Cr-Ni-Mo AUSTENITIC

stainless steel

Adding stainless quality to life

COLUMBUS STAINLESS [Pty] Ltd

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Cr-Ni-Mo AUSTENITIC stainless steel

Introduction

The Cr-Ni-Mo austenitics are molybdenum bearing austenitic stainless steels having very good corrosion resistance in many aggressive environments.

The molybdenum addition ensures more resistance to pitting and crevice corrosion in chloride containing media, sea water and chemical environments such as sulphuric acid compounds, phosphoric and acetic acids.

The lower rate of general corrosion in mildly corrosive environments gives the steel good atmospheric corrosion resistance in polluted marine atmospheres. As they are austenitic, they have excellent ductility, formability and toughness even at sub-zero temperatures.

316L - 1.4404

has a low carbon content to minimise the problem of carbide precipitation during welding and permits the use of the steel in the as-welded condition in a wide variety of corrosive applications.

This grade also complies to the requirements of 1.4402 which has been specifically designed for use in tank containers and has enhanced mechanical properties to aid in tank container design.

316L - 1.4435

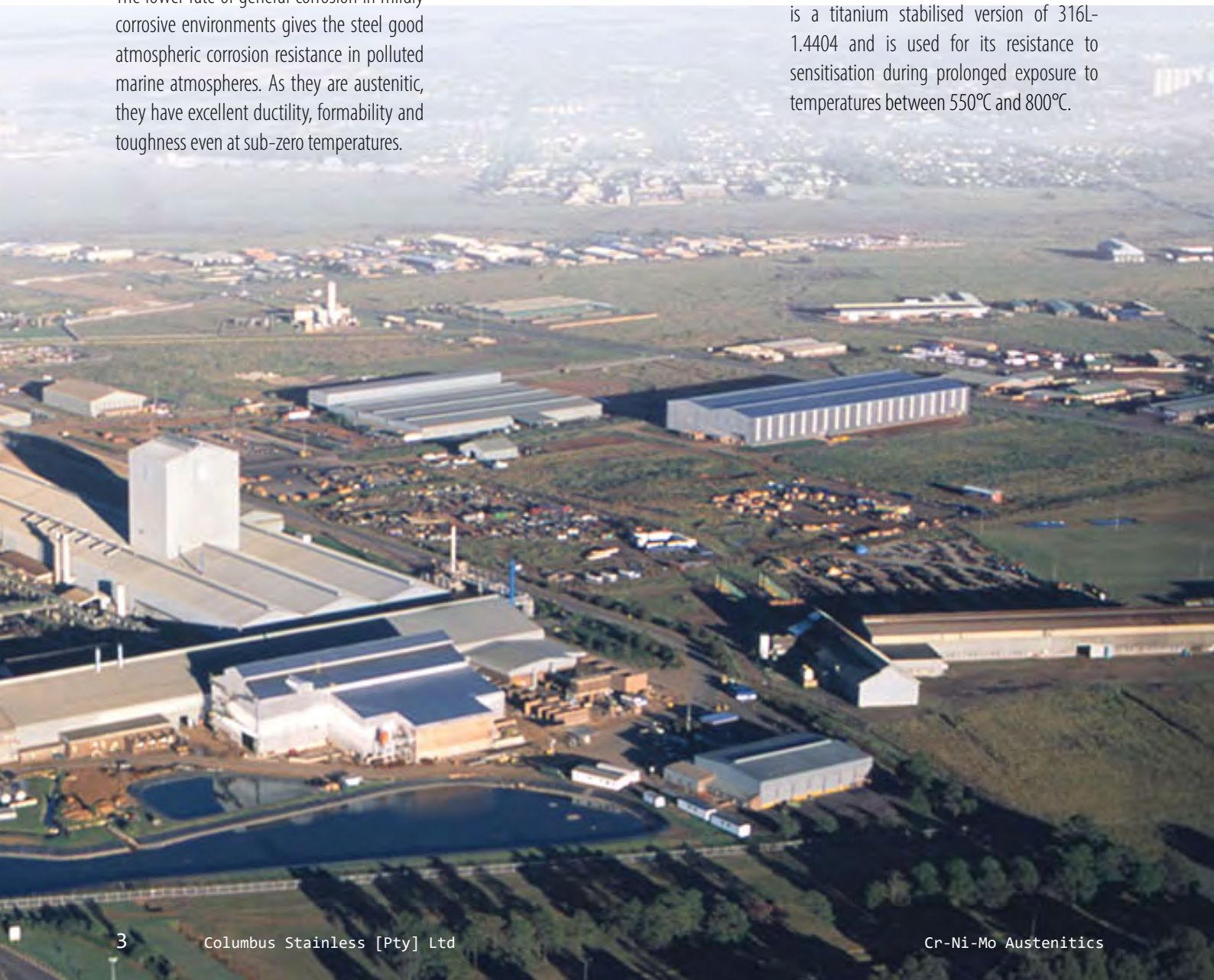
has a higher molybdenum content than U-316L-1.4404 and this improves the pitting and crevice corrosion resistance even further.

316LN

has a higher nitrogen content to improve the strength.

316Ti

is a titanium stabilised version of 316L-1.4404 and is used for its resistance to sensitisation during prolonged exposure to temperatures between 550°C and 800°C.



Product range

The latest revision of the Product Catalogue should be consulted, as the product range is subject to change without notice.

The Product Catalogue is available from the Technical Department or can be found at www.columbus.co.za

Specifications and tolerances

Columbus Stainless (Pty) Ltd supplies the Cr-Ni-Mo austenitics to ASTM A240, ASME SA240, EN 10088-2 and EN 10028-7.

Columbus Stainless (Pty) Ltd normally supplies material to the following tolerances:

HOT ROLLED

ISO 9444 - material processed as coil		ISO 9444-2	
ISO 18286 - material processed as plate		ISO 18286	
ASTM A480	ASTM A480M	EN 10051	EN 10029
ASME SA480	ASME SA480M	IS 6911	
JIS G 4304	JIS G 4312		

COLD ROLLED

ISO 9445	ISO 9445-2
ASTM A480	ASTM A480M
ASME SA480	ASME SA480M
IS 6911	
JIS G 4305	JIS G 4312

Other specifications and tolerances may be available on request.

Further information is available in the Product Catalogue, which can be obtained from the Technical Department or can be found at www.columbus.co.za

Further information:

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Cr-Ni-Mo AUSTENITIC stainless steel

Chemical composition

In accordance with the Columbus Stainless mill specification, ASTM A240 and EN 10088-2.

	C	Si	Mn	P	S	N	Cr	Mo	Ni	Other
316L 1.4404	0.03	0.75	2.0	0.045	0.015	0.10	16.5 18.0	2.0 2.5	10.0 13.0	
316L 1.4435	0.03	0.75	2.0	0.045	0.015	0.10	17.0 18.0	2.5 3.0	12.5 13.0	
316LN	0.03	0.75	2.0	0.045	0.015	0.12 0.16	16.5 18.0	2.0 2.5	10.5 13.5	
316Ti	0.08	0.75	2.0	0.045	0.015	0.10	16.5 19.0	2.0 2.5	10.5 13.5	Ti: 5x(C+N)0.7

Compositions are ranges or maximum values.

Mechanical properties

In accordance with ASTM A240, EN 10088-2 and EN 100095, where applicable.

	Rm (MPa)	$Rp_{0.2}$ (MPa)	$Rp_{1.0}$ (MPa)	A (%)	Max Hardness (HRB)
316L 1.4404	530 to 680 (≤8 mm) 520 to 670 (>8 mm)	240 (CR) 220 (HR)	270 (CR) 260 (HR)	40 (≤8 mm) 45 (>8 mm)	95
316L 1.4435	550 to 700 (≤8 mm) 520 to 670 (>8 mm)	240 (CR) 220 (HR)	270 (CR) 260 (HR)	40 (≤8 mm) 45 (>8 mm)	95
316LN	580 to 780	300 (CR) 280 (HR)	330 (CR) 320 (HR)	40	95
316Ti	540 to 690 (≤8 mm) 520 to 670 (>8 mm)	240 (CR) 220 (HR)	270 (CR) 260 (HR)	40	95

Minimum values, unless Max or range is indicated.
() Indicates applicable gauge range.
CR = Cold Rolled - HR = Hot Rolled
The table assumes certifications to both ASTM A240 and EN 1088-2

PROPERTIES AT ELEVATED TEMPERATURES

The properties quoted below are typical of annealed 316L and 316Ti type steels. These values are given as a guideline only, and should not be used for design purposes.

Short time elevated temperature tensile strength (MPa)

	100°C	200°C	300°C	400°C	500°C	600°C	700°C	800°C	900°C	1000°C	1100°C
316L types	490	480	460	440	420	395	305	180	70	30	15
316Ti	535	540	530	510	505	480	395	275	150	75	20

Short time elevated temperature 0.2 proof stress (MPa)

	100°C	200°C	300°C	400°C	500°C	600°C	700°C	800°C
316L types	215	170	150	135	130	120	115	100
316Ti	225	220	190	165	160	155	150	145

Short time elevated temperature elongation (%)

	100°C	200°C	300°C	400°C	500°C	600°C	700°C	800°C	900°C	1000°C	1100°C
316L types	52	51	48	47	45	47	49	55	61	66	71
316Ti	52	50	47	47	49	56	62	7	72	71	69

Maximum recommended service temperature

Continuous °C	Intermittent °C
920	870

In oxidizing conditions

Creep and creep rupture properties

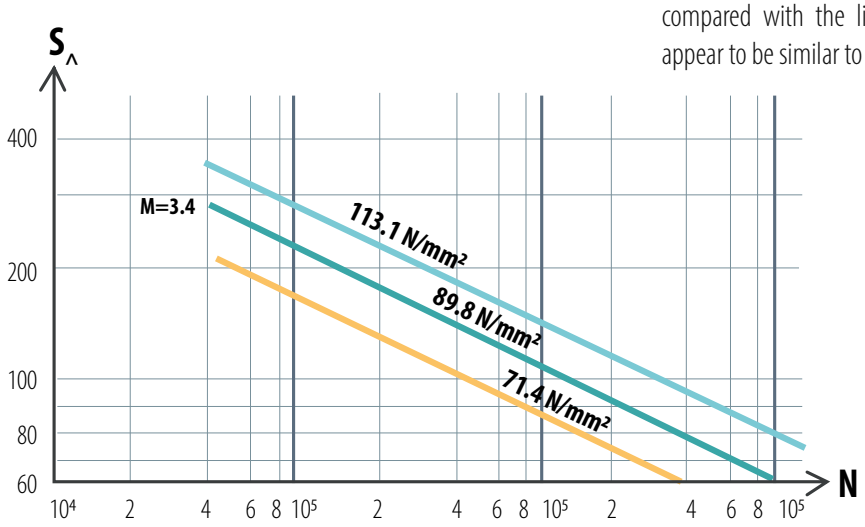
	Stress (MPa) to produce 1% strain		Stress (MPa) to produce rupture	
Temperature (°C)	10000 hours	100000 hours	1000 hours	10000 hours
550	225	125	320	270
600	145	80	220	170
650	95	55	160	110
700	65	35	110	70
750	40	20	75	45
800	30	15	55	30
850	20	10	35	20

FATIGUE CONSIDERATION

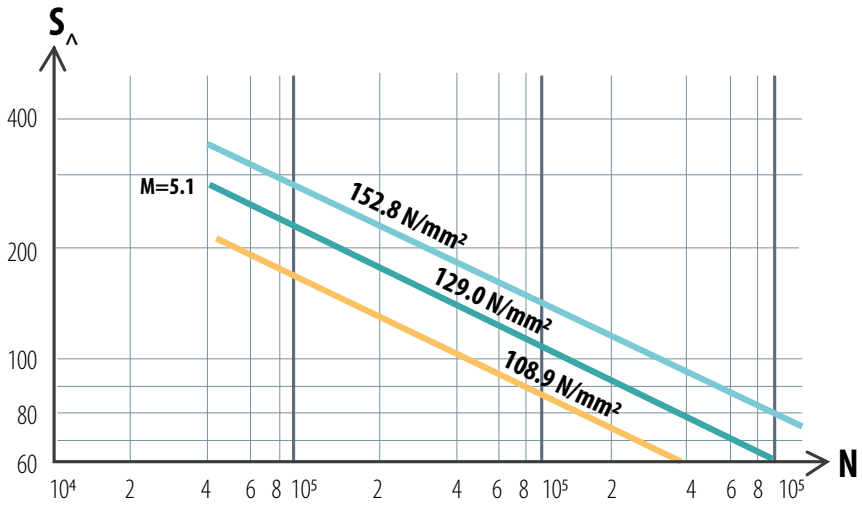
When looking into the fatigue of austenitic stainless steels, it is important to note that design and fabrication - not material, are the major contributors to fatigue failure. Design codes (e.g. ASME and BS 5500) use data from low-cycle fatigue tests carried out on machined specimens to produce conservative S-N curves used with stress concentration factors (k_1 c) or fatigue strength reduction factors (k_1).

In essence, the fatigue strength of a welded joint should be used for design purposes, as the inevitable flaws (even only those of cross-sectional change) within a weld will control the overall fatigue performance of the structure.

The curves show results of welded joints under variable loading for austenitic stainless steel U-316Ti following Eurocode 3. When compared with the literature, the fatigue properties of U-316 Ti appear to be similar to those of mild steel.



Fatigue strength of stainless steel specimens with longitudinal rib



Fatigue strength of stainless steel specimens with transverse rib

Physical properties

The values given below are for 20°C, unless otherwise stated.

Density (kg/m^3)		8000
Modulus of Elasticity in Tension (GPa)		193
Modulus of Elasticity in Torsion (GPa)		70
Specific Heat Capacity (J/kg K)		500
Thermal Conductivity at	100°C (W/m K)	16.2
	500°C (W/m K)	21.5
Electrical Resistivity (x10^{-9} Ω m)		740
Mean Coefficient of Thermal Expansion from	0 to 100°C (x10^{-6} K^{-1})	15.9
	0 to 300°C (x10^{-6} K^{-1})	16.2
	0 to 500°C (x10^{-6} K^{-1})	17.5
	0 to 700°C (x10^{-6} K^{-1})	18.5
Melting Range (°C)		1390 1430

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Thermal processing and fabrication

ANNEALING

Annealing of the Cr-Ni-Mo austenitics is achieved by heating to between 1010°C and 1120°C for 60 minutes per 25 mm thickness (2.5 min/mm) followed by water or air quenching. The best corrosion resistance is achieved when the final annealing temperature is above 1070°C. 316Ti should not be annealed above 1060°C. Controlled atmospheres are recommended in order to avoid excessive oxidation of the surface.

WELDING

The Cr-Ni-Mo austenitics have good welding characteristics and are suited to all standard welding methods. Either matching or slightly over-alloyed filler wires (e.g. ERW 309Mo) should be used.

For maximum corrosion resistance, the higher nitrogen type 316LN should be annealed after welding to dissolve any chromium nitrides which may have precipitated.

The weld discolouration should be removed by pickling and passivation to restore maximum corrosion resistance.

COLD WORKING

The Cr-Ni-Mo austenitics are extremely tough and ductile and can thus be readily deep drawn, stamped, headed and upset without difficulty.

Since austenitic stainless steels work harden, severe cold forming operations should be followed by annealing.

STRESS RELIEVING

The Cr-Ni-Mo austenitics can be stress relieved at 450°C to 600°C for 45 minutes per 25 mm thickness (1.5 min/mm) with little danger of sensitisation. A lower stress relieving temperature of 400°C maximum must be used with 316LN with longer soaking times.

HOT WORKING

The Cr-Ni-Mo austenitics can be readily forged, upset and hot headed. Uniform heating of the steel in the range of 1150°C to 1250°C is required. The finishing temperature should not be below 900°C. Upsetting operations and forgings require a finishing temperature between 930°C and 980°C.

Forgings should be air cooled. All hot working operations should be followed by annealing and pickling and passivation to restore the mechanical properties and corrosion resistance.

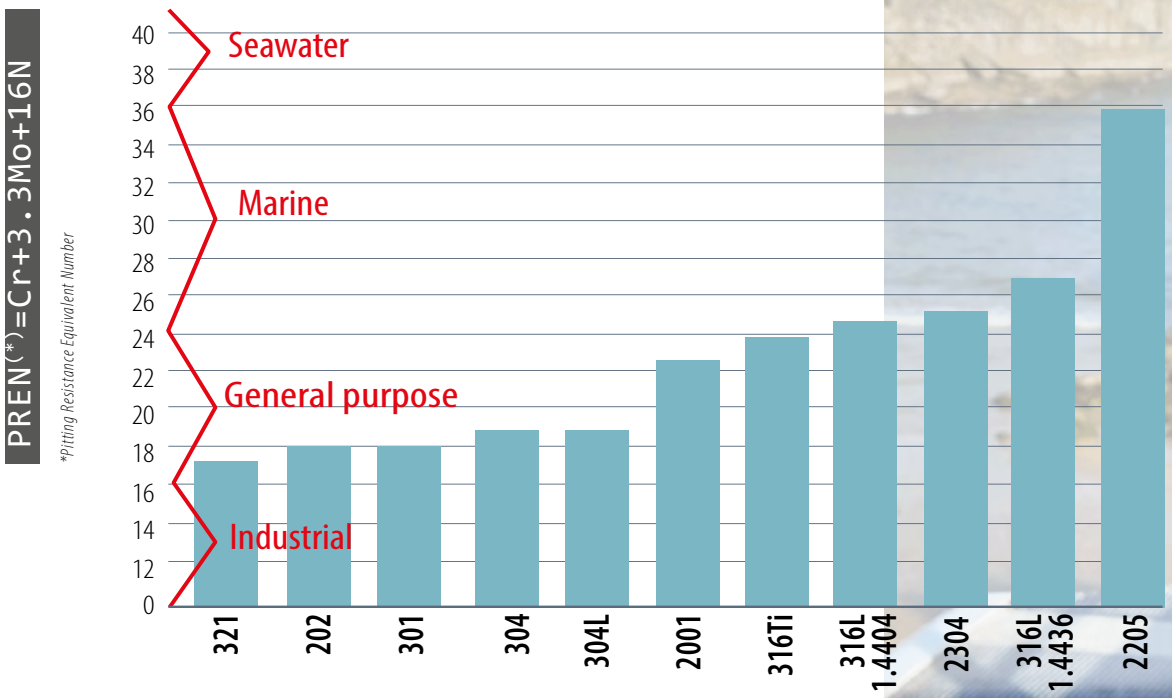
MACHINING

Like all the austenitic stainless steels, this alloy group machines with a rough and stringy swarf. Rigidly supported tools with as heavy a cut as possible should be used to prevent glazing.

Resistance to corrosion

The diagram summarises the corrosion (pitting) resistance of the austenitic and duplex stainless steels produced at Columbus Stainless.

This would indicate that the corrosion resistance of the Cr-(Mn)-Ni austenitic types are all similar and suitable for general purpose applications.



ATMOSPHERIC CORROSION

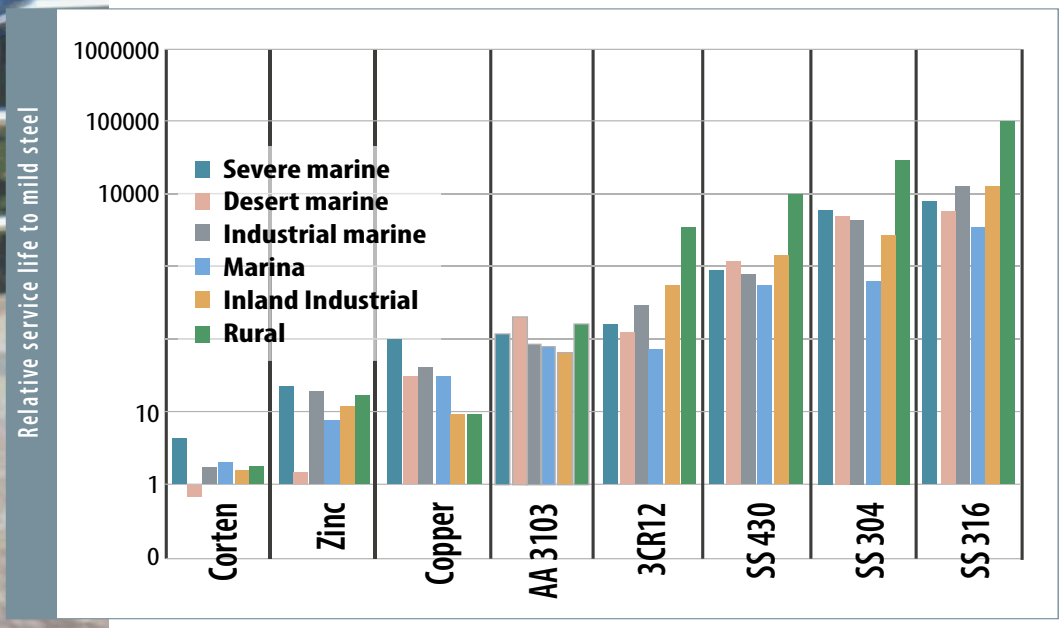
The atmospheric corrosion resistance of austenitic stainless steel is unequalled by virtually all other uncoated engineering materials. Stainless steel develops maximum resistance to staining and pitting with the addition of molybdenum. For this reason, it is common practice to use the Cr-Ni-Mo austenilics grades in areas where the atmosphere is highly polluted with chlorides, sulphur compounds and solids, either singly or in combination. However, in urban and rural areas the Cr-(Mn)-Ni austenitics generally perform satisfactorily.

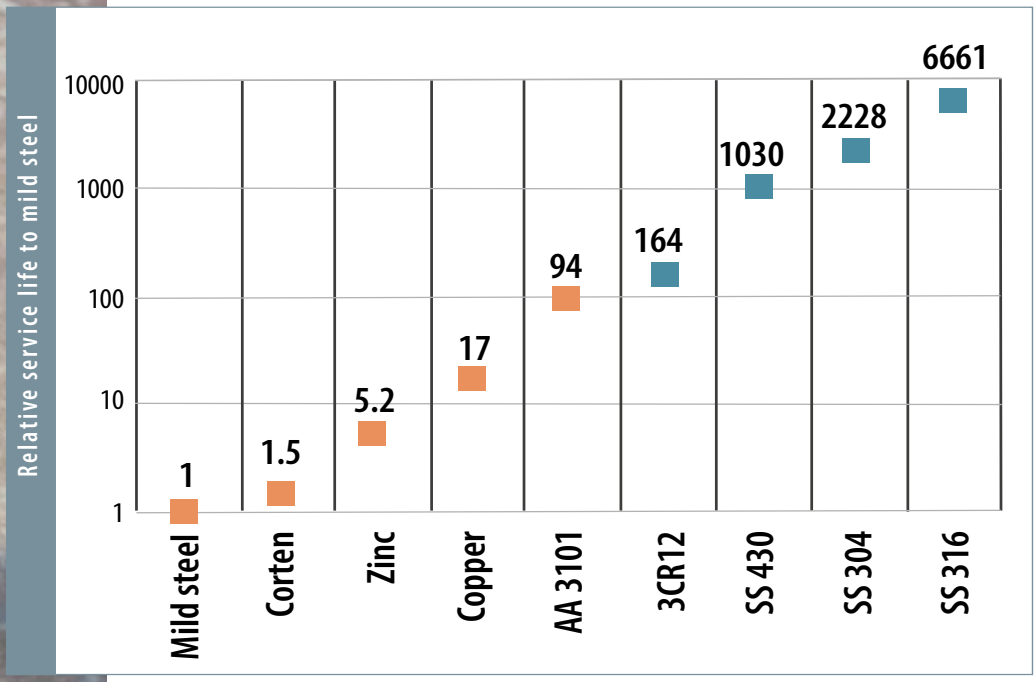
From the report 'Atmospheric Corrosion Testing in Southern Africa - Results of a Twenty Year Exposure Programme' by BG Callaghan, Division of Materials Science and Technology, CSIR, the adjacent graphs can be constructed.

These graphs show the relative life of eight metals compared to mild steel in six different atmospheric environments. The graph can be summarised to give an average relative life of the different metals in atmospheric conditions. In appearance, all the metals showed

Cr-Ni-Mo AUSTENITIC stainless steel

discolouration at the more severe sites after 20 years. None of the metals were washed during the exposure programme and this clearly emphasises the importance of keeping stainless steel clean and that stainless steel is a LOW maintenance (not NO maintenance) option in atmospheric corrosion applications.



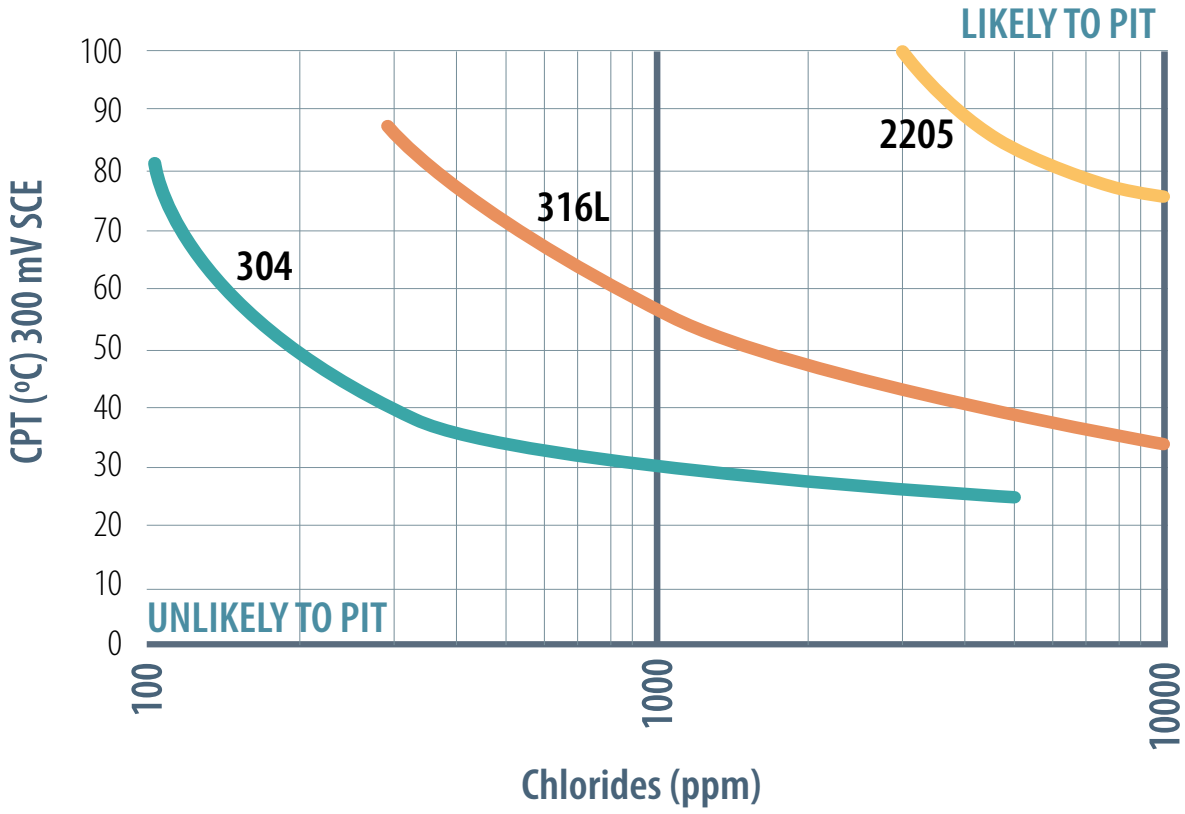


GENERAL CORROSION

The Cr-Ni-Mo austenitics have superior corrosion resistance to the Cr-(Mn)-Ni austenitics. They have good resistance to most complex sulphur compounds such as those found in the pulp and paper industry and they have good resistance to pitting in phosphoric and acetic acids.

PITTING CORROSION

Pitting resistance is important, mainly in applications involving contact with chloride solutions, particularly in the presence of oxidising media. These conditions may be conducive to localised penetration of the passive surface film on the steel and a single deep pit may well be more damaging than a much greater number of relatively shallow pits. Where pitting corrosion is anticipated, steels containing molybdenum (such as the Cr-Ni-Mo austenitics) should be considered. The adjacent diagram shows the critical temperature for initiation of pitting (CPT) at different chloride contents for 304, 316L and 2205 types (potentiostatic determination at +300mV SCE, pH = 6.0).



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OXIDATION RESISTANCE

Cr-Ni-Mo austenitics have good oxidation resistance in intermittent service up to 870°C and in continuous service to 920°C.

STRESS CORROSION CRACKING

Stress corrosion cracking (SCC) can occur in austenitic stainless steels when they are stressed in tension in chloride environments at temperatures in excess of about 60°C. The stress may be applied, as in a pressure system or it may be residual arising from cold working operations or welding.

Additionally, the chloride ion concentration need not be very high initially, if locations exist in which concentrations of salt can accumulate.

Assessment of these parameters and accurate prediction of the probability of SCC occurring in service is therefore difficult. Where there is a likelihood of SCC occurring, a beneficial increase in life can be easily obtained by a reduction in operating stress and temperature. Alternatively, specially designed alloys, such as duplex stainless steels, will have to be used where SCC cracking is likely to occur.

INTERGRANULAR CORROSION

Sensitisation may occur when the Heat Affected Zones of welds in some austenitic stainless steels are cooled through the sensitising temperature range of between 450°C and 850°C. At this temperature, a compositional change may occur at the grain boundaries.

If a sensitised material is then subjected to a corrosive environment, intergranular attack may be experienced. This corrosion takes place preferentially in the heat affected zone away from and parallel to the weld. Susceptibility to this form of attack, often termed 'weld decay', may be assessed by the following standard tests:

a) boiling copper sulphate/sulphuric acid test as specified in ASTM A262, Practice E.

b) for non titanium stabilised grades only, boiling nitric acid test as specified in ASTM A262, Practice C.

The Columbus Stainless Cr-Ni-Mo austenitics have low carbon contents and are resistant to sensitisation and can be specified for welded structures unless the higher carbon types are required for their increased strength at elevated temperatures. In this case, 316 Ti should be specified

Some recommendations

Handling and transport

Before shipping, make sure every chain and steel element is not in contact with stainless steel. Raffia or wooden elements must be used at possible contact places.

When outside storage is required, material should be covered by a waterproof canvas.

Avoid contact with the ground using wooden blocks and store stainless steel and carbon steel separately. This way we avoid problems with contamination by oils, dirt or by contact among different materials.

When stainless steel has to be moved with lift trucks, the forks should be protected with nylon.

Avoid carbon steel slings, use nylon or polypropylene ones wherever possible.

Fabrication and installation

Make sure stainless steel is contamination free before starting to work. If there is any, it will be removed by pickling or mechanical means (*).

If cleaning is required, do it with pressurized water. Do not use sea or brackish water.

All tools employed in the installation must be made of stainless steel and these should have been never used with carbon steel. If this is not possible, tools must be carefully cleaned before use.

Stainless steel should be processed in machines exclusively dedicated to this material, in order to avoid contamination by projections or oxide traces from other materials.

Excessive temperature oxidation or *blueing* due to abrasive cutting, should be removed with pickling paste. Good refrigerated cutting tools help to avoid the problem.

If coating may be considered for aesthetic reasons, surface preparation is extremely important and may be performed either by acid pickling or mechanical means such as blasting.

(*) It is always advisable to contact the supplier

Some applications

Aggressive environments

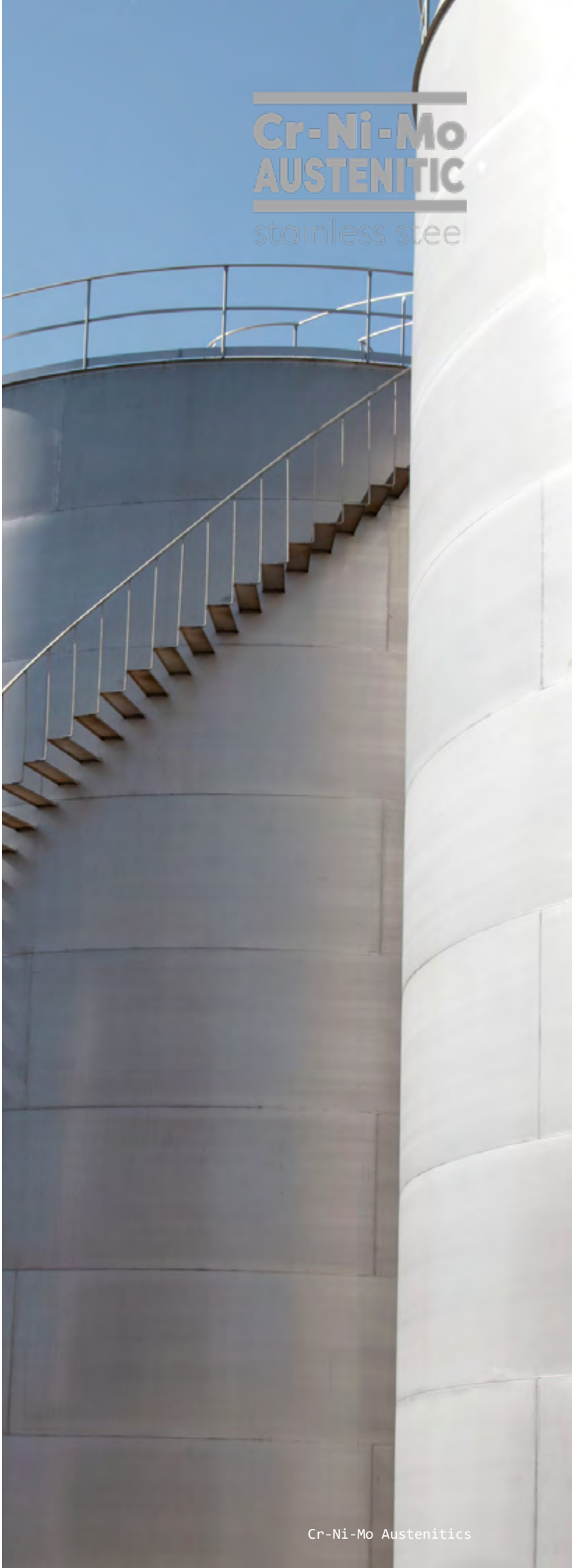
Corrosive applications

Container tanks for chemicals and food

Chemical and Mining process equipment

Chimney flues

Food handling equipment



Certificates

Columbus Stainless' product meets the following international standards:

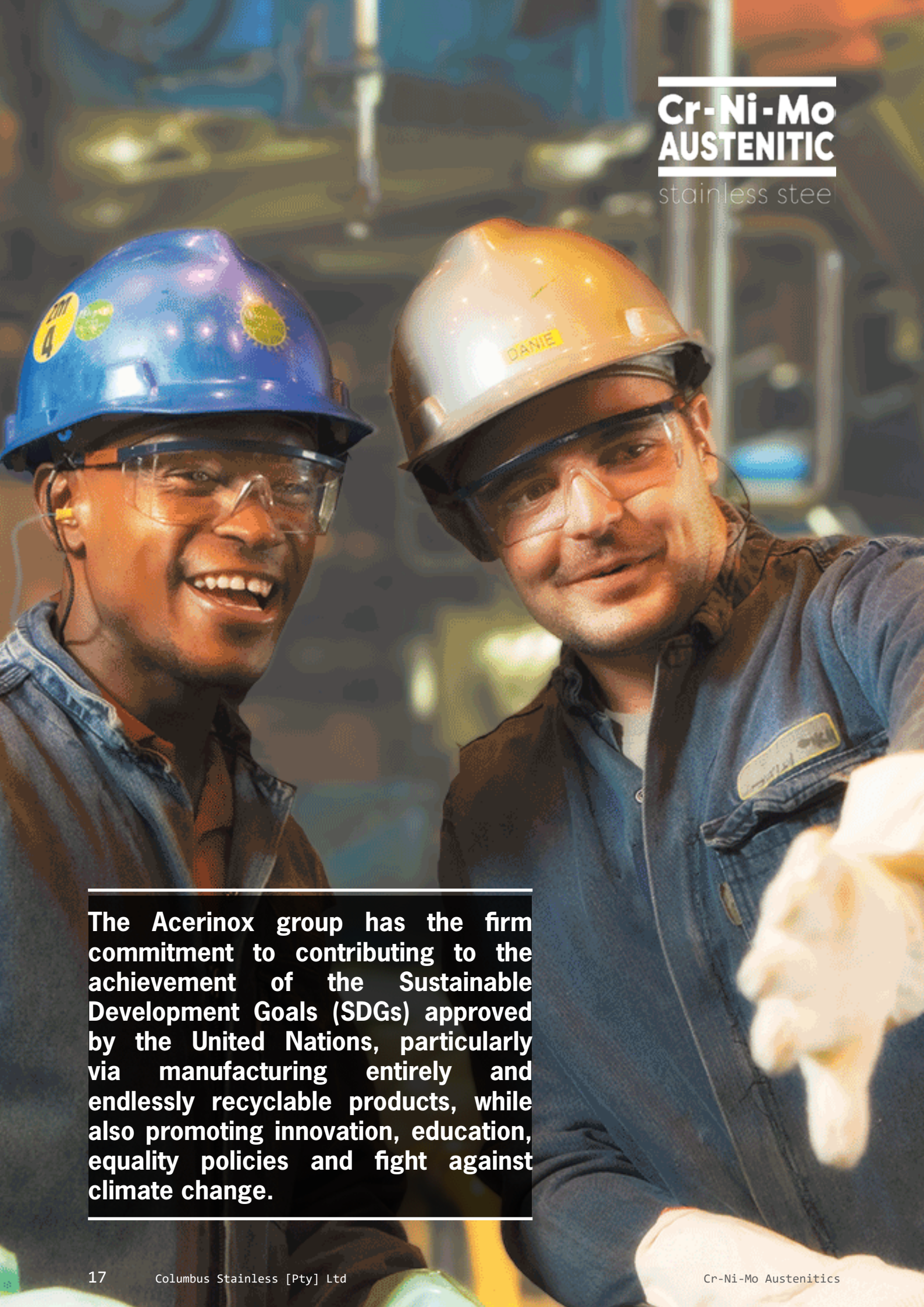
PED 2014/68/EU Certificate	BIS Certification Mark License
CPR 305/2011/EU Certificate	PESR Certificate
CPR Declaration of Performance	JIS G4304 & G4305 Certificate of Compliance
	JIS G4312 Certificate of Compliance

Available at www.columbus.co.za/quality/product-certifications or scan the code:

Committed to sustainable growth

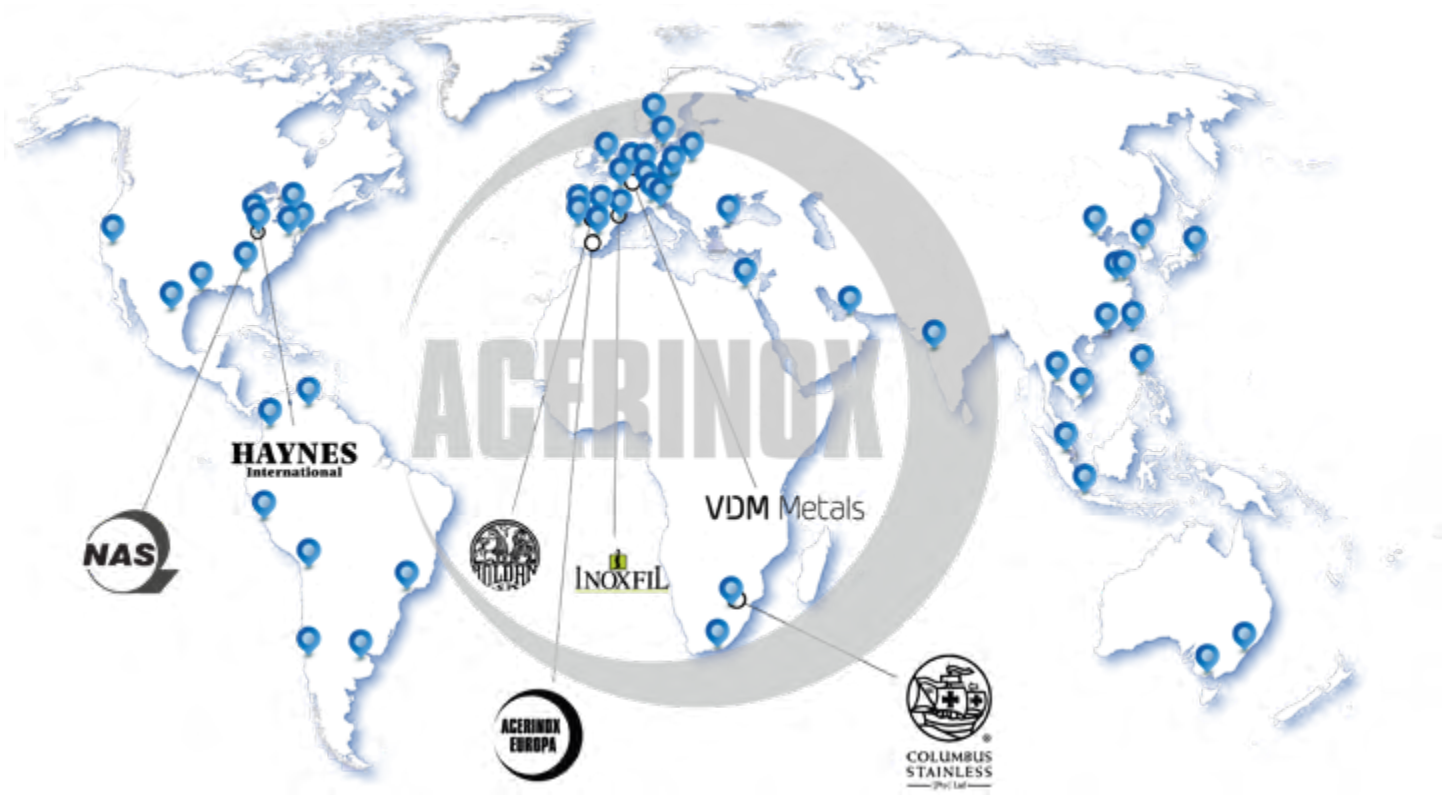
Acerinox is one of the major scrap recyclers wherever it is located. The production in the factories of Acerinox is transformed into final products which return to the factories as scrap to be melted again. This is a cycle that could be infinite due to the material properties.

Columbus Stainless also ensures optimum utilisation of raw materials and energy sources by focusing on the reduction of waste in both power, water and raw materials. Not only do these reduce the impact on the environment but also reduce the costs of producing quality products.



The Acerinox group has the firm commitment to contributing to the achievement of the Sustainable Development Goals (SDGs) approved by the United Nations, particularly via manufacturing entirely and endlessly recyclable products, while also promoting innovation, education, equality policies and fight against climate change.

Acerinox: the confidence of a strong group



Acerinox is the Spanish multinational global leader in stainless steel manufacturing. With a total production capability of 3.5 million tonnes per year. Acerinox owns factories worldwide confirming its global presence, stainless steel flat products manufacturing at Acerinox Europa, North American Stainless and Columbus Stainless; and Roldan, Inoxfil and North American Stainless for long products manufacture. In March 2020, VDM Metals, worldwide leader in high performance alloys manufacture and design, has also become part of the group. In November 2024, Acerinox completes the acquisition of Haynes International, U.S. leading manufacturer and marketer of technologically advanced high-performance alloys.

Every Acerinox facility satisfies the quality and environmental controls required by each country legislation, apart from the application of the Environmental Management System according to ISO 14001. Furthermore, subsidiaries assume higher standards than legal requirements in areas such as quality, safety and sustainability.

Scrap plays a key role in all Acerinox fabrication processes. Thus, a great value is added bringing it back to the material life cycle, reducing the environmental impact with the use of the same material for centuries.

Columbus Stainless was founded in 1966 in South Africa. It is the only integrated stainless steel factory on the African continent and today is the main supplier of stainless steel solutions for both the domestic and the continent market.

The factory is equipped with the most efficient and technologically advanced machinery in the sector, has seen the most significant technological advances in the sector, and has a considerable competitive advantage due to its location, not only for distributing its finished products, but also thanks to its proximity to the raw material extraction sources, especially chrome. It also supplies semi-finished flat products to other Acerinox Group factories.

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Columbus Stainless is the premier Stainless Steel Manufacturer and Provider in Africa. Our plant is technologically advanced, fully integrated and a single-site operation. This gives us flexibility to adjust quickly to changes in the market. We supply high-quality flat-rolled stainless and carbon steel products.


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