LDX 2101® Comparative for Bar

LDX 2101® Summary/Overview

Outokumpu	EN	UNS
LDX 2101®	1.4162	S32101

Characteristic properties

High strength
Good fatigue resistance
Good corrosion resistance
High resistance to stress corrosion cracking
High energy absorption
Very good machinability

Applications

General-purpose applications and environments
Building and storage construction
Structural members
Reinforcement bars
Rotors, impellers, shafts
Water treatment
Pulp and paper equipment
Fittings
Fasteners

General Characteristics

LDX 2101® is a low-alloyed, general purpose duplex stainless steel. Its high mechanical strength is similar to that of other duplex grades and its good corrosion resistance is on par with that of most standard stainless steel grades. Combined, these properties can be utilized to arrive at a design optimized with respect to strength, maintenance, durability and long-term cost efficiency.

Chemical characteristics

The chemical composition is shown in Table 1.

Microstructure

The balanced chemical composition of LDX 2101 results in a microstructure containing approximately equal amounts of ferrite and austenite after annealing at a temperature of about 1920°F /1050°C. Due to its relatively low alloying content, LDX 2101 is less prone to precipitation of intermetallic phases than other duplex steels. The high nitrogen content results in rapid re-formation of austenite in weld thermal cycles.

Mechanical Properties

LDX 2101 has high mechanical strength due to its duplex microstructure and high nitrogen content. In Table 2 the minimum values for the grade are presented.

Fatigue

The high tensile strength of duplex steels also implies high fatigue strength. Table 3 shows the result of pulsating tensile fatigue tests (R=0.1) in air at room temperature. The fatigue strength has been evaluated at 2 million cycles and probability of rupture is 50%. Since the test was made using round polished test bars from hot rolled plate, correction factors for surface roughness, notches, welds, etc, are required in accordance with classical theory relating to fatigue failure. As shown by the table, the fatigue strength of the duplex steels corresponds approximately to the yield strength of the material.

Table 1

Steel Grade	International Steel No.		Typical composition, %					
	EN	ASTM	C	N	Cr	Ni	Mo	Others
304	1.4301	304	0.04	0.04	18.1	8.3	—	—
316L	1.4404	316L	0.02	0.04	17.2	10.2	2.1	—
Outokumpu 2304	1.4362	S32304	0.02	0.10	23	4.8	0.3	—
2205 Code Plus Two ®	1.4462	S32205*	0.02	0.17	22	5.7	3.1	—
LDX 2101®	**1.4162**	**S32101**	**0.03**	**0.22**	**21.5**	**1.5**	**0.3**	**5Mn**

* Also available in S31803

Typical Mechanical Properties (Thickness 0.187”-0.500”)

Table 2

Type	Typical	ASTM
LDX 2101®		
Proof Strength (R_p0.2), KSI	75	65 min
Tensile Strength (R_m), KSI	104	94 min
Elongation (A_5), pct.	37	30 min
Hardness, R_c	17	28 max
304L		
Proof Strength (R_p0.2), KSI	44	25 min
Tensile Strength (R_m), KSI	89	75 min
Elongation (A_5), pct.	55	40 min
Hardness, R_b	81	92 max
316L		
Proof Strength (R_p0.2), KSI	43	25 min
Tensile Strength (R_m), KSI	85	70 min
Elongation (A_5), pct.	53	40 min
Hardness, R_b	79	92 max

Fatigue, pulsative test

Table 3

Minimum value	LDX 2101®		2205 Code Plus Two®		316L	
	MPa	KSI	MPa	KSI	MPa	KSI
Yield Strength 0.2%	478	69	497	72	280	40
Tensile Strength	696	100	767	111	578	83
Fatigue Strength	500	72	510	73	360	52

Standard deviation of fatigue srength, for the entire population ~ 30 MPa/ 5 KSI

Corrosion Resistance

The corrosion resistance of LDX 2101 is generally good, and the grade is therefore suitable for use in a wide range of general-purpose applications and environments. The corrosion resistance is in general at least as good as that of Cr-Ni grades such as 304 and in most cases as good as Cr-Ni-Mo grades such as 316L. A brief description of the resistance to different types of corrosion is described below.

Uniform corrosion

Uniform corrosion is characterized by a uniform attack on the steel surface in contact with a corrosive medium. The corrosion resistance is generally considered good if the corrosion rate is less than 0.1 mm/year (see Table 4). LDX 2101 has a better resistance than 304 and in most cases performs as well as 316. One exception is sulfuric acid as shown in Figure 1.

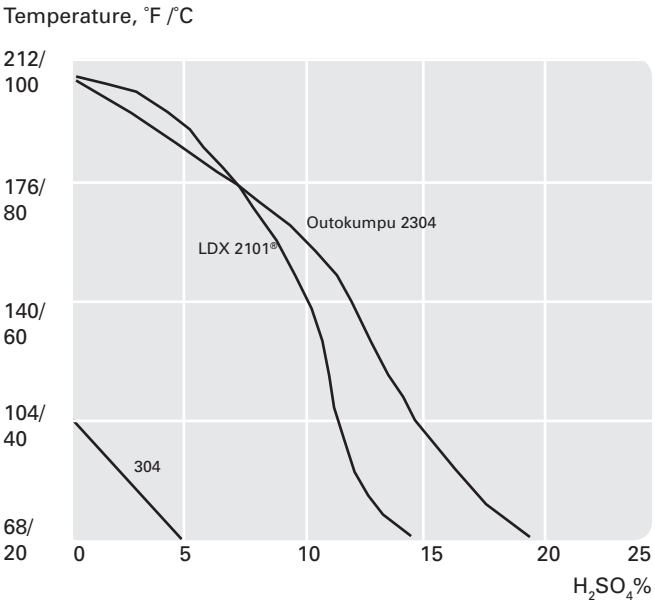


Fig. 1 Isocorrosion curves, 0.1 mm/year, in sulphuric acid

Pitting and crevice corrosion

The resistance to pitting and crevice corrosion increases with the content of chromium, molybdenum and nitrogen in the steel. The resistance to these types of corrosion, which are mainly caused by chloride containing environments, is good due to the grade’s high chromium and nitrogen content. The pitting corrosion resistance has been evaluated using the Avesta Cell (ASTM G 150). Figure 2 shows that the resistance is higher than that normally obtained with Cr-Ni grades such as 304 and approaching that of Cr-Ni-Mo grades such as 316L.

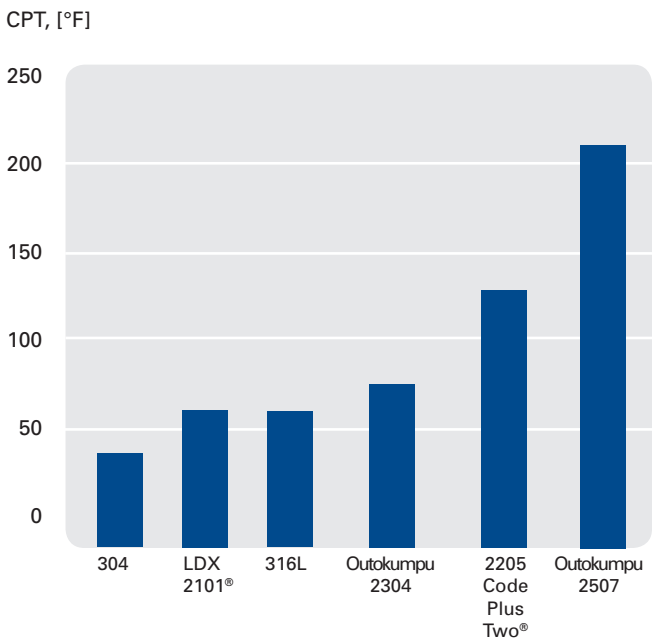


Fig. 2 Typical CPT values in 1M NaCl for tested stainless steels tested in ground conditions according to ASTM G150.

Uniform Corrosion Results

Table 4

Test solution	Conc, wt%	Critical temperature °F (°C)		
		316L	304	S32101
Hydrochloric Acid				
HCl	0.2	>bp	>bp	>bp
HCl	1.0	86(30)	86(30)p	140(55)
$HCl+FeCl_3$	$1.0HCl + 0.3FECl_3$	25p	20p	20
Sulfuric Acid				
H_2SO_4	10	122(50)	N.T.	167(75)
	60	<59(<15)	N.T.	<86(<30)
	96.4	113(45)	N.T.	86(30)
Phosphoric Acid				
H_3PO_4	85	203(95)	176(80)	214(100)
Nitric Acid				
HNO_3	10	>bp	>bp	>bp
	65	214(100)	214(100)	221(105)
Organic Acids				
Acetic acid CH_{3-} COOH	80	>bp	214(100)	>bp
Acetic acid+ acetic anihydride CH3COOH+ $(CH_3CO)_2O$	50+50	248(120)	<bp	221(105)
Formic acid HCOOH	50	104(40)	<50(<10)	203(95)
Sodium Hydroxide				
NaOH	50	194(90)	185(85)	185(85)

N.T.= Not Tested *bp.= Boiling Point* *p.= Pitting Corrosion*

Atmospheric corrosion

A steel's resistance to atmospheric corrosion is strongly linked to its resistance to uniform corrosion and localized corrosion such as pitting and crevice corrosion. Since LDX 2101 shows good resistance to these types of corrosion, it may be assumed that the resistance to atmospheric corrosion is good. Accordingly LDX 2101 should be sufficiently resistant in most environments.

Stress corrosion cracking

Like all duplex steels, LDX 2101 shows good resistance to chloride-induced stress corrosion cracking (SCC). Many test methods are used to rank the different steel grades with respect to their resistance to SCC. One such test method is the U-bend test according to MTI Manual no. 3, in which the specimens are exposed to 3M magnesium chloride (MgCl2) solution at 100° C for 500 hours. The U-bending was performed both longitudinal and transverse to the rolling direction. The results are shown in Table 5.

Intergranular corrosion

Due to its duplex microstructure LDX 2101 offers very good resistance to intergranular corrosion. Duplex stainless steels are less susceptible to this kind of corrosion than austenitic stainless steels.

Results from U-bend stress corrosion testing in $MgCl_2$ **Table 5**

	Longitudinal/Transverse
LDX 2101®	No SCC (some uniform corrosion)
Outokumpu 2304	No SCC (some uniform corrosion)
304	SCC cracks + pitting corrosion

Summary of Test Results for the Wick Test Table 6

Material UNS No.	Number of Specimens	
	Tested	Failed due to SCC
S30400	2	2
S32101	6	0
S32304	2	0
S32205	2	0

Fabrication

Hot Forming

Hot forming is performed in the temperature range 2000-1650° F /1100-900° C and should be followed by solution annealing. It should, however, be observed that the strength is low at high temperatures.

Cold Forming

Due to the high proof strength of duplex material, greater working forces than those required for austenitic steel are usually needed for cold forming. Figure 3 shows the effect of work hardening on LDX 2101.

LDX 2101 is suitable for most forming operations used in stainless steel fabrication. However, due to the grade's higher mechanical strength and lower toughness, operations such as deep drawing, stretch forming and spinning are more difficult to perform than with austenitic steel. The grade's high strength, may give rise to a relatively high spring back.

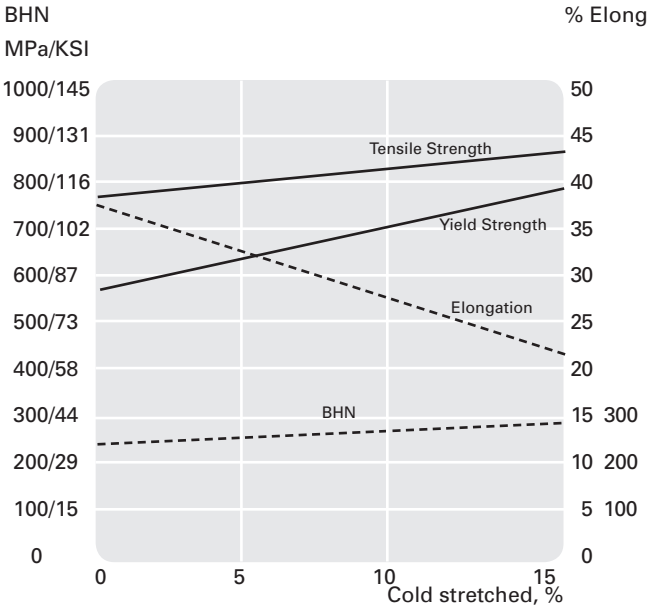


Fig. 3 Mechanical properties of LDX 2101® after cold deformation.

Summary of Test Results for Concentrated Calcium Chloride **Table 7**

Material UNS No.	Exposure time [h]	Number of Specimens			
		U-bend		4-PB	
		Tested	Failed due to SCC	Tested	Failed due to SCC
S30400	96	6	6	—	—
	340	—	—	4	4
S32101	500	6	0	2	0
S32304	500	6	0	2	0
S32205	500	6	0	2	0
S23750	500	—	—	2	0

Heat treatment

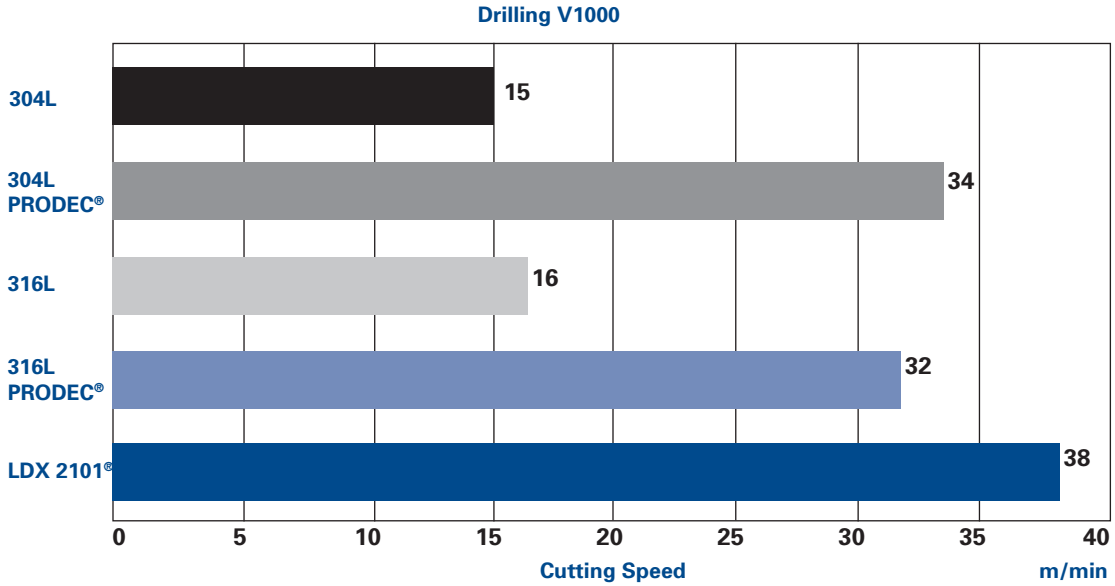
LDX 2101 is solution annealed at 1870°-1970° F/1020°-1080° C. Rapid cooling is recommended after annealing.

Machining

LDX 2101 has shown excellent machining properties. Other duplex steels are generally more difficult to machine than conventional austenitic stainless steel such as 316L, due to the higher hardness.

Drilling with standard method, V1000 for HSS tools

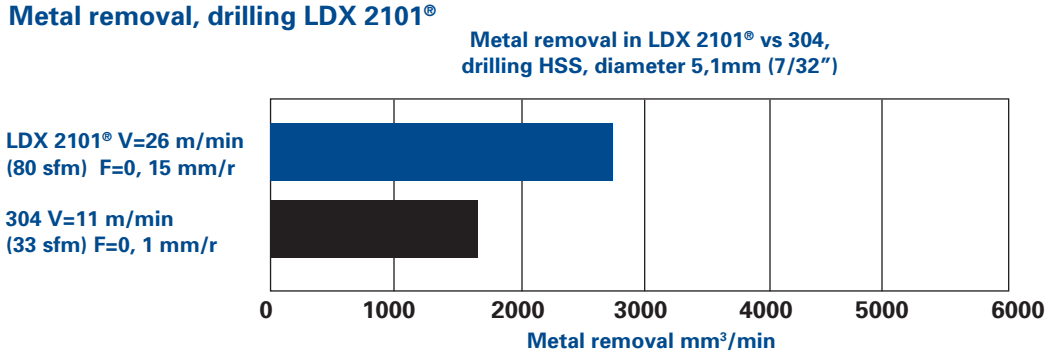
Table 8



V1000 can be explained as the cutting speed that gives a tool lifetime for a drilled length of 1000mm, 40 inch.
Tool Wedevag Double X
Prodec is a registered Outokumpu trademark for steel grades with improved machinability.

Metal removal, drilling LDX 2101®

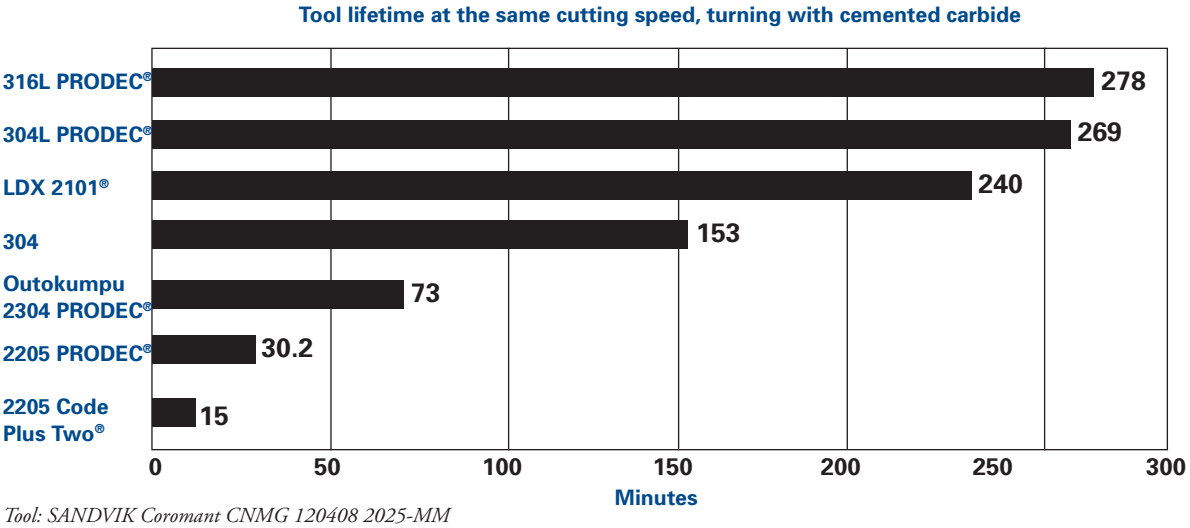
Table 9



Relevant cutting speed in respective steel grade for the same tool lifetime.
Tool Wedevag Double X

Tool lifetime at 126m/min (380 sfm), turning

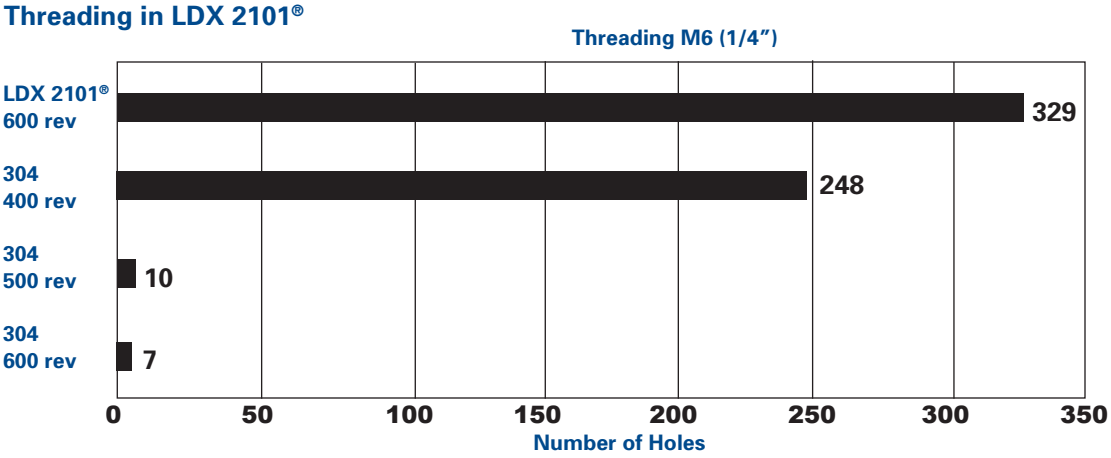
Table 10



Tool: SANDVIK Coromant CNMG 120408 2025-MM
Prodec is a registered Outokumpu trademark for steel grades with improved machinability.

Threading in LDX 2101®

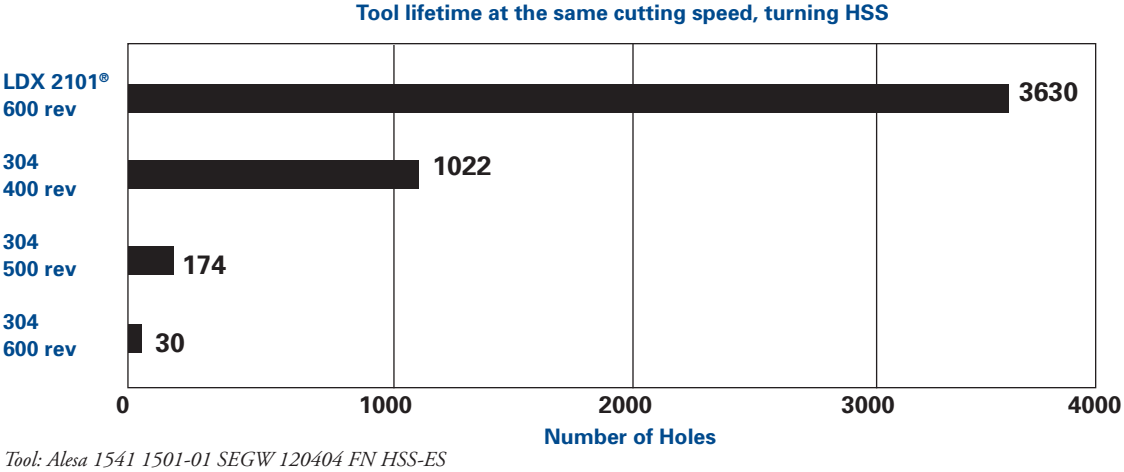
Table 11



Tool: Vaporized HSS-Co tap, NORIS-SALO-REX-VA HSSE C

Tool lifetime at 26m/min (80sfm), turning with HSS tool

Table 12



Tool: Alesa 1541 1501-01 SEGW 120404 FN HSS-ES

LDX 2101® Machining Guide

Table 13

Operation	Depth of cut or width (in)	HSS Tooling			Carbide Tooling		
		Cutting Speed (SFM)	Feed (IPR)	Tool Grade	Cutting Speed (SFM)	Feed (IPR)	Tool Grade
Turning	0.04-0.15	45-120	0.001-0.006	T15	80-700	0.0025-0.012	P15-M25
Forming	0.200	45-120	0.0005-0.006	T15	80-813	0.0005-0.010	P15-M25
Cut-off or Grooving	0.04-0.15	Up to 120	0.001-0.005	T15	80-360	0.001-0.008	M25
Drilling	All	40-120	0.003-0.009	M35	80-810	0.0025-0.012	P15-M25
Reaming	All	40-120	0.003-0.025	M35	80-810	0.0025-0.012	P15-M25
Taping	All	Up to 120	N/A	M35	—	—	—
Single Point Threading	—	—	—	—	114-490	Thread Size: 3/4"-10 Passes: 9-11	M20

- *Small differences in cutting speed will affect tool lifetime*
- *Higher feed rate tends to give better surface and chip formation*
- *TiAlN coated high speed steel tools provide much longer tool lifetime than un-coated*
- *Results can vary depending upon tooling and machine set-up*
- *These are actual results obtained from production tests*

Welding

LDX 2101 has a good weldability and can be welded using the same processes used for other duplex steels.

In general the recommendations for welding duplex steels also apply for LDX 2101. However, the restrictions in arc energy are less tight than for conventional duplex steels due to the grade's low alloy content and high nitrogen level. Normally, the special LDX 2101 filler or a filler of type 2209 should be used for optimum properties. Welding without filler is possible, and reasonably good properties can be obtained in the 'as-welded' condition.

Product specification and approvals

LDX 2101 is standardized by ASTM/ASME. It has an EN number and work is in progress to obtain EN standardization for flat, bar and tubular products. Outokumpu has received a patent for LDX 2101.

Products

Table 14

Hot rolled plate, sheet and strip	Dimensions according to Outokumpu product program.
Cold rolled sheet and strip	Dimensions according to Outokumpu product program.
Billet, wire rod and bar	Dimensions according to Outokumpu product program.
Pipe	Dimensions according to Outokumpu product program.
Welding consumables	Filler material in the form of covered electrodes of AC/DC type, MIG, TIG, FCW and SAW wire and also welding flux are supplied by Avesta Welding AB, Avesta

Material Standards

Table 15

ASTM A240/ASME SA-240	Heat-resisting Cr and Cr-Ni stainless steel plate/sheet/strip for pressure purposes
ASTM A276	Stainless and heat-resisting steel bars/shapes
ASTM A479/ASME SA-479	Stainless steel bars for boilers and other pressure vessels
ASME Boiler and Pressure Vessel Code Case 2418-1	21 Cr-5Mn-1.5Ni-N (UNS S32101), Austenitic-Ferritic Duplex Stainless Steel Section VIII, Division 1

1223EN, Schaumburg, USA, February 2009.

Outokumpu is a global leader in stainless steel. Our vision is to be the undisputed number one in stainless, with success based on operational excellence. Customers in a wide range of industries use our stainless steel and services worldwide. Being fully recyclable, maintenance-free, as well as very strong and durable material, stainless steel is one of the key building blocks for sustainable future.

What makes Outokumpu special is total customer focus – all the way, from R&D to delivery. You have the idea. We offer world-class stainless steel, technical know-how and support. We activate your ideas.

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