



THE SUGAR INDUSTRY

THE FERRITIC SOLUTION

ISSF
INTERNATIONAL
STAINLESS STEEL



FERRITIC STAINLESS STEEL APPLICATIONS



Foreword

FERRITICS AND SUGAR

"The sugar industry is a striking case where ferritic stainless steels are a clearly superior and relatively low-cost alternative to the commonly-used carbon steels. From a practical point of view, the resistance of these steels to corrosion and abrasion and their strength put them streets ahead. Then, since they contain no nickel, ferritics are price-stable and relatively inexpensive. These factors combined add up to impressive Life Cycle Cost benefits.

"There has been a lack of information available to users and potential users of stainless steel concerning ferritic grades. ISSF therefore recently published the brochure 'The Ferritic Solution' and a video of the same title*. The present booklet is one of several follow-up publications on ferritics in specific applications. My thanks go to the International Chromium Development Association (ICDA)** for generously co-funding the booklet, as it did the two initial projects.

"I am also grateful to the end-users and equipment manufacturers who have kindly allowed us to publish their testimonials about the advantages of utility ferritics in this sector. They clearly show how important it is to choose these grades when designing, installing or replacing equipment. Given the tight margins in today's sugar industry, every saving is important and extending the life of equipment and reducing maintenance costs is an absolute priority."

*Both brochure and video are available free of charge from ISSF and can also be viewed on the ISSF website (www.worldstainless.org) and downloaded.

**ICDA website: www.icdachromium.com

Jürgen Fechter

Chairman
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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 73 company and affiliated members in 26 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.

Contents

FERRITICS – FOR SWEET SUCCESS	4
VIEWPOINT	11
USINA SAMAÚMA	
SPRAY ENGINEERING DEVICES LIMITED	
USINA ALTA MOGIANA	
AB TECHNO ENGINEERING	



CASE STUDY: Sugar Production in Brazil	12
APPENDICES	14

FERRITICS – FOR SWEET SUCCESS

Corrosion/abrasion-resistant, strong, stable in price... ferritic stainless steels save costs in a tough industry.



There are two main raw materials from which we make sugar: sugar cane or sugar beet.

Sugar cane accounts for about two-thirds of the world's sugar production. This is an increasingly competitive business as more open, international trading conditions impose greater pressures on the market. Reducing costs and improving productivity are a priority.

Beet sugar accounts for about a third of the world's sugar production. The European Union, the U.S. and Russia are the world's three largest sugar beet producers, although only the European Union and Ukraine are significant exporters of beet sugar.

An assessment of the performance of basic grades of stainless steel in the sugar beet industry has revealed benefits which, in some cases, have led to a 50% drop in plant-maintenance costs. These grades have been used successfully in these applications for a number of years.

“...basic grades (...) have led to a 50% drop in plant-maintenance costs.”

HARSH CONDITIONS

Corrosion and rapid wear of factory equipment are widely recognized as major production-cost and quality problems in the sugar industry.

The short life of equipment and the need for excessively frequent cleaning and maintenance – often involving disruption of crop processing – can make producing sugar an excessively expensive exercise. Even the quality of the sugar is affected.

The origin of the problem, both in the processing of beet and cane, is that the materials handled are highly corrosive and/or highly abrasive, according to the stage of processing. The other factor in the equation is the nature of the steels used to construct the plant equipment.

THE OLD WAY

Sugar producers used to use almost exclusively carbon steel for their equipment, on grounds of its low cost. This ultimately proved a false economy, since carbon steel performs poorly in terms of resistance to corrosion and abrasion.

Stainless steel, however, is strong on exactly these two points. The general environment created by abrasive particles, moisture, heat, acidity and exposure to the



elements is hostile to conventional steels. To utility stainless steels, this is home.

In consequence, since the 1970s, we have witnessed a gradual shift to stainless steels in sugar plants. In fact, in some countries, the use of stainless steel is now mandatory.

There remains some inertia, due to the fact that stainless steel's initial cost is higher than that of carbon steel. It is clear today, however, that with carbon steel what is gained on initial investment is more than lost later on.

ILLUSORY OBSTACLE

Any inertia is exacerbated by the fact that, for historical reasons, users and potential users of stainless steels have tended to believe (wrongly) that only expensive, nickel-containing, "austenitic" (300-series) grades are really corrosion resistant.

The above idea seems to rest on the misconception that nickel is the corrosion-resistant ingredient. In fact, while nickel enhances ductility (and makes austenitics non-magnetic) it does not provide the corrosion resistance. Chromium is the magic ingredient that allows all stainless steels to resist corrosion. The higher the chrome content, the higher the resistance.

“Chromium (...) allows all stainless steels to resist corrosion.”

Nickel is both expensive and highly unstable in price – and this is inevitably reflected in the cost of austenitic stainless steel grades.



Cigar, India, Type 409



Heat exchanger, Type 444

THE NEW DIRECTION

In the sugar industry and elsewhere, the good news is that “ferritic” (400-series) grades, that contain no nickel, will often do the job perfectly.

Basically just iron, carbon and chromium, ferritics are the original stainless steels – magnetic, corrosion-resistant, abrasion-resistant and boasting remarkable properties, including high tensile strength. They are relatively inexpensive and stable in price.

Better still, the upstream processes in sugar plants are handled superbly by the most basic ferritic grades – known as “utility” stainless steels. These are especially low in cost. For the more corrosive downstream processes, higher-alloyed ferritics have proved ideal for almost all applications.

The sulphiting stage is the only phase in the process where an austenitic grade is required. Elsewhere ferritics can provide all the qualities required, including excellent atmospheric corrosion resistance.

Unlike austenitics, ferritics are immune to stress corrosion cracking, thanks to their ferrite atomic structure.

“...upstream processes (...) are handled superbly by the most basic grades.”

LIFE CYCLE COST

Considerable performance-testing has been carried out in sugar plants in various countries in recent years, focussing on monitoring surface condition, material thickness, the presence of deposits and corrosion (general, pitting, crevice and microbiological). The results prove conclusively that ferritics are the perfect answer.

For sugar producers, this solid, practical experience finally opens the door wide to stainless steels and to the significant Life Cycle Cost advantages their use implies.

Looked at in terms of overall lifetime cost, ferritic stainless steels win over carbon steels by a massive margin. Their greater initial cost is more than offset by several factors. Their high-strength, corrosion resistance and low-wear properties mean that they can be used at reduced thicknesses and that cleaning and maintenance are vastly reduced. They win over austenitics, of course, mainly by being affordable and stable in price.

“...ferritic stainless steels win over carbon steels by a massive margin.”

Beyond these factors, reduced corrosion and consequent smoother finish leads to less friction in pipelines and, therefore, lower power consumption.

Still on the subject of savings, equipment-dismantling costs are lower than with carbon steel – dismantling is simply less frequent. Stainless steel also has a higher scrap value than carbon steel.

THE MAGIC OF STAINLESS STEEL

Stainless steel’s corrosion resistance is due to the presence of chromium (Cr) as an alloying element. Steel has to contain at least 10.5 percent of it to become “stainless” (i.e. highly corrosion-resistant).

When alloyed with iron and carbon, chromium forms an invisible, protective surface film of chromium oxide. This so-called passive layer also provides corrosion resistance and increases scaling resistance, wear resistance and tensile strength. If damaged, the layer repairs itself spontaneously, in the presence of oxygen.

Stainless steel boasts exceptional physical and mechanical properties. For fabricators, it offers ease of manufacture. For the end user, it guarantees important Life Cycle Cost (LCC) advantages. In many cases, protective surface treatments are unnecessary and stainless steel often requires little or no maintenance.

FIVE FERRITIC FAMILIES

ISSF classifies ferritic grades in five groups – three families of “standard” grades and two of “special” grades.

Basic (Grade 1) grades, often called “utility” grades, are low-cost, 10-14%-chromium, ferritic stainless steels described by standards ASTM A240 / UNS S41003 and EN10088-2 1.4003.

The term “utility” refers to the great usefulness of these steels. They offer a particularly advantageous combination of toughness, weldability, strength, corrosion resistance and wet-abrasion resistance. This allows them to be used in thicker gauges. In addition, hot-rolled plate welds are very tough. This powerful combination makes these grades suitable for a very wide range of applications.

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 and 410 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

Non-exhaustive list. See ISSF brochure “The Ferritic Solution” pp. 60-61 for complete details.

Utility grades are a superior alternative to coated or galvanized carbon steels in numerous applications – notably those involving wet abrasive/corrosive conditions. In addition, their strength allows a reduction of weight in structural applications. They are not prone to stress corrosion cracking.



Slit carrier sides and runners, Brazil, Type 410

The least costly of all stainless steels, they out-perform carbon steels by miles in sugar-plant applications.

Under mildly corrosive conditions, utility grades such as Type 410 may develop a uniform, rust-coloured patina. This does not affect the structural integrity of the steel and is not a problem in applications where aesthetic beauty is of no concern.

The higher-alloyed ferritics contain more chromium and, in the case of the so-called stabilised grades, additional elements such as titanium (Ti), niobium (Nb) and molybdenum (Mo). These grades are equivalent to austenitics in performance – but at lower cost. They are suitable for more aggressively corrosive applications.

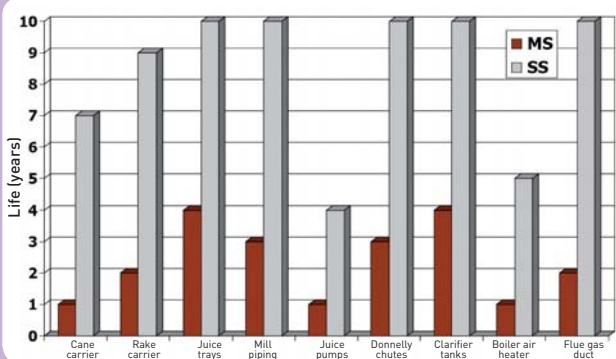
Type 410 resists corrosion in the high-heat and high-steam areas of the condenser and ducting as well in the sticky, corrosive environment of the syrup tank. Similarly, it is ideal for the tops of molasses tanks.

This exceptionally useful grade is also great for boiler-emission scrubber construction, thanks to its corrosion resistance and the fact that it is not prone to embrittlement.

“...the perfect solution for upstream applications, where abrasion is the main issue.”

CARBON V STAINLESS STEEL

A 2006 study at four sugar mills in India revealed that in many cases stainless steel equipment lasts 5 times longer than equipment made of carbon steel.



TYPE 410 – BASIC IS BEAUTIFUL

In sugar plants, basic, Type 410 utility stainless steel, containing 11% Cr, has proved the perfect solution for upstream applications, where abrasion is the main issue.

It is used, for example, in the cane table and cane carrier. Inside the mill, it is used for the Donnelly chutes, as an overlay for the mill rolls and in the mill troughs, the mill flange, diffuser parts, etc.

The material’s abrasion-resistance is also immediately evident to the eye in bagasse conveyors, where the bagasse actually polishes it to a just-like-new shine.

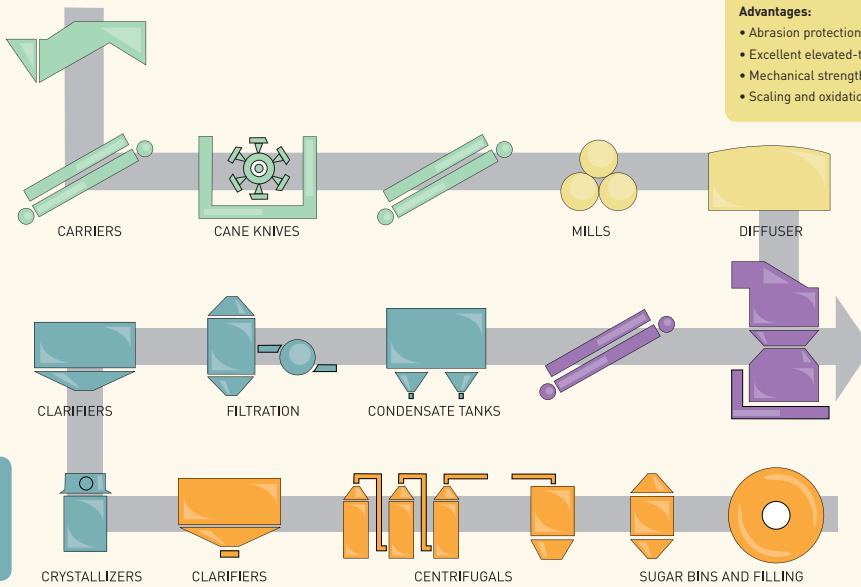


TYPE 410 UTILITY STAINLESS STEELS IN CANE SUGAR PROCESSING

RAW CANE HANDLING

Advantages:

- Corrosion/abrasion resistance
- Excellent slideability, improved flow
- Maintenance-free
- Long service life
- Good forming and fabrication characteristics



PRESSURE FEED MILL AND DIFFUSERS

Advantages:

- Abrasion protection
- Excellent elevated-temperature performance
- Mechanical strength
- Scaling and oxidation resistance

BAGASSE HANDLING

Advantages:

- Corrosion/abrasion resistance
- Excellent slideability, improved flow
- Maintenance-free
- Long service life
- Good forming and fabrication characteristics

DOWNSTREAM OPERATIONS

Advantages:

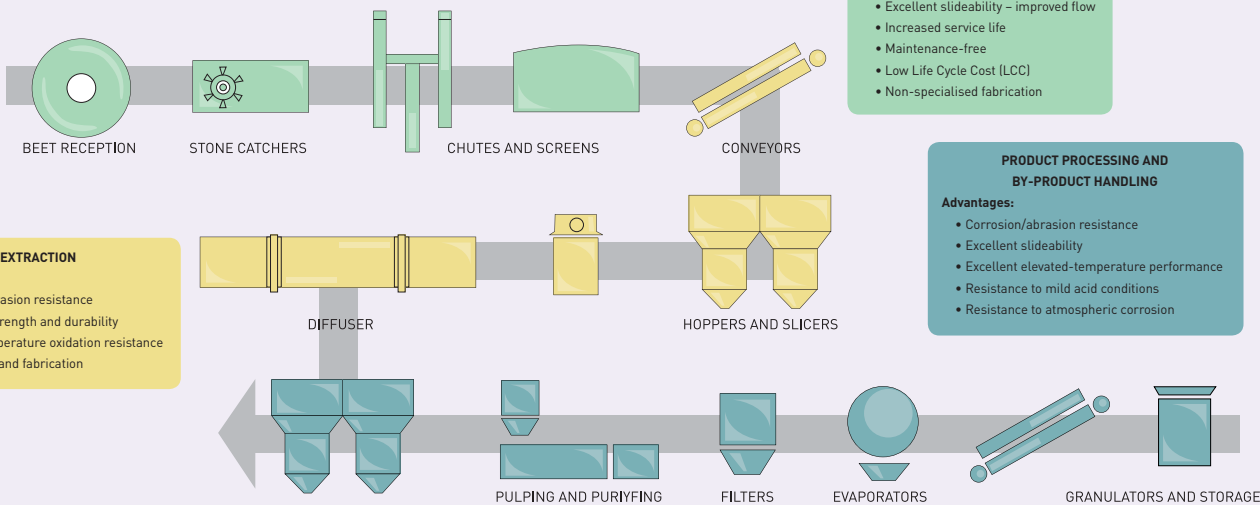
- Resistance to aggressive corrosive conditions
- Excellent elevated-temperature performance
- Wide range of material forms to suit design requirements
- Maintenance-free

JUICE PRODUCTION AND HANDLING

Advantages:

- Resistance to acidic conditions
- Corrosion resistance
- Excellent elevated-temperature performance

TYPE 410 UTILITY STAINLESS STEELS IN BEET SUGAR PROCESSING



BEET HANDLING

Advantages:

- Resistance to wear and corrosion
- Excellent slideability - improved flow
- Increased service life
- Maintenance-free
- Low Life Cycle Cost (LCC)
- Non-specialised fabrication

EXTRACTION

Advantages:

- Corrosion/abrasion resistance
- Mechanical strength and durability
- Elevated-temperature oxidation resistance
- Easy welding and fabrication

PRODUCT PROCESSING AND BY-PRODUCT HANDLING

Advantages:

- Corrosion/abrasion resistance
- Excellent slideability
- Excellent elevated-temperature performance
- Resistance to mild acid conditions
- Resistance to atmospheric corrosion

TYPE 439 – TOUGH STUFF

At stages in the process where corrosion is more severe, ferritic Groups 2 and 3 provide the solution. They are used in sugar-cane juice ducts, heaters, evaporators, boiling pans, crystallization units and dryers, amongst other applications.

Type 439 is a 17%-chromium grade, offering very good corrosion resistance. It contains small amounts of titanium and niobium, to “stabilise” it. A stabilised grade has better resistance to intergranular corrosion, which can affect stainless steels that have been exposed to high temperatures (during welding or actual use) in oxidizing/acid environments.

Type 439 can handle all sugar-plant applications except sulphiting (for which Type 316 austenitic stainless steel is necessary) and the last two evaporation stages in a multi-stage evaporation process. This grade is, however, highly suitable for use in the first evaporation processes and in boiling pans.

TYPE 444 – EVEN TOUGHER!

The higher-alloyed Type 444 (18% Cr) performs splendidly in almost all sugar-plant applications too. Its 2% molybdenum content greatly improves corrosion resistance in chloride environments. In the last two evaporation stages and in the case of high corrosion/abrasion risk, Type 444 could be considered. However, as with Type 439, Type 444 is unsuitable for the sulphiting process. By the same token, if cleaning is of an acid type with inhibitor, the use of an austenitic grade is recommended.

For parts of the plant exposed to the elements, Type 444 has good generalised corrosion resistance and oxidation resistance, similar to Types 304 and 316. Type 444 has better pitting-corrosion resistance than does Type 316.



THIN TUBES = THERMAL EFFICIENCY

The mechanical properties and high corrosion-resistance of Types 439 and 444 make it possible to reduce tube thickness (from 2.65 mm for carbon steel tubes to 1.2/1.5 mm for 439/444 tubes).

As well as being economical in terms of the cost of the steel, this increases the thermal efficiency of the installation. In fact, the thermal conductivity coefficient of Types 439 and 444 (and Type 410) is higher than that of austenitic Type 304.

“...the thermal conductivity of Types 410, 439 and 444 is higher than that of Type 304.”

The rougher surface of carbon steel favours deposits or formations (oxides, solids, etc.) that negatively affect heat-exchange capacity. The low tendency for scaling on the surface of Type 444 and 439 stainless steels, on the other hand, means that thermal exchange with these stainless steel tubes is actually higher than with carbon steel. They are also easier to clean – which is a highly important factor.

SAFER, BETTER-QUALITY SUGAR

Stainless steels are preferred materials in the food industry. This must be extended to sugar, the production equipment of which deserves the same high level of material selection.

Stainless steel is chemically inert in contact with food and therefore affects neither sugar’s taste nor its appearance. It is also biologically inert, so there is little risk of microorganism colony growth. Should this occur it is easy to eradicate.

The fact that plant equipment stays intact thanks to stainless steel’s corrosion/abrasion resistance means there is no metallic migration to the end-product.

ETHANOL AND BEYOND

Ethanol production is long-established as an activity at sugar mills and the sugar industry is already a major producer of ethanol.

Utility stainless steels are used in ethanol plants for fermenter and storage tanks and good results have been achieved over the past 15 or more years. In fact, ferritic grades are as appropriate for ethanol plants as they are for sugar mills.

Types 439 and 444 in cane sugar processing

Sector	Equipment	Grades	
Extraction (conventional)	Cush Cush rotational screen	439	444
	Cane juice tubing/imbibition		444
	Cane juice spouts	439	444
Extraction (diffuser)	Diffuser cane ducts	439	444
	Diffuser top	439	
Steam generation	Gas cleaner, pre-air tubing		444
Cane treatment	(Vertical/horizontal) sugar cane heater	439	444
	Mirrors		444
	Decantation tank, rotation sieve, float, tubing, flash balloon	439	444
Cane evaporation	Pre-evaporation tubes (1st and 2nd process) (1)	439	444
	Pre-evaporation tubes (3rd and 5th process) (1)		444
	Mirrors, body and calender coating, condensers, tubing, entrainment separator, honey and syrup tanks		444
Sugar milling	Tubes or boatload and continuous annealing kiln (1)	439	444
	Mirrors		444
	Annealing kiln internal coating, horizontal and vertical crystallizer, massecuite reheater	439	444
	Masseccuite agitator		444
	Tubing, sugar conveyors, keg lifts, honey and syrup tanks	439	444
	Entrainment separator, condensers		444
Distillery residue	Distillery residue up to and above 40°C		444

Note: (1) Low roughness and high corrosion resistance for less scaling and easy cleaning, allowing for more efficient thermal exchange

Keeping the stainless steel surface clean and dry between crops greatly improves its corrosion resistance.

The hibernation of heaters, evaporators and annealing kilns between crops with sodium hydroxide (lye), by maintaining pH above 10, protects the stainless steel tubes from corroding, protects the sidewall and cleans the external part of the tube truss, thereby recovering thermal exchange capacity.

VIEWPOINT



Conveyor belt side-plate
Type 410

Viewpoint

ALBERON TOLEDO
INDUSTRIAL DIRECTOR
USINA SUMAÚMA
BRAZIL

“Usina Sumaúma is located in the northeastern part of Brazil and processes 0.9 million tons of cane a year. We first used Type 444 stainless steel in the structure and pipes of evaporation-system equipment in 2001.

“In 2002 we began using Type 410 to replace carbon steel for the sugarcane conveyor belt side-plates. With carbon steel, plates 8 mm thick were required. These would last for three crops and require maintenance during each crop. On the other hand, Type 410 utility stainless steel allowed plates of only 6.35 mm thickness. These are currently in their sixth crop, have needed no maintenance and are showing a real thickness of 5.60 mm.

“We are obviously very pleased with the cost reduction our unit has gained with this material.”



Juice heater, Type 410

Viewpoint

VIVEK VERMA
MANAGING DIRECTOR
SPRAY ENGINEERING DEVICES LIMITED
NOIDA
INDIA

“We use 1,000 to 12,000 tons of stainless steel a year in the equipment we design and develop for the agro-processing and sugar-processing industries. About 30 percent of this is ferritic, mostly grade 409.

“We started using stainless steel in 1995, primarily for its corrosion resistance. Having started with austenitic Type 304, for cost reasons we had to also find alternatives. Type 409 was found to perform well. The secret, of course, is to select the most suitable and cost-effective grade for the application in question.

“Changing from carbon steels to 409, we had to make some processing adjustments, but these are now stabilised. Customers were initially ill-informed about ferritics and had some misperceptions about them. Since we took responsibility for the performance of the equipment, however, they felt safe to try it and the results have been highly encouraging.

“Ferritics are the future of stainless steel. We’re looking forward to increasing the share of these grades in our business. They will help us be an even more cost-effective supplier of quality products.”



Feeding table, Type 410

Viewpoint

FERNANDO ANTÔNIO
AS COSTA FIGUEIREDO VICENTE
INDUSTRIAL DIRECTOR
USINA ALTA MOGIANA
BRAZIL

“Three years ago, Usina Alta Mogiana defined a strategy to increase the use of stainless steel in sugar production at its industrial plant. The aim was to obtain a higher-quality product (eliminating black spots) and reduce the need for maintenance during and between the crops.

“We looked at replacing carbon steel with Type 304 austenitic stainless steel, but could not easily compare the higher initial cost of Type 304 with the lower maintenance costs over the life of the equipment. In 2003, we started the replacement process using Type 444 ferritic. Today, 100 percent of the pipes in our evaporation system are Type 444.

“Our industrial plant currently has 85 percent automated and 15 percent manual sugar-cane cutting. This increases residues and degradation of equipment by abrasive wear. With carbon steel, we had to carry out maintenance during the crop, which meant higher production-costs. Consequently, we’re trying to develop new products for these applications.

“In 2005, we began testing Type 410 ferritic for the juice entrance and extraction equipment. According to results obtained so far, we expect Type 410 to last at least two crops without needing maintenance, possibly three. In a qualitative sense, we think that this will bring great benefits and that this kind of steel is ideal for the application. The next step is to analyse quantitatively the benefit of replacing carbon steel with 410, in applications where abrasive wearing occurs.

I can already say we’re very pleased with the results achieved up to now and have had no difficulties working or welding these steels. Types 410 and 444 are a great contribution to our sector, which I believe will have to reduce maintenance costs even further in future.”



Vacuum pan, Type 439

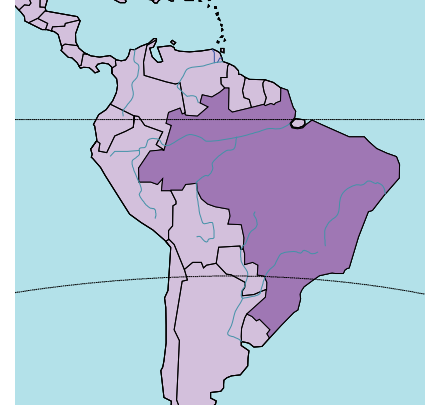
Viewpoint

A. BOBER
DIRECTOR
AB TECHNO ENGINEERING
WARSAW
POLAND

“We use stainless steel for vacuum pans, the tube sheets and tubes of juice heaters, falling film evaporators and massecuite mixers. About 20 percent of our consumption of stainless steel is ferritic Type 439, which we use in heating chambers. We introduced this grade about 15 years ago, originally as tubes for Robert evaporators and juice heaters, basically because it was less costly than austenitic Type 304. It was the right decision and we’re very happy with Type 439.”

CASE STUDY

Sugar production in Brazil



Researchers compared ferritic stainless steel Type 410 with carbon steel at several plants in Brazil, over six-years.

Their conclusion: “Ferritic stainless steels have the best cost-benefit ratio compared to mild steel, austenitic stainless steels and copper. As a result, the best life cycle costing and long term multiple benefits in terms of process, downtime and quality of sugar. Stainless steels are preferred materials in the food industry. This must be extended to sugar, the production equipment of which deserves the same high level of material selection.”

CANE CONVEYOR (1)



One part of the cane conveyor is stainless Type 410 (shown here after one cleaning process) and the rest carbon steel.



After two years of use and the crushing of 2 million tons of sugar cane, the carbon steel surface was very scratched and there was a thickness loss of 4 mm (original thickness was 9.50 mm). Stainless steel Type 410, on the other hand, had a thickness loss of only 0.37 mm (original thickness 6.35 mm).

EVAPORATOR TUBES



Type 444 stainless steel tubes being installed in the final evaporation process. For such an operation it is important that expansion at the ends of the tubes is carried out gently.



Both Type 439 and Type 444 tubes are able to withstand diameter expansion of around 25% without rupture. This elongation potential is much greater than that required to attach the tubes to the perforated plate of the evaporation units.

DONNELLY CHUTE

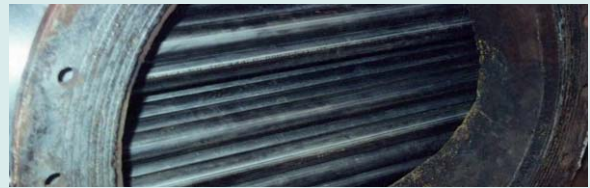


A Donnelly chute, in Type 410, that has been in operation for 2 years and shows no signs of wear. Its surface condition remains comparable to its original state. This type of equipment is often made of stainless Type 304 (18% Cr and 8% Ni). Type 410 is the correct specification, given that abrasion is the main source of concern in Donnelly chutes.

EVAPORATION UNIT



An evaporation-process unit, in Type 444 stainless steel. It consists of 7,000 1.5 mm tubes, 25.4 mm perforated plate and 6.35 mm sheet for the body.



Heater tubes in ferritic stainless Type 439: another successful use of stainless steel.

CANE CONVEYOR (2)



The side of this carbon steel sugar-cane conveyor side plate has suffered severe pitting corrosion, due to droplets of sugar-cane juice deposited on the horizontal surface of the conveyor. This is after 4 years of use and the crushing of 3.2 million tons of sugar cane.



At the same mill, a Type 410 sugar-cane conveyor side plate after 6 years of operation and the crushing of 5 million tons of sugar cane. Thickness loss is negligible (0.5 mm) and there is no pitting corrosion.

BOILING PANS



The body of carbon steel boiling pans suffer oxidation. In some mills, an epoxy coating is applied to the pan's internal surface. This, however, is released into the final product (sugar).



A boiling pan with stainless steel internal cladding, 1.5 mm thick, made by welding Type 439 sheets over a carbon steel body. It has been in use for 12 years.

APPENDICES

SOME FERRITIC ADVANTAGES

Hygiene and quality

- Chemically inert (no influence on sugar's taste or colour);
- Biologically inert (minimal risk of microorganism colony growth);
- Significant reduction of "black spots" in the sugar;
- Minimal tendency for bacterial formation on the surface;
- No metallic migration to the end-product.

Properties

- Excellent corrosion and oxidation resistance;
- Excellent atmospheric corrosion resistance;
- Very high abrasion resistance;
- Very high wet-sliding abrasion resistance;
- Low friction allows low angle of friction on bulk-solid handling equipment;
- Suitable mechanical properties for sugar-industry processing;
- Higher thermal conductivity/efficiency than Type 304;
- Excellent weldability (weldable in section thicknesses up to 30 mm);
- Immune to stress corrosion cracking;
- Easy to shape.

Design

- No need for a corrosion allowance on material thickness (allowing thinner gauges than carbon steel);
- Stable price.

Operation

- Thickness reduction favours the heat-exchange process;
- High heat-exchange capacity in evaporators and boiling pans throughout the process, due to the low surface scaling;
- Easier and more efficient cleaning (due to smooth surface);
- Less maintenance and downtime.

LCC

- Reasonable initial investment cost;
- Long service life;
- Longer useful life than Type 304;
- Low maintenance and replacement costs;
- Better cost/benefit ratio than other materials.

PROPERTIES AND CHARACTERISTICS

		Type 439 (ferritic)	Type 304 (austenitic)	Carbon steel	Advantage for ferritic
Fabrication		welded	welded	welded	
Annealed		no	yes/no	no	
Thickness	mm	1.2-2	1.2-2		
Density	Kg/dm ³	7.73	7.93	7.82	+++
R _m (tensile strength)	Mpa	450	600	430	++
R _{p0,2%} (yield strength)	Mpa	370	300	310	
A% (elongation)	%	45%	60%	34%	++
Linear elongation	mm/100°C	9.8	16.1	11.3	+++
Expanding operation		+++	+++	++	+++
Thermal conductivity	W/m ² /°C	24	16	39	+++
General corrosion	range 0-100	80	80	20	=/304
Stress corrosion	range 0-100	100	20	100	+++

ACKNOWLEDGEMENTS

ISSF is grateful to Philippe Richard (ArcelorMittal Stainless, France), who coordinated a working group consisting of Lucien Matthews (Columbus Stainless [Pty] Ltd), Ken Dewar (Columbus Stainless [Pty] Ltd), Colin Barnes (Columbus Stainless [Pty] Ltd), R. K. Goyal (Jindal), Paulo Balsamo (ArcelorMittal Stainless, Brazil), Deepak Jain (Jindal), Jean-Noël Langlois-Berthelot (ArcelorMittal Stainless Tubes, France).

Thanks are also due to English-language consultant and writer Paul Snelgrove (Paris, France), for his help in preparing the booklet and to Francesca Gavagnin (MBCom, Paris, France) for designing and producing it.

PHOTO CREDITS

ISSF wishes to thank the companies and individuals who have contributed photographs to this publication. Where the original source of a photograph used is not known, ISSF extends its apologies to the copyright owner.

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