THE FERRITIC SOLUTION

PROPERTIES | ADVANTAGES | APPLICATIONS

ISSF INTERNATIONAL STAINLESS STEEL FORUM

icda

THE ESSENTIAL GUIDE TO FERRITIC STAINLESS STEELS

International Stainless Steel Forum (ISSF)

Founded in 1996, the International Stainless Steel Forum (ISSF) is a non-profit research organisation that serves as the world forum on various aspects of the international stainless steel industry. Whilst having its own Board of Directors, budgets and Secretary General, ISSF is part of the International Iron and Steel Institute (IISI). ISSF now comprises some 67 company and affiliated members in 24 countries. Jointly, they are responsible for around 85 percent of worldwide stainless steel production. A full list of members can be found on the ISSF website: www.worldstainless.org.

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"THE FERRITIC SOLUTION"

BY JEAN-YVES GILET, CHAIRMAN OF THE ISSF MARKET DEVELOPMENT COMMITTEE

ISSF first discussed a project to promote ferritic grades in February 2004, many members having pointed out that no joint industry effort was being made in this direction.

Under the guidance of the Market Development Committee, an international group of experts, led by Philippe Richard, started by gathering market statistics on ferritic grades and applications. They received contributions from all around the world – especially Japan, where the ferritics market is the most developed.

The ICDA soon proposed to join the initiative and co-fund the project. This we accepted with great pleasure, as a concrete example of cooperation between international business organisations.

During the project's start-up phase, nickel prices hit the roof and interest in more price-stable grades increased dramatically. ISSF then gave the project highest priority! I am now proud to present the results, which will 'hit the market' at just the right time.

I strongly believe that ferritic stainless steels can and should be much more widely used. The purpose of this publication is to bring about more extensive use of these grades.

Stainless steels are 'stainless' because their chromium content gives them remarkable resistance to corrosion. Ferritic grades, containing only chromium and possibly other elements (Mo, Ti, Nb, etc.), are no exception. Well-known standard ferritic grades 409, 410 and 430 are readily available all over the world. Very successfully used in important applications, such as washing-machine drums and exhaust systems, they actually have much broader application potential, in numerous fields.

More recently-developed ferritic grades, such as 439 and 441 meet an even broader range of requirements. They can be formed to more complex shapes and joined using most conventional joining methods, including welding. Thanks to the addition of molybdenum, the resistance of ferritic grade 444 to localised corrosion is at least equal to that of austenitic grade 316.

Since ferritic grades do not contain nickel, their cost is lower and more stable than that of austenitic stainless steels. They can therefore:

- complement type 304 within the stainless steel family (although 304 remains a versatile and commonly used grade);
- be an alternative to the 200 series (offering generally better usage properties);
- substitute for other materials in many areas (e.g. carbon steel, Cu, Zn, Al, plastic, etc.), thanks to their special technical properties – the drivers for replacement being, usually, technical and Life Cycle Cost benefits.

Ferritic stainless steels' magnetism is not a 'negative' quality somehow associating it with ordinary carbon steel. On the contrary, magnetism is a special asset of these excellent stainless steels, marking them out from other stainless steel grades.

To get the best results from ferritics, it is essential that:

- new users be trained in forming and joining techniques;
- the user consult his stainless steel producer regarding correct grade selection;
- the user acquire his material from a reliable source, able to offer proven guarantees as to the grade, quality and origin of the material supplied.

The high quality of the team's efforts and the strong support of the ICDA allow us today to present a reference document for our stainless steel business. It benefits from highly interesting testimonials from customers, showing a lively interest in new developments. ISSF is grateful for all these contributions.

Jean-Yves Gilet
Chairman
Market Development Committee
ISSF

ISSF INTERNATIONAL STAINLESS STEEL FORUM

Foreword

"A STEEL WHOSE TIME HAS COME"

BY FRIEDRICH TEROERDE OF THE INTERNATIONAL CHROMIUM DEVELOPMENT ASSOCIATION

I must first thank ISSF for inviting the ICDA to write the foreword to The Ferritic Solution – a publication that is inevitably eloquent on the subject of chromium.

The ICDA was set up in Paris, in 1990, and currently boasts some 96 Members from 26 countries across 5 continents. Our mission is to tell the world the positive story of chromium.

Chromium is used in iron and steel to produce stainless steel and other alloys. In stainless steel, chromium is a special ingredient. It is the alloying element that makes stainless steel "stainless", giving it its remarkable corrosion and oxidation resistance. Chromium is both readily available and easily recycled in its stainless steel form, posing no threat to the environment.

As a body representing the chromium producers, we are sponsoring this handbook because we believe it will develop the chromium industry. Chromium is never used alone. The Market Development Committee of ICDA has therefore been implementing projects of common interest with sister organisations like ISSF for some years. Chromium is the basic element of all families of stainless steel – at an average content level of 18 percent. The annual consumption of stainless steel is increasing at a compound growth rate of 5 percent and the material is used in an increasing number of applications in the food, beverage, mining and automotive industries and in architecture.

You will be aware that nickel, used in "austenitic" stainless steels is subject to considerable price fluctuations, due to stock market factors. In fact, in the last few years, the nickel price has increased to unprecedented levels, greatly affecting the cost of austenitic grades.

Ferritics, the second great family of stainless steels, contain no nickel. They do, however, contain chromium. In the context of our own development, given the exceptional growth in the stainless steel market, we feel we should strongly encourage the broader use of ferritic grades, at this time.

We were therefore delighted when ISSF asked us to support its project to identify and develop new ferritic market applications. The admirable aim of this project is to achieve sustainable growth in the stainless steel market and build a bright future for these excellent grades.

Looking at information already available on ferritic grades, one finds plenty of material on stainless steel in general but little dedicated specifically to ferritics – although such grades have existed for almost 100 years! This lack has encouraged ISSF to create the current handbook. It provides essential information on the technical properties, advantages and potential applications of ferritic grades and gives fabrication recommendations. It also attempts to correct certain popular misconceptions regarding the use and characteristics of ferritic stainless steels.

In conclusion, ICDA is aware that the volatility of nickel presents a major problem for stainless steel users. We are keen to support the industry and its customers by participating in the search for alternative solutions. It is clear to us that, thanks to its proven technical qualities and cost advantages, ferritic stainless steel is a steel whose time has come.

The following pages will guide existing and potential stainless steel users in extending the use of ferritic grades into new and exciting application areas.

Friedrich Teroerde
Chairman
Market Development Committee
ICDA

FERRITIC STAINLESS STEEL IS IDEAL FOR THE EXTERNAL SURFACES OF PROFESSIONAL KITCHEN EQUIPMENT.

THE SHINING APPEARANCE OF FERRITIC IS A SYMBOL OF CLEANLINESS AND HYGIENE IN FOOD-CONTACT APPLICATIONS.

What they're saying about ferritics

The economic advantages and technical merits of ferritic grades have been appreciated by certain market sectors for a number of years. The following testimonials, representing both existing and evolving markets, show that these benefits are becoming more widely understood.

STEFAN RAAB

DIRECTOR CORPORATE PURCHASING OF PRODUCT MATERIALS, BSH BOSCH UND SIEMENS HAUSGERATE GMBH, MUNICH, GERMANY

"We use stainless steel in about a third of our products. Our reason for using this material is partly functional, because of its corrosion resistance, and partly aesthetic. The share of ferritic stainless steel is approximately 50 percent at this time. Our intention is to increase this, mainly because ferritic gives the customer the benefits of stainless steel in terms of functional qualities and design, in many application areas, but within a limited cost frame. We will use ferritic grades wherever corrosion resistance and formability allow."

ROBERTA BERNASCONI

MANAGER, GLOBAL TECHNOLOGY – MATERIALS, WHIRLPOOL CORPORATION, CASSINETTA DI BIANDRONNO, ITALY

"As a manufacturer of home appliances, we use ferritics for our refrigerators and washing machines and are evaluating conversion to ferritics for cooking appliances and dishwashers. The cost advantage is such that it makes sense for us and our customers that we should make more use of these grades.

"We accordingly design our products with the necessary manufacturing considerations in mind and occasionally select a coated grade and even a fingerprint-protected coated grade, if need be, to ensure long service life. We may, on occasion, use a higher-alloyed ferritic grade. The important thing is to benefit from the economic advantages of using ferritics.

"We find them excellent for our applications and, given the high cost of nickel, the future, in our case, definitely lies with these excellent steels."

JEAN-LOUIS LALBA

MARKET BUYER FOR GROUPE SEB, (TEFAL, ROWENTA, KRUPS, MOULINEX, ARNO, ALL CLAD, PANEX, ETC.), RUMILLY, FRANCE

"We use about 15,000 metric tons of stainless a year, of which some 40 percent is ferritic. Our group originally used ferritics for cookware lids, for which they are ideal, for the stamped or brazed bases of induction cookware and for oven housings. This has extended to include frying pans, in those cases where the result is entirely satisfactory for the end-user.

"Often, in such applications, the corrosion resistance, deep drawing and polishing characteristics of ferritics have proved very acceptable both for us and our customers. There are cases where very demanding manufacturing or in-service requirements will exceed the limits of ferritic grades, in terms of one or more of these qualities or in terms of ease of processing. And there is even irrational prejudice against ferritics in some countries! However, we find these grades to be a perfect choice in many instances. Indeed, their magnetic nature is essential to stainless steel induction cookware. And, of course, the price of ferritics is stable and reliable.

"Given our good experience of ferritics, we intend to extend their use to other applications."

IN THE SUGAR INDUSTRY,
FERRITIC STAINLESS STEEL
HAS PROVED SUPERIOR
TO CARBON STEEL
ON EVERY LEVEL.

GAETANO RONCHI

SENIOR MANAGER, METALS PROCUREMENT, IKEA

"We use stainless steel for pots & pans, cutlery – including knives – and bathroom and kitchen accessories. Our current annual consumption, of 60,000 tons a year, is growing by about 15 percent a year. A substantial part of this is ferritic.

"In mid-2003, IKEA decided to adopt ferritic grades as general-purpose stainless steels, largely due to the material's stable, predictable price. Tests showed that articles with welded seams require a grade with higher chrome content than standard 430 for optimum corrosion resistance and that welded components need further processing to meet requirements. However, the decision represented a breakthrough for our development of stainless steel articles. Our sales growth and the use of stainless steel in new-product design would have been seriously jeopardised had we stayed with austenitic grades.

"A significant number of IKEA's stainless steel articles are manufactured by an Asian OEM and the success of our transition to ferritics has been due to educating and training the Group's purchase offices in Asia and its OEM subcontractors. Our target is to phase out austenitic grades completely, replacing them with upgraded ferritics. We are currently testing new ferritic grades with enhanced deep-drawing or corrosion-resistance properties."

MICHAEL LEUNG

ASSISTANT MANAGER,
YIU HENG INTERNATIONAL COMPANY LIMITED, MACAO

"The main products of our subsidiary Xinhui RiXing Stainless Steel Products, based in Guangdong Province, China, are stainless steel cookware and kitchen utensils. At the time of writing, the company consumes about 800 metric tons of stainless steel per month, of which 66-70 percent is ferritic. When we launched our factory, in 1999, we just used 400-series grades on the bottom of cookware. We began using them for cookware bodies in 2002.

"Low cost is not the only reason for favouring ferritics. Ferritic grades are magnetic and have good thermal conductivity. They are easy to recycle, which helps save the planet's resources. Changing from 304 to ferritic means that the manufacturer becomes more competitive and the consumer gets a safe product at a lower price. We must correct the unfounded prejudice that because ferritics are magnetic they are low-quality and have poor corrosion resistance.

"In factories where 304 is predominantly used, changing to ferritic grades means adjusting the manufacturing process and dies. This is costly. Our experience, however, shows that total production costs can be lowered with ferritics.

"Overall, we are very satisfied with ferritics. A good range of ferritic grades has been developed, to meet a wide variety of requirements. We hope ferritic stainless steel becomes widely available in steel service centres and becomes more extensively used in a broad range of sectors."

ATUSHI OKAMOTO

MANAGER OF NO.1 PRODUCTION SECTION, OSAKA WORKS,
TAKARA STANDARD CORP., JAPAN

"Takara Standard is a major Japanese manufacturer of kitchen and bathroom products. We use stainless steel for sinks and top panels of built-in kitchens and for bathtubs and mounting components of built-in baths. This company has used ferritic grades for about 40 years, for the simple reason that their properties are sufficient for these applications.

"We are successful with ferritics because our product design takes into account the specific mechanical properties of these grades and we have appropriate press-forming and die technology. We have met no major problems with ferritic grades. When an intricate shape is required, we carry out trials, to establish the best processing parameters.

"To conclude, we are very satisfied with ferritic stainless steels. I would like to see guidelines issued to help companies choose the right ferritic grade for their application."

OTHER TESTIMONIALS FOLLOW ON
THE LEFT-HAND PAGES BEFORE EACH CHAPTER...

FERRITIC STAINLESS STEEL WELDED TUBES HAVE A DYNAMIC FUTURE IN THE TUBE MARKET, DUE TO THE TECHNICAL AND ECONOMIC MERITS OF THESE GRADES.

WHAT THEY'RE SAYING ABOUT FERRITICS

CLOVIS TRAMONTINA

PRESIDENT, TRAMONTINA, SÃO PAULO, BRAZIL.

"As a major Brazilian manufacturer of household goods and tools, with an intense export activity, Tramontina currently uses about 850 tons of stainless steel per month, of which almost 30 percent is ferritic. The products for which we mainly use ferritics are economical trays and cutlery, sinks and the base of pans.

"We have used ferritics since 1974, when we started to produce pans and serving sets at our plant in Farroupilha. Our main reason for introducing ferritics was the lower cost of this raw material, coupled with the fact that their characteristics and properties are very satisfactory for these applications.

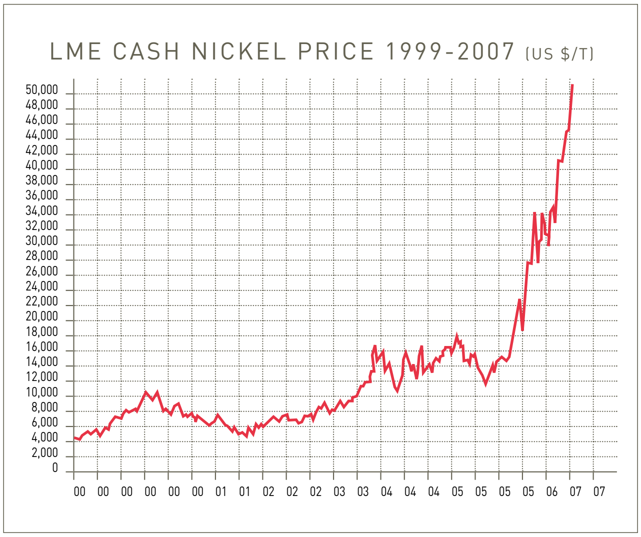
"In terms of deep-item manufacturing, such as lay-on sinks, ferritics are not as easy to work with as austenitics and require an intermediate rolling process. However, I still consider ferritic stainless steel as a good choice, due to the cost/benefit ratio. Being easy to clean and maintain, the material is hygienic. It also has all the aesthetic merits of stainless steels and is available in various surface finishes.

"To sum up, we're happy with ferritics and have used them for a long time now. In fact, we're always looking for new applications in which to use them and benefit from the cost advantage."

The "fabulous ferritics"

In the face of an explosion in raw-material costs, ferritic stainless steels are emerging as a useful solution in many applications where cost-saving material substitution has become an imperative.

In recent years, prices of raw materials such as aluminium, copper, zinc and nickel have exploded. Stainless steel producers and users, notably, are greatly affected by the high and volatile nickel price – which fluctuates daily. Nickel is a constituent of the widely used "austenitic" (300-series) stainless steel grades.



Stainless steel producers have no control over these phenomena, whose inevitable effect is to both push up and destabilize the cost of their nickel-containing grades. This situation is forcing some existing users of these grades to seek materials that cost less than austenitics but which might still provide fabrication and in-service characteristics adequate for their product or application.

The situation can also scare off potential users of stainless steel, who may believe that stainless steels possessing the qualities they need are financially out of reach.

LOWER COST, STABLE PRICE

The good news is that ferritic (400-series) stainless steel grades – low and stable in price yet boasting impressive technical characteristics – are waiting in the wings, ready to prove an excellent alternative material for many supposedly "austenitic-only" applications.

Professional griddle, in grade 430.

Canopy, in grade 446M, S. Korea.

Containing no nickel, ferritic grades basically consist of iron and chromium (min. 10.5%). The price of chromium – the ingredient that makes "stainless" steel especially corrosion resistant – is historically relatively stable. Certain ferritic grades contain additional alloying elements, such as molybdenum, to enhance specific properties.

Ferritic stainless steels share most of the mechanical and corrosion-resistance properties of their more expensive cousins, the austenitics, and even improve on austenitics in certain characteristics. Why pay for nickel if you don't have to?

Users of copper, aluminium or austenitic stainless steels in search of another solution can take heart. Ferritics are often an affordable and technically ideal way to benefit fully from stainless steel's unique qualities.

"Why pay for nickel if you don't have to?"

THE 5 FERRITIC "FAMILIES"

Ferritic grades fall into five groups – three families of standard grades and two of "special" grades. By far the greatest current use of ferritics, both in terms of tonnage and number of applications, centres around the standard grades. Standard ferritic stainless steels are plainly, therefore, totally satisfactory and entirely appropriate for many demanding applications.

Containers, in grades 409L and 410L.

STANDARD FERRITIC GRADES
~91% of total volume in 2006

Group 1	Group 2	Group 3
10%-14%	14%-18%	14%-18% stabilised
30%	48%	13%
Types 409, 410, 420 Cr content: 10%-14%	Type 430 Cr content: 14%-18%	Types 430Ti, 439, 441, etc. Cr content: 14%-18%. Include stabilising elements such as Ti, Nb, etc.

Group 1 (type 409/410L) 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 rust 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 and, recently, LCD monitor frames.

Group 2 (type 430) is the most widely used family of ferritic alloys. Having a higher chromium content, Group 2 grades show greater resistance to corrosion and behave most like austenitic grade 304. In some applications, these grades are suitable to replace type 304 and are usually of high enough grade for indoor applications. Typical uses include washing-machine drums, indoor panels, etc. Type 430 is often substituted for type 304 in household utensils, dishwashers, pots and pans. For information on its welding characteristics, see p. 37 *et seq*.

Group 3 includes **types 430Ti, 439, 441, etc.** Compared with Group 2, these grades show better weldability and formability. Their behaviour is even, in most cases, better than that of 304 austenitic grades. Typical applications include sinks, exchanger tubes (the sugar industry, energy, etc.), exhaust systems (longer life than with type 409) and the welded parts of washing machines. Group 3 grades can even replace type 304 in applications where this grade is an over-specification.

> *"Standard ferritic stainless steels are totally satisfactory and entirely appropriate for many demanding applications."*

SPECIAL FERRITIC GRADES
~9% of volume in 2006

Group 4	Group 5
Added Mo	Others
7%	2%
Types 434, 436, 444, etc. Mo content above 0.5%	Cr content: 18%-30% or not belonging to the other groups

Group 4 includes **types 434, 436, 444, etc.** These grades have added molybdenum, for extra 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. Type 444's corrosion-resistance level can be similar to that of type 316.

Group 5 (types 446, 445/447 etc.) has additional chromium and contains molybdenum, for extra corrosion and scaling (oxidation) resistance. This grade is 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 and extremely demanding applications stand out. For years, ferritic grades have been very extensively used in two extremely demanding applications: automotive exhaust systems and washing-machine drums.

Exhaust systems are exposed to high temperatures and corrosive environmental conditions. The use of stainless steel (ferritic) makes it possible to extend the warranty period of these parts.

Washing-machine drums have to withstand detergents and a virtually constantly humid environment. In this context, however, localised corrosion would be utterly inadmissible.

Car owners and householders will readily testify to their satisfaction with the long life of their washing-machine drums and exhaust systems. For manufacturers of these products, "fabrication friendliness" and major economic advantages are additional factors making ferritic stainless steel the obvious choice.

"...in many cases, ferritics are emerging as a better choice than more expensive materials."

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

Solar water heater, Taiwan, China.

TODAY'S EXCELLENT FERRITICS

Top-quality ferritic stainless steels have existed for some years now and much intensive research and development has gone into defining the remarkable grades currently available.

They are neither new to the market nor to their highly-experienced producers. Strangely, though, attitudes to these steels seem tinged with misconception and ignorance, for largely historical reasons. Grade 430 was once the only grade available and early, pioneering users may have received insufficient technical support regarding the use of this grade – especially, perhaps, in the case of welded structures or more corrosive conditions. In any event, the false idea took hold, in some quarters, that ferritics are "inferior" and that only austenitics will do.

Ferritics moved on a long time ago! Full technical support is available today and the range of grades has greatly increased and diversified, to meet users' needs, in terms of properties. Since these properties are broadly comparable to those of austenitics, it is wrong to see ferritic grades as either inferior or superior. They are just different – and usefully so.

Overpass noise-absorbing plate, Japan.

Indeed, in many cases, ferritics are emerging as a better choice than more expensive materials. They may more closely match the actual specification of a particular application, providing just the qualities needed – no less and, equally importantly, no more.

Milk tanker, cladding in grade 430, S. Africa.

FINE FOR FORMING

Every bit as malleable as carbon steel, ferritic grades are suitable for most forming operations. They are less malleable than austenitic stainless steels, which have exceptional properties, but in many cases austenitics are "over-specified".

Carbon steel and ferritic stainless steel demonstrate equivalent forming behaviour. One need only think, therefore, of the complex shapes into which carbon steel is currently formed (e.g. car bodies) to appreciate the broad possibilities for ferritic stainless steels. Given correct adaptation of tooling and choice of grade, countless shapes may be formed using ferritic grades.

PROUD TO BE MAGNETIC

A widely held misconception is that because ferritics are magnetic they are not "real" stainless steels and will rust like carbon steel. This is nonsense. Purely for reasons of atomic structure, some stainless steels are magnetic and some are not. Corrosion resistance is not a matter of atomic structure but one of chemical composition – in particular chromium content. Magnetism has nothing to do with it.

"A widely held misconception is that because ferritics are magnetic they are not "real" stainless steels and will rust like carbon steel. This is nonsense."

In fact, the magnetism of ferritic grades is one of the material's major assets, having many existing and potential uses and advantages, ranging from sticking memos on the fridge to storing knives and other metallic implements. Indeed, it is essential that pans used in "induction" cooking are magnetic, since the process involves generating heat in the cookware itself by transfer of magnetic energy.

Refrigerator, cladding in grade 430.

SPECIAL TECHNICAL ADVANTAGES

Stainless steel is an especially durable, low-maintenance material, with considerable Life Cycle Cost advantages over carbon steel. It is also 100% recyclable: over 60% of new stainless steel is made from melted scrap.

Stainless steel's main properties can be summarised as follows:

- corrosion resistance
- aesthetic appeal
- heat resistance
- low lifecycle cost
- full recyclability
- biological neutrality (meets EU RoHS requirements)
- ease of fabrication

Ferritic stainless steels boast all the advantages that stainless steels have over carbon steels in terms of corrosion resistance, low Life Cycle Cost and longevity. In addition, their advantages over their close cousins, the austenitic grades, do not just stop at costing less. Ferritics actually outshine austenitics in several characteristics.

FERRITIC SPECIAL TRUMP CARDS

- Ferritics are **magnetic**.
- Ferritics have **low thermal expansion** (they expand less than austenitics when heated).
- Ferritics have **excellent high-temperature oxidation resistance** (they are less prone to scaling than austenitics).
- Ferritics have **high thermal conductivity** (they conduct heat more evenly than austenitics).
- Ferritics stabilised with niobium have **excellent creep resistance** (they deform less than austenitics in response to long-term stresses).
- Ferritics are **easier to cut and work** than austenitics (which require special tools and more powerful machines and generate greater tooling wear).
- Ferritics are significantly **less prone to springback** than austenitics, during cold forming.
- Ferritics have **higher yield strength** (similar to that of popular carbon steels) than type 304 austenitics.
- Ferritics, unlike austenitics, are **not prone to stress corrosion cracking**.

PERFECTION IS MATCHING THE SPEC

In current market conditions, existing and potential users should, above all, avoid "over-specifying" when choosing a steel for a given application.

Historically, austenitic grade 304 has been the most widely developed and readily available stainless steel grade, due to the broad spectrum of applications for which it is suitable. Today's ferritic stainless steel grades, properly specified, can often be substituted for 304, to excellent effect.

Close and realistic examination of the fabricating and in-service qualities required will often reveal that an economically advantageous ferritic grade can perfectly adequately meet these specifications, for both fabricator and end-user.

"Today's ferritic stainless steel grades, properly specified, can often be substituted for 304, to excellent effect."

Kitchen line-up, in grade 430, S. Africa.

Sometimes, a reasonable in-service compromise (e.g. advising end-users to clean their product's surface regularly) is all that is required to keep a particularly inexpensive ferritic grade immaculately corrosion-free for the life of the product.

Cladding panels, in coated grade 430, Italy.

"A STEEL WHOSE TIME HAS COME"

Given the quality of today's ferritic grades, their price advantage and the exceptional properties that can be obtained by using additional alloying elements, the opportunities for ferritic stainless steels seem unlimited.

This brochure tries to make the qualities of ferritics easily understandable, describing them in relatively simple terms. Its aim is to encourage the greater use of stainless steels in general by increasing awareness of the merits of these lower-cost grades. This is part of a stainless steel industry initiative to help users specify the correct grades for their application.

The following pages examine the properties of today's ferritics, the roles of the various alloying elements and the many existing and potential applications of these steels.

IN CERTAIN ENVIRONMENTS FERRITIC STAINLESS STEELS PROVIDE AN AESTHETIC, DURABLE AND ECONOMICAL SOLUTION FOR URBAN FURNITURE REQUIREMENTS.

DOMINIQUE MARET

MARKETING DIRECTOR, FAURECIA EXHAUST SYSTEMS, FRANCE

"As a worldwide automobile equipment supplier, Faurecia's main use of stainless steels is in exhaust systems. Of the 200,000 metric tons or so of stainless steel that we use for this purpose annually, some 90 percent is ferritic. In fact, we've been using ferritics since the mid-1970's, when we started producing catalytic converters conforming to U.S. emission standards. Ferritics have much lower thermal expansion characteristics than austenitics, which was a crucial factor in the durability of these catalytic converters.

"Ferritics are a success story for us because our deep understanding of the specific behaviour of the grades in different exhaust environments means we can choose the right grade for the right application. Of course, formability limitations and the need to avoid intergranular corrosion need to be taken into account in both product design and manufacturing process. We increasingly require continued progress with ferritics in the areas of high temperature performance above 900°C and corrosion resistance. We believe that such improvements to ferritic grades will bring them closer to the performance of austenitics, but still at a lower and more stable cost. That said, we're already very satisfied with ferritics."

Corrosion resistance properties

Stainless steels are "stainless" because their chromium content gives them exceptional resistance to corrosion.

All steels are prone to corrosion, to varying degrees. Stainless steels, however, are significantly more corrosion resistant than carbon steels, due to the chromium they contain. Chromium (not nickel, as is sometimes imagined) is the key ingredient in the corrosion resistance of stainless steels.

"...ferritics and austenitics can be seen as two interchangeable stainless steel families."

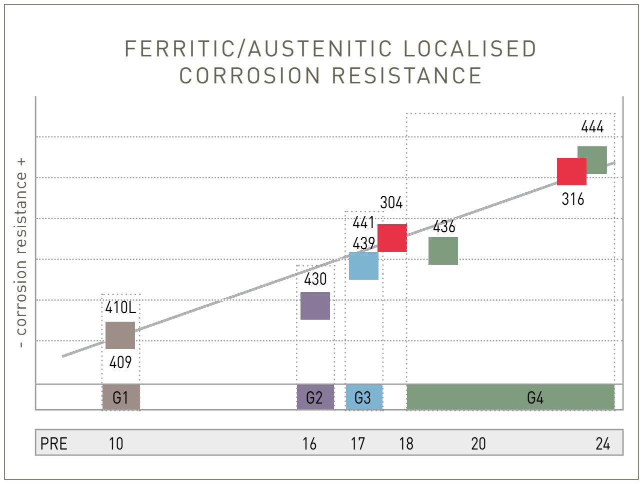
LOCALISED CORROSION RESISTANCE

Stainless steel applications are mostly maintenance-free but, in some cases, light maintenance (removal of deposits, for example) may be necessary, to ensure corrosion-free service life.

The corrosion resistance of stainless steels is determined more by chemical composition than by austenitic or ferritic atomic structure. Indeed, in terms of resistance to corrosion, ferritics and austenitics can be seen as two interchangeable stainless steel families.

Moisture separator reheater in grade 439, Europe.

A comparison of the corrosion-resistance properties of the five ferritic "groups" with those of austenitic type 304 clearly highlights the key role of chromium and shows that the corrosion resistance of nickel-containing (austenitic) grades can be matched by the majority of ferritic families.



The above chart shows that only molybdenum-containing ferritic grades have better localised ("pitting") corrosion resistance than 304. However, stabilised ferritic standard grades, although positioned slightly below 304, still have very good resistance to pitting corrosion.

Radiator grill and trim, in grade 436.

Partially 444 building cladding, Brazil.

Group 1 ferritics are best suited to non-severe conditions, such as inside the home (where the material is either not exposed to water contact or gets regularly wiped dry) or outdoors in contexts where some superficial corrosion is acceptable. In such contexts, this group of ferritics has a longer 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.

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

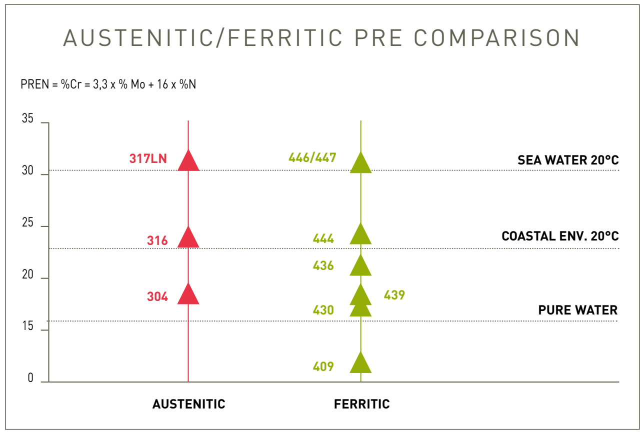
Group 5 includes, for example, grades with a very high chromium content of around 29% Cr, plus 4% Mo, which makes them as corrosion resistant in seawater as titanium metal.

Storage tank, in grade 444, Brazil.

"Nickel plays no role in resistance to pitting corrosion."

THE PRE FACTOR

The "PRE" or Pitting Resistance Equivalent number is a measure of the relative pitting corrosion resistance of a stainless steel grade in a chloride-containing environment. The higher a grade's PRE value, the more corrosion resistant that grade will be.



The PRE comparison table shows at a glance that for every austenitic grade there is a ferritic grade with comparable corrosion resistance.

In the commonly used shortened form of the PRE formula PRE=%Cr+3.3%Mo, molybdenum (Mo) is expressed as being 3.3 times more effective than chromium against pitting corrosion. However, chromium is always essential for providing the basic corrosion resistance. Molybdenum cannot replace this "base" amount of chromium in stainless steels, but can be used to boost corrosion resistance.

Nickel content is not considered in the formula, since in most applications it plays no role in resistance to pitting corrosion.

AVOIDING CORROSION

Stainless steel's "passive" layer (see p. 59) needs oxygen to remain intact. An accumulation of deposits can deprive the steel of oxygen at critical points, which could lead to corrosion. Propagation of corrosion may lead to eventual rupture of the part.

Barbecue and trolley, in grade 430, Italy.

CORROSION RISK FACTORS

- embedded particles
- superficial deposits
- surface defects
- structural discontinuities
- salinity (salty areas, seawater, etc.)
- increase of temperature
- highly acidic conditions (strong acids)
- a strongly “reducing” environment

CORROSION-PREVENTING FACTORS

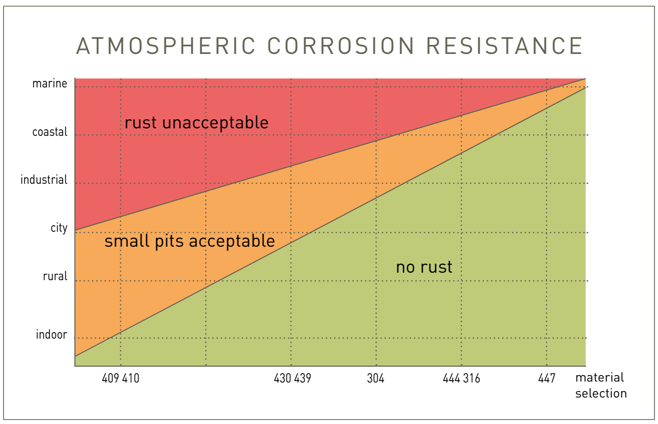
- a clean surface
- a smooth surface
- a pre-passivated surface
- ageing of the surface
- the washing effect (e.g. rain)
- higher chromium content
- oxidising conditions (O_2 – not too strong)
- adding molybdenum

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 to 14.

Railway station safety barrier, in SUS430J1L, Japan.

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 impurities. It is often initiated by the presence of chlorides or sulphur compounds – in an industrial environment. Typical conditions could be, for example, chloride deposits in a humid, marine atmosphere.



Different environments require different ferritic (400-series) or austenitic (300-series) grades, to resist atmospheric corrosion. In industrial, coastal and marine environments, some localised (pitting) corrosion may be acceptable, in certain applications.

"Ferritic grades can be used in atmospheric environments of widely varied corrosive severity."

CHOICE OF GRADE

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 the correct material choice.

RULES OF THUMB

- In the case of an aggressive environment, select a grade with a higher chromium and/or molybdenum content.
- Avoid rough surface finishes – favour a fine-polished surface with a low Ra value.
- Optimize design for "washability" (e.g. min. 15° slope on upward-facing surfaces).
- Avoid "crevice-like" geometries.
- Keep surface clean, by regular washing, to avoid staining and dust accumulation.

Electrification box, in painted grade 410, S. Africa.

OXIDATION RESISTANCE

Unlike the two above types of corrosion, high-temperature cyclic oxidation is "dry corrosion" occurring at high temperatures (>500°C) and in oxidizing atmospheres, with or without thermal cycle.

When stainless steels are heated, their chromium content forms a protective chromium oxide surface "scale" that delays further oxidation. The scale and the metal substrate will have different thermal expansion behaviour, which can affect the scale's stability, especially in service conditions of frequent thermal cycling. The expansion coefficient of the scale is very low and if that of the metal is too high, excessive scale will be generated, which will spall or crack when the metal cools and contracts.

Thanks to their lower thermal expansion coefficient, ferritic grades are much less prone than austenitic alloys to high-temperature cyclic oxidation scaling. Where there is no spalling or cracking, there is no new oxidation. This is a particular advantage in applications such as heating systems, burners or exhaust systems, including manifolds.

BROAD APPLICATION POSSIBILITIES

These interesting corrosion-resistance properties are far from being ferritic stainless steel's only attractions. They are already enough, however, to win friends for ferritics in the current climate of high material costs.

Close examination of the properties of ferritics tends to pay dividends. Some existing austenitic users might find, on examining their specification, that a ferritic grade is actually highly appropriate for their application.

Gymnasium roof, in grade 445, S. Korea.

...ferritic grades are much less prone than austenitic alloys to high-temperature cyclic oxidation scaling.

Burner, in grade 430.

Manifold, in grade 441.

Potential stainless steel users may be surprised by the exceptional qualities of ferritics – and discover that stainless steel is a viable option after all!

LIFE CYCLE COSTING: AN INVALUABLE GUIDE

The value of carrying out a Life Cycle Costing study on any potential application cannot be stressed too highly. Such a study will often reveal that stainless steel – generally seen as a costly solution – is actually the lower-cost option, viewed long-term.

Stainless steel's corrosion resistance means longer life, less maintenance, higher resale value, better appearance, etc. It renders painting or galvanizing unnecessary. And as if this were not inducement enough, the lower investment cost of ferritic grades can be a clinching argument in favour of stainless steel as a material choice.

Already widely used and respected, ferritic grades are nonetheless still being "discovered". The numerous well-proven existing applications, however, light the way to many exciting new possibilities for these fine steels.

...the lower investment cost of ferritic grades can be the clinching argument in favour of stainless steel...

INDUCTION COOKING REQUIRES THE MAGNETIC PROPERTIES OF FERRITIC GRADES.

WHAT THEY'RE SAYING ABOUT FERRITICS

SEUNG TAE BAEK

TEAM LEADER WASHING MACHINE PROCUREMENT, LG ELECTRONICS, KOREA.

"We use ferritic stainless steels mostly in washing-machine drums and have done so from an early stage in our development of automatic washing machines. In fact, in 2006, we used some 15,500 tons of ferritics, against 2,500 ton of austenitics, so ferritics accounted for 86 percent of our stainless steel consumption.

"The advantage for us is simply that ferritic grades have very satisfactory mechanical qualities but are less costly than austenitics. Technically, advances in moulding technology and the development of higher-quality ferritic grades mean we can use ferritics very successfully these days. Cracking and creasing in the press remains an occasional source of defects and we need to improve aspects of the deep drawing process. However, with ferritics we get a result that satisfies everyone in terms of both price and quality."

Mechanical and physical properties

Ferritic stainless steel grades are fabrication-friendly and suitable for a very wide range of applications.

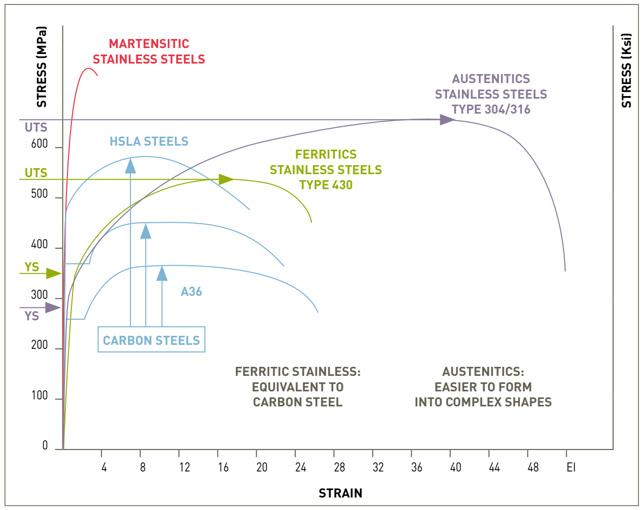
Ferritics have good mechanical properties, occupying an intermediate position in this respect when compared to the other stainless steel families. They have higher yield strength than austenitics, while their elongation and forming properties are equivalent to those of carbon steels. Their physical properties include two characteristics in which they out-perform austenitic grades: thermal expansion and thermal conductivity.

MECHANICAL PROPERTIES

Generally speaking, the mechanical properties of a metallic alloy are those that describe the material's ability to compress, stretch, bend, scratch, dent or break. The most commonly used criteria for evaluating mechanical characteristics are:

- **Strength**: the degree of resistance of a material to deformation. Two critical values are generally considered:
  - yield strength, or the stress the material can be subjected to before permanent plastic deformation occurs;
  - tensile strength, or the stress it can be subjected to before rupture/failure.
- **Hardness**: the degree of resistance to indentation by an applied load.
- **Toughness**: the capacity to absorb deformation energy before fracture.
- **Ductility (or plasticity)**: the ability to deform plastically without fracturing.

Some of these properties can be measured by a tensile test. The resulting stress-strain curves make it possible to determine yield strength (YS), ultimate tensile strength (UTS) and total elongation at failure (E). These tests result in the definition of a stress-strain curve charting the performance of the metal in response to various loads.



UTS is measured in MPa (1Mpa = 1N/mm³ = 145PSI = 0.1kg/mm³) and represents maximum resistance at failure. YS refers to the beginning of the "plastic" phase, where elongation no longer disappears when the stress is removed.

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

Bus body frame, in grade 410, S. Africa.

Escalator steps, in grade SUS430, Japan.

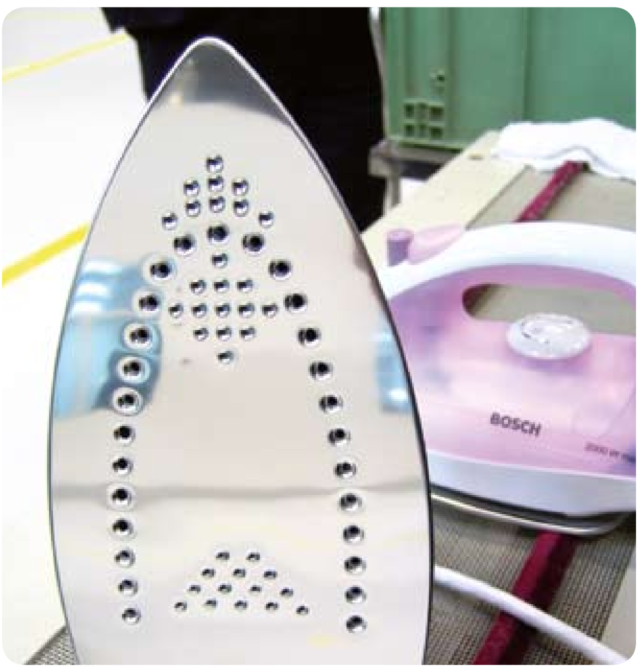
"...their elongation and forming properties are equivalent to those of carbon steels."

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.

MECHANICAL PROPERTIES (COLD ROLLED)

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	--	--	--	--	X2CrTi12	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

The above table expresses properties in terms of U.S., Japanese and European standards, comparing ferritic grades with standard austenitic grade 304. Rm = ultimate tensile strength, Rp02 = yield strength and A5/A80 = elongation to fracture.



Soleplate of electric iron, in buffed grade 430.


Boiler inner tube, in grade 444, S. Korea.

PHYSICAL PROPERTIES

The physical properties of a metallic alloy concern the material's ability to conduct heat, conduct electricity, expand or shrink, etc.

Ferritics are magnetic. They also have some other useful advantages over austenitic grades. Their thermal conductivity, for instance, is notably high. This means that they spread heat comparatively efficiently – which makes them highly suitable for applications such as electric irons or heat exchangers (tubes or plates).

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.

PHYSICAL PROPERTIES

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 10⁻⁶/°C	0~600°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

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.

AS STRONG AS CARBON STEEL, LOW-CHROMIUM FERRITIC GRADES ARE ALSO CORROSION RESISTANT. FERRITIC RAIL ORE WAGONS THEREFORE HAVE A LOWER LIFE CYCLE COST (LCC).

AESTHETIC AND HYGIENE FACTORS MAKE FERRITIC AN IDEAL MATERIAL FOR GAS HOBS.

WHAT THEY'RE SAYING ABOUT FERRITICS

ZHANG SEN

DIRECTOR OF STAINLESS STEEL PURCHASING, QINGDAO HAIER INTERNATIONAL TRADING CO. LTD., PEOPLE'S REPUBLIC OF CHINA

"As one of the world's leading white goods home-appliance manufacturers, the Haier Group uses ferritics in a broad range of products, including washing machines, dish washers, gas cookers, kitchen extractor hoods and microwave ovens. Having started using these grades before the year 2000, we currently use around 14,500 metric tons of ferritics a year, representing about 85% of our total stainless steel consumption. Ferritic grades are less costly than austenitic grades and are ideally suited to these applications.

"Compared with austenitic grade 304, standard ferritics neither meet the deep-drawing requirements of every part nor show as good corrosion resistance in chloride environments, nor do they have the same welding characteristics. However, they remain excellent materials for home appliances and, in terms of manufacturing, the adapted grades we use have good punching and drawing properties. So we're happy with ferritics.

"With the nickel price going up crazily, our purchasing costs for stainless steel have increased sharply. Replacing austenitics with ferritics not only lowers our raw-material costs but also saves resources and protects our environment.

I would go so far as to say that while austenitics dominate today's stainless steel market, the future of stainless-steel consumption lies with ferritics."

Forming ferritic grades

Thanks to their good drawing characteristics, ferritic stainless steels can meet the challenges of complex, three-dimensional designs.

Since their use in complex designs does not impair any of their remarkable corrosion resistant, heat resistant and decorative qualities, ferritic grades are often the right choice for both industrial and consumer products.

Stamped top and bottom of boilers, in grade 441, S. Africa.

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 a combination of stretching and deep drawing deformations.

Although the overall drawing capacity of austenitic grades is better than that of ferritics, some ferritic grades (notably titanium-stabilised, 17% chromium grades) show excellent drawing performance.

DRAWING FERRITIC GRADES

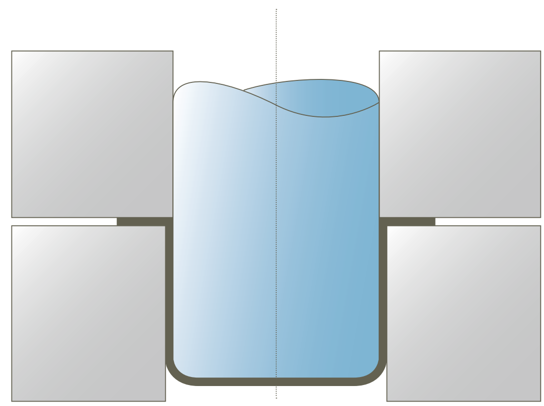
Drawing is the process most commonly used for forming hollow objects from a flat sheet or "blank". The good drawing behaviour of ferritic stainless steels, coupled with their considerable price advantage, can make ferritics the optimum choice.

"...some ferritic grades show excellent drawing performance."

HOW DRAWING WORKS

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 blankholder to form the walls or "skirt" of the part.

DEEP DRAWING



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

Sink, in grade 430, Japan.

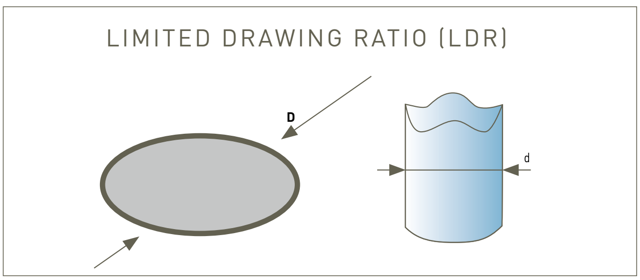
Microwave oven, in grade 430, BA finish, S. Korea.

SUCCESSFUL DRAWING MEANS

- The absence of fracture
- Excellent surface appearance
- Minimum material consumption
- High fabrication productivity
- Low tool wear

THE LDR FACTOR

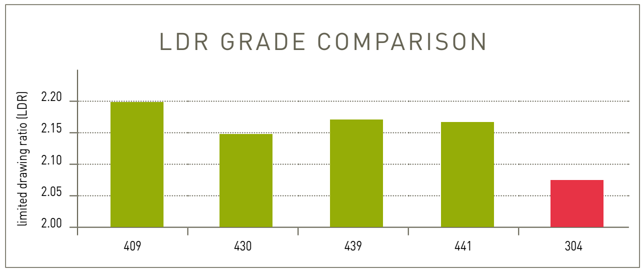
The Limited Drawing Ratio (LDR) is an important deep-drawability parameter.



Limited Drawing Ratio (LDR) 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.

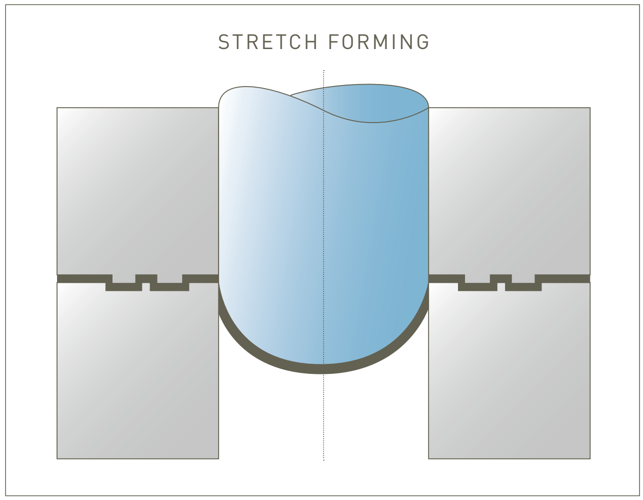
"Ferritics have higher LDR values than austenitics, which makes them particularly suitable for drawing."

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



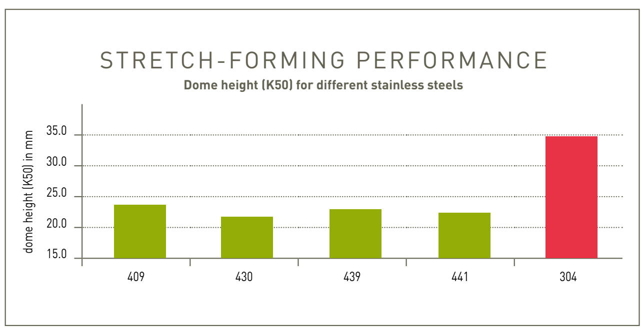
STRETCH-FORMING FERRITIC GRADES

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



In stretch-forming, the drawn area becomes thinner.

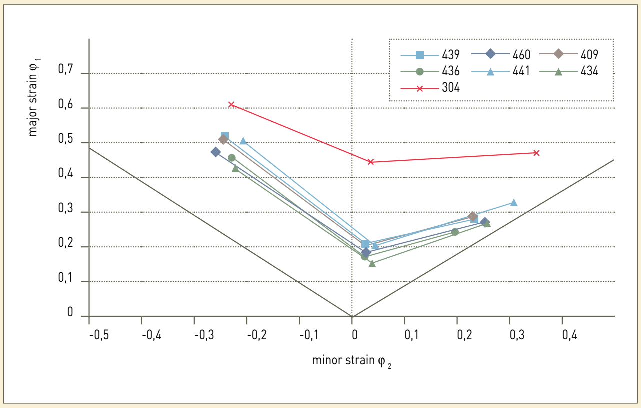
The table below compares the stretching performance of various grades "Dome height" refers to the maximum degree of deformation before "necking" (the phase just before failure) of a blank undergoing stretching.



FORMING LIMIT CURVES

In practice, industrial forming operations involve a combination of both pure drawing and pure 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 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 a grade's formability.

HOW FERRITICS BEHAVE

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 catalytic converter housing, in grade 441.

"Titanium-stabilised grade 430Ti is often chosen to replace an austenitic in applications involving deep drawing."

"RIDGING"

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

With and without surface defect.

This defect takes the form of a series 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.

Dryer drum: 409 welded sheet, formed by expansion.

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

Stamped manifold, in grade 441.

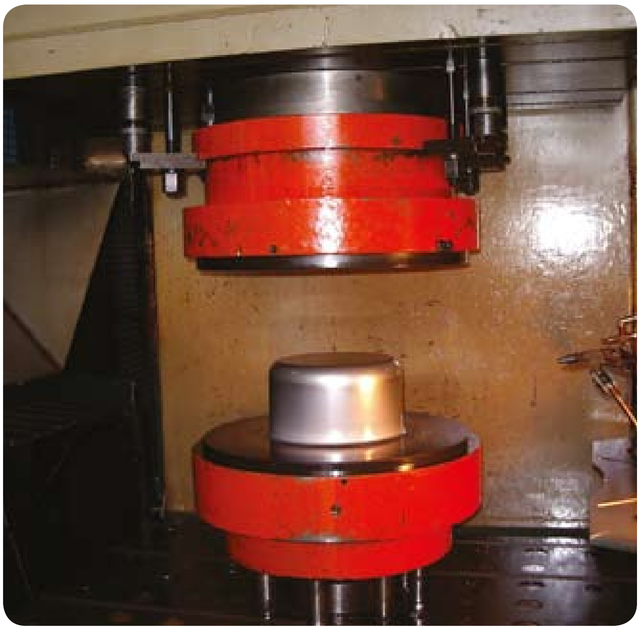
LUBRICATION

Good lubrication of the blank and the tooling is essential for successful drawing, to avoid altering the surface appearance and to prevent 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. Lubricants used with stainless steels are special oils with high pressure resistance and containing little or no chlorine. 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, tooling (mold and die) can be made of copper, iron or aluminium bronze.



Surface treatments, such as a TiCN layer, 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.

"Lubricants used with stainless steels are easily removable from a component after drawing."

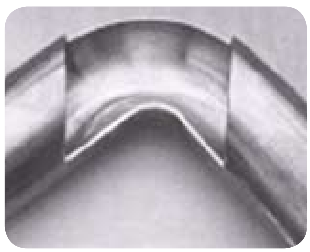
THE FORMING PROPERTIES OF THE MAIN STEEL GROUPS

The table below 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.

Welded bended tubes of a manifold, in grade 441.

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

	Carbon Steel	Ferritic SS	Austentific SS
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



Bending of 430Ti welded tube.

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

1.4003 hydroformed welded tube.

Deformation of the weld (1.4003).

THE CASE FOR FERRITICS

While the tables and curves show that austenitics are superior, overall, in terms of formability, the ferritic cost advantage is such that looking into the use of a ferritic grade can often pay clear dividends. Favouring the drawing method, especially, allows a remarkably wide use of ferritic grades. Indeed, in certain specific cases – such as deep drawing or springback effects – 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 on hand, to help users find ways to make ferritic grades work and to ensure that the most appropriate grade is chosen for any given application.

"...favouring drawing allows exceptionally wide use of ferritic grades."

INCREASINGLY STRINGENT ANTI-POLLUTION REGULATIONS PLUS TECHNICAL AND ECONOMIC REQUIREMENTS MAKE FERRITIC THE BASIC MATERIAL FOR EXHAUST SYSTEMS.

WHAT THEY'RE SAYING ABOUT FERRITICS

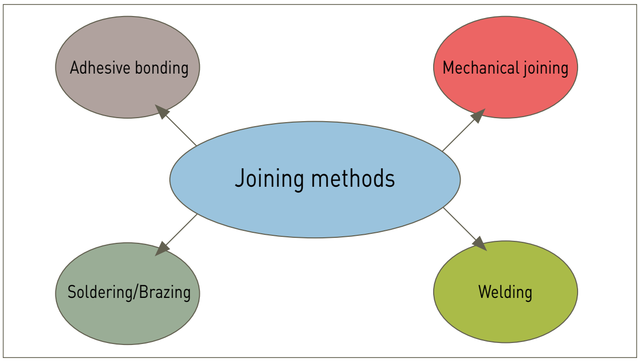
BERNHARD BLAESER

DIRECTOR, MACADAMS BAKING SYSTEMS (PTY) LTD SOUTH AFRICA

"My company makes baking ovens and provers. With the substantial increases in austenitic prices in the recent past, many players in the industry have moved away from or are in the process of moving away from stainless steel altogether. This is especially so in non-heat applications, like the external panels of ovens, and other bakery equipment not directly in contact with food. As ferritic prices have not been as severely affected, an alternative is to substitute ferritic. In essence then, manufacturers should consider substituting austenitics with ferritics, rather than dropping stainless steel entirely."

Joining ferritic grades

Ferritic grades are well suited to all the numerous methods of joining stainless steels.



- **Welding**: achieving complete joining of two or more materials through melting and re-solidification of the base and filler metals.
- **Soldering**: producing joining of materials by heating them to soldering temperature (below the solidus of the base metal) in the presence of filler metals with a liquidus of < 450°C.
- **Brazing**: the same as soldering but coalescence occurs at > 450°C.
- **Mechanical joining**: includes clinching, seaming, riveting and mechanical fasteners.
- **Adhesive bonding**: achieved by pressing clean, activated surfaces together after applying a bonding agent that bonds using either oxygen, water or a chemical reaction.

"Ferritic grades have some useful advantages over austenitics, when it comes to welding..."

WELDING

Of the many welding processes developed for carbon steels that can be used with stainless steels only a few are really appropriate for these materials 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 makes possible structures of lighter weight (through the optimal use of materials), joins all commercial metals and provides design flexibility.

The welding characteristics of stainless steels are affected 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 austenitics 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.

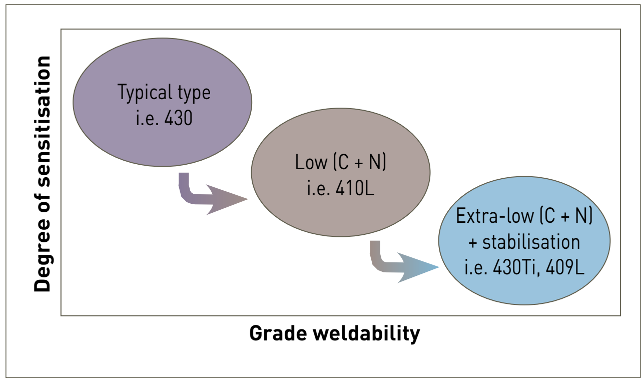
To ensure complete stabilisation, Ti content must be five times greater than carbon content, or Nb plus Ti must be three times greater than carbon content. Sometimes, the introduction of nitrogen into this formula can be advisable, to refine the grain in the melted zone.

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.

Exhaust system welding, grade 439, S. Korea.

"...stabilised ferritic grades are virtually immune to intergranular corrosion."



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 chrome in the weld zone. Alternatively, austenitic filler metal can be used, with an overmatch of Cr and Mo alloying elements.

Welded tank, grade 444, Europe.

PROTECTIVE GASES

Being high in chromium, stainless steels are highly oxidizable 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 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.

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.

WELDING FERRITIC STEELS: REMEDIES

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 550~800°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

ARC WELDING

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

GAS TUNGSTEN ARC WELDING (GTAW OR TIG/WIG)

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

Welded tank, grade 441, S. Africa.

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).

Ferritic tube mill, Brazil.

GAS METAL ARC WELDING (GMAW OR MIG)

Unlike the GTAW process, in GMAW (also known as the Metal Inert Gas 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 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's 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.

Welded structural frame in grade 1.4003.

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;
- "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 the lower and more precisely adjusted welding powers (due to low electrical and thermal conductivities) and higher electrode forces.

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.

Soldering a gutter, tin-coated grade 430Ti.

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

- They require only a low-temperature heat source.
- 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.

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

Before and after pickling.

Brazing welded tubes, grade 441.

PICKLING, PASSIVATION AND DECONTAMINATION

The slight discoloration 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%HNO3 + 2%HF) or using pickling pastes designed specially for welds.

It can be followed by a passivation and decontamination treatment – to help the passive layer (see p. 59) reform quickly and remove organic metallic residues (iron-rich particles). The process involves immersion in a cold 20%-25% nitric acid bath.

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

MECHANICAL JOINING

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

Mechanical joining of stainless steels		
Mechanical fasteners	Without any additional part	Riveting
Screws Self-piercing and thread-forming screws	Clinching Seaming	Self-piercing rivets

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.
- 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 ensure that none of the surfaces in contact are liable to induce corrosion due to galvanic coupling. To avoid this risk, parts to be joined should preferably be made from the same stainless steel or an equivalent grade. Certainly any screws, bolts, fasteners or rivets should be of 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 to 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.

Auto-riveting on 430, 1.5 mm.

CLINCHING

This relatively recent joining technique can be readily applied to stainless steels, thanks to their high ductility. Being 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 an adhesive bonding, producing a hermetically sealed joint, to avoid risk of crevice corrosion. This can also damp vibrations.

SEAMING

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.

Exploded display of washing-machine interior.

ADHESIVE BONDING

Adhesive bonding can be employed to reinforce mechanical joints, and in its own right for joining thin stainless steel sheets.


Bonding of guttering, tin-coated 430Ti.

The advantages of adhesive bonding are:

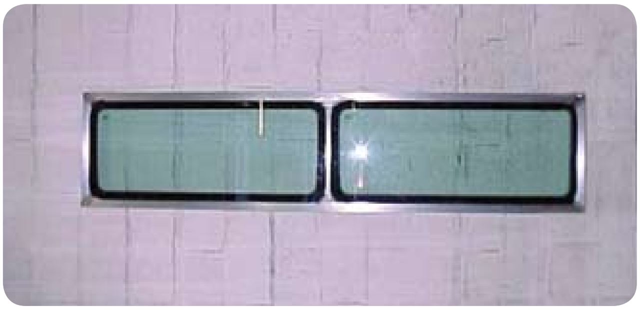
- There is no modification of the surface appearance, geometry or microstructure of the assembled areas.
- Dissimilar materials can be joined easily and aesthetically.
- Correctly designed, joints can have excellent fatigue strength.
- The method can provide thermal, electrical or acoustic insulation.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

Points to take into consideration, however, include the fact that such joints will tend to have a temperature limit of 200°C and will have a certain sensitivity to moisture. Adhesive joints will not be as strong as joints produced by welding or brazing. For this reason they are mostly used to produce lap joints, with the load spread over a sufficient area to limit local stresses.

It is also possible that a smooth-surfaced stainless steel (especially bright annealed) will not have good adhesive properties.

After roughening, surfaces should be very clean, dry and well prepared. The essential condition for good bonding is satisfactory wetting of the substrate by the adhesive.

As an example of adhesive bonding, bus and coach manufacturers now often construct a body frame of stainless steel shaped sections, often in ferritic grade 1.4003/410. The skin (sheet and/or glass) is adhesively bonded to this body frame. This approach increases the vehicle's life and reduces its weight.


Windows bonded to a 1.4003 tubular frame.


HANJIN
H A N J I

WHAT THEY'RE SAYING ABOUT FERRITICS

NICK MCDONALD

MARKETING MANAGER, LINCAT LIMITED, LINCOLN, UK

"Established in 1971, Lincat has been a front runner in the manufacture of professional kitchen equipment for 36 years. Grade 430 ferritic stainless steel, which we've used from the start, is the absolute bedrock of our product range.

"This grade ideally matches the spec of these applications and is an economical way of enjoying the advantages of stainless steel, which are so important when dealing with food preparation and presentation. In addition, 430's relatively low thermal expansion characteristic is a big technical plus in high-temperature applications. We make virtually everything in 430 ferritic, except some components, such as the inner tanks of wet-well bains-marie, where we are still using 304. On the fabrication side, our products are designed to be very easy to keep clean and 430 is an easy material to work with in this respect.

"Staying closely in touch with our customers' needs, we've built a reputation for outstanding product reliability and sturdy, durable construction. Grade 430 ferritic is an essential part of the equation. We and our customers are very satisfied with it."

Products and applications

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

Ferritic stainless steels are straight chromium steels, containing no 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.

Their range of uses is currently under-explored and the pages that follow 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.

This publication aims to inspire actual and potential users of ferritic stainless steels by illustrating existing, successful applications. It further aims to encourage responsible and informed material selection – optimal matching of material and application has never been more important.

AUTOMOTIVE

EXHAUST SYSTEM COMPONENTS

Grade 1.4509/441, diesel particle filter, Peugeot 607, Faurecia

EXHAUST SYSTEM COMPONENTS

Grade 1.4509/441, manifold, Faurecia

EXHAUST SYSTEM COMPONENTS

Grade 1.4512/409, silencer, Faurecia, S. Korea

EXHAUST SYSTEM COMPONENTS

Grade 304 & 441, diesel particle filter, E Class Mercedes, Faurecia

EXHAUST SYSTEM COMPONENTS

Grade SUS430J1L catalytic converter shell, honeycomb in 20%Cr-5%Al

EXHAUST SYSTEM COMPONENTS

Grade 1.4509/441, catalytic converter, Faurecia

DECORATIVE TRIM

Grade SUS430, S. Korea

DECORATIVE TRIM

Grade SUS430J1L, Japan

DECORATIVE TRIM

Grade SUS430, S. Korea

DECORATIVE TRIM

Grade 1.4016/430, black-coated trim, USA

DECORATIVE TRIM

Grade 1.4113/434, USA

S.U.V. FRONT ELEMENT

Grade 1. 4513, Plastic Omnium, France

CAR BOOT SILL

Grade 1.4510/430Ti, Peugeot 307, France

HEADLIGHT

Grade 1.4513, head-light trim, Italy

TRUCK

Grade 1.4113, truck decorative trim, USA

CLAMPS

Grades 1.4509/441 and 1.4016/430

FILTERS

Grade 1.4512/409L, Taiwan, China

BRAKE DISCS

Grade 1.4028/420

THERMOSTAT

Grade 1.4512/409, France

PADDLE WHEEL

Grade 1.4512/409, 1.5 mm thick, France

BUILDING & CONSTRUCTION

ACCESSORIES

IRONMONGERY – WINDOW HINGES & FASTENERS

Grade 1.4016/430, Europe

GUTTERING

Grade 1.4510/439, tin-coated, Europe

GUTTERING

Grade 1.4510/439, Europe

CHIMNEY DUCT

Grade 1.4510/439, Cheminées Poujoulat, France

CONSTRUCTION

SQUARE-TUBE EXTERIOR INSULATING MEMBERS

Grade SUH409L (1.4512/409), JSSA, Japan

EMERGENCY HOUSING

Grade 1.4016/430, painted, VERNEST® and Centro Inox, Italy

COMMUNICATION-SYSTEM SHELTER

Grade SUS436L (1.4526/436), JSSA, Japan

FACTORY BUILDING

Grade 1.4003, Columbus new finishing mill, S.Africa

ROOF STRUCTURE

Roof-support: a potential application for ferritics.

BUILDING

Grade SUS445J1 & SUS445J2, Nakano Sakaue Bldg., 1996, Japan

BUILDING

Resin coated SUS445J2, Phoenix Resort, 1994, Japan

BUILDING

Outer parts SUS445J1, inner SUS304, Nihonbashi Mitsui Bldg., 2005, Japan

CIVIL CONSTRUCTION

NOISE-ABSORBING PLATE FOR OVERPASS

Grade SUS436 (1.4526/436), JSSA, Japan

STRUCTURAL STEELWORK OF BRIDGE

Grade 1.4003/410 painted, SASSDA, South Africa (bridge in service for over 8 years).

INNER WALL OF TUNNEL

Grade SUS430J1L (1.4016/430), JSSA, Japan

INNER WALL OF TUNNEL

Grade 1.4016/430, painted, Monte Mario Tunnel, Centro Inox, Italy

WINDBREAKER FENCE

Grade SUS445J2, JSSA, Japan

PLATFORM SCREEN DOOR

Grade 1.4510/439, hair-line finish, KOSA, S. Korea

ELECTRIFICATION MASTS

Grade 1.4003 (first major application in 1982, along seashore – 10m from surf, no corrosion), S. Africa

POWER GENERATION

Grade 1.4003/ 410, X-grid cooling tower packing, S. Africa

CLADDING

BUILDING FAÇADE CLADDING

Grade SUS445M2, low-reflectivity matt finish, ASSDA, Australia

BUILDING FAÇADE CLADDING

Grade 1.4521/444 brushed no. 4 (horizontal panels), Vivo Building, Rio de Janeiro, Nucleo Inox, Brazil (coastal environment)

BUILDING FAÇADE CLADDING

Grade SUS445J2, Future Science Museum, JSSA, Japan

BUILDING FAÇADE CLADDING

Grade 1.4526/436, Ugine & Alz Steel Service Centre, Arcelor Mittal Stainless, Katowice, Poland

LIFTS

ESCALATOR STEPS

Grade SUS430LX (1.4016/430), Japan

LIFT PANELS

Grade 1.4510/439

ROOFING

MEDIADOME ROOF

Grade SUS445J2, Kitakyushu Mediadome (Fukuoka Pref.)1998, Japan

SCHOOL ROOF

Grade 430Ti (standing seam technique), Ugine & Alz, Austria

GYMNASIUM ROOF

Grade 445, KOSA, S. Korea

CANOPY

Grade 446, KOSA, Seoul, S. Korea.

CHALET ROOF

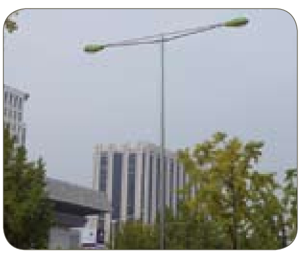
Grade 1.4510/430Ti (standing-seam technique), Ugine & Alz, Germany.

AIRPORT ROOF

Grade SUS447J1, Kansai Airport terminal building (architect Renzo Piano), JSSA, Osaka, Japan

URBAN FURNITURE

LAMP POST



Grade 1.4510/439, electro-polished welded pipe, KOSA, Seoul, S. Korea

POST BOXES

Grade 1.4003/410, painted, SASSDA, South Africa. "Utility" ferritics are often painted, when aesthetic considerations are important.

TICKET MACHINE ON RAILWAY PLATFORM

Grade 1.4003/410, painted (15 years in service), SASSDA, UK

ELECTRIFICATION BOXES

Grade 1.4003/410, painted (15 years in service), SASSDA, S. Africa

COMMERCIAL FOOD EQUIPMENT

BAKERY OVEN

Grade 430, Macadams Baking Systems (PTY) Ltd, S. Africa

GAS COOKING EQUIPMENT

Grade 430, Lincat, UK

COFFEE SERVER

Grade SUS430J1, JSSA, Japan

HEATED MERCHANDISER

Grade 430, Lincat, UK

CONVEYOR TOASTER

Grade 430, Lincat, UK

MICROWAVE OVEN

Grade 430 (interior and exterior), JSSA, Japan

BURNER RANGE

Grade 430 (gas hob), POSCO, S. Korea

REFRIGERATOR

Resin-coated SUS430J1L panel, JSSA, Japan

COFFEE MACHINE

Grade 430, Lincat, UK

RESTAURANT TROLLEY

Grade 430

DISPLAY MERCHANDISER

Grade 430, Lincat, UK

WALL CUPBOARD

Grade 430, Lincat, UK

HOME & OFFICE

In the following applications, ferritic (400-series) grades are now established as ideal, on grounds of their aesthetic quality, their resistance to cleaning and disinfection agents, their low thermal expansion coefficient and their magnetism (for induction cooking). They also offer considerable economic advantages over other materials.

DOMESTIC COOKING EQUIPMENT

GAS COOKER

KOSA, S. Korea

VARIOUS

TKN, Germany

MICROWAVE OVEN

Grade SUS430J1, JSSA, Japan

GAS COOKING TOP

TSSDA, Thailand

BARBECUE

Grade 1.4016/430, windscreen and brazier, Ompagrill and Centro Inox, Italy

BARBECUE

Grade 1.4016/430 barbecue, USA

COOKWARE AND POTS

WOK

INDUCTION COOKWARE

Groupe SEB (Tefal)

PRESSURE COOKER

Grade 430, Groupe SEB

PANS

Grade 430, POSCO, S. Korea

DISHWASHERS

DISHWASHER

Grade 430 interior panel

DISHWASHER

Resin coated SUS430J1L outer panel, JSSA, Japan

ELECTRICAL APPLIANCES

DISHWASHER

Grade 430 (exterior and interior panel), Haier, PRC

MIXER

Grade 1.4513, TKN, Italy

MIXER

Grade 430

ELECTRIC RICE COOKER

Resin coated SUS430, JSSA, Japan

ELECTRIC KETTLE

Resin coated SUS430, JSSA, Japan

EQUIPMENT

SHELVES

Grade 1.4016/430, horizontal shelves, Graepel and Centro Inox, Italy

RUBBISH CONTAINER

Grade 1.4016/430, Graepel and Centro Inox, Italy

PARTITION

Grade 430, POSCO, S. Korea

HANDRAIL

Grade 430 welded tube

LCD FRAME

Grade 410, POSCO, S. Korea

HOODS

KITCHEN HOOD

Grade 430, Blanco, TKN, Germany

KITCHEN HOOD

Grade 430, Falmec, Nucleo Inox, Brazil

KITCHENWARE

LIQUID DISPENSER

Grade 430

ELECTRIC KETTLE

Grade 430, Groupe SEB

PASTA COOKING POT

Single layer SUS430J1L (induction heating), JSSA, Japan

REFRIGERATORS

FRIDGE & FREEZER

Grade 430 panel

FRIDGE & FREEZER

Grade 430 door panel, TKN, Germany

SINKS

DOMESTIC KITCHEN SINK

Grade 430, Tramontina, Brazil

WASHING MACHINES

DRUM

Grade 430 (drum and exterior panel), TKN, Germany

DRUM

Grade 430 drum, LG Electronics, S. Korea

DRYERS

DRUM

Grade SUS430, JSSA, Japan

DRUM

Grade 409, Whirlpool, Europe

TABLEWARE

ASIAN SPOON

Grade 430

CUTLERY

400-series grades, IKEA

INDUSTRY

Ferritic is extensively used where the maintenance of carbon steel is a virtual impossibility.

DAM OUTLET PIPES

Painted grade 1.4003/410, Columbus, S. Africa

FLOOD CONTROL GATES

Painted grade 1.4003/410, Columbus, S. Africa

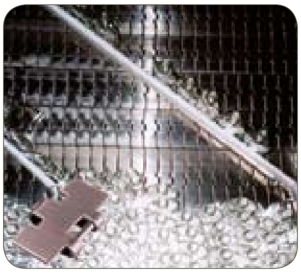
TANKS

Grade SUS430J1L, coloured-resin coated (outer jacket), JSSA, Japan

FRACTIONATING COLUMN

Grade 410S, Europe

CONVEYOR BELT



Grade 410S, Europe

BURNERS

BURNERS

Grade 1.4509/441 (high oxidation resistance)

BURNER

Grade SUS430, boiler gas burner, JSSA, Japan.

BOILERS

BOILER INNER TUBE

Grade 1.4521/444, KOSA, S. Korea

"HYDROBOIL" INSTANT BOILING WATER HEATER

Grade 1.4521/444, ZIP Industries and ASSDA, Australia

BOILER

Grade 444, Europe

HOT WATER TANK

Grade 1.4521/444, Europe

HOT WATER TANK

Grade SUS444, JSSA, Japan

FOOD PROCESSING

WALLS & CEILINGS

Grade 445M2, Melbourne, Australia

HEAT EXCHANGERS

Substitution from cupro-nickel (due to erosion by vapour and migration of copper), carbon steel (erosion problems) and 304 (higher thermal expansion than the carbon steel frame).

MOISTURE SEPARATOR REHEATER WELDED TUBES

Grade 1.4510/439, VALTIMET, Europe

FEEDWATER HEATER WELDED TUBES

Grade 1.4510/439, VALTIMET, Europe

CONDENSER WELDED TUBES

Grade 1.4510/439, VALTIMET, Europe

SOLAR WATER HEATERS

SOLAR WATER HEATER

Grade SUS444, Suncue Company Ltd. and YUSCO, Taiwan, China

SOLAR WATER HEATER

Grade 1.4509/441 (cylinder), Sun Tank and SASSDA, S. Africa

SOLAR WATER HEATER

Solar panels: frame and collector a potential application for ferritic grades 441/444.

SUGAR INDUSTRY

CONVEYOR SYSTEM

Grade 1.4003/410, Columbus, S. Africa. Here, ferritic has lasted over 18 years.

SLATE CARRIER

Grade 1.4003/410, Columbus, S. Africa. This machine has been in service 22 years.

SCALDING JUICE HEATER COVER

Grade 1.4003/410, Columbus, S. Africa. Carbon steel (top) compared to ferritic (bottom) after 6 years in service.

HEAT EXHANGER TUBES

Grade 1.4521/444, Nucleo Inox, Brazil

CRYSTALISER & DIFFUSER

Grade 1.4003/410, Columbus, S. Africa

TANKS

WATER TANKS & PIPES

Grade 444, Brazil
.

WATER TANK

Grade 444, KOSA, S. Korea

WATER TANK

Partially in grade SUS444, finish no. 4, JSSA, Japan

WATER TANK

Partially in grade SUS444, finish no. 4, JSSA, Japan

FERMENTATION AND STORAGE TANK

Grade 444, Nucleo Inox, Brazil. Sander Inox has successfully produced such tanks for 7 years.

FERMENTATION AND STORAGE TANK

Grade 444, Nucleo Inox, Brazil

MOTORCYCLE

MOTORCYCLE EXHAUST

Grade 1.4512/409L, YUSCO, Taiwan, China

MOTORCYCLE EXHAUST

Grade 1.4509/441, Centro Inox, Italy. The new Vespa ET2 is equipped with a ferritic catalytic silencer.

MOTORCYCLE EXHAUST

Grade 409L

MOTORCYCLE EXHAUST

Grade 409L, Acesita, Brazil

DISC BRAKE ROTOR

Grade SUS410SM1, JSSA, Japan

VARIOUS

Grade 420 brake dics, 1.4113 decorative trim, Italy

TRANSPORTATION

BUS & COACH BODY FRAME

Grade 1.4003/410, Columbus, S. Africa.

BUS & COACH BODY FRAME

Grade 1.4003/410 (lower part painted), Columbus, S. Africa.

BUS & COACH BODY FRAME

Grade 1.4003 welded tubes and panel, Solaris Bus & Coach Co. Poland

CONTAINER

Grade 1.4003/410 (frame and panels), POSCO, S. Korea

CONTAINER

Grade 1.4003/410, painted (frame and door panels)

COAL WAGON

Grade 1.4003/410 (panels), Columbus, S. Africa. In service for over 20 years.

COAL WAGON

Grade 1.4003/410 (panels), Columbus, S. Africa. In service for over 15 years.

COAL WAGON

Grade 1.4003 (interior of previous), SASSDA, S. Africa

COAL WAGON

Grade 1.4003/410, painted, Europe

COAL WAGON

Grade 409/410, painted, TISCO, PRC

COAL WAGON

Grade 1.4003, SASSDA, S. Africa

TRAMWAY

Grade 1.4003/410 (body frame and painted panels), Europe


SIEMENS

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

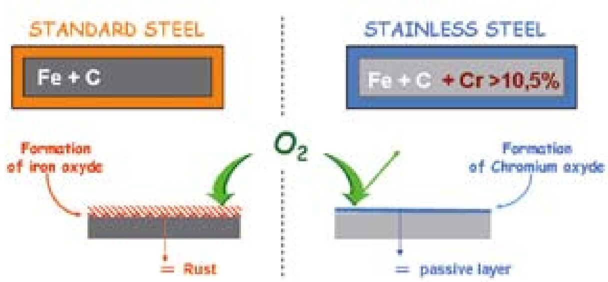
Stainless steel was "discovered" around 1900–1915. As with many discoveries, it was actually the result of the accumulated efforts of several scientists. Research was published in England, France and Germany on alloys with compositions that would be known today as the 410, 420, 430, 442, 446 and 440C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

Stainless steels must have a very low level of carbon. For many years it was difficult to obtain such a low carbon level, which explains the late arrival of good ferritic grades (in the 1980s).

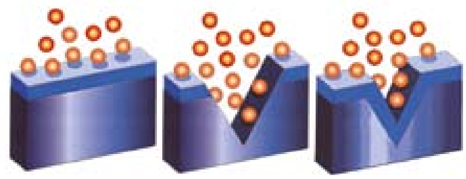
THE GRADES AND THEIR CHEMISTRIES

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.

THE PASSIVATION PROCESS



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.

THE 5 GROUPS OF FERRITIC GRADES

Group 1	Group 2	Group 3	Group 4	Group 5
10%-14%	14%-18%	14%-18% stabilised	Added Mo	Others
Types 409, 410, 420 Cr content: 10%-14%	Type 430 Cr content: 14%-18%	Types 430Ti, 439, 441, etc. Cr content: 14%-18%. Include stabilising elements such as Ti, Nb, etc.	Types 434, 436, 444, etc. Mo content above 0.5%	Cr content of 18%-30% or not belonging to the other groups

STANDARDS: - ASTM A 240 - 06C, Nov. 2006

- EN 10088-2, Sept. 2005

- JIS G 4305, 1991

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)	0.15	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

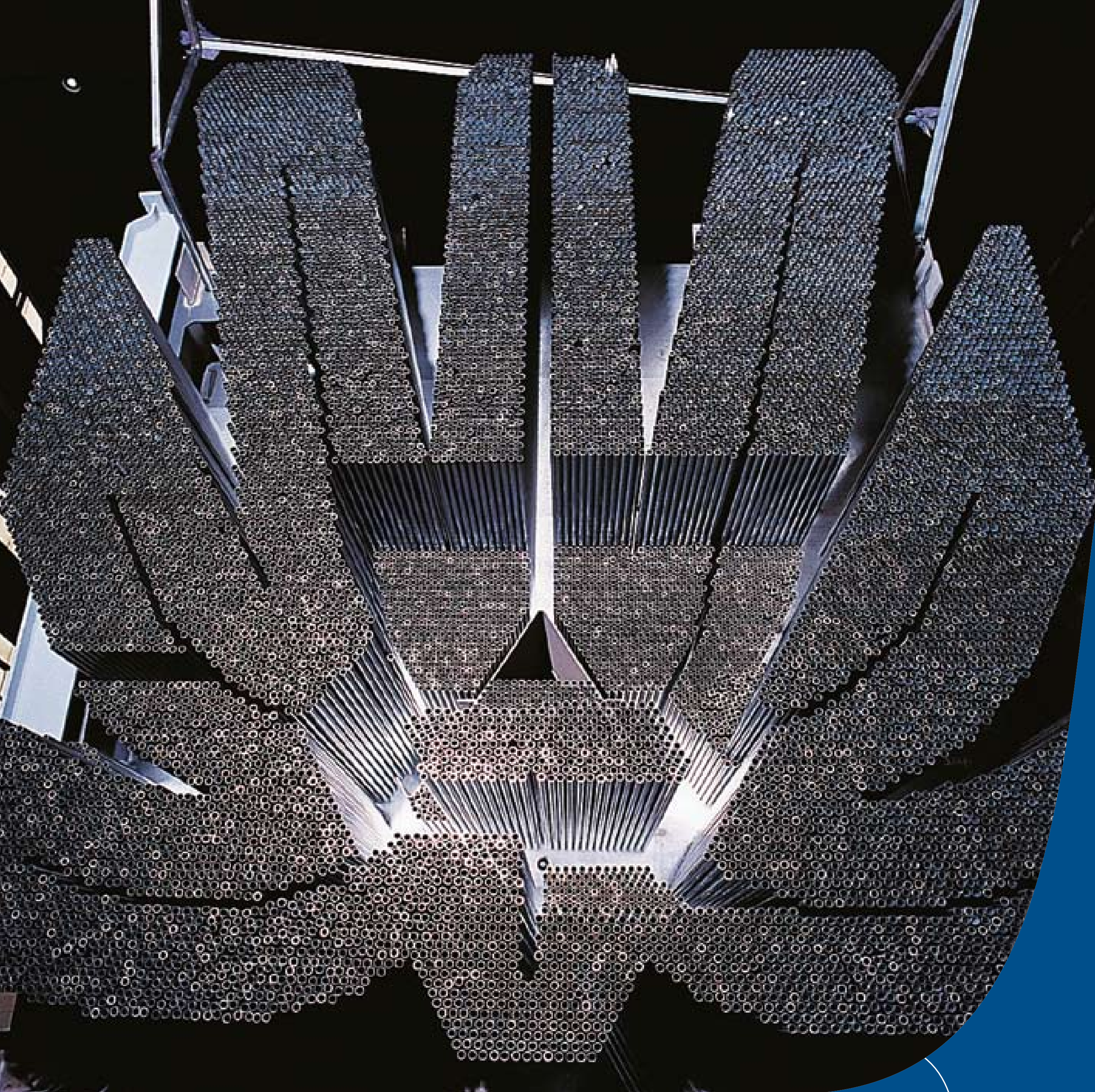
	AISI, ASTM	Chemical component (Maximum weight %)													Standard	Ref.
		C	Si	Mn	P	S	Cr	Mo	Ti	Nb	Cu	Al	N	Ni		
14%-18%Cr stabilised	430J1L	0.025	1.0	1.0	0.04	0.03	16.0-20.0			8x(C+N)-0.8	0.3-0.8		0.025		JIS	SUS430J1L
	430LX	0.03	0.75	1.0	0.04	0.03	16.0-19.0		0.1-1.0					0.6	JIS	SUS430LX
	439	0.03	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			0.15	0.03	0.5	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 %)													Standard	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



IMPRESSIVE USE OF FERRITIC WELDED TUBES IN A POWER STATION CONDENSER.

Surface finishes

Surface finishing treatments applied to stainless steels can take many forms. The main finishes are described below. Ferritic surface finishes are the same as those for austenitic and other grades.

Description	ASTM	EN 10088-2	Notes
Hot rolled	1	1E/1D	A comparatively rough, dull surface produced by hot rolling to the specified thickness, followed by annealing and descaling.
Cold rolled	2D	2D	A dull, cold rolled finish produced by cold rolling to the specified thickness, followed by annealing and descaling. May also be achieved by a final light pass on dull rolls.
Cold rolled	2B	2B	A bright, cold rolled finish commonly produced in the same way as No. 2D finish, except that the annealed and descaled sheet receives a final cold roll pass on polished rolls. This is a general-purpose cold rolled finish and is more readily polished than No. 1 or No. 2D.
Bright Annealed	BA	2R	BA finish produced by performing bright annealing in an inert atmosphere after cold rolling. Smoother and brighter than No. 2B.
Brushed or dull polished	No. 4	1J/2J	A general-purpose bright polished finish obtained by finishing with a 120-150 mesh abrasive, following initial grinding with coarser abrasives.
Satin polished (matt)	No. 6	1K/2K	A soft satin finish having lower reflectivity than brushed (or dull polished) finish. It is produced by a Tampico brush.
Bright polished (mirror)	No. 8	1P/2P	The most reflective finish commonly produced. It is obtained by polishing with successively finer abrasives then buffing with a very fine buffing compound. The surface is essentially free of grit lines caused by preliminary grinding operations.
Electropolished surfaces	-	-	This surface is produced by electrolytic attack. This electrochemical process improves the surface finish by removing peaks of surface irregularity.

(NB: the above table is not official and should be used only as a guide)


2D


2B


BA


no. 4


no.6

APPENDICES

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APPENDICES

Acknowledgements

ISSF is grateful to Friedriche Teroerde (ICDA) for writing the Foreword to this brochure and to Philippe Richard (Arcelor Mittal Stainless, France), who coordinated a working group consisting of Jacques Charles (Ugine & Alz , France), Peir-Teh Huang (Yusco, Taiwan, China), Kwangyuk Kim (Posco, South South Korea), Jochen Krautschick (ThyssenKrupp Nirosta, Germany), Juan Antonio Simon (Acerinox, Spain) and Hideaki Yamashita (JFE, Japan). Thanks also go to Benoît Van Hecke (Euro Inox, Belgium) for checking the text and to Paul Snelgrove, freelance consultant and English-language writer (Paris, France), for his invaluable help in preparing the brochure.

Thanks are also due to de blauwe peer (Ghent, Belgium) for design and production, to MBCOM (Paris, France) for designing the cover and to Stevens Creative Printing (Merelbeke, Belgium) for printing.

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DATE OF PUBLICATION APRIL 2007 - COPYRIGHT - ISBN 2-930069-51-1

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