Recycling Ferritic Stainless Steel

TEAM STAINLESS

Team Stainless promotes the many benefits of stainless steel to a sustainable society. Team Stainless is an informal cooperation among associations of the stainless steel and alloying element industries. It has a global mission.

This publication has been developed by the members of Team Stainless.

TEAM STAINLESS

euro inox
The European Stainless Steel Development Association

IMOA
INTERNATIONAL MOLYBDENUM ASSOCIATION

ISSF
INTERNATIONAL STAINLESS STEEL FORUM

Nickel INSTITUTE
knowledge for a brighter future

icda
International Chromium Development Association

IMnI
International Manganese Institute

Contents

The key messages of this brochure

For fabricators

- Provide a bin for ferritic waste.
- Collect ferritic off-cuts by grade, especially that containing molybdenum.

For the general public

- Recycle your ferritic stainless steel (i.e. do not let it end up in landfill).

For municipal waste-recycling centres

- Perform more manual separation.

For scrap processors

- Pursue research into continuous-belt sorting for magnetic scrap.
- Encourage fabricators to sort ferritic stainless.

For stainless steel producers

- Ensure you use ferritic scrap and benefit from its environmental advantages (EAF: Electrical Arc Furnace).

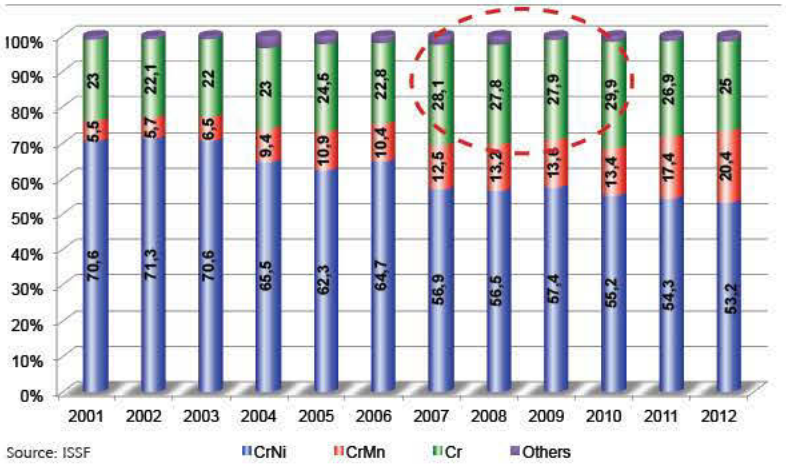
Ferritics step to the fore

The purpose of this brochure is to help develop and grow the systematic separation of ferritic stainless steel scrap in the metals recycling chain, both in the factory and at the end-of-life of products.

In simplistic terms, stainless steels come in two main forms: austenitic (alloyed with chromium and nickel) and ferritic (alloyed with just chromium). The increasingly popular ferritic grades of stainless steel contain no nickel. Their "stainless" corrosion-resistance comes from their chromium content – chromium being the alloying element responsible for the corrosion resistance of all stainless steels. The more of this valuable element we can recycle the better.

Ferritic grades of stainless steel have long been a material of choice for certain major applications, notably automotive exhaust systems and white goods – for example, washing-machine drums.

Important manufacturers in these sectors already return ferritic stainless steel scrap systematically to the melting shop. Between 2007 and 2010, however, there was a significant increase in the use of ferritics in new applications (highlighted in the graph below), often involving small and medium-size manufacturers. These industries do not usually separate ferritic stainless scrap.



The worldwide production of crude stainless steel from 2001, by three main categories of stainless steel: chromium-nickel (300 series - austenitic), chromium-manganese (200 series - austenitic) and chromium only (400 series - ferritic)

In the past, ferritic stainless steels have tended to be overlooked, due to the erroneous belief that they were insufficiently corrosion resistant and hard to work in manufacturing. Another reason was the limited range of grades and a lack of availability. In recent years, due to instability on the alloying-element markets and the relative price-stability of ferritic stainless steel, new grades have been developed, extending potential ferritic applications. Hence, the stainless steel industry continues to look for lower-cost alternatives to certain traditional grades which do not jeopardise technical performance.

MANY GRADES, MANY APPLICATIONS

Ferritic grades fall into five groups – two families of standard grades and three of "special" grades. Standard grades mainly contain only chromium. The special grades contain other elements, such as molybdenum, titanium, niobium, etc.

The well-known standard ferritic grades readily available all over the world are: 409/1.4512, 410/1.4000 and 430/1.4016. In recent decades, further grades have been developed: 434/1.4113, 436/1.4513, 439/1.4510, 441/1.4509 and 444/1.4521. Even more recent grades, with higher chromium content, such as 445/1.4621 and 446, meet an even broader range of requirements.

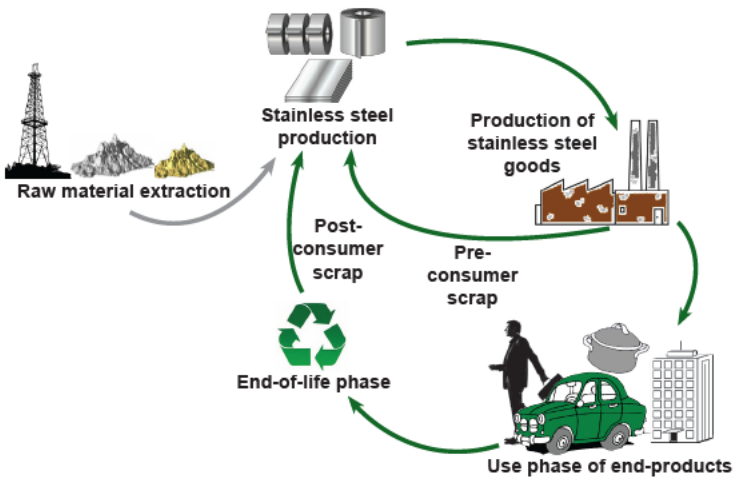
Examples of stainless steel applications: building facade, catering equipment, water pipes, elevator, truck AdBlue tank, water tank.

The reputation of ferritics has risen significantly in recent years. This is partly due to global communication by the stainless steel industry on the properties and workability of these fine grades – which has paved the way for many new applications. Ferritics are now extensively used in kitchenware and catering equipment, barbecue grills, building facades and interiors, furniture and decorative items, automotive trim, superheater and reheater tubes, burners, air-conditioning ducts, water tanks and many other contexts. As even more new applications emerge and ferritic use increases, it is becoming more and more necessary – and viable – to extend the recycling of these grades.

Economic and environmental good sense

Today, the material flow for stainless products demonstrates that the recycling of pre- and post-consumer stainless steel scrap is already common practice.

In the production of stainless steel, a scrap blend and other raw materials – chromium, molybdenum, nickel and other elements – are melted together in an electric furnace before going into a converter for refining. The molten stainless steel is then cast into slabs or billets, before the production of plate, sheet, coil, wire or other product forms, in preparation for use by industrial manufacturers. These manufacturers produce the stainless steel items we use every day, including cutlery, pots & pans and kitchen sinks, and inumerable architectural, industrial and other components.



The flow of stainless steel through society

Unlike many industrial and engineering materials, stainless steel can be re-melted over and over again at each stage of this cycle without any loss in quality. It is 100% recyclable.

THE FERRITIC PREDICAMENT

For austenitic grades (which have valuable nickel content), the recycling chain is securely in place. This is not the case for ferritics. Generally, in scrap yards, magnetic scrap (for example carbon steel) and non-magnetic scrap (for example austenitic stainless steel) are separated from each other by magnet. Therefore, ferritic stainless steel scrap – magnetic, like carbon steel – is inevitably left mixed with the carbon steel scrap, unnoticed. It is the Cinderella of stainless steels in the scrap yard.

The following data (source Reck et al. 2013, Yale University) shows that stainless steel scrap is already favoured in the production of stainless steel. Scrap used for stainless production:

	2005	2010
Overall scrap	57%	51%
Stainless steel scrap	38.3 %	33%
Carbon steel scrap	18.6 %	18%

Scrap input in 2010 was lower than in 2005, due to China's growing production. China currently uses much less scrap than other regions (estimated to be about 25% in 2010).

AN END USER'S VIEW

"For the production of its houseware, IKEA has shifted from 90% austenitic, in 2005, to 95% ferritic in 2012. Some 85% of this production is carried out in mainland China.

"Ferritic scrap is valuable and OEM's waste is totally recycled. Our Asian OEM suppliers sell 2/3 of their "new" ferritic scrap to dealers, who transfer it to qualified scrap collectors. The other 1/3 of their production waste is reused internally for components. Final waste, that they can't use, is sold to this qualified network of scrap collectors.

"China is moving towards a more structured recycling industry and its scrap-collection system is much more organized than in the past. Indeed, international scrap processors have recently started investing in China. Continuous growth in the use of ferritics is expected over the next 20 years, so it seems clear that the recycling of ferritic stainless steel will make economic and environmental good sense.

"Most of IKEA's stainless steel articles are sourced from Asia, including China (90%), Taiwan and Korea. The steel situation in mainland China and Asia generally is in transition. Stainless scrap is recycled because of its value and quality, rather than because the system is organised for that. It's not yet as standardised as it is in Europe. Requirements are less strict. Much of the stainless steel in circulation is 'first generation'. The recycling of goods like washing machines, has not yet started because, being relatively new here, they're all still in use."

Gaetano Ronchi, former IKEA consultant

Further downstream in the recycling process, the presence of ferritic material amongst carbon steel scrap pollutes the carbon steel during re-melting. At the same time, valuable chromium is lost and cannot be usefully recycled.

BENEFITS ALL ROUND

The recycling of more ferritic scrap would be generally advantageous, reducing the cost of producing stainless steel, preserving valuable alloying elements and helping protect the environment.

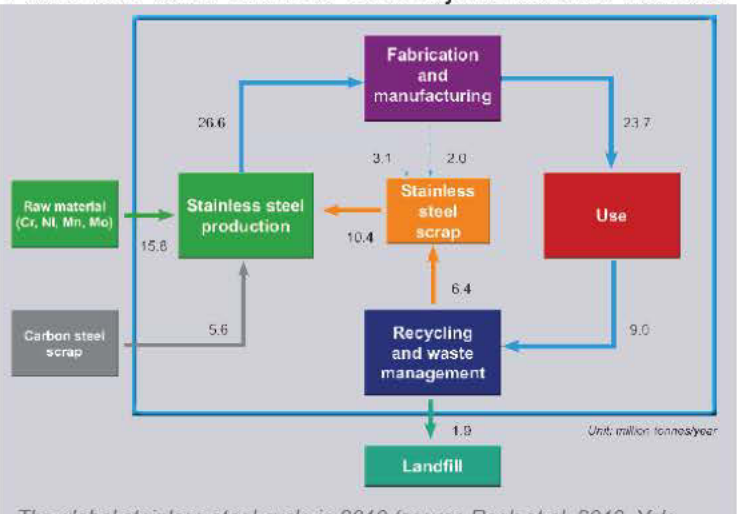
Developing the separate recycling of ferritic stainless steel – and a separate market for ferritic scrap – is a logical and attractive opportunity in metals recycling. Given the recent and forecast growth in the use of ferritics in new applications, the small and medium-sized industrial manufacturers concerned should be encouraged to sort ferritic scrap.

The recycling of stainless steel

Until the late 20th century, the evolution of modern mass-production technologies encouraged a "throw-away" society. This attitude has now changed.

The advent of product stewardship (using products safely throughout their life and then disposing of them responsibly) plus the increasing drive to save materials and energy are both factors favouring scrap recovery and recycling. Today, environmental factors are at the forefront of material selection for specifiers. Stainless steel's long service life, its 100% recyclability and its valuable raw materials make it an excellent environmental performer.

Fewer and fewer stainless steel objects become waste at the end of their useful life. Many are already systematically separated and recovered, to go back into the production process. This recycling is performed on a large scale around the world.



The global stainless steel cycle in 2010 (source Reck et al. 2013, Yale University, 2010).

"NEW" AND "OLD" SCRAP

THE SCRAP PROCESSOR'S ROLE

For scrap processors, waste is a 'primary material' in an advanced society. These companies are miners, but on the surface of the Earth.

Their yards receive scrap – steel, non-ferrous metals and plastics at the end-of-life of equipment such as cars, electronic equipment and white goods. They send the materials they extract, such as copper or stainless steel, into specific product chains, where they undergo processing. The processed results are sent to customers for recycling.

Stainless steel is one of the friendliest materials for the Earth. At the end of its long life, it is recycled to create new stainless steel. In this context, the recycling industry has become a vital player in providing a stable supply of high-quality secondary raw material. Today, when you sell something – for example a dishwasher – you have to think about the end of its life and charge a fee to cover its recycling. This is a relatively recent practice. Previously, products were simply thrown into landfill or a shredder.

The business of the scrap processor is to collect and buy scrap and offer a tailor-made product to stainless steel producers. They collect waste from different sources, including OEMs and eco-organisations with which they have contracts concerning end-of-life products such as washing machines and fridges. In processing the scrap and preparing accurate austenitic stainless steel scrap blends, they must ensure a very low level of residuals.

Apart from the traditional uses of ferritic stainless steel, where the industrial waste is already sorted, for the scrap processor ferritic scrap volumes are currently low. For this to evolve, they will have to wait for the end-of-life of new applications and, above all, talk to manufacturers in these sectors.

Today, ferritic stainless steel goes into the scrap processors' austenitic blends. It would definitely be in their interest to rescue more chromium, for example by separating it from carbon steel scrap.

The sorting of both ferritic and austenitic industrial shop-floor waste (called “new” scrap) is already common practice for many OEMs. The second type of scrap (“old” or reclaimed scrap) includes industrial equipment, tanks, washing machines, exhaust pipes and kitchen sinks, etc., which have reached the end of their service life.

VALUABLE STAINLESS ALLOYING ELEMENTS

Metal recycling is a vital component of the global metal industry. From the stainless producer’s point of view, making stainless steel from scrap uses less energy than creating it afresh, through mining, smelting and refining the original raw materials, which, as explained, include chromium, nickel and molybdenum. These alloying elements are non-renewable resources. It is becoming increasingly important to save more stainless steel from waste.

Recycling practices around the world

EUROPE

In recent years, the importance of sorting and recycling alloyed and non-alloyed metals has grown, because of the monetary value of these materials. Today, everyone is aware of the value of scrap such as copper, aluminium and stainless steel.

According to European scrap recyclers, the stainless steel scrap categories are:

- “Revert” scrap coming directly from the production of the stainless steel mill (coil/sheet).
- “New” scrap – when a manufacturer fabricates a finished product, some steel will be cut off. This waste comes straight out of production. It goes back into the loop within 3 to 5 months.
- “Old” (or reclaimed) scrap – material recovered after use in end products. This collected scrap comes to recycling companies from small and medium-sized scrap-collecting companies who collect waste, including plastic, rubber and metal, from various sources. Dealing in small tonnages, they sell this material to scrap processors. There are thousands of these companies everywhere, providing a decentralised service.

Scrap can come back in just a few years, in the case of electronics, to almost a century when applied in buildings. Average lifetimes have been estimated to be 50 years for buildings and infrastructure, 14 years for vehicles, 30 years for other transportation modes (rail, ship, aircraft), 25 years for industrial machinery and 15 years for household appliances and metal goods.

The impact of CO_2 emissions is becoming more and more important and will have an effect on costs in the near future. Using stainless steel scrap, emissions are much lower than using primary metal.

Today, recycled stainless steel is a global market. In Europe and other developed countries, stainless steel scrap processing involves accumulating sufficient material to go into a furnace. The processor supplies a highly accurate and consistent blend of chromium-nickel alloyed metal to the customer. What the customer puts into his furnace is 8% nickel, 17% chromium (304 grade scrap) or 2% molybdenum, 10% nickel, 17% chromium (316 grade). These two major austenitic categories represented 71% of production in 2000 (see graph p. 2) but recently shifted to 55%, with the development of ferritics (the 400 series) and chromium-manganese (the 200

series). The growth of ferritics means that there is now a more even balance in the scrap mix.

Every grade coming into a scrap yard has to be separated. But the scrap processor sells austenitic, not ferritic. Currently, there is no real market for ferritic scrap. The processor therefore incorporates it in his austenitic blend.

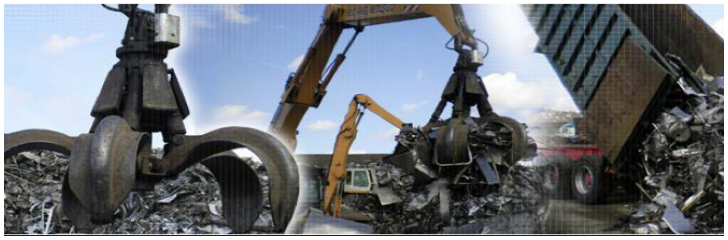
Since ferritic scrap is magnetic, it is lost in the carbon steel scrap if it is not coming from a major application such as washing machine drums – where it is already separated. A mix of carbon and ferritic stainless steel scrap destroys the value of the ferritic. It brings down the chromium content and, at the same time, is not useable for carbon steel production, since chromium is an impurity.

Today, there is interest in research into technology for separating ferritic scrap from other magnetic metals. It is a question of quantity, of course, but if it becomes possible, separating ferritic from such a mix would create higher value from ferritic scrap and motivate scrap-processing companies to create a market dedicated to ferritic. Since the ferritic/austenitic ratio has shifted in favour of ferritic, this development is on the way.

JAPAN

Japan is very conscious of the need to recycle and has an approach to recycling resembling that in Europe. While there are as yet no specific environmental policies concerning scrap (other than that for radioactive scrap), a “consumer electrical appliance recycling regulation” has been introduced requiring consumers to pay a recycling fee, to promote the recycling of valuable elements.

In terms of stainless steel, local producers of ferritic grades are very interested in the recycling of ferritics. The value of ferritic waste has risen significantly in Japan in the last 10 years, due to Japan’s long history of innovation and to the growth of local ferritic use. Several new applications using ferritic have emerged, including heat pumps, water tanks, induction cooking utensils and kitchenware. Based on a 2006 estimate, there is an increase in the amount of ferritic being recycled.



Recycling of domestic waste is well developed in Japan, with separate containers for paper, plastic, bottles, cans, etc. There are also many small scrap dealers. Domestic metal scrap is collected by municipalities, by stores taking back your old item when you buy a new one and, finally, by stores handling both new and second-hand products. Scrap dealers also recover metal scrap directly.

Japan’s numerous stainless steel scrap dealers collect scrap from coil centres, manufacturers, processing plants, etc. Some press or shred their scrap. The coil centre either sells the material back to the mill (if it belongs to the same group) or to a scrap yard.

The scrap recycling system is similar to that in Europe, with Japanese scrap dealers collecting all kinds of scrap. Sorting these materials is carried out either by magnet or by hand, without the aid of sophisticated sorting equipment, other than a hand-held X-ray gun (a labour-intensive process involving item-by-item analysis). In fact, the separating of shredded ferritic stainless and carbon steel scrap

has not been carried out in Japan, but scrap dealers are trying to improve their sorting system, because of the increasing value of ferritic.

In Japan, most stainless scrap is melted in electric-arc furnaces. In stainless production, there is also a trend towards increased use of scrap for melting in ladles, converters, etc.

Japan imports scrap from Korea, the U.S., Taiwan, Thailand and other Asian countries and exports scrap mainly to Korea but also to China, Taiwan and Hong Kong.

SOUTH AMERICA

The use of stainless steel in South America, which is an emerging market, is mostly centred in Brazil, where estimated consumption in 2012 was around 400 kt.

The Brazilian stainless steel market differs from that of more mature markets, such as Europe, the U.S. and Japan. The segmentation of demand for steel is linked to the Brazilian economy, which is diversified and has a broad industrial base, including mining and quarrying, manufacturing, agribusiness and services. A rough segmentation (using 2012 data) would be: capital goods (the greatest share in Brazil, in response to the development of infrastructure and heavy industry) and tubes 45%, automotive and transport 15%, white goods and appliances 12%, construction 10%, cutlery 8%, others 10%. Compared to other emerging economies such as India and China, the use in the consumer-durables industries in Brazil represents only about half of total consumption.

Currently, the average share of ferritic in the Brazilian market is estimated at 51%, with 48% being austenitic grades. White goods and exhaust systems predominantly use ferritic, with a ratio of 95% and 90% respectively. About 50% of cutlery and cooking utensils are ferritic. It is also used in new applications, such as tanks, pipes, especially in the sugar-mill industry (90%) and in building facades, etc.

From 2005 to 2012, the use of ferritic stainless grew at an annual average rate of 12%, due to the material's suitability for the requirements of Brazilian industry.

Data on scrap in Brazil is scarce, because it is an emerging market and the use of stainless is very low. Brazilians have not yet acquired the culture where the life-cycle cost of products is taken into account. The culture there is still to buy cheaply and replace in a few years. However, a 2012 estimation of stainless scrap came to around 60,000 tonnes, not including waste material returned directly from customers to the steel mills.

In Brazil, all types of stainless steel residue are recycled:
- Scrap, of which there are two types, as in Europe: “new” scrap from the mills and “old” scrap from end-of-life products.
- Turnings, which are waste from drilling during the machining process.
- Soft powder, which is from the grinding process, collected by filter.
- Slag, with chromium and nickel content. This comes from small foundries.

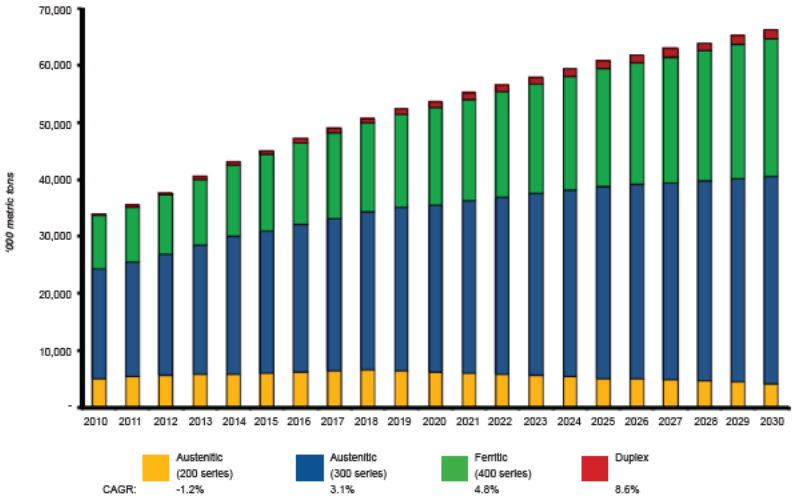
Recycling in Brazil is a bottleneck. The material that arrives in the yards is either not relevant or not as well separated as in other countries. Smaller scrap dealers do not have the technology to analyse. Things will improve, however, because local companies are starting to conform to international standards.

Today, ferritic scrap is fed into the austenitic blend. Brazil currently exports most of its stainless scrap, because the local stainless producer uses more prime material, being geographically close to the mines.

The future of ferritic recycling

While today some ferritic is saved in austenitic recycling, the return of as much chromium as possible to the production cycle will be particularly valuable in the future – especially the new ferritics, which have a higher chromium content.

In recycling, specialised expertise and sophisticated technology is needed to separate and prepare blended batches (chemically controlled and stored by type) corresponding to the specifications of stainless steel producers. If we wish to save chromium from being added to carbon steel scrap, it will be necessary to invest in developing ways to identify more ferritic scrap in the yards.
This is particularly important because of the significant expected increase in ferritic volume (see graph below) and could be facilitated by:
- increasing direct sorting by small and medium-sized industrial fabricators;
- introducing an incentive for this practice;
- separating ferritic stainless steel throughout the recycling chain (not mixing it with austenitic);
- pursuing research into continuous-belt X-ray sorting machines for magnetic scrap (already in progress for high-value alloys such as copper);
- encouraging sorting of magnetic waste by the general public.



The forecast doubling of ferritic stainless steel production by 2030. (Source: SMR)

Today, austenitic stainless steels are very thoroughly recycled. The day will come when ferritic grades will receive equal attention in the recycling process, through the development of an adequate system of separation and the encouraging of fabricators to practise sorting.

This publication is a first step in an awareness campaign to encourage this intelligent direction in metals recycling.

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