COLUMBUS STAINLESS [Pty] Ltd

Pocket Guide

Adding Stainless Quality to life

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Contents

Introduction

Stainless steels are iron based (ferrous) materials, containing at least 11% chromium. Other alloy additions are made such as nickel, molybdenum, titanium, niobium, vanadium and nitrogen. Stainless steels are classified according to their internal crystal (micro) structure which results from the various alloy contents. Columbus Stainless produces the three main classifications of stainless steel, namely:

AUSTENITIC: Contain chromium and nickel with low to very low carbon contents, identified by the AISI 300 & 200 series, excellent corrosion and high temperature oxidation resistance - good strength - strength and hardness can be increased by cold work - excellent weldability and formability - high hygiene factor - excellent cryogenic properties - non-magnetic in the annealed condition.

FERRITIC: Plain chromium alloys of low carbon content, also identified by the AISI 400 series - good corrosion resistance - good strength - cannot be hardened by heat treatment - fair weldability in thin gauges - magnetic.

DUPLEX: Contain chromium, molybdenum, a small amount of nickel and very low carbon contents, not identified by the AISI series - have a duplex (mixed) crystal structure of austenite/ ferrite - excellent corrosion resistance, particularly to pitting, crevice corrosion and stress corrosion cracking - very good strength - good weldability and formability - magnetic.

Chemical Composition

Classification		Type		Composition										
		Grade	ACX	C	Si	Mn	P	S	N	Cr	Mo	Nb	Ni	Other
FERRITICS	Utility	3CR12	C211	0.03	1.0	2.0	0.040	0.030		10.5 -12.5			0.3 - 1.5	Ti: 4x(C+N) to 0.6
		3CR12L	C220	0.03	1.0	1.5	0.040	0.015	0.03	10.5 -12.5			0.3 - 1.0	
		410S	C420	0.08	1.0	1.0	0.040	0.015		11.5 - 13.5			0.6	
	Standard	40910	C800	0.03	1.0	1.0	0.040	0.015	0.03	10.5 - 11.7			0.5	Ti: 6x(C+N) to 0.5
		40920	C801	0.03	1.0	1.0	0.040	0.015	0.03	10.5 - 11.7			0.5	Ti: 8x(C+N) to 0.5
		430	C500	0.08	1.0	1.0	0.040	0.015		16.0 - 18.0			0.75	
		430DDQ	C530	0.08	1.0	1.0	0.040	0.015		16.0 - 18.0				Al: 0.30 max
		439Nb	C515	0.03	1.0	1.0	0.040	0.015	0.03	17.0 - 19.0		0.35		Ti: 4x(C+N) + 0.2 to 7.5
		441	C845	0.03	1.0	1.0	0.040	0.015		17.5 - 18.5		3xC+0.3 to 1.00		Ti: 0.1 to 0.6
	Moly	436	C550	0.08	1.0	1.0	0.040	0.015		16.0 - 18.0	0.8-1.25	5xC to 9.8		
		444	C555	0.025	1.0	1.0	0.040	0.015	0.03	17.5 - 19.5	1.8-2.5		1.0	Ti: 4x(C+N) + 0.2 to 7.5
DUPLEXES	Lean	2001	C920	0.03	1.0	4.0-6.0	0.040	0.015	0.05-0.17	19.5 - 21.5	0.6		1.0 - 3.0	Cu: 1.0 max
		2304	C940	0.03	1.0	2.5	0.040	0.015	0.05-0.20	22.0 - 24.0	0.1-0.6		3.5 - 5.5	Cu: 0.1 to 0.6
	Standard	2205	C900	0.03	1.0	2.0	0.030	0.015	0.14-0.20	22.0 - 23.0	3.0-3.5		4.5 - 6.5	

Classification		Grade	ACX	C	Si	Mn	P	S	N	Cr	Mo	Nb	Ni	Other
AUSTENTICS	Cr-Ni-Mn	202	C335	0.08	1.0	7-9	0.045	0.015	0.15	15.0-17.0			3.5-5.0	Cu: 2.0 max
	Cr-Ni	1.4318	C111	0.03	1.0	2.0	0.045	0.015	0.07-0.20	16.5-18.0			6.0-8.0	
		301	C115	0.03	1.00	2.0	0.045	0.015	0.2	16.5-18.5			6.0-8.0	
		304/304H	C120	0.07	0.75	2.0	0.045	0.015	0.10	18.0-19.5			8.0-10.5	
		304DQ	C160	0.07	0.75	2.0	0.045	0.015	0.10	18.0-19.5			8.5-10.5	
		304DDQ	C181	0.07	0.75	2.0	0.045	0.015	0.10	18.0-19.5			9.0-10.5	
		304L	C151	0.03	0.75	2.0	0.045	0.015	0.10	18.0-19.5			8.0-10.5	
		304LS	C152	003	0.75	2.0	0.045	0.005-0.015	0.10	18.0-19.5			8.0-10.5	
		304LDDQ	C200	0.03	0.75	2.0	0.045	0.015	0.10	18.0-19.5			10.0-10.5	
		321	C315	0.08	0.75	2.0	0.045	0.015	0.10	17.0-19.0			9.0-12.0	Ti: 5x(C+N) to 0.7
	Cr-Ni-Mo	316L-1.4404	C240	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	C300	0.03	0.75	2.0	0.045	0.015	0.10	17.0-18.0	2.5-3.0		12.5-15.0	
		316LN	C320	0.03	0.75	2.0	0.045	0.015	0.12-0.16	16.5-18.0	2.0-2.5		10.0-12.5	
		316Ti	C280	0.08	0.75	2.0	0.045	0.015	0.10	16.5-18.0	2.0-2.5		10.5-13.5	Ti: 5x(C+N) to 0.7
	Heat resistant	309S-1.4833	C340	0.08	0.75	2.0	0.045	0.015	0.11	22.0-24.0			12.0-14.0	
		309S Si-1.4828	C309	0.20	1.5-2.5	2.0	0.045	0.015	0.11	19.0-21.0			11.0-13.0	
		310S/310H-1.4845	C350	0.08	1.5	2.0	0.045	0.015	0.11	24.0-26.0			19.0-22.0	

*Compositions are maximum values, unless otherwise stated.

* Stabilisation may be by use of titanium or niobium or zirconium. For ASTM A240, Ti+Nb>4(C+N)+0.20. For EN10088-2, according to the atomic mass of these elements and the content of carbon and nitrogen, the equivalence shall be the following: Nb (% by mass) = Zr (% by mass) = 7/4 Ti (% by mass) i.e. when replacing titanium with niobium nearly double (1.75) the niobium is needed.

Mechanical properties / General information (properties for annealed condition in transverse direction)

Classification		Type	Tensile Strenght (MPa)	0.2% Proof Stress (MPa)	Elongation (% in 50mm)	HRB max	General Corrosion Properties	Pitting Corrosion Properties	Formability Properties	Toughness	Welding Properties
FERRITICS	Utility	3CR12	460	280(<3), 300(≥3)	18	95	Fair	Fair	Fair	Good	Good
		3CR12L	460	280(<3), 300(≥3)	18	95					
		410S	415	205	20(≤1.27), 22(<1.27)	89			Good	Fair	
	Standard	40910	380-560	220	25	88				Low	Restricted
		40920									
		430	450-630	280(CR), 260(HR)	20(≤1.27), 22(<1.27)	89	Moderate	Moderate			
		430DDQ	450-630	280	26	89			Very Good		
		439Nb	420-600	240	23	89					
		441	430-630	250	18	88		Good	Good		
	Moly	436	480-560	300	25	89	Very Good	Very Good	Very Good		
		444	420-640	320	20	90					
DUPLEXES	Lean	2001	620	450	25	25*	Good		Good	Very Good	Very Good
		2304	650-850(CR) 630-800(HR)	450(CR) 400(HR)	25	32*	Very Good				
	Standard	2205	700-950(CR) 655-840(HR)	500(CR) 460(CR)	25	31*	Excellent	Excellent			

AUSTENITICS	Cr-Ni-Mn	202	515	205	40	99	Moderate	Moderate	Excellent	Excellent	Excellent
	Cr-Ni	1.4318	650-850(CR) 630-830(HR)	350(CR) 330(HR)	45	100	Good	Good			
		301	550	220	45	100					
		304DQ 304/304H	540-750(CR) 520-720(HR)	260(CR) 250(HR)	45	90					
		304DDQ							Drawing		
		304L	520-700(CR) 500-700(HR)	220(CR) 200(HR)	45	92			Deep Drawing		
		304LS							Excellent		
		304LDDQ									
		321	520-700(CR) 515-700(HR)	220(CR) 200(HR)	40	95			Deep Drawing		
	Cr-Ni-Mo	316L-1.4404	530-700(CR) 520-680(HR)	240(CR) 220(HR)	40(CR) 45(HR)	95	Very Good	Very Good	Excellent		
		316L-1.4435	550-700(CR) 520-670(HR)	240(CR) 220(HR)	40(CR) 45(HR)	95					
		316LN	580-780	300(CR) 280(HR)	40	95					
		316Ti	540-690(CR) 520-670(HR)	240(CR) 220(HR)	40	95					
	Heat resistant	309S-1.4833	515-700	210	40	95	Very good oxidation resistance		Very Good	Very Good	Good
		309S Si-1.4828	550-750	230	30	96					
		310S-1.4845	515-700	210	40	95	Very good oxidation resistance				

Minimum values, unless maximum or range is indicated. ( ) - Applicable gauge range. HR - Hot rolled. CR - Cold rolled.

* HRC. This table assumes certification to both ASTM & EN 10088-2 or 10095, where applicable.

Physical properties (properties at room temperature, unless otherwise stated)

Property	Unit	3CR12 3CR12L 410S	40910 40920	430 430DDQ	439Nb 441	436 444	2001 2304 2205	202	All 301LN 304 304L	321	All 316L 316Ti	All 309S	310S
Density	kg/m^3	7680	7700	7800	7700	7750	7860	7800	7900	7800	8000	7900	7900
Modulus of elasticity	GPa												
in tension		200	200	200	210	220	200	200	193	193	193	200	200
in tension		77	77	65		65			86	86	70	70	70
Specific heat capacity	J/kg K	478	460	460	460	430	470	460	500	500	500	500	500
Thermal conductivity	W/m K												
at 100°C		30.0	23.0	26.1	24.2	26.8	17.0	24.2	16.2	16.1	16.2	15.6	14.2
at 500°C		40.0	25.0	26.3	26.3	27.1	21.1	30.6	21.5	22.2	21.5	18.7	18.5
Electrical resistivity	$1x10^{-8}\Omega^n$	67	61	60	63	57	80	74	72	72	72	78	78
Coefficient of thermal expansion	µm/m K												
0-100°C		11.1	11.1	10.4	10.2	10.8	13.0	16.2	17.2	16.6	15.9	15.9	15.9
0-300°C		11.7	11.7	11.0	11.4	11.6	14.0	17.2	17.8	17.2	16.2	16.6	16.2
0-500°C		12.3	12.4	11.4	11.6	12.0	14.5	18.6	18.4	18.6	17.5	17.2	17.0
Melting range	°C	1430-1510	1480-1530	1425-1510	1390-1460	1405-1495	1410-1460	1400-1450	1400-1450	1390-1430	1430-1510	1400-1450	1400-1450
Magnetic		yes	yes	yes	yes	yes	yes	no	no	no	no	no	no

Properties at elevated temperatures

Values given below are typical of Columbus products and should not be used for design purposes.

Short-time elevated temperature strength: tensile strength in MPa at indicated temperature.

Temperature °C	100	300	500	700	900	
3CR12/3CR12L/410S	545	415	330			(1)
40910/40920	380	350	280	110		
430/430DDQ	490	450	330	100		(2)
439Nb	420	360	250	30		
441	460	400	350	200		
436	540	480	410	200		
444	500	440	380	160		
2001	570	530				(3)
2304	580	490				(3)
2205	630	560				(3)
All 304 types	530	480	400	240	70	
All 304L types	480	430	350	200	50	
321	540	510	420	260	100	
All 316L types	530	510	420	250	90	
316Ti	540	500	450	320	130	
All 309S types	580	525	470	300	125	
310S	600	530	475	315	135	

(1)Do not exceed 800oC as a phase transformation occurs.
(2)Do not use in temperature range of 450oC to 500oC.
(3) Do not use in temperature range of 300oC to 1 000oC.

Maximum recommended service temperature: in oxidising conditions.

Max Temperature °C	Continuous	Intermittent
3CR12/3CR12L/410S/40910/40920	620	730
430/430DDQ	730	870
439Nb	830	930
441	850	950
444	850	950
2001/2304/2205	300	300
202	780	750
All 304/304L/321 types	830	800
All 316L/316Ti types	920	870
All 309S types	1100	980
310S	1200	1030

Creep strength: stress in MPa required for a creep rate of 1% in 10 000hr.

Temperature °C	400	500	600	700	800
3CR12/3CR12L/410S	270	56	13	3	0.6
430/430DDQ	272	92	31	4	0.7
All 304 types		233	108	50	23
321			131	51	20
316Ti			147	63	29
All 309S types		141	72	29	8
310S		145	84	36	9

Equivalent specifications

Type	UNS	Common name and AISI	EN name	EN number
3CR12	-	3CR12	-	-
3CR12L	S41003	-	X2CrNi12	1.4003
410S	S41008	410S	-	-
40910	S40910	409	X2CrTi12	1.4512
40920	S40920			
430	S43000	430	X6Cr17	1.4016
430DDQ				
439Nb	S43932	439Nb	X3CrTi17	1.4510
441	S43490	441	X2CrTiNb18	1.4509
436	S43600	436	X6CrMoNb17-1	1.4526
444	S44400	444	X2CrMoTi18-2	1.4521
2001	S32001	-	X2CrMnNi20-5-1	1.4482
2304	S32304	2304	X2CrNiN23-4	1.4362
2205	S32205	2205	X2CrNiMoN22-5-3	1.4462
	S31803	-		
202	-	-	-	-
301LN	S30153	301LN	X2CrNi18-7	1.4318
304	S30400	304	X5CrNi18-10	1.4301
304H				
304DQ				
304DDQ				

304L	S30403 S30400	304L 304	X2CrNi18-9 X5CrNi18-10	1.4307 1.4301
304LS				
304LDDQ			X2CrNi19-11 X2CrNi18-9 X5CrNi18-10	
321	S32100	321	X6CrNiTi18-10 X8CrNiTi18-10	1.4541 1.4878
316L-1.4404	S31603 S31600	316L 316	X2CrNiMo17-12-2 X5CrNiMo17-12-2 X2CrNiMo17-12-3 X2CrNiMo18-14-3 X3CrNiMo17-13-3	1.4404 1.4401 1.4432 1.4435 1.4436
316L-1.4435				
316LN	S31653 S31651	316LN 316N	X2CrNiMoN17-11-2	1.4406
316Ti	S31635	316Ti	X6CrNiMoTi17-12-2	1.4571
309S-1.4833	S30908 S30909 S30900	309S 309 309M	X12CrNi23-12	1.4833
309S Si-1.4828	-	-	X15CrNiSi20-12	1.4828
310S-1.4845	S31008 S31000 S31009	310S 310M 310	X8CrNi25-21	1.4845

Welding

The following is a brief outline of the significant welding par ameters. Additional details are available on request

GENERAL WELDING REQUIREMENTS

- Ensure a clean and uncontaminated weld area - free of carbon (mild) steel, paint, oil, grease, crayons etc.
- Tack correctly to ensure correct and consistent gap widths.
- Avoid positional welding if possible.
- Avoid arc strikes on the fabrication. Use a striker pad of scrap stainless steel. Use run-on and run-off tabs.
- Any temporary attachment must be of equivalent stainless steel and tacked in position with an electrode of equivalent grade. Such attachment must be carefully ground off.
- Maintain a short arc and adequate gas shielding. Take special care when welding in the open or under draughty conditions.
- Use stainless steel wire brushes to remove slag/scale. All grinding discs and abrasives must be iron free and used only on stainless steel.
- Restore passivity/corrosion resistance of the weld area.
- Remove scale either mechanically or chemically. Mechanically by use of dedicated abrasive/ discs. Chemically by pickling with nitric/hydrofluric acid formulations. Do not use formulations of hydrochloric acid.
- Wash thoroughly after pickling.

POWER SUPPLY

- Direct Current (DC) recommended for the welding of stainless steel.

MMA	DC electrode positive
TIG	DC electrode negative
MIG	DC electrode positive
SAW	DC electrode positive

Refer to manufacturer's instructions for welding parameters.

AUSTENITIC STAINLESS STEELS

- Weldability excellent for all welding processes.
- Welding processes most commonly used are MMA, MIG, TIG and SAW.
- Parent metal and consumable combinations are:

202 use 308L	301LN use 308L
304 use 308L	304L use 308L, 347
309/309S use 309L	310/310S use 310L
306 use 316L, 318	316L use 316L, 316Nb
316Ti use 316Nb	321 use 347

- Nb (niobium) is used in consumables because Ti (titanium) suffers losses in the arc.
- Autogenous TIG can be used for welding thin gauges.
- Heat input: Limit the heat input and inter-pass temperatures.

- Passivate with nitric acid formulation if weld is mechanically de-scaled, application is critical or marginal or general surface contamination of the fabrication by carbon (mild) steel has occurred.
- Wash thoroughly after passivation.
- Post-weld heat treatment is generally not required.

CONSUMABLES

- Electrodes must be kept and used in prime condition. Avoid exposure to dampness or contamination of the coating.
- Electrode coatings are specially formulated. Never use an electrode if the coating is damaged. Never strip an electrode of its coating and use it as a filler wire.
- Filler wires are specially produced to closely controlled compositions. Never use ordinary stainless steel wire nor sheet trimmings as filler material.
- Avoid contamination and mix-up of filler wires. Electrodes of basic, basic rutile, acid rutile, high efficiency and metal powder (synthetic) types are utilised.
- Basic type requires highest level of welder skill. Gives high integrity welds.
- Acid rutile type easiest to use, general purpose welding for less critical applications.

SHIELDING GASES

- For TIG welding use pure Argon.
- For MIG welding use Argon plus 1-2% Oxygen.

FERRITIC STAINLESS STEELS

- Weldability poor. Welding generally limited to thin gauges only.
- Welding process most commonly used is TIG. Autogenous welding for thinner gauges. Filler wire is used for thicker gauges. 309L is often used on Standard Ferritics and 316L on Moly Ferritics.

UTILITY FERRITIC STAINLESS STEELS

- Weldability good. Welding processes most commonly applied are MMA, MIG and TIG. SAW is not recommended.
- Consumables: Fabricator experience has led to a preference for 309L. 308, 316L and 309LMo can also be used.
- Heat input and inter-pass temperature must be controlled (0.5 to 1.5kJ/mm and 150oC respectively). Use stringer beads for multi-pass welding. Avoid weaving. Avoid positional welding as far as possible. Avoid cross-over and adjacent welds where possible.

DUPLEX STAINLESS STEELS

- Weldability good. Virtually all welding processes, except for oxyacetylene, due to carbon contamination, are suitable.
- Heat input and inter-pass temperatures must be controlled (0.5 to 2.0kJ/mm and 150oC respectively).
- Consumables: 2209 is generally recommended although 309L electrodes can be used to weld to austenitic or ferritic stainless steels.

Typical Applications

3CR12 3CR12L 410S	Ore cars, coal wagons, freight cars, rail cars, bus chassis, bus frames, chutes, conveyor equipment, tanks, x-grid in cooling towers, reefer iso containers. Also in material handling equipment (chutes and liners), particularly in wet sliding abrasion conditions and structural applications in corrosive industries, ladders, walkways, cable racks, roofing, cladding and palisade fencing, etc.
40910 40920	Automotive exhaust pipes, silencers and catalytic converters. Coated electrification boxes.
430	Sinks, wash troughs, urinals, toilets, trim for domestic equipment, kitchen and cafeteria utensils and cutlery, roofing and cladding.
430DDQ	Difficult to form components, where U-430 is normally used, and coinage.
439Nb	Difficult to form components eg. exhaust system components, evaporator tube in the sugar industry, domestic appliances, geysers and heat exchanger tubing.
441	Catalytic converters for more arduous conditions than 409 (near exhaust manifold), heat exchangers, tubes, geysers, burners and evaporator tube in the sugar industry.
436	Automotive exhausts with superior corrosion resistance to U-441. Automotive trim.
444	Marine environments for roofing and cladding, hand railing, balustrading, walkways, outdoor furniture, cable racks, heat exchangers, tubes, geysers, solar panels, water tanks, food processing, brewery and wine making equipment.
2001	Pulp and paper, food and drink and architecture. Process and storage tanks, ducting and structural applications. Pipe supports, guttering, walkways, cable racking, strapping, clamps, etc. in aggressive environments.
2304	Environments containing chlorides and in polluted marine environments, desalination, pipe work, tanks, process vessels for more aggressive corrosive liquids and conditions in chemical, petrochemical, pulp and paper, pollution control, hydrometallurgical and petroleum industries.
2205	Marine environments in the oil and gas extraction and processing industries, the chemical industry, the pulp and paper industry and the mining industry (mineral beneficiation plants). Also used for heat exchangers where chloride bearing water or brackish water is used as the cooling medium.

202	Cookware, sinks, cutlery, catering equipment, abattoirs, strapping, clamps and cable racking.
301LN	Primarily used as temper rolled for strength in structural applications such as railway carriages, aircraft components, conveyor belts, slat chain, springs, wiper blades, clips. It is also used for utensils and tableware; automobile trim.
304 304H 304DQ 304DDQ 304L 304LS 304LDDQ	Cookware, sinks, cutlery, catering equipment, hospitals, food and beverage, abattoirs, pharmaceutical, oil and gas, cryogenic as well as pipe work, tanks and process vessels for a large variety of corrosive liquids. H grades have superior high temperature creep resistance. DQ (drawing quality) and DDQ (Deep Drawing Quality) have superior drawing characteristics. U-304LS has superior machinability.
321	Furnace components, equipment exposed to elevated temperature and/or aqueous cycles.
316L-1.4404 316L-1.4435	Environments containing chlorides and in polluted marine environments, desalination, pipe work, tanks, process vessels for more aggressive corrosive liquids and conditions in chemical, petrochemical, pulp and paper, pollution control, hydrometallurgical and petroleum industries.
316LN	Same applications as U-316L-1.4404, where high strength is required.
316Ti	Furnace components, equipment exposed to elevated temperature and/or aqueous cycles.
309S-1.4833 309S Si-1.4828	Furnace parts, high temperature containers, catalytic converters, exhaust systems etc. Si grade gives superior oxidation resistance.
310S-1.4845	Furnace parts, muffles, radiant tubes, ammonia converters, etc.

Tolerances - Hot Rolled

Min gauge (mm)	Max gauge (mm)	- tol (mm)	+ tol (mm)
2.5	2.5	0.23	0.23
>2.5	3	0.25	0.25
3	<4	0.29	0.29
>3.5	<5	0.25	0.31
5	<6	0.25	0.34
6	<8	0.25	0.35
8	8	0.25	0.42
>8	10	0.30	1.15
>10	20	0.30	1.40
>20	25	0.30	1.55
>25	50	0.30	1.80
>50	63.5	0.30	2.55

Tolerances are according to ASTM A480M, ISO 9444-2 and ISO 18286.

Tolerances - Cold Rolled

Min gauge (mm)	Max gauge (mm)	- tol (mm)	+ tol (mm)
	0.3	0.030	0.030
>0.3	<0.5	0.040	0.040
0.5	0.5	0.045	0.045
>0.5	0.8	0.050	0.050
>0.8	1.0	0.060	0.060
>1.0	<1.2	0.070	0.070
1.2	1.5	0.080	0.080
>1.5	<2.0	0.090	0.090
2.0	2.5	0.100	0.100
>2.5	<3.0	0.120	0.120
3.0	3.0	0.130	0.130
>3.0	<5.0	0.140	0.140
5.0	6.0	0.150	0.150

Tolerances are according to ASTM A480M and EN ISO 9445-2.

Identification of surface finishes

Columbus	ASTM/ASME	EN	DIN	Description
Unground	-	-	-	Slabs with no grinding.
Ground	-	-	-	Slabs with grinding.
HR	-	1U	a1	Hot rolled (not heat treated, not descaled). Suitable for products which are to be further worked (e.g. re-rolling).
HRA	-	1C	Ic	Hot rolled and heat treated (not descaled). Suitable for industrial heat resisting and materials handling applications.
No 1	No 1	1D	IIa	Hot rolled, heat treated and descaled. Suitable when smoothness and uniformity of finish are not important.
2D	No 2D	2D	IIIb	Cold rolled, heat treated and pickled. Dull, smooth finish. Suitable for forming applications.
2B	No 2B	2B	IIIc	Cold rolled, heat treated and pickled. Bright and smoother finish than 2D (obtained by skin passing or tension levelling).
2E	No 2B	2E	-	Cold rolled, heat treated and mechanically descaled, may be followed by pickling. Rough and dull finish.
No 3	No 3	2G	-	
No 4	No 4	2G	IV	A linearly textured polished finish, one or both sides, with a typical surface roughness (Ra) of about 1.2 µm.
TR	TR	2H	-	Finish obtained by CR A+P+TR
SB	No 6	2J	-	ScotchBrite finish, one or both sides, with a transverse Ra <0.5 µm.
SSB	-	-	-	Superior ScotchBrite finish, one or both sides, with a transverse Ra <0.25 µm.
BA	Bright Annealed Finish	2R	IIId	Cold rolled, bright annealed finish, retained by final annealing in a controlled atmosphere furnace (may be skin passed). Smooth, bright, reflective finish.
BE	-	-	-	Columbus 2B cold rolled, but final anneal in a controlled atmosphere furnace.

Corrosion

Media	Utillity Ferritics			Cr-Ni Austenitics			Cr-Ni-Mo Austenitics			Duplex		
	20°C	60°C	100°C	20°C	60°C	100°C	20°C	60°C	100°C	20°C	60°C	100°C
Aldyhydes	R[1]	R[1]	R[1]	R[1]	R[1]	R[1]	R[1]	R[1]	R[1]	R[1]	R[1]	R[1]
Acetic acid (10%)	R	R	ND	R	R	R	R	R	R	R	R	R
Acetic acid (glacial and anhydrous)	ND	ND	ND	R	R	ND	R	R	R	R	R	ND
Acetic anhydride	R[2]	NR	ND	R[2]	NR	NR	R	R	NR	R	R	R
Acetyle	NR	NR	NR	R[3]	R[3]	R[3]	R[3]	R[3]	R[3]	R[4]	NR	NR
Alcohols	R	R	R	R	R	R	R	R	R	R	R	R
Alphatic esters	R	ND	ND	R	R	R	R	R	R	R	R	R
Alkyl chlorides	R[5]	ND	ND	R[5]	R[5]	R[5]	R[5]	R[5]	R[5]	R	R	R
Alum	ND	ND	ND	R	R6	NR	R	R[1]	NR	R	R	NR
Ammonia	R	R	R	R	R	R	R	R	R	R	R	R
Amyl acetate	R	R	R	R	R	R	R	R	R	R	R	R
Aniline	R	R	R	R	R	R	R	R	R	R	R	R
Antimon tricyhloride	NR	NR	NR	R[5]	NR	NR	R[5]	R[5]	NR	R	R	NR
Aromatic solvents	R	R	R	R	R	R	R	R	R	R	R	R
Atmospheric : Industrial	R[7]	ND	ND	R[7]	ND	ND	R	ND	ND	R	ND	ND
Atmospheric : Marine	R[7]	ND	ND	R[7]	ND	ND	R	ND	ND	R	ND	ND
Atmospheric : Rural	R[7]	ND	ND	R	ND	ND	R	ND	ND	R	ND	ND
Ascorbic acid	R[1]	ND	ND	R[1]	R[1]	R[1]	R	R	R	R	R	R
Benzoic acid	R	R	R	R	R	R	R	R	R	R	R	R
Boric acid	R	R	R	R	R	R	R	R	R	R	R	R
Brines, saturated	NR	NR	NR	R[8]	NR	NR	R[8]	NR	NR	R	R	R
Bromide (gaseous)	NR	NR	NR	R[9]	NR	NR	R[9]	R[9]	R[9]	R	ND	ND
Bromide (aqueous)	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Butyl acetate	R	R	R	R	R	R	R	R	R	R	R	R
Calcium chloride	NR	NR	NR	NR	NR	NR	R[8]	NR	NR	R[10]	R[10]	R[10]
Carbon disulphide	R	R	R	R	R	ND	R	R	ND	R	R	R
Carbonic acid	R	R[9]	NR	R	R	R	R	R	R	R	R	R
Carbon tetrachloride	R	R	R	R	R	R	R	R	R	R	R	R
Caustic soda and potash	ND	R[6]	R[6]	R	R	R[6]	R	R	R[6]	R[6]	R[6]	ND
Cellulose paint	R	R	R	R	R	R	R	R	R	R	R	R
Chlorates of Na, K, Ba	ND	ND	ND	R[1]	R[1]	R[1]	R[1]	R[1]	R[1]	R	R	R
Chlorine, dry	ND	ND	ND	R	R	R	R	R	R	R	R	ND
Chlorine, wet	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	ND
Chlorides of Na, K, Mg, Ca, Ni, NH4, Al, Sn, Zn	R[5]	NR	NR	R[10]	NR	NR	R[9]	R[11]	R[11]	R	R	ND
Chlorosulphonic acid	ND	ND	ND	NR	NR	NR	R[10]	NR	NR	ND	ND	ND
Chromic acid (80%)	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Citric acid	NR	NR	NR	R[6]	R[6]	R[6]	R	R	R[6]	R	R	R
Cresylic acids (50%)	R	R	R	R	R	R	R	R	R	R	R	R
Detergents, synthetic	R	R	R	R	R	R	R	R	R	R	R	R
Emulsifiers (all concentrations)	ND	ND	ND	R	R	R	R	R	R	R	R	R

NR = The material is not recommended • ND = No data is available • R = Indicates that the material is resistant to the named chemical up to the temperature shown, subject to limitations indicated by the footnotes on page 21.

Corrosion (continued)

Media	Utillity Ferritics			Cr-Ni Austenitics			Cr-Ni-Mo Austenitics			Duplex		
	20°C	60°C	100°C	20°C	60°C	100°C	20°C	60°C	100°C	20°C	60°C	100°C
Esters ethersand	R	R	R	R	R	R	R	R	R	R	R	R
Fatty acids (>C6)	R	R	R	R	R	R	R	R	R	R	R	R
Ferric chloride	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Fluorinated refrigerants, aerosols, eg freon	R[5]	R	NR	R[5]	R	R	R[5]	R	R	R	R	R
Fluoride, dry	ND	ND	ND	R	ND	ND	R	ND	ND	R	R	ND
Formic acid	NR	NR	NR	R	NR	NR	R	R	ND	R	R	RND
Fruit juices	R12	NR	NR	R[12]	R	R	R	R	R	R	R	R
Gelatine	R[1]	R[1]	ND	R[1]	R	R	R[1]	R	R	R	R	R
Glycol	R	R	R	R	R	R	R	R	R	R	R	R
Hydrobromic acid (50%)	NR	NR	NR	NR	NR	ND	NR	NR	ND	NR	NR	ND
Hydrochloric acid (10%)	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	ND
Hydrocloric acid (concentrated)	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	ND
Hydrocyanic acid	R	ND	ND	R	R	ND	R	R	ND	R	R	ND
Hydrofluoric acid	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Hydrogen peroxide (30%)	R	R	ND	R	R	R	R	R	R	R	R	R
Hydrogen sulphide	R[5]	R[5]	R[5]	R[5]	R[5]	R[5]	R[5]	R[5]	R[5]	R[5]	R[5]	R[5]
Hydrochlorite (Na 12-14%)	R[14]	ND	ND	R[14]	NR	NR	R[14]	NR	ND	R[14]	ND	ND
Ketones	R	ND	ND	R	R	R	R	R	R	R	R	R
Lactic acid (100%)	NR	NR	NR	R	NR	NR	R	R	NR	R	R	ND
Lead acetate	R	R	R[6]	R	R	R	R	R	R	R	R	R
Lead perchlorate	NR	NR	NR	R[1]	R[1]	R1	R	R[1]	ND	ND	ND	ND
Lime (CaO)	R	R	R	R	R	R	R	R	R	R	R	R
Manganate, potassium (K)	R[6]	ND	ND	R	R	R	R	R	R	R	ND	ND
Meat juices	R[7]	NR	NR	R	R	ND	R	R	ND	R	R	R
Mercuric chloride	NR	NR	NR	NR	NR	NR	NR	NR	NR	R	R	R
Milk and milk products	R	NR	NR	R	R	R	R	R	R	R	R	R
Molasses	R	R	R	R	R	R	R	R	R	R	R	R
Monoethanalamine	R	R	R	R	R	R	R	R	R	R	R	R
Naphthalene	R	R	R	R	R	R	R	R	R	R	R	R
Nitrates of Na, K, HN3, Ag	R	R	R	R	R	R	R	R	R	R	R	R
Nitric acid (< 25%)	R	R[15]	NR	R	R	R	R	R	R	R	R	R
Nitric acid (50%)	R	R[15]	NR	R	R	R	R	R	R	R	R	R
Nitric acid (90%)	R	NR	NR	R	NR	NR	R	NR	NR	R	NR	NR
Nitric acid, fuming	ND	ND	ND	R	R[2]	NR	R	NR	NR	R	NR	NR
Oil, diesel, petroleum spirits	R	R	R	R	R	R	R	R	R	R	R	NR
Oils, essential	R	R	R	R	R	R	R	R	R	R	R	R
Oils, lube with aromatic adds	R	R	R	R	R	R	R	R	R	R	R	R
Oils, vegetable and animal	R	R	R	R	R	R	R	R	R	R	R	R
Oxalic acid	NR	NR	NR	R[6]	NR	NR	R[6]	N[16]	N[16]	NR	R	R
Perc achloric id	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR

NR = The material is not recommended • ND = No data is available • R = Indicates that the material is resistant to the named chemical up to the temperature shown, subject to limitations indicated by the footnotes on page 21.

Corrosion (continued)

	Utillity Ferritics			Cr-Ni Austenitics			Cr-Ni-Mo Austenitics			Duplex		
Media	20°C	60°C	100°C	20°C	60°C	100°C	20°C	60°C	100°C	20°C	60°C	100°C
Phenol	R	R	R	R	R	R	R	R	R	R	R	R
Phosphoric acid (20%)	NR	NR	NR	R	R	R	R	R	R	R	R	R
Phosphoric acid (50%)	NR	NR	NR	R	R	NR	R	R	R	R	R	R
Phosphoric acid (95%)	[NR]	NR	NR	R	R	NR	R	R	NR	R[17]	R[17]	R[17]
Phosphorous pentoxide	ND	ND	ND	R	R	R[5]	R	R	R[5]	R	R	R
Pyridine	R	R	R	R	R	R	R	R	R	R	R	R
Sea water	NR	NR	NR	R[17]	NR	NR	R[9]	NR	NR	R	R	R
Silicic acid	[R]	R	R	R	R	R	R	R	R	R	R	R
Sodium peroxide	NR	NR	NR	R[16]	NR	NR	R[6]	R[16]	R[16]	R	R	R
Sodium silicate	R	R	R	R	R	R	R	R	R	R	R	R
Sodium sulphate	R6	R[6]	NR	R	R	NR	R	R	NR	R	R	NR
Starch	R	R	R	R	R	R	R	R	R	R	R	R
Sugar, syrup, jam	R12	R[12]	R[12]	R[12]	R	R	R	R	R	R	R	R
Sulphamic acid	NR	NR	NR	R[18]	NR	NR	R	R	R[19]	R	R	NR
Sulphates (Na, K, Mg, Ca, Al, Fe)	R	R	R	R	R	R	R	R	R	R	R	R
Sulphates	[NR]	NR	NR	R	R	R	R	R	R	R	R	R
Sulphur dioxide, dry	[R]	R	R	R	R	R	R	R	R	R	R	R
Sulphur dioxide, wet	NR	NR	NR	R	NR	NR	R	R	NR	R	R	NR
Sulphur dioxide, ag, soln (96%)	NR	NR	NR	R	NR	NR	R	R	R	R	R	R
Sulphur trioxide	NR	NR	NR	NR	NR	NR	R[5]	R[5]	R[5]	R[5]	R[5]	R[5]
Sulphuric acid (<50%)	NR	NR	NR	NR	NR	NR	R[16]	NR	R	R	R	NR
Sulphuric acid (70%)	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Sulphuric acid (95%)	R[15]	NR	NR	R	NR	NR	R	NR	R	R	NR	NR
Sulphuric acid, fuming	R[2]	R[2]	NR	R	R[2]	NR	R	NR	R	R	R	NR
Tannic acid (10%)	R	R	NR	R	R	R	R	R	R	R	R	R
Tartaric acid	NR	NR	NR	R	R	R	R	R	R	R	R	R
Trichloroethylene	R[5]	R[5]	R[5]	R[5]	R[5]	R[5]	R[5]	R[5]	R[5]	R[5]	R[5]	R[5]
Urea (30%)	R	R	R	R	R	R	R	R	R	R	R	R
Water, pure	R	R	R	R	R	R	R	R	R	R	R	R
Yeast	R	R	R	R	R	R	R	R	R	R	R	R

NR = The material is not recommended • ND = No data is available • R = Indicates that the material is resistant to the named chemical up to the temperature shown, subject to limitations indicated by the footnotes on page 21.

1 = Not if chlorides are present
2 = Limited data
3 = Depends on the acid
4 = Dry acid fumes, attack may occur if moisture builds up
5 = Anhydrous
6 = Depends on concentration
7 = May discolour with time
8 = In strong solutions only when inhibited
9 = Pitting possible in stagnant conditions
10 = Possibility of pitting
11 = May cause stess corrosion cracking
12 = When free of SO2
13 = May cause contamination of product
14 = Dilute hypochlorites can be used to sterilise some stainless steels
15 = General corrosion may become excessive
16 = 10%
17 = In the absence of impurities
18 = Dilute
19 = Some attack at high temperatures

PITTING AND CREVICE CORROSION RESISTANCE

Exposure in chloride containing media can result in localised corrosion.
In order of increasing resistance to localised corrosion: 3CR12 < 430 < 304L < 316L < 2205.

CONDITIONS FOR AVOIDING PITTING AND CREVICE CORROSION

- Design vessels for complete drainage - avoid sharp corners and stagnant areas.
- Close crevices and lap joints by continuous welding.
- Remove solids in suspension. Prevent sedimentation. Ensure continous agitation and adequate flow rates.
- Use compressive non-absorbent gaskets or inert sealing compounds.
- Ensure non-impairment of passive surface. Repair/restore any affected areas.

Conversion factors

SI Units: Where SI units differ from technical metric units, the conversions are given for both. The following list details the main SI units and their symbols which are used throughout these tables.

Length	Mass	m
Area	square meter	m2
Volume	cubic meter	m3
Mass	kilogram	kg
Density	kilograms per cubic metre	kg/m3
Force	newton	N
Pressure, stress	pascal	Pa (N/m2)
Viscosity, dynamic	pascal second	Pa.s
Viscosity, kinematic	square metre per second	m2/s
Energy	joule	J
Power	watt	W(J/s)

LENGTH			
1km	0.621371mile	1mile	1.60934km
1m	1.09361yd 3.2898ft	1yard 1foot	0.9144m 0.3048m
1cm	0.393701in	1inch	25.4mm
1mm	0.03937in	1milli-inch (thou)	25.4µm
1µm	39.3701µin	1µin	0.0254µm

MASS	
1tonne	1 000kg 0.89420ton 2204.62lb
1kg	0.01968cwt 2.20462lb
1g	0.03527oz
1ton	1016.05kg 1.01605tonne
1cwt	50.8023kg
1lb	0.45359kg
1oz	28.349g

DENSITY	
1kg/m3	1.686lb/yd3 0.6243lb/ft3
1g/cm3	62.4280lb/ft3
1ton/yd3	1328.94kg/m3
1lb/yd3	0.593kg/m3
1lb/ft3	16.0185kg/m3
1lb/in3	27.6799g/cm3

PRESSURE, STRESS	
1Pa (N/m2)	0.01mbar 0.000145 lbf/in2
1kPa (kN/ m2)	0.01kgf/cm2 10mbar 20.885lbf/ft2 0.2953in Hg
1kgf/cm2	98.0665kPa 14.223lbf/in2
1bar	100kPa 14.5038lbf/in2
1mbar	100kPa 2.0885lbf/ft2
1atm	101.325kPa 14.6959lbf/in2
1mm Hg (torr)	133.322Pa 0.01934lb/in2
1mm H2O	9.80665Pa 0.001422lb/in2
1lbf/in2	6.89476kPa 0.07031kgf/cm2 68.9476mbar
1lbf/ft2	47.8803Pa 0.4788mbar

VOLUME CAPACTITY			
1m3	1.30795yd^3	1ml (cm^3)	0.0352 fl oz
1dm3 (litre)	0.03531ft^3 0.21997imp gal 1.7605pint 0.2642US gal	1yd^3 1ft^3 1in^3 1imp gal	0.76455m^3 28.3168dm^3 16.3871cm^3 4.54609dm^3
1cm3 (m)	0.06102in^3 0.0352fl oz	1US gal 1pint	3.78541dm^3 0.56826dm^3
1 litre (dm3)	0.21997imp gal 1.7605pint	1fl oz	28.4131cm^3

AREA			
1km2 (100 hectares)	247.105acres	1$mile^2$	2.58999km2
1hectare (ha)	2.47105acres 10 000m2	1acre (4840 yd^2)	4046.86m2 0.404686ha
1m2	1.19599yd2	1yd^2	0.836127m2
1cm2	0.155in2	1ft^2	0.092903m2
1mm2	0.00155in2	1in^2	645.16mm2

POWER	
1hp	745.700W (J/s)
1ft lbf/s	1.35582W

TEMPERATURE	
°F	1.8(oC)+32
°C	(°F-32)/1.8
K	°C+273.15

FORCE	
1N	0.10197kgf 0.22481lbf
1kN	101.971kgf 224.809lbf
1kgf (kilopond)	9.80665N 2.20462lbf
1dyne	105N 0.224809x 10-5lbf
1lbf	4.44822N 0.45359kgf
1tonf	9.96402kN 1016.05kgf

ENERGY	
1MJ	0.277778kWh
1J	0.737562ft.lbf
1kgfm	9.80665J 7.23301ft.lbf
1therm	105.506MJ
1kWh	3.6MJ
1Btu (British thermal unit)	1.05506kJ

1ton/ft^2	107.252kPa 1.094kgf/cm^2
1in Hg	3.38639kPa 0.491lbf/in^2
1ft H^2O	2.98907kPa 0.030kgf/cm^2 22.3997mmHg

VISCOSITY, DYNAMIC	
1Pa.s (Ns/m2)	0.0208854lbf/ft^2
1c P (centipoise)	2.09954 x 10-5 lbf.s/ft^2
1c P (centipoise)	2.08854 x 10-5 lbf.s/ft^2 0.001Pa.s
1lbf.s/ft^2	17.8803Pa.s
1lb/ft.s	1488.16cP 1.48816kg/ms

VISCOSITY, KINEMATIC	
1m^2s	10.7639ft^2/s
1cSt (centistokes)	5.58001in^2/s 1mm^2/s 106m^2/s
1ft^2/h	0.092903m^2/h 25.8064cSt
1in^2/s	654.16mm^2/s 645.16cSt

Hardness conversion table

Vickers Hardness no	Brinell* Hardness no	Rockwell C 150kg load 120° diamond core	Rockwell B 100kg load 1/16in steel ball
740		61.8	
720		61.0	
700		60.1	
680		59.2	
660		58.3	
640		57.3	
620		56.3	
600		55.2	
580		54.1	
560		53.0	
540	(496)	51.7	
520	(480)	50.5	
500	(465)	49.1	
480	(448)	47.7	
460	433	46.1	
440	415	44.5	
420	397	42.7	

* Brinell hardness tests should not be carried out on materials harder than 400 BHN, as the hardened ball indentor would itself tend to suffer distortion.

Vickers Hardness no	Brinell* Hardness no	Rockwell C 150kg load 120° diamond core	Rockwell B 100kg load 1/16in steel ball
400	379	40.8	
380	360	38.8	(110.0)
360	341	36.6	(109.0)
340	322	34.4	(108.0)
320	303	32.2	(107.0)
300	284	29.8	(105.0)
280	265	27.1	(103.5)
260	247	24.0	(101.0)
240	228	20.3	98.1
220	209	(15.7)	95.0
200	190	(11.0)	91.5
180	171	(6.0)	87.1
160	152	(0.0)	81.7
140	133		75.0
120	114		66.7
100	95		56.2

Disclaimer

The material contained in this manual has been designed as a guide for customers of Columbus Stainless (Pty) Ltd. However, the material contained herein is not intended as a substitute for any person's procedures and should not be used or relied upon for any specific or general application without first obtaining competent advice.

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