting material that maintains its characteristics over

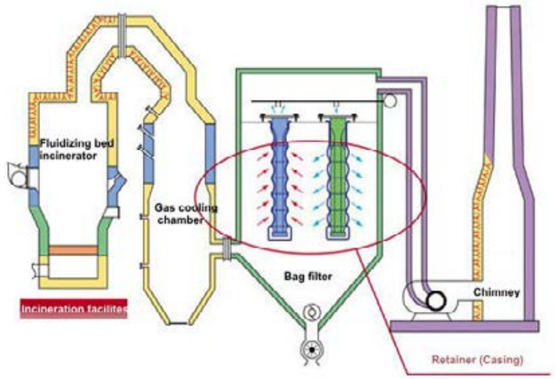
time, resisting stress and degradation due to moisture, air, light, high and low temperatures, and the corrosive action of some substances used for vineyard treatments. Stainless steel is a material with high mechanical strength and excellent flexibility. The trellis and vineyard post holes allow easy and quick assembly of the wires and accessories. The reflectivity of stainless steel allows for greater diffusion of light and heat during winter.

Producer: Thema Inox Srl; themainox.it

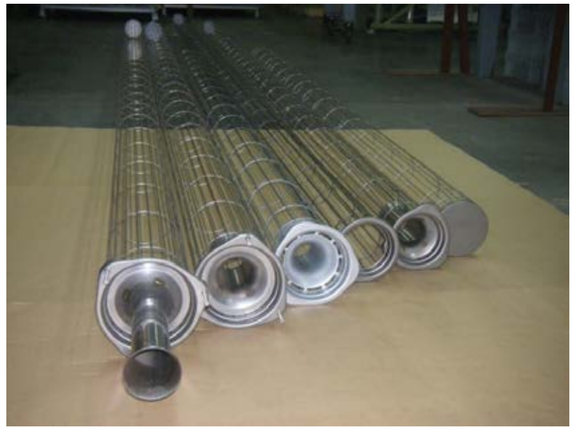
Retainers

Grade:	SUS430J1L (NSSC180)

The casing for the bag filter retainers at incineration facilities is made of ferritic stainless steels.



Furnace model diagram
Picture courtesy of Japan Stainless Steel Association



Picture courtesy of Japan Stainless Steel Association

Heat exchanger

Grades:	444

444 ferritic stainless steel has excellent corrosion resistance, weldability and low-temperature impact properties, and is therefore used in heat exchangers, water tanks and other fields.

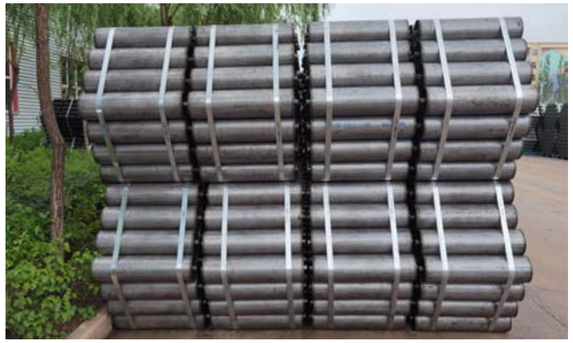
Picture courtesy of the Stainless Steel Council of China Iron and Steel Association

Coal conveyer belt

Grade: TSZ410

With high toughness and corrosion resistance this steel is mainly used in coal belt conveyor rollers, brackets and other fields.

Stainless steel is a material of excellent corrosion resistance and good mechanical properties, long service life, low maintenance cost, and its scrap is 100% recyclable. This low-cost, high-strength stainless steel was developed to replace the traditional carbon steel used for belt conveyor rollers and supports, it can achieve lower energy consumption, resource conservation and environmental

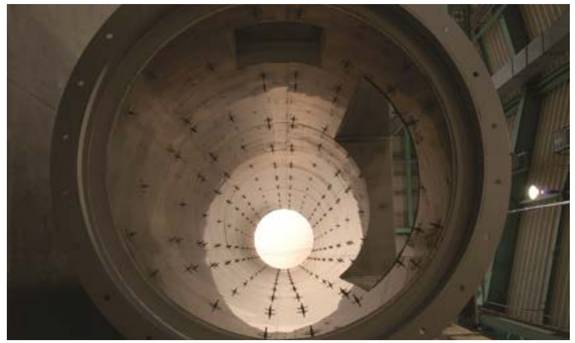


Picture courtesy of the Stainless Steel Council of China Iron and Steel Association

friendliness throughout the life cycle of this equipment and meet the demand for low-carbon, green and sustainable development in the field of belt transportation in the coal industry.

Lining for flue duct

Grade: SUS443J1 2D (KD)

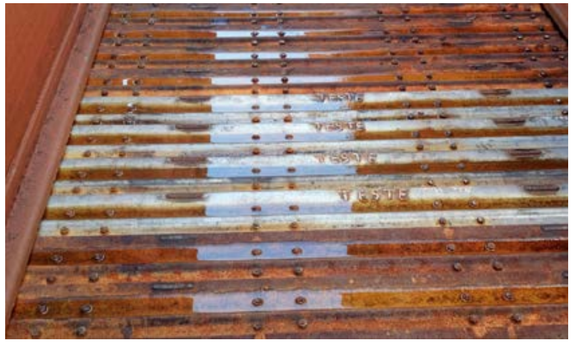


Picture courtesy of Fujimoro Sangyo

Private power generators have attracted a lot of attention to ensure the power in preparation for an emergency such as an earthquake. Stainless steel has been applied to the inner lining of the flue ducts connecting to the generator. Since the temperature of the lining is very high by exhaust gas, a special structure is required to reduce the thermal strain. Ferritic stainless steel with a low thermal expansion coefficient is essential to reduce the thermal strain and it results in relaxation of the special structure. This contributes to the improvement of workability to line the flue duct with stainless steel. SUS443J1 with a low thermal expansion coefficient and excellent corrosion resistance against exhaust gas is considered to be suitable for this use. Therefore we expect that this kind of stainless steel will contribute to the spread of the flue duct market connecting to the private power generator.

Cane carrier slats

Grade:	DIN WS 1.4003 (K03 APERAM) /#1

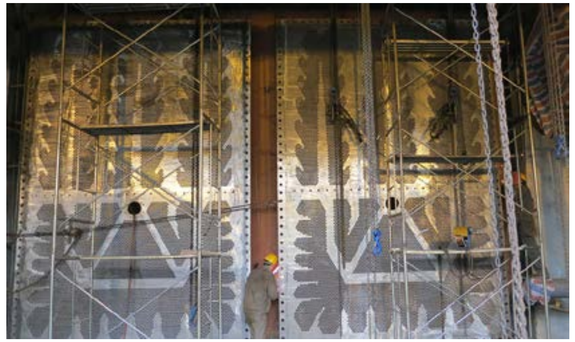


Picture courtesy of Aperam South America

Slats are an important component of cane carriers which are used to transport sugar cane from the reception to the crushing process. These cane carrier slats are formed in rectangular pieces which form a part of the metal tracks that transport the sugar cane. The size of each track varies according to the size of the mill, but each track uses an average of 250 to 300 slats and each slat weighs approximately 30 kg. The slats have traditionally been made from carbon steel SAE 1020/1045 with thickness around 8 mm or 6.35 mm, but the development of ferritic grade 1.4003 (Aperam K03) stainless steel, by Aperam South America, in conjunction with a local manufacturer, has provided a stronger, more corrosion resistant, alternative which, because of its higher strength, enables the manufacturer to reduce the gauge to 5 mm (carbon steel slats are 6.35 mm), with a significant saving in the weight of the manufactured units. This provides a double advantage - lower life cycle costs for the materials and lower handling and transport costs for the finished units.

Tubes for power plant condensor

Grade:	B446 /2B



Picture courtesy of Baosteel

Baosteel have supplied the ferritic grade B446 (with 28% Chrome and 3% Molybdenum), with excellent corrosion resistance and good weldability, to manufacture condenser tubes in the Taiwan Xingda Power Plant to replace Titanium and Copper alloys. This material is also suitable for use in condenser tubes and heat exchanger tubes in the petrochemical industry, de-salination plants, roofing and wall panelling for buildings in coastal environments, caustic soda plants, manufacturing plants for organic acid (such as acetic acid and lactic acid) and other industrial applications requiring high corrosion resistance.

Expanded metal mesh

Grade: EN 1.4003

Picture courtesy of Aperam South America

Expanded Metal is a cost-effective and efficient form of fencing or enclosure which is produced from solid sheets or plates of metals, such as stainless steel. Because it is manufactured from a solid sheet of metal, without weaving or welding, the “weave” can never unravel and the resultant sheet is more secure.

The expanded metal is produced by simultaneously slitting and stretching a sheet or plate, which expands the cuts into diamond shaped holes of a uniform size and shape. Because there is no metal loss in the expanding process, this form of fencing or enclosure is cost effective and saves significantly on raw materials. A mining company of Catas Altas city in Minas Gerais State, Brazil, working in conjunction with Aperam South America, have used 5mm sheets of ferritic grade 1.4003 and austenitic grade 304 to produce expanded metal fences and enclosures for Brazil’s very active mining industry, because its increased strength and corrosion resistance give it a greater durability in the very aggressive conditions which are experienced in underground mining. The result is clean structure that is secure and relatively simple to install.

Heat exchanger fin tubes for chillers

Grade: 430J1L /BA

Picture courtesy of POSCO

POSCO has developed a ferritic grade 430J1L for the manufacture of heat exchanger fin tubes for industrial absorption chillers. The liquids used in the fin tubes may cause pitting corrosion and stress corrosion cracking, but this material has been found to be particularly well suited to resisting these forms of corrosion. Welding and annealing conditions have been optimized to make it easier to form the fins on the surface of the tubes. Being a ferritic grade, the material has a relatively stable price structure.

Shoe Sole Catcher

Grade: SUS443J1 (JFE443CT)

Picture courtesy of Japan Stainless Steel Association

"Fall" has caused the most work-related accidents in recent years in Japan, and the number of fall-related casualties has steadily risen in the last three years. And the biggest cause of fall is "slip" . Stainless steel "shoe sole catcher" is a sheet product which can drastically reduce the cases of slip-induced fall, a social problem of our time.

This product exhibits strong anti-slip capability even under extremely slippery conditions where water or oil is splashed, for example. In fiscal 2020, JFE443CT, a chrome-grade stainless steel noted with superb drawability and puncturability was adopted, which led to improved slip prevention with higher protrusions.

Picture courtesy of Japan Stainless Steel Association

Such advantages are highly appreciated, and the product is currently used in about 600 entities, centered on facilities with high safety awareness including steelworks and submarines of the Japan Maritime Self-Defense Force. Since Shoe Sole Catcher can make a great contribution to cut down cases of "fall", the worst culprit of work-related accidents, the product is expected to generate huge demand in the future.
Consumption: Average 2 tons/month

Source: Japan Stainless Steel Association

Appendices: The chemical composition of ferritic stainless steels

Ferritic stainless steels have properties similar to those of mild steel but show much better corrosion resistance. Their development began over a century ago.

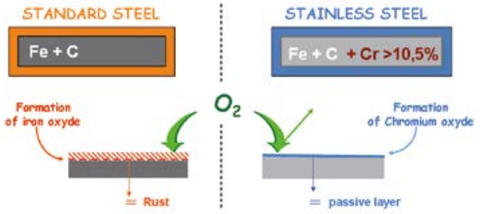
Early ferritics

Stainless steel was “discovered” around 1900–1915. As with many discoveries, it was actually the result of the accumulated efforts of several scientists. Research was published in England, France and Germany on alloys with compositions that would be known today as the 410, 420, 430, 442, 446 and 440C grades.

Stainless steels must have a very low level of carbon, standard grades are in the range of 0.08 %. High performance ferritic grades are even lower in carbon: in the case of grade 444, Cmax is as low as 0,025 %. For many years it was difficult to obtain such a low carbon level, which explains why advanced ferritic grades for more demanding applications only became available in the 1980s.

The grades and their chemistries

Chromium (Cr) is by far the most important alloying element in the production of stainless steel. It forms the “passive” surface film that makes stainless steel corrosion resistant and increases scaling resistance, wear resistance and tensile strength.



A minimum of 10.5% chromium content (by weight) is required for the protective, self-repairing surface layer of chromium oxide to form reliably. The higher the chromium content, the stronger the passive layer.

If the stainless steel surface is machined or accidentally damaged, the passive layer instantaneously re-forms, in the presence of air or water.

Chemical composition and international standards

The following tables show the chemical analysis of the five groups of ferritic stainless steels. Please note these analyses can differ. When in doubt, please consult with the standards institute in your area.

GROUP 1	AISI/ASTM	Chemical component (Maximum weight %)														Standard	Ref.
		C	Si	Mn	P	S	Cr	Mo	Ti	Nb	Cu	Al	N	Ni			
10%-14% Cr	403 (M)	0.25	0.5	1.0	0.04	0.03	11.5-13.0									JIS	SUS403
		0.12-0.17	1.0	1.0	0.04	0.015	12.0-14.0									EN	1.4024
	405	0.08	1.0	1.0	0.04	0.03	11.5-14.5					0.1-0.3		0.6		UNS	S40500
		0.08	1.0	1.0	0.04	0.015	12.0-14.0									EN	1.4000
		0.08	1.0	1.0	0.04	0.015	12.0-14.0					0.1-0.3				EN	1.4002
		0.08	1.0	1.0	0.04	0.03	11.5-14.5					0.1-0.3				JIS	SUS405
	409L	0.03	1.0	1.0	0.04	0.02	10.5-11.7		6x(C+N)-0.5	0.17			0.03	0.5		UNS	S40910
		0.03	1.0	1.0	0.04	0.02	10.5-11.7		8x(C+N)-0.5	0.1			0.03	0.5		UNS	S40920
		0.03	1.0	1.0	0.04	0.02	10.5-11.7		[0.08+8x(C+N)]-0.75				0.03	0.5		UNS	S40930
		0.03	1.0	1.0	0.04	0.02	10.5-11.7		0.05-0.2	0.18-0.4			0.03	0.5		UNS	S40945
		0.03	1.0	1.0	0.04	0.02	10.5-11.7		6x(C+N)-0.75				0.03	0.5-1.0		UNS	S40975
		0.03	1.0	1.5	0.04	0.015	10.5-12.5						0.03	0.3-1.0		UNS	S40977
		0.03	1.0	1.0	0.04	0.015	10.5-12.5		6x(C+N)-0.65					0.5		EN	1.4512
		0.08	0.7	1.5	0.04	0.015	10.5-12.5		0.05-0.35					0.5-1.5		EN	1.4516
		0.03	1.0	1.0	0.04	0.03	10.5-11.75		6xC-0.75					0.6		JIS	SUH409L
	410(M)	0.08-0.15	1.0	1.0	0.04	0.03	11.5-13.5							0.75		UNS	S41000
		0.08-0.15	1.0	1.5	0.04	0.015	11.5-13.5							0.75		EN	1.4006
		0.15	1.0	1.0	0.04	0.03	11.5-13.5									JIS	SUS410
	410L	0.03	1.0	1.5	0.04	0.03	10.5-12.5						0.03	1.5		UNS	S41003
		0.03	1.0	1.0	0.04	0.03	12.0-13.0			9(C+N)-0.6			0.03	0.5		UNS	S41045
		0.04	1.0	1.0	0.045	0.03	10.5-12.5						0.1	0.6-1.10		UNS	S41050
		0.03	1.0	1.0	0.04	0.03	11.0-13.5									JIS	SUS410L
		0.03	1.0	1.5	0.04	0.015	10.5-12.5							0.3-1.0		EN	1.4003
	410S(M)	0.08	1.0	1.0	0.04	0.03	11.5-13.5							0.6		UNS	S41008
		0.08	1.0	1.0	0.04	0.03	11.5-13.5							0.6		JIS	SUS410S
	420J1(M)	0.16-0.25	1.0	1.0	0.04	0.03	12.0-14.0									JIS	SUS420J1
		0.16-0.25	1.0	1.5	0.04	0.015	12.0-14.0									EN	1.4021
	420J2(M)	0.26-0.40	1.0	1.0	0.04	0.03	12.0-14.0									JIS	SUS420J2
		0.26-0.35	1.0	1.5	0.04	0.015	12.0-14.0									EN	1.4028
		0.36-0.42	1.0	1.0	0.04	0.015	12.5-14.5									EN	1.4031
		0.43-0.50	1.0	1.0	0.04	0.015	12.5-14.5									EN	1.4034

GROUP 2	AISI/ASTM	Chemical component (Maximum weight %)														Standard	Ref.
		C	Si	Mn	P	S	Cr	Mo	Ti	Nb	Cu	Al	N	Ni			
14%-18% Cr	420	0.08	1.0	1.0	0.045	0.03	13.5-15.5	0.2-1.2	0.3-0.5					1.0-2.5		UNS	S42035
		0.08	1.0	1.0	0.04	0.015	13.5-15.5	0.2-1.2	0.3-0.5					1.0-2.5		EN	1.4589
	429	0.12	1.0	1.0	0.04	0.03	14.0-16.0									UNS	S42900
		0.12	1.0	1.0	0.04	0.03	14.0-16.0									JIS	SUS429
	429J1(M)	0.25-0.4.0	1.0	1.0	0.04	0.03	15.0-17.0									JIS	SUS429J1
	430	0.12	1.0	1.0	0.04	0.03	16.0-18.0							0.75		UNS	S43000
		0.08	1.0	1.0	0.04	0.015	16.0-18.0									EN	1.4016
		0.12	0.75	1.0	0.04	0.03	16.0-18.0									JIS	SUS430
	1.4017	0.08	1.0	1.0	0.04	0.015	16.0-18.0							1.2-1.6		EN	1.4017
	440(M)	0.6-0.75	1.0	1.0	0.04	0.03	16.0-18.0									JIS	SUS440A

GROUP 3	AISI/ASTM	Chemical component (Maximum weight %)														Standard	Ref.
		C	Si	Mn	P	S	Cr	Mo	Ti	Nb	Cu	Al	N	Ni			
14%-18% Cr stabilised	430J1L	0.025	1.0	1.0	0.04	0.03	16.0-20.0			8x(C+N)-0.8	0.3-0.8		0.025			JIS	SUS430J1L
	430LX	0.03	0.75	1.0	0.04	0.03	16.0-19.0		0.1-1.0					0.6		JIS	SUS430LX
	439	0.03	1.0	1.0	0.04	0.03	17.0-19.0		[0.2+4x(C+N)]-1.10			0.15	0.03	0.5		UNS	S43035
		0.05	1.0	1.0	0.04	0.015	16.0-18.0		[0.15+4x(C+N)]-0.8							EN	1.4510
		0.03	1.0	1.0	0.04	0.03	17.0-19.0		[0.2+4x(C+N)]-0.75							UNS	S43932
		0.03	1.0	1.0	0.04	0.015	17.5-18.5		0.1-0.6	[0.3+(3xC)]						UNS	S43940
		0.03	1.0	1.0	0.04	0.015	16.0-17.5			0.35-0.55						EN	1.4590
		0.025	0.5	0.5	0.04	0.015	16.0-18.0		0.3-0.6							EN	1.4520
		0.02	1.0	1.0	0.04	0.015	13.0-15.0			0.2-0.6						EN	1.4595
	430Ti	0.05	1.0	1.0	0.4	0.015	16.0-18.0		0.6							EN	1.4511
	441	0.03	1.0	1.0	0.04	0.03	17.5-18.5		0.1-0.6	9xC+0.3-1				1.0		UNS	S44100
		0.03	1.0	1.0	0.04	0.015	17.5-18.5		0.1-0.6	3xC+0.3-1						EN	1.4509

GROUP 4	AISI/ASTM	Chemical component (Maximum weight %)														Standard	Ref.
		C	Si	Mn	P	S	Cr	Mo	Ti	Nb	Cu	Al	N	Ni	Other		
Added Mo	415	0.05	0.6	0.5-1.0	0.03	0.03	11.5-14.0	0.5-1.0						3.5-5.5		UNS	S41500
	434	0.12	1.0	1.0	0.04	0.03	16.0-18.0	0.75-1.25								UNS	S43400
		0.08	0.75	0.8	0.04	0.015	16.0-18.0	0.9-1.4								EN	1.4113
		0.08	1.0	1.0	0.04	0.015	16.0-18.0	0.8-1.4		[7x(C+N)+0.1]-1.0			0.04			EN	1.4526
		0.12	1.0	1.0	0.04	0.03	16.0-18.0	0.75-1.25								JIS	SUS434
	436	0.12	1.0	1.0	0.04	0.03	16.0-18.0	0.75-1.25	8x(C+N)-0.8				0.025			UNS	S43600
		0.025	1.0	1.0	0.04	0.015	16.0-18.0	0.9-1.4	0.3-0.6							EN	1.4513
		0.025	1.0	1.0	0.04	0.03	16.0-19.0	0.75-1.25	8x(C+N)-0.8				0.025			JIS	SUS436L
	1.4419(M)	0.36-0.42	1.0	1.0	0.04	0.015	13.0-14.5	0.6-1.0								EN	1.4419
	1.4110(M)	0.48-0.60	1.0	1.0	0.04	0.015	13.0-15.0	0.5-0.8							V≤0.15	EN	1.4110
	1.4116(M)	0.45-0.55	1.0	1.0	0.04	0.015	14.0-15.0	0.5-0.8							0.1≤V≤0.2	EN	1.4116
	1.4122(M)	0.33-0.45	1.0	1.5	0.04	0.015	15.5-17.5	0.8-1.3						≤1.0		EN	1.4122
	1.4313(M)	≤0.05	0.7	1.5	0.04	0.015	12.0-14.0	0.3-0.7					≥0.02	3.5-4.5		EN	1.4313
	1.4418(M)	≤0.06	0.7	1.5	0.04	0.015	15.0-17.0	0.8-1.5					≥0.02	4.0-6.0		EN	1.4418
	436J1L	0.025	1.0	1.0	0.04	0.03	17.0-20.0	0.4-0.8	8x(C+N)-0.8				0.025			JIS	SUS436J1L
	444	0.025	1.0	0.7-1.5	0.04	0.03	17.5-19.5	1.75-2.5	0.2+4(C+N)-0.8					1.0		UNS	S44400
		0.025	1.0	1.0	0.04	0.015	17.0-20.0	1.8-2.5	4x(C+N)+0.15-0.8				0.03			EN	1.4521
		0.025	1.0	1.0	0.04	0.03	17.0-20.0	1.75-2.5	8x(C+N)-0.8				0.025			JIS	SUS444

GROUP 5	AISI/ASTM	Chemical component (Maximum weight %)														Stand-ard	Ref.
		C	Si	Mn	P	S	Cr	Mo	Ti	Nb	Cu	Al	N	Ni			
Others	445	0.02	1.0	1.0	0.04	0.012	19.0-21.0			10x(C+N)-0.8	0.3-0.6		0.03	0.6		UNS	S44500
	445J1	0.025	1.0	1.0	0.04	0.03	21.0-24.0			0.7-1.5			0.025			JIS	SUS445J1
	445J2	0.025	1.0	1.0	0.04	0.03	21.0-24.0	1.5-2.5					0.025			JIS	SUS445J2
	446	0.06	0.75	0.75	0.04	0.02	25.0-27.0	0.75-1.5	0.2-1.0		0.2		0.04			UNS	S44626
		0.01	0.4	0.4	0.02	0.02	25.0-27.5	0.75-1.5		0.05-0.2	0.2		0.015	0.5		UNS	S44627
		0.025	0.75	1.0	0.04	0.03	24.5-26.0	3.5-4.5	[0.2+4(C+N)]-0.80				0.035	3.5-4.5		UNS	S44635
		0.03	1.0	1.0	0.04	0.03	25.0-28.0	3.0-4.0	6x(C+N)-1.0				0.04	1.0-3.5		UNS	S44660
		0.01	0.4	0.4	0.03	0.02	25.0-27.5	0.75-1.5					0.015	0.5		JIS	SUSXM27
	447	0.01	0.2	0.3	0.025	0.02	28.0-30.0	3.5-4.2			0.15		0.02	0.15	(C+N) 0.025	UNS	S44700
		0.03	1.0	1.0	0.04	0.03	28.0-30.0	3.6-4.2	6x(C+N)-1.0				0.045	1.0		UNS	S44735
		0.025	1.0	1.0	0.03	0.01	28.0-30.0	3.5-4.5	[4x(C+N)+0.15]-0.8				0.045			EN	1.4592
		0.01	0.4	0.4	0.03	0.02	28.5-32.0	1.5-2.5					0.015			JIS	SUS447J1
	448	0.01	0.2	0.3	0.025	0.02	28.0-30.0	3.5-4.2			0.15		0.02	2-2.5	(C+N) 0.025	UNS	S44800

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worldstainless is a not-for-profit research and development association which was founded in 1996 as the International Stainless Steel Forum.

Its primary roles are to undertake stainless steel industry beneficial tasks that are better coordinated centrally in the fields of

- Promoting industry and material sustainability benefits
- Conserving resources and promoting the circular economy
- Providing economic and industry-leading statistics
- Support industry health & safety needs and developments
- Outlining market development and expansion opportunities
- Maintaining brand reputational positioning
- Materials education

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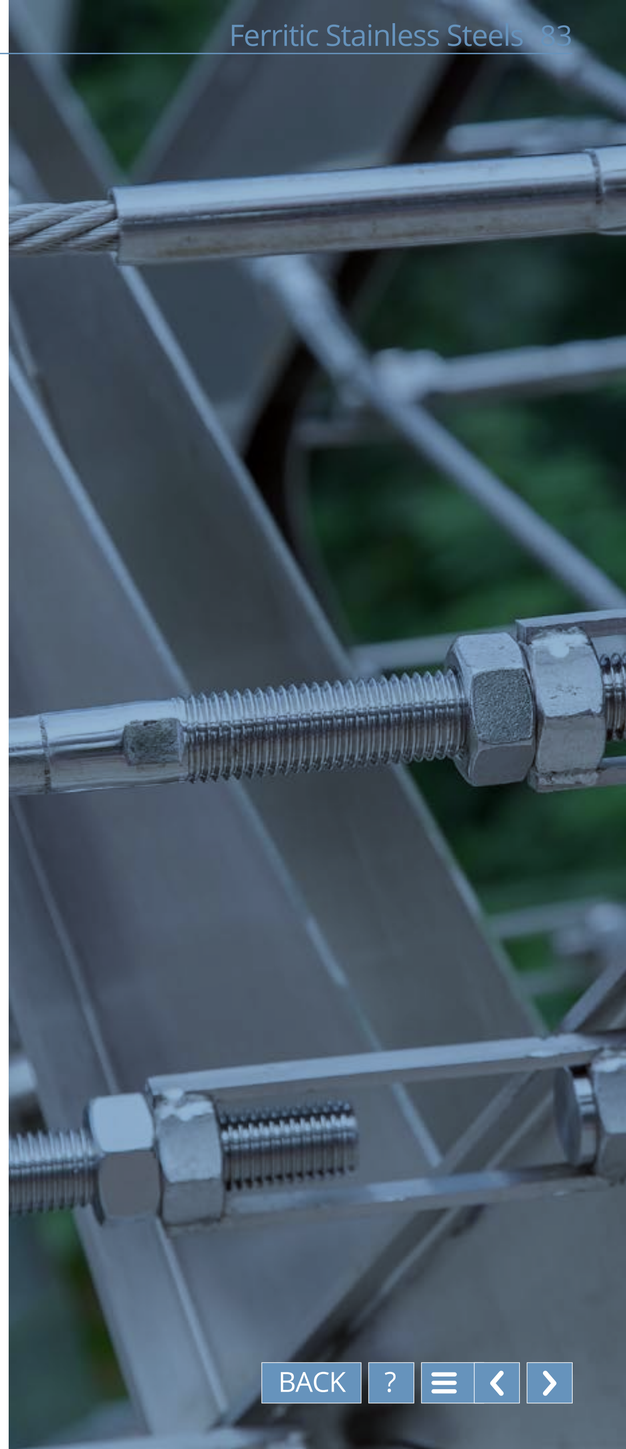

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