“New 200-series” steels:

An opportunity or a threat to the image of stainless steel?

History

Properties

Applications

Advice

A technical guide to chrome-manganese austenitic stainless steels and advice for potential users

November 2005

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About the 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 63 company and affiliated members, in 23 countries. Jointly, they are responsible for around 85 percent of worldwide stainless steel production.

Executive summary

Chrome-manganese austenitic stainless steel grades ("standard 200-series") with well-defined and well-documented technical properties have proved acceptable materials for specific applications for many years – for example in North America and India. However, there has recently been a significant increase in the use of new and more economical chrome-manganese grades (which can be referred to as "new 200-series" grades), notably in **Southeast Asia and especially China**.

These new grades use different chemistries, characterised by reduced chromium (≤15%) and extra-low nickel content. In some cases copper is added and trace element content may be poorly controlled.

The increase in the production and use of these "new 200-series" grades is **not currently matched by an adequate level of user knowledge**. There is therefore a risk that they may be used in **unsuitable applications** – as an ill-judged cost-saving strategy, or through **ignorance of the in-service conditions necessary** for the material to perform well over time.

There are so far **no international standards and references** for the proper use of "new 200-series" grades. It should be pointed out that **the properties of some of these grades are in many respects not comparable to those of well-established stainless steels – for example in terms of corrosion resistance, formability and weldability**. Since they are non-magnetic, however, a buyer could mistakenly assume them to be the equal of chrome-nickel austenitic grades, which are widely known to be non-magnetic. Indeed, there have even been cases of **mislabelling and fraud** – which could seriously threaten stainless steel's positive image.

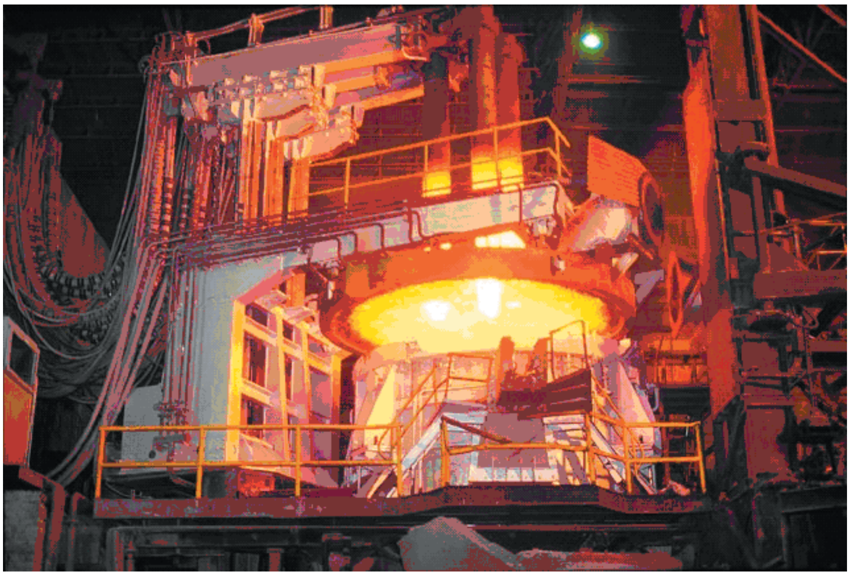
Finally, other potential concerns surrounding "new 200-series" grades include problems with scrap traceability, if not well managed, in the recycling process.

The overall situation risks becoming a nightmare for end users, fabricators and producers, since high quality, long service and durability are key attributes of stainless steel's success. Ever concerned to provide long-lasting solutions, ISSF therefore considers it has a responsibility to support user/supplier dialogue and help users make responsible and well-informed material selection decisions. Furthermore, ISSF members are committed to ensuring that the quality of stainless steel and its products should be consistent and reliable.

It is imperative that anyone considering using stainless steel **compare the nature and in-service conditions of the intended application with the properties of the grades considered. It is strongly recommended that end-users considering 200-series grades consult only highly reputable and informed suppliers** able to provide good quality grades, of known and reliable origin, and offer impartial advice. Where 200-series grades are considered for use, viable alternatives can often be found amongst chrome-nickel (300-series) and ferritic (400-series) grades.

The ISSF members listed at the end of this document, including both stainless steel producers and stainless steel development associations, are committed to ensuring transparency in the marketplace. Achieving this includes providing information and guidance for those seeking help in choosing the right stainless steels for their specific needs.

An overview of stainless steel



The best-known characteristic of the ferrous alloy known as stainless steel is its remarkable resistance to corrosion. In most applications, stainless steel is a durable and low-maintenance material. It is also 100% recyclable.

This corrosion resistance is due to the material's chromium content, which, when exposed to oxygen, forms a thin surface-layer of chromium oxide that protects the metal from air and water. This layer has the ability to self-repair if damaged, in a phenomenon known as "self-passivation". It is also responsible for the material's characteristic shiny appearance.

There are four basic types of stainless steel, defined by their crystalline microstructure (see box).

The four types of stainless steel

Austenitic

Austenitic stainless steels contain a significant amount of chromium, and sufficient nickel or manganese to "stabilise" the "austenite" microstructure that gives these steels good formability and ductility (and makes them non-magnetic). A typical composition is 18% chromium and 8% nickel, as found in the popular "304" grade – to use the American Iron and Steel Institute (AISI) designation. Austenitic grades can be highly durable and corrosion resistant and have high ductility, low yield stress, relatively high tensile strength and good weldability. They have a very wide range of uses.

Ferritic

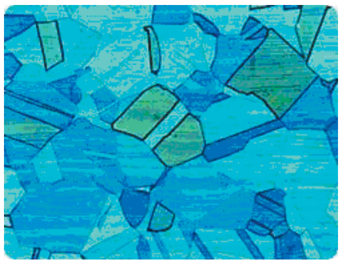
Ferritic stainless steels have properties similar to those of mild steel but show better corrosion resistance. Most common are 12% and 17% chromium-containing grades – the former used mostly in vehicle exhaust systems and the latter mostly in cooking utensils, washing machines and indoor architecture. Being magnetic, these steels are easily distinguished from austenitic stainless steels.

Austenitic-Ferritic (Duplex)

These stainless steels, which contain some nickel, have a roughly 50% ferritic and 50% austenitic microstructure and are both strong and ductile. They are mostly used in the process industry and in seawater applications.

Martensitic

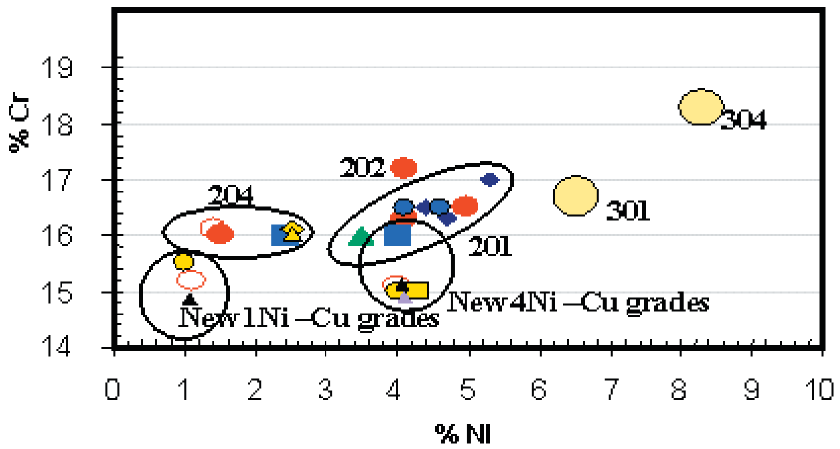
Like ferritic grades, martensitic grades contain 12%-17% chromium. However, they have higher carbon content and are subjected to specific heat treatments during production, making them very hard and strong. They are used for turbine blades, cutlery, razor blades, etc.



The austenitic microstructure of stainless steel

Chrome-manganese austenitic grades in brief

Adding nickel is the classic way to preserve an austenitic structure in stainless steel. However, adding manganese, combined with nitrogen, can have the same effect – and at lower material cost, under present market conditions. Chrome-manganese grades are characterised by considerably reduced nickel content and the addition of manganese and, often, nitrogen and copper (which also have austenite-forming properties). The most typical chrome-manganese grades are often referred to simply according to their nickel content: namely "4% Ni" and "1% Ni".



Nickel/chrome balance in austenitic grades

The chromium and nickel content of "standard" chrome-manganese grades and 301 and 304 chrome-nickel grades is higher than that of "new" copper-containing chrome-manganese grades.

As well as currently being significantly cheaper, from a material cost point of view, chrome-manganese stainless steels can offer good formability (ductility) and/or strength, depending on their chemistry. Indeed, certain grades (equivalent to 201-, 202- and 205-series) even offer about 30% higher "mechanical properties" (yield strength) than the classic 304-series chrome-nickel grade – allowing designers to cut weight.

Reducing nickel, on the other hand, reduces the maximum chromium content possible in the alloy. Less chromium means less corrosion resistance and a consequent narrowing of the range of applications for which the material is suitable.

Table 1: Chemical composition of standard grades

Grades	Chemical Composition (wt %)					
	C	Mn	Cr	Ni	N	Cu
AISI 201 / UNS S20100	0.15 max	5.50 - 7.50	16.0 - 18.0	3.50 - 5.50	0.25 max	-
AISI 202 / UNS S20200	0.15 max	7.50 - 10.0	17.0 - 19.0	4.00 - 6.00	0.25 max	-
UNS S20430 / 204 Cu	0.15 max	6.50 - 9.0	15.5 - 17.5	1.5 - 3.5	0.05 - 0.25	2.0 - 4.0
UNS S20500	0.12 - 0.25	14.0 - 15.50	16.5 - 18.0	1.0 - 1.75	0.32 - 0.40	-
304 / UNS S30400	0.08 max	2.0 max	18.0 - 20.0	8.0 - 10.5	-	-

(AISI = American Iron and Steel Institute. UNS = Unified Numbering System)

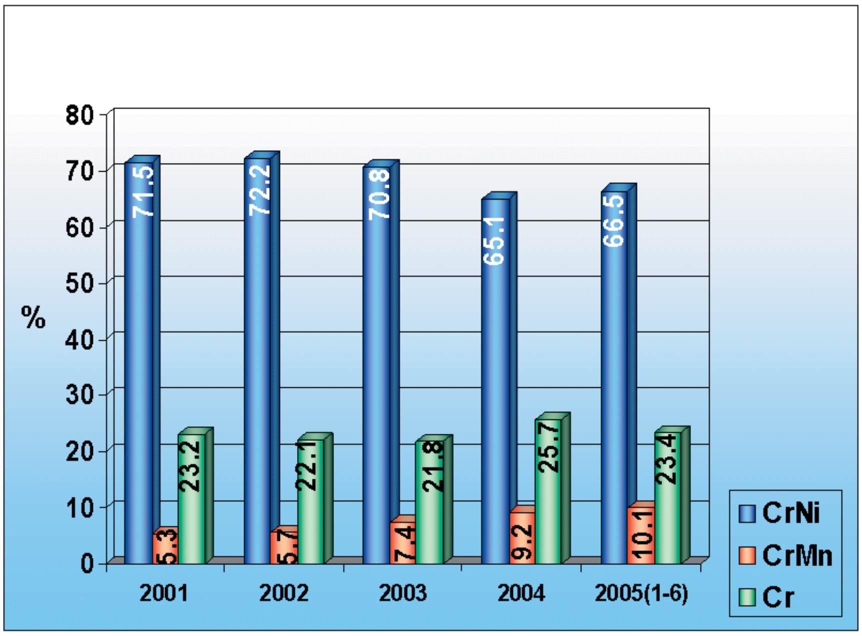
Chrome-manganese grades then and now

Chrome-manganese grades were first developed in the early 1930s. Their use increased during the 1950s, in America, as a way of conserving available nickel, and new grades have continued to be developed up to the present day. Rises in the material's popularity have been linked to world nickel price volatility (that is, increased nickel prices) and advances in steel production technology.

In the late 1980s, a nickel crisis caused the Indian government to reduce nickel imports. This led to a huge and sustained increase in tonnage of chrome-manganese grades produced and developed in that country. Increased knowledge of the in-service properties of these grades consequently began to be acquired and many highly suitable applications for the grades emerged.

These "new" chrome-manganese steels are austenitic and similar in appearance to popular 300-series steels. There is therefore a risk that users who are ill informed about the qualities of the material they are buying may believe a chrome-manganese grade to be effectively equivalent to a chrome-nickel (300-series) grade for their application, when it is not. They may even be misled by the erroneous belief that if a stainless steel is non-magnetic it must be "chrome-nickel". There have even been cases of deliberate mislabelling reported, in cases where these "new 200-series" steels have been fraudulently sold as type 304.

There are also cases of some small producers using inferior production methods, resulting in the production of chrome-manganese grades with high sulphur and/or carbon residues. Such residues further weaken corrosion resistance and weldability.



Worldwide crude stainless steel production

Comparing chrome-nickel, chrome-manganese and ferritic/martensitic (Cr) grades, this chart shows that chrome-manganese grades now represent almost 10% of the world stainless steel market.

The new century saw both a new period of high volatility in nickel prices and a rise in consumption of stainless steel in China. Continuous pressure to cut costs, especially from the Asian market, has since resulted in the development of austenitic grades ever lower in nickel and chromium, often not covered by international codes or specifications. In fact, numerous chrome-manganese grades are company-specific and identified simply by a title given to them by the producer.

It is thus plainly desirable at this time to educate users, so they can make more informed material-selection choices, and to encourage upstream responsibility and enhanced supply-chain traceability.

Properties of chrome-manganese grades

The mechanical, corrosion-resistance and fabrication properties of chrome-manganese stainless steels are greatly influenced by the specific chemistry of the grade concerned – in a trade-off of gains and losses.

Mechanical, fabricating and processing properties

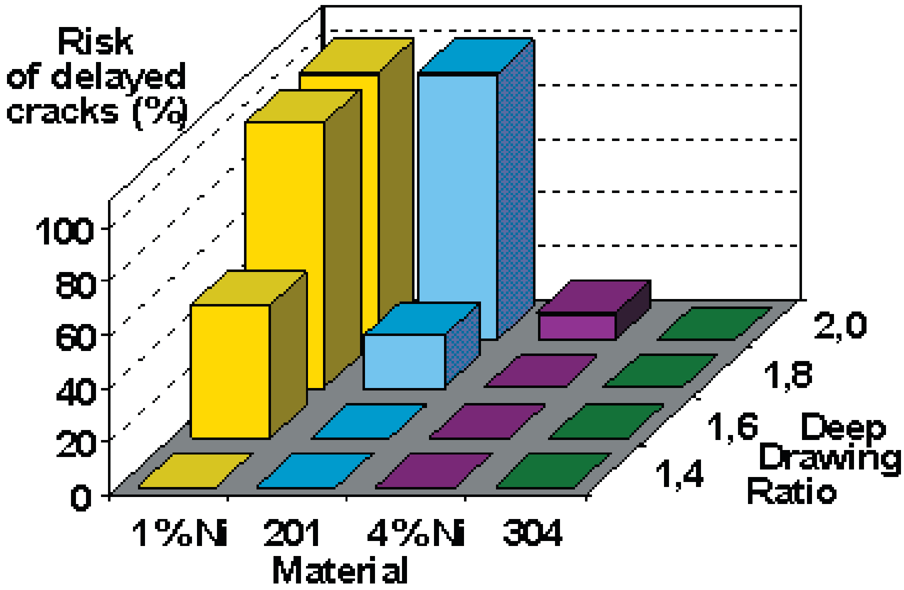
As has been said, reducing **nickel** by adding **manganese** reduces the amount of **chromium** that can be added, adversely affecting corrosion-resistance. The addition of **nitrogen** has the effect of further stabilising the austenitic phase, allowing more chromium to be added.

Chrome-manganese stainless steel grades may have the same appearance as the more expensive chrome-nickel grades but may exhibit different in-service behaviour.

Nitrogen also acts as a hardening agent. High levels of manganese and nitrogen, with chromium, make grades with very high mechanical properties (yield strength), sometimes 30% harder and stronger than “304” chrome-nickel steel. These high-nitrogen grades are, however, harder to form – which may increase fabrication costs.

Softer grades for easier “deep-drawing” – requiring less power in production and permitting the use of installed fabrication equipment originally designed for ductile 300 grades – can plainly be obtained by reducing nitrogen. However, this inevitably means lower chromium content. Adding **copper** is a solution here, in that it permits nitrogen content to be reduced, with nickel and chromium content remaining stable. Copper’s austenite-forming qualities can alternatively be exploited to further reduce nickel content (with nitrogen content kept stable). The more copper there is the easier the steel is to draw. The less nickel there is the cheaper the material becomes. These relative improvements do not, however, mean that “200” grades can always replace “300” grades, since the range of service conditions in which “200” grades maintain their corrosion resistance is narrower.

Chrome-manganese grades are also sensitive to “martensitic transformations” (a microstructure change that can occur during deformation), especially when nickel is reduced. As a result, 4% Ni and, notably, 1% Ni grades show a marked tendency to delayed cracking after deep-drawing. A post-forming heat treatment can avoid the problem but will increase fabrication costs.



Forming: deep-drawing properties

Putting together "risk of delayed cracks" and "deep-drawing ratio" (degree of depth of drawing) shows that the new 4% Ni grades are more prone to cracking than is grade 304 and that 1% Ni grades are particularly susceptible.

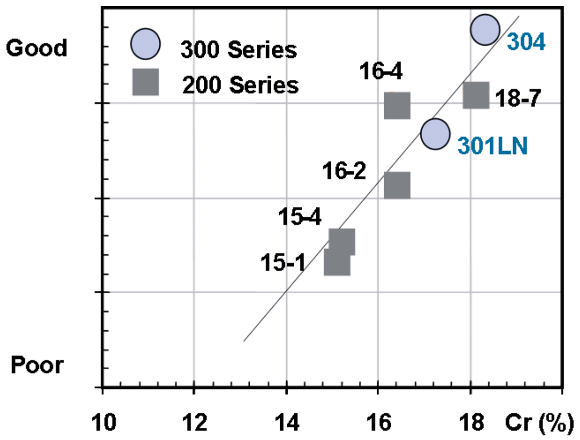
Corrosion resistance

Chromium is the critical factor in the corrosion-resistance properties of all grades of stainless steel. Low chromium means less corrosion resistance. Many chrome-manganese grades recently produced contain less chromium than does grade 304 and consequently show greater susceptibility than chrome-nickel grades to all types of corrosion.

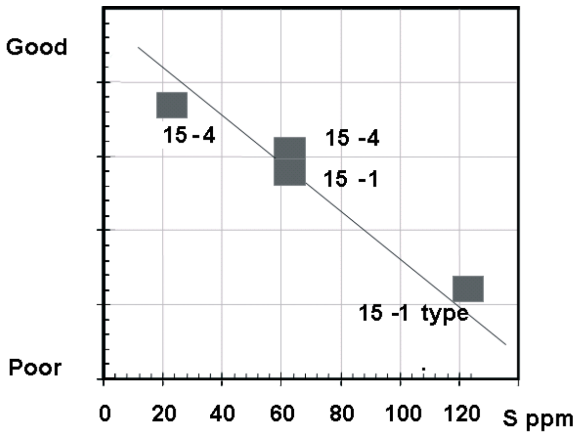
"Pitting corrosion", for example, is a localised corrosion often related to exposure to water and chloride, resulting in hindrance to stainless steel's self-passivation process. Lower chromium content clearly decreases the pitting corrosion resistance of austenitic grades. High levels of sulphur, which are known to cause pitting, have been observed in some poorly produced chrome-manganese steels.

This sensitivity to pitting corrosion illustrates that small variations in chemical composition, particularly

Chromium content influence



Sulphur content influence

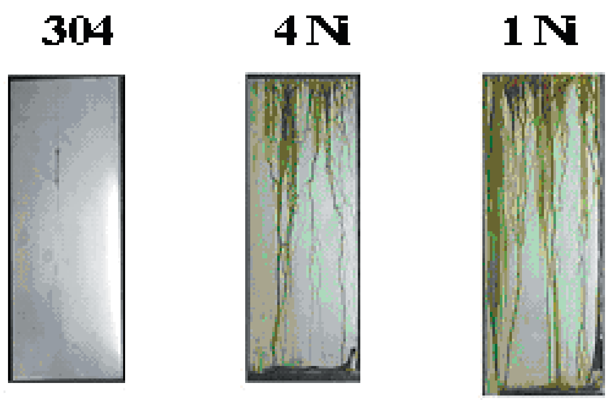


Pitting corrosion resistance

Pitting corrosion resistance is directly linked to chromium and sulphur content. The more chromium present, the higher the corrosion resistance will be. Sulphur, however, lessens corrosion resistance (grades shown contain 15% chromium).

chromium content, may have a significant impact on in-service behaviour. It is therefore critical that users obtain their material from reputable manufacturers, to be sure of optimal quality control and traceability.

"Crevice corrosion", results from stagnation of liquids to which the steel is exposed and consequent depletion of oxygen in crevices. Fasteners and mechanical joints are particularly at risk, in this respect. Deposits can be another cause. In this case, high local acidification of the liquid results in greater corrosion proneness. These phenomena may propagate very quickly and be harder to predict than pitting corrosion.

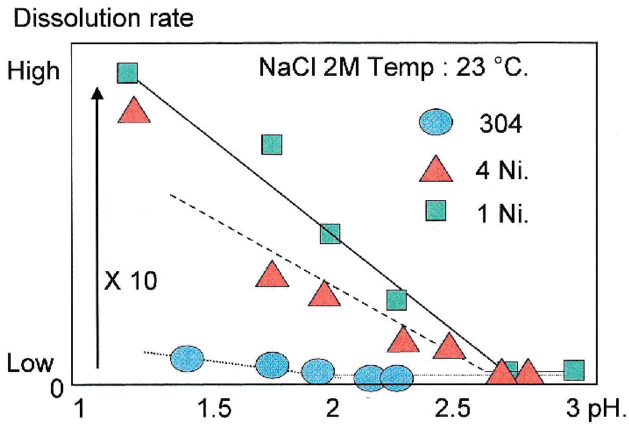


Corrosion resistance in a chloride-containing solution

After a 575-hour salt-spray test on "304" chrome-nickel, 4% Ni and 1% Ni, the 4% Ni, 1% Ni samples showed significant corrosion. These chrome-manganese grades are unsuitable for marine-environment applications.

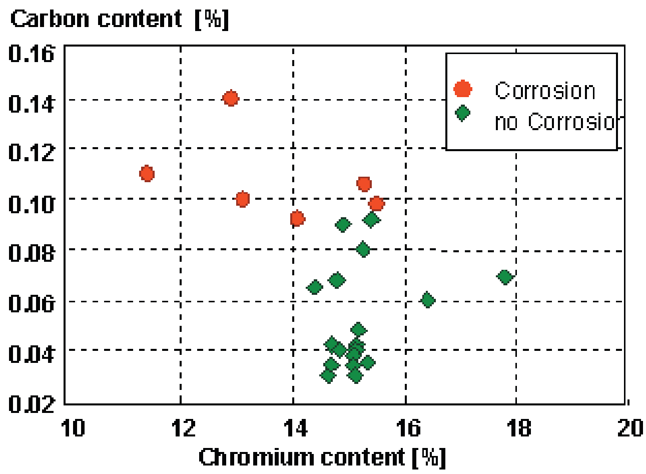
At low pH-levels, there is a correlation between nickel content and crevice corrosion resistance

"Inter-granular corrosion" can cause cracks in weld-deposit areas in high-carbon grades or heavy-gauge low-nickel grades. The cooling that occurs after welding causes precipitation of chromium carbides, which "steal" chromium from the surrounding metal, making it vulnerable to corrosion. Post-weld heat treatment (PWHT) may reduce the problem, but will increase fabrication costs.



Crevice corrosion resistance

At low pH (acidic conditions) the dissolution (corrosion) rate of 1% Ni grade in a crevice is 10 times higher than that of chrome-nickel grade 304.



Fabrication: welding and IGC

In both chrome-nickel and chrome-manganese grades, intergranular corrosion can occur as a result of welding. The corrosion-prone examples in this test are poorly produced chrome-manganese grades from an emerging market.

Possible applications: a rough guide

It is clear that, in comparison with, for example, chrome-nickel grade 304, some chrome-manganese grades (especially the economical grades recently introduced) are more suited to applications involving less severe corrosion conditions.

Steel industry experience of the behaviour of many chrome-manganese grades on the market is currently limited. Rough guidelines nonetheless emerge in the following table, which breaks down industry experience by application type. "Standard 200-series" grades are defined by the following typical chemistries:

- **4% nickel grades:**
  4% Ni, min 16% Cr, max 0.08% C, max 0.005% S
- **1% nickel grades:**
  1% Ni, min 15.5% Cr, max 0.1% C, max 0.005% S

"New 200-series" grades, with lower levels of Cr and higher levels of trace elements may not be suitable for the listed applications.

Applications for "standard 200-series" grades

The following tables show the performance of "standard 200-series" grades of stainless steel in various domestic and industrial applications.

Warning! ISSF has no experience of "new 200-series" grades in these applications.

Home and office appliances including white goods

Dry applications	Positive experience
White goods	
• Dishwashers	Very limited experience (risk of crevice corrosion).
• Washing machines	Very limited experience.
Cutlery/cookware	
• Cutlery	Positive experience.
• Cookware/hollow-ware	Positive experience (minimum 16% chrome recommended) with doubts concerning use of dishwashers. Some restrictions and maintenance requirements for 1% Ni.
In-house water tank	20º C: Positive experience.

Architecture/building/construction

Indoor	Positive experience.
Outdoor, non-coastal	Positive experience (non-critical applications).
Outdoor, industrial environment	Some restrictions and maintenance aspects with 4% Ni. Not recommended for 1% Ni. Minimum chrome 17.5%.
Outdoor coastal/road (salt)	Not recommended.

Food and beverage

Various applications	Positive experience with 4% Ni. Some restrictions and maintenance aspects with 1% Ni. Avoid pH lower than 3.

Transportation

Structural, bus body	Positive experience with 4% Ni. Very limited experience with 1% Ni.
Decorative, motorcycle rims	Some restrictions and maintenance aspects.
Chemical tanks	Not recommended.

General industrial and process-industry machinery and equipment

Chemical	Very limited experience with 4% Ni. Not recommended for 1% Ni.
Chemicals and strong acids	Not recommended.
Oil and gas, pulp and paper	Not recommended.
Nuclear industry	Not recommended.
Water treatment, water systems	Very limited experience.
Sugar industry	Positive experience with 4% Ni. Very limited experience with 1% Ni.

Electrical machinery/equipment

General	Very limited experience.

Metal industry

General	Very limited experience with 4% Ni. Some positive experience with 1% Ni (abrasion-resistant applications).

Automotive industry

Exhaust systems	Very limited experience.
Accessories, interior decorative	Positive experience.
Accessories, exterior decorative	Some restrictions and maintenance aspects.
Structural	Some restrictions and maintenance aspects.

Advice to potential users

In conclusion, it must be stressed that, although the "new 200-series" grades are non-magnetic, the properties of some of these grades are in many aspects not comparable to well-established stainless steels, for example in terms of corrosion resistance, formability, weldability…

It is therefore imperative that anyone considering using these grades compare the nature and in-service conditions of the intended application with the properties of the grades considered.

ISSF members recommend doing this in consultation with a highly reputable and informed supplier. Only such a supplier will be able to offer good quality grades of known and reliable origin and offer impartial advice. Whenever "200-series" grades are considered for use, there are often viable 300- and 400 series alternatives.

Potential users of 200-series grades are strongly recommended to separate 200-series scrap from other stainless steel types of scrap. Good traceability in the recycling process is imperative in order not to jeopardize the high overall recyclability of stainless steel.

ISSF members including both stainless steel producers and stainless steel development associations listed below are committed to give transparency to the market that means information and guidance to those seeking help in choosing the right stainless steel for their specific need.

List of ISSF members

ISSF members are either stainless steel producers or stainless steel development associations (SSDAs). SSDAs are called affiliated members.

Stainless steel producing members

- Acciairie Valbruna
- Acerinox S.A.
- Acesita S.A.
- Aichi Steel Corporation
- Arcelor
- Baoshan Iron and Steel Co. Ltd (Stainless Steel Branch)
- Changwon Specialty Steel Co. Ltd.
- Cogne Acciai Speciali SPA
- Columbus Stainless (Pty) Ltd.
- Daido Steel Co., Ltd.
- Edelstahlwerke Südwestfalen GmbH
- Industeel
- INI Steel Company
- JFE Steel Corporation
- Jindal Stainless Ltd.
- JSC Dneprospetsstal
- Nippon Kinzoku Co., Ltd.
- Nippon Metal Industry Co. Ltd.
- Nippon Steel and Sumikin Stainless Corporation
- Nippon Yakin Kogyo Co., Ltd.
- Nisshin Steel Co., Ltd.
- North American Stainless
- Outokumpu Oyj
- Panchmahal Steel Limited
- POSCO
- Shanghai Krupp Stainless (SKS)
- Slovenska industrija jekla d.d./Slovenian steel Group
- Steel Authority of India Ltd. (SAIL)
- Taihan Electric Wire Co. Ltd.
- Taiyuan Iron and Steel (Group) Co. Ltd. (TISCO)
- Takasago Tekko K.K.
- Tang Eng Iron Works Co. Ltd.
- Thainox Steel Limited
- ThyssenKrupp Acciai Speciali Terni S.p.A.
- ThyssenKrupp Mexinox S.A. de C.V.
- ThyssenKrupp Nirosta GmbH
- Ugine & ALZ
- Ugitech
- Yieh United Steel Corporation (YUSCO)
- Zhangjiagang Pohang Stainless Steel Co., Ltd (ZPSS)

Affiliated members (SSDAs)

- Australian Stainless Steel Development Association (ASSDA)
- BSSA - British Stainless Steel Association
- Cedinox
- CENDI
- Centro Inox
- Edelstahl-Vereinigung e.V.
- Euro Inox
- EUROFER
- Institut de Développement de l'Inox (ID Inox)
- Informationsstelle Edelstahl Rostfrei (ISER)
- Indian Stainless Steel Development Association (ISSDA)
- Japan Stainless Steel Association (JSSA)
- Jernkontoret
- Korea Iron and Steel Association (KOSA)
- New Zealand Stainless Steels Development Association (NZSSDA)
- Nucleo Inox
- Southern Africa Stainless Steel Development Association (SASSDA)
- Specialty Steel Industry of North America (SSINA)
- Stainless Steel Council of China Specialist Steel Enterprises Association (CSSC)
- Swiss Inox
- Taiwan Steel and Iron Industries Association
- Thai Stainless Steel Development Association (TSSDA)
- Union de Empresas Siderúrgicas (UNESID)

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