

# STAINLESS STEEL IN THE SOUTH AFRICAN SUGAR INDUSTRY

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Until five years ago South African sugar engineers and technologists were reluctant to consider stainless steel for these reasons:

- (i) cost,
- (ii) different fabrication techniques compared to traditional mild steel,
- (iii) lack of knowledge about stainless steel.

This paper attempts to clarify the above points, highlight some of the progress made to date and outline future applications.

TABLE 1

A.I.S.I. Series	Metallurgical Structure	Major Alloying Elements	Basic Properties
400	Ferritic	Fe. Cr.	Magnetic Non Hardenable
	Martensitic	Fe. Cr. C.	Magnetic Hardenable
300	Austenitic	Fe. Cr. Ni.	Non Magnetic Hardenable

The metallurgical types of Stainless Steel and their basic properties

### (a) Stainless steel as a material

"Stainless Steel" is not a single metal—it is the name given to a group of iron based alloys containing a minimum of 11% chromium. Although the basic stainless steels are divided into three metallurgical categories, it will be noted from Table 1, that the A.I.S.I. numbering system only differentiates between the nickel containing Stainless Steel (300 series) and the non-nickel containing Stainless Steel (400 series). The A.I.S.I. specifications cover a large range of stainless steels many of which are tailor made to operate at temperatures of  $-273^{\circ}\text{C}$  to  $+1000^{\circ}\text{C}$ , to combat a wide range of acids, alkalis, gases etc., and with mechanical properties ranging from the hardness of razor blade steel to the ductility of deep drawing steel.

Fortunately the sugar technologist has only 3 stainless steels to consider, and Table 2 gives the respective A.I.S.I. specifications.

TABLE 2

A.I.S.I. No.	Chromium %	Nickel %	Molybdenum %
304	18	8	—
316	18	10	3
430	17	—	—

The basic composition of A.I.S.I. 430, 304, 316.

### (i) A.I.S.I.—304.

This is the basic stainless steel in the 300 series, containing 18% chromium and 8% nickel. It is one of the most versatile stainless steels having excellent corrosion resistance, extremely good ductility, and excellent weldability. Most sugar engineers will be familiar with this grade due to its extensive use as tubing for juice extraction.

### (ii) A.I.S.I.—316.

This is another nickel containing stainless steel similar in mechanical properties to A.I.S.I. 304. The addition of 2–3% molybdenum greatly increases the pitting resistance and so this stainless steel is only used in applications calling for ultra high corrosion resistance, e.g. highly by acidic or alkaline environments.

### (iii) STELEX 430.

This is a straight 17% chrome stainless steel made by Southern Cross Steel Co. (Pty) Ltd. at Middleburg to the basic A.I.S.I. 430 specification.

Stalex 430 does not have quite the same level of corrosion resistance as A.I.S.I. 304, but being a nickel free stainless steel, it is significantly cheaper whilst offering vastly better resistance to corrosion than mild steel.

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The U.T.S. values and relative hardness of these stainless steels are compared to mild steel and 70/30 brass in Table 3.

TABLE 3

	Mild Steel	Stalex 430	A.I.S.I. 304/316	Brass 70/30
U.T.S. p.s.i.	60 000	75 000	85 000	45 000
MN/m <sup>2</sup>	413.685	517.107	586.054	310.264
h bar	41.369	51.711	58.605	31.026
Hardness B.H.N.	120	190	180	120

Note: 10 000 psi = 68.948 meganewtons per square metre  
 = 6.895 hectobars  
 14 500 psi = 10 hectobars

The strength and hardness characteristics of Stainless Steel compared to mild steel and 70/30 brass

(b) *Stainless Steel Costs.*

The kg for kg costs of the stainless steels as compared to mild steel and 70/30 brass are given in Table 4.

TABLE 4

Mild Steel	1
70/30 Brass	10
Stalex 430	4½
A.I.S.I. 304	8½
A.I.S.I. 316	13

The basic cost comparison of mild steel 70/30 brass and Stainless Steel.

Although the initial material costs of stainless steel appears prohibitive, practical experience in the sugar industry over the past 2 years has shown that the thickness of stainless steel can be reduced by at least 25% compared to mild steel with the resultant savings in material, handling, and fabrication. In several instances more complex fabrications such as pan condensers have been made in STELEX 430 at only double the price of mild steel and with far superior corrosion and abrasion characteristics.

Experience to date has shown that a life of 10—12 times is possible with Stelex 430 against conventional mild steel, and thus the saving on maintenance and replacement cost is more than offset by the initial capital cost of stainless steel.

(c) *Stainless Steel Fabrication.*

Most mill engineers have now developed welding, and fabrication techniques for Stelex 430 and A.I.S.I. 304 to suit their own staff and workshop lay out. Excellent weldability for Stelex 430 has been achieved by using the standard austenitic electrodes, such as A.I.S.I. 310. In many cases STELEX 430 has been successfully welded in as a replacement part of a mild steel construction using these same electrodes.

The higher hardness and strength of the stainless steels has posed certain cutting problems in view of the limited shearing capacities in most units. However the introduction of powder and disc cutting now appears to have overcome these difficulties.

**Stainless Steel in Crushing/Juice extraction**

Stalex 430 has made a significant contribution to machinery life and reduction of maintenance costs in this part of the mill. It has been proved to be ideal for abrasive areas such as intercarrier bottoms and boots, and current results indicate an average wear of 0.25mm—0.38mm per season as compared to an average loss of 3.81mm—4.46mm for mild steel plates subjected to similar duty. At two mills the last two intercarriers in the tandem show that the Stelex 430 plates installed have even less wear ± 0.05mm (± .002in) during one seasons operation. Thus in comparison with mild steel, a life factor of over 10—12 times has been obtained from Stelex 430 for an initial installation cost including raw material of 3 times that of mild steel.

Some Mills, to save on initial capital, are now using 6mm Stelex 430 as liners instead of the conventional 10mm or 12mm mild steel.

Continuing on the tandem, Donnelly chutes situated over the rollers have been fabricated from 3mm Stelex 430 and after one season operation, no wear has taken place, (± 0.05mm). Juice gutters, maceration tanks, under pans have all been fabricated from Stelex 430 usually in 5mm thickness, and on testing a maceration tank after 3 full seasons operation, other than the removal of the original mill scale, there was no sign of wear and even more important, no pitting attack. (See Fig. 1a & 6) In this case it is worth noting that 5mm Stelex 430 was used for the fabrication in place of 10mm mild steel, again saving on material cost.

In diffusers some experimental plates of perforated Stelex 430 have been installed and after one season are standing up far better than the mild steel counterparts. In addition, Stelex 430 is being used as side plates to combat the corrosion that normally occurs in this area.

Primary juice lines are also an excellent application for Stelex 430 and piping of 100mm × 3mm wall and 150mm × 3mm wall are being installed this year at three sugar mills, also supplied are collars and pressed bends, fabricated from Stelex 430.

Screw conveyors especially the bottoms have shown good results with Stelex 430 although trouble has been experienced with the flights. This is a welding problem and with the correct technique is being overcome. Juice scale tanks have now been manufactured and installed in three mills, and once again Stelex 430 lends itself to this type of application.

At several mills this year Stelex 430 is being used as a repair material for badly corroded or eroded plates, as it can easily be welded to mild steel.

Prior to the introduction of Stelex 430 many vessels e.g. maceration tanks and storage tanks were fabricated from A.I.S.I. 304, which now appears to be a

quality (and price) in excess of the normal requirements.

It is apparent that STELEX 430 has opened up applications to the use of stainless steel in the mill operation which were previously considered far too expensive with the traditional 300 series stainless steels.

### Stainless steel in the processing operation

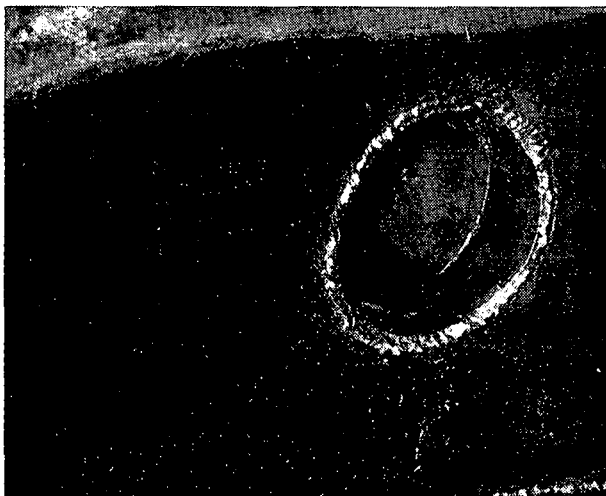
In contrast to the rapid progress with STELEX 430 in the crushing operation A.I.S.I. 304 has been a well established material for centrifuges etc. in the sugar processing operation. However recent upheavals in the price of copper together with more advanced techniques for the manufacture of stainless steel tubing has resulted in the significant use of A.I.S.I. 304 for juice heater and evaporator tubes in place of 70/30 brass.

Stainless steel tubing for this application is currently less than half the price of brass tubes. The superior mechanical strength of A.I.S.I. 304 (See Table 3) allows the use of 18g stainless steel tubing compared with 16g or 14g brass.

This thinner wall facilitates easier expansion of the tubes into the tube plate, furthermore stainless steel has a better resistance to scaling, and cleaning operations do not have to be as frequent or as stringent as brass. Whilst South African installations are still giving satisfactory results after 5—6 years operation, some overseas mills have now had stainless steel tubes for over 12 years.

Some overseas mills have used A.I.S.I. 430 tubes for over 8 years, but limited supplies have to date precluded the wide spread use.

The resistance to pitting of STELEX 430 has been employed extensively in pan condensers with excellent results. Vacuum pipes are also being fabricated from 6mm thick STELEX 430 compared to 10mm mild steel, which helps considerably with the erection of these pipes.



**FIGURE 1a:** Maceration tank in Stelex 430 showing no signs of corrosive attack.



**FIGURE 1b:** An identical tank in mild steel under same conditions as tank in 1a. Shows heavy pitting attack.

### Conclusion

Experience in the South African sugar industry over the past three years indicates that A.I.S.I. 304 is a well established material for juice evaporator and heater tubes, and should continue to grow at the expense of brass.

The many successful applications of the recently introduced STELEX 430 indicates that there will be a rapidly increasing demand for this stainless steel to combat general corrosion and abrasion particularly in the crushing operation.

### Discussion

**Mr. Moor:** Dr. Roffey dealt with corrosive properties but not with strength and fatigue resistance.

**Dr. Roffey:** The fatigue limit of the 430 series will be slightly lower than that of the 300 series, but the fatigue limit of the 300 series is considerably higher than that of mild steel.

As regards mechanical properties. With the 300 series, work hardening will take place depending on the amount of cold work. The U.T.S. can go up from 17 tons square inch to 32 tons square inch with about 10% cold work, which is approximately a 90° bend.

Recent developments in the U.K. have produced a stainless steel with 60 tons U.T.S. and 55 tons yield strength, in a fully ductile state.

Generally speaking, all stainless steels are stronger than mild steel and several stainless steels are now available with the strength of very high tensile steels.

**Mr. Elliot:** What sort of treatment should be given in a mill to tubing with regard to passivation or annealing?

**Dr. Roffey:** In terms of softening the austenitic stainless steels are the opposite of mild steel.

To soften stainless steel you must heat it higher than 1050°C and then quench. The only way you can harden it is by working it.

If you heat it with a gas torch you will get carbide precipitation and the stainless steel may become sensitised and will corrode badly at the sensitised areas.

Passivation and removal of oxide films is carried out using a ten percent nitric acid solution with one percent hydrofluoric acid and, if desired, a small amount of potassium dichromate.

**Mr. Stender:** Chromium stainless steel is sensitive to chrome carbide precipitation in the welding process. Can you make any recommendations?

**Dr. Roffey:** A low carbon stainless steel or titanium or niobium stabilised stainless steels should be used.

A welding rod with high nickel and high chromium content should also be used with the same low carbon analysis or titanium additions as the parent metal.

**Mr. Williams:** Will this also apply to building up stainless steel shafting?

I once built up a pump shaft by metallising and after a short time it left the parent metal.

**Dr. Roffey:** This was probably because the wrong rod was used. It is usually safe, with the 300 and 400 series, to use the type 310 rod.

**Mr. Renton:** The 410 series has been recommended for mills for abrasion resistance but this has not been mentioned in the paper.

Also, there has been more use of stainless steel in

centrifugal baskets in the sugar industry but there have been some unfortunate results because of stress corrosion.

**Dr. Roffey:** I omitted 410 because it is difficult to fabricate. It has 12% chromium and very high carbon so that it is hard and brittle.

It is difficult to combat stress corrosion cracking in stainless steel. The trouble in centrifugals has been due to a combination of stress and corrosion. Their combination gives a force many times stronger than either of them individually and therefore failure, when it comes, is rapid. The main corrosion is due to chlorides and in all cases the stress has to be tensile. Therefore, the ways to eliminate stress corrosion cracking are either to apply a compressive stress, to eliminate chlorides, or to use a material that is not susceptible, such as Inconel, which can be expensive.

**Mr. Fokkens:** We like to insert stainless steel liners into tanks. Is a 310 electrode the one to use to weld stainless steel to mild steel?

**Dr. Roffey:** Yes, the 310 is the correct electrode to use.