D-50 HIGH DUCTILITY MARINE STEEL

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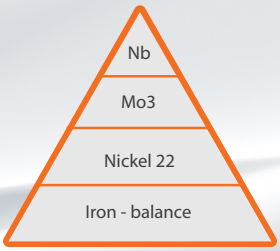
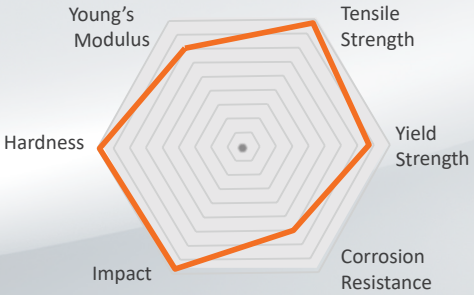
Composition %



Combination of Properties



This unique austenitic stainless steel has superior strength and corrosion resistance in comparison with conventional stainless steels such as 317L, 316L, 304L and 321, whilst it still is available at a competitive price. D-50 builds on the UNS S20910 XM-19 material specification, offering consistent superior mechanical strength.

THE BENEFITS OF D-50

- > High Strength
- > Excellent General Corrosion Resistance
- > Resistant to Crevice Corrosion in Sea Water
- > Resistant to Pitting Corrosion in Sea Water
- > Excellent Resistance to Intergranular Attack
- > Excellent Resistance to Sulphide Stress Cracking in Air
- > Good Resistance to Stress Corrosion Cracking
- > Outstanding Cryogenic Properties
- > Excellent Toughness with High Impact Properties
- > Very Low Magnetic Permeability
- > Can be Welded by conventional MIG and TIG shielded Processes
- > Can be hot worked to produce a very fine grain to allow inspection by UT and dye penetrant methods.

MECHANICAL PROPERTIES

Condition	0.2% Proof Stress MPa (ksi)	Tensile Strength MPa (ksi)	Elongation %	Hardness R_c	Impact Strength J
Forged*	380 55	690 100	35	55	100
Typical	440-490 (64-71)	750-790 (109-115)	45-48	56-70	110

*Hot forged solution annealed and water quenched. D-50 High Ductility Marine Steel can be produced in medium and high strength conditions due to Nitrogen and Molybdenum additions and the application of specialised manufacturing techniques. Contact the metallurgists at Copper Alloys to discuss custom properties.

CHEMICAL COMPOSITION

C %	Si%	Mn%	P%	S%	Ni%	Nb%	Mo%	N%	V%
<=0.06	<=0.75	4-6	<=0.04	<0.03	20.5-23.5	0.1-0.3	1.5-3.0	0.2-0.4	0.1-0.3

D-50 HIGH DUCTILITY MARINE STEEL

BACKGROUND

D-50 High Ductility Marine Steel is unique in the austenitic stainless steel range as it offers both high strength and excellent corrosion resistance in most aggressive environments.

The alloy has superior corrosion resistance than 316L and 304L stainless steel and in addition has approximately twice the yield strength.
It also maintains its mechanical strength at both elevated and sub-zero temperatures and, unlike other stainless steels does not become magnetic when cold worked.

PHYSICAL & MECHANICAL PROPERTIES

Property	Metric	Imperial
Density	7.88 g/cc^3	0.2847lbs/in^3
Specific Heat	487 J/Kg.K	0.1163Btu/lb/°F
Melting Point	1380-1406°C	2516-2562°F
Annealing Temperature	1065-1120°C	1065-1120°F
Electrical Resistivity	81 μΩ.cm	31μΩ.in
Thermal Conductivity	13.2 W/M.K	7.627 Btuft/hr/ft^2/°F
Coefficient of Thermal Expansion	19.4 x 10^{-6}/°C m/m 100-400°C	10.8x10^{-6}/°F in/in 212-752°F
Youngs Modulus	19.8 x 10^4 MPa	28.14 x 10^6 lbs/in^2
Magnetic Permeability	<1.01	<1.01
Poisson's Ratio	0.312	0.312
Fatigue Rotating Beam Annealed 1121°C /2050°F	290MPa @10^8 cycles In air	42 ksi @ 10^8 cycles In air
Fatigue Rotating Beam Annealed 1121°C /2050°F	152MPa @10^8 cycles In seawater	22 ksi @ 10^8 cycles In seawater
Shear Strength Annealed 1121°C /2050°F	779 Mpa	113ksi

CORROSION RESISTANCE

Sulphide Stress Cracking

Field service experience has confirmed the resistance of XM-19 to sulphide stress cracking in both air and oil field applications. The alloy was included in the 1996 revision of NACE MR-01-75 "Sulfide Stress Cracking Resistance Metalliic Materials for Oil Field Equipment." at hardness levels up to RC 35 maximum.

Stress Corrosion Cracking Resistance

In common with most stainless steels D-50 may stress corrosion crack in hot chloride environments. When laboratory tested under accelerated conditions in boiling 42% $MgCl_2$ solution the alloy came between 304 and 316 stainless in its resistance to cracking.

Sea Water Corrosion

D-50 has excellent resistance to pitting and crevice corrosion in sea water application. It is more resistant than 316L stainless steel where crevice corrosion can occur under marine mollusc's or other marine organisms.
Tests have indicated only 0.025mm (0.001") attack under marine attachments, when exposed for 18 months.

Intergranular Attack

When sensitized at 675°C (1250°F) for one hour D-50 has excellent resistance to intergranular attack. If material is annealed at 1066°C (1950°F) it also has good resistance to inter granular attack for many applications. However for thicker sections that are to be welded and used in strongly corrosive medias, then a higher pre-anneal at 1121°C (1121°F) is preferred to optimise the corrosion resistance.

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COMPARATIVE CORROSION DATA XM-19/316L/317L STAINLESS STEELS

Test Media	Corrosion rate in mm/year unless stated[1]		
	XM-19 (D-50)	316L	317L
	Annealed 1121°C	Annealed	Annealed
10% $FeCl_3$ 25°C plain*	<.001g/in^2	0.11g/in^2	N/A
10% $FeCl_3$ 25°Ccrevice*	<.001g/in^2	186g/in^2	N/A
5% H_2SO_4 80°C	<.001	0.06	0.038
10% H_2SO_4 80°C	0.028	0.1	0.049
20% H_2SO_4 80°C	0.133	0.48	0.155
5% H_2SO_4 Boiling	0.131	0.26	0.093
10% H_2SO_4 Boiling	0.356	0.73	0.465
20% H_2SO_4 Boiling	1.64	2.20	1.30
1% HCl 80°C	<.001	N/A	0.148
2% HCl 80°C	0.439	N/A	0.263
65% HNO_3 Boiling	0.007	0.012	0.012
70% H_3PO_4 Boiling	0.154	0.202	0.201
33% Acetic Acid Boiling	<.001	<.001	<.001
20% Formic Acid Boiling	<.001	0.027	N/A
40% Formic Acid Boiling	0.032	0.034	N/A
10%HNO_3+1%HF 35°C	0.007	0.064	N/A
10% HNO_3+1%HF 80°C	0.069	0.442	N/A

Source Table 29 Electralloy data bulletin E-50
*Exposure for 50hrs with rubber bands for crevice tests.
[1] Tests average of five 48hr hour periods

ELEVATED TEMPERATURE SHORT TERM TENSILE TESTS

Condition	Test Temp		0.2% YS		UTS		Elongation	R in A
	°C	°F	MPa	ksi	MPa	ksi	%	%
Annealed 1066°C 25mm dia Bar	24	75	538	78	855	124	40.5	67.5
	93	200	455	66	772	112	40.5	67.5
	204	400	400	58	702	102	37.5	67
	316	600	372	54	676	98	37.5	64
	427	800	345	50	648	94	39.5	63
	538	1000	331	48	614	89	36.5	62.5
	649	1200	303	44	552	80	36.5	63
	732	1350	290	42	469	68	42.5	71.5
	816	1500	221	32	345	50	59.5	85

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TYPICAL STRESS-RUPTURE TESTS

Condition	Test Temperature		Stress to Failure					
			100hrs		1000hrs		10,000hrs *	
	°C	°F	MPa	ksi	MPa	ksi	MPa	ksi
Annealed 1066°C (1950°F) 25mm dia bar	538	1000	627	91	607	68	496	72
	593	1100	496	72	427	62	324	47
	649	1200	379	55	262	38	152	22
	732	1350	145	21	82.7	12	41.4	6
	816	1500	69	10	25.5	3.7	9.0	1.3

*Estimated

TYPICAL CREEP STRENGTH

Condition	Stress for min Creep Rate					
	Test Temperature		0.0001%/hr		0.00001%/hr	
	°C	°F	MPa	ksi	MPa	ksi
Annealed 1121°C (2050°F) 25.4mm dia bar	593	1100	283	41	238	34.5
	649	1200	152	22	110	16

TYPICAL CRYOGENIC PROPERTIES

Condition	Test Temperature		0.2% Proof Stress		UTS		Elong	R in A
	°C	°F	MPa	ksi	MPa	ksi	%	%
Annealed 1121°C (2050°F) 25.4mm dia bar	-73	-100	586	85	1007	146	49.5	65
	-196	-320	883	128	1558	226	41	51

TYPICAL CRYOGENIC PROPERTIES

Condition	Test Temperature		Charpy V-notch Annealed		Charpy V-notch Simulated HAZ*	
	°C	°F	Joules	ft lbs	Joules	ft lbs
Annealed 1121°C (2050°F) 25.4mm dia bar	24	75	230	170	230	170
	-73	-100	156	115	156	115
	-196	-320	68	50	68	50

*Heat treated at 677°C for 1 hr to simulate weld heat affected zone
Tables from Electralloy Bulletin E-50

D-50 HIGH DUCTILITY MARINE STEEL

WELDING

In addition to the superior mechanical properties and corrosion resistance, D-50 can be welded successfully by using conventional processes normally associated with austenitic stainless steels.
Inert gas shielding of the weld pool is important to prevent gas absorption from the atmosphere which could result in porosity.
Stainless steel is readily weldable with arc processes and has excellent weld joint properties which can be obtained without the need of pre-heating or post weld heat treatment.
When welding, matching filler rod should be used such as XM-19W (AWS E/ER 209) and DIN 1.3964.

MACHINING

Carbide tools are suggested for rates better than 50% of Type 304	
Machining Type	Suggested starting rates are:
Single Point turning :	Roughing - 0.15" depth, 0.015"/rev feed -175 SFM Finishing - 0.025" depth, 0.007"/rev feed - 200 SFM
Drilling :	1/4" Dia hole - 0.004"/rev feed - 60 SFM 1/2" Dia hole - 0.007"/rev feed - 60 SFM 3/4" Dia hole - 0.010"/rev feed - 60 SFM
Reaming :	Feed - same as drilling - 100 SFM
Side and Slot Milling :	Roughing - 0.25" depth - 0.007"/tooth feed - 125SFM Finishing - 0.050" depth - 0.009"/tooth feed - 140SFM

These rates are for carbide tools,
Type C-2 for roughing, drilling and reaming.
Type C-3 for finishing.

RELATED SPECIFICATIONS

USA

Bar	ASTM A193, ASTM A194, ASTM A276, ASTM A314, ASTM A479, AMS 5764
Plate	ASTM A240 and AMS 5861
Forgings	ASTM A182M, ASTM A193, ASTM A194, ASTM A276, ASTM A479, AMS 5764 NACE MR-O1-75/ISO 15156-3, NACE MR0103-2003 Schlumberger SH329392 & SH619188

Europe

DIN 1.3964
X2CrNiMnMoNNb21.16.5.3

APPLICATIONS

With almost double the yield strength of 316L, superior corrosion resistance, excellent cryogenic properties and extremely low magnetic permeability D-50 is a preferred choice over many other austenitic stainless steels.
It is used extensively in petrochemical, oil exploration, chemical fertilizer, nuclear fuel processing, paper, textile and food processing industries. It also finds many applications in the marine sector.
Typical component applications include fasteners, pumps, marine hardware, valves and many other end uses which require high strength coupled with excellent corrosion resistance.
Where other austenitic stainless steels are marginal as regards properties, D-50 offers a cost competitive alternative and also offers a competitive edge on some of the more expensive alloys such as super duplex and nickel based alloys.

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Table 6 - Comparison of Corrosion Resistance Between Marine Alloys

	CAL Elite Marine Alloys			Other commonly used Marine-Alloys (also offered by CAL)								
Material	**Extreme Strength Cupro Nickel**	**High Strength Copper-Nickel-Manganese-Aluminium Alloy**	**Wrought Copper-Nickel-Chrome (CNC) Alloy**	**Wrought Nickel Aluminium Bronze (NAB)**	**Cast Nickel Aluminium Bronze (NAB)**	**70/30 Cupro Nickel**	**90/10 Cupro Nickel**	**Naval Brass**	**Nickel-Copper Alloy**	**Nickel-Copper-Aluminium-Titanium Alloy**	**Stainless Steel**	**Stainless Steel**
Base composition	CuNi14Al2	CuNi15Mn4-Al1Fe	CuNi30Cr1 MnFeSiZrTi	CuAl9Ni5Fe4	CuAl9Ni5Fe4	CuNi30Mn1Fe	CuNi10Fe1Mn	CuZn37Sn1	NiCu30 Fe2Mn1	NiCu30Al-3Fe1MnTi	FeCr18Ni9	FeCr18Ni-12Mo2
Specification Property	**CAL T-1000** (DIN 2.1504)	**CAL T-850** (Def Stan 02-835)	**CAL CNC-1 / CNC-2** (Def Stan 02-886 Def Stan 02-824)	Def Stan 02-833 NES 833 DGS 1043 CW307G	Def Stan 02-747 NES 747 CC333G	Def Stan 02-780 NES 780 CN107 C71500 CW354H	Def Stan (NES) 779 / CN102 / C70600 / CW352H	CZ112 / CW712R/ C46400	NA13 / UNS N04400	NA18 / UNS N05500	304 Stainless	316 Stainless
General corrosion rate per year	0.02mm / 0.0008"	0.025mm / 0.001"	0.02mm / 0.0008"	0.025-0.05mm / 0.001-0.002"	0.07mm / 0.002"	0.03mm / 0.001"	0.03mm / 0.001"	0.05mm / 0.002" (4 x at 60°C)	0.03mm / 0.001"	0.03mm / 0.001"	0.025mm / 0.001"	0.07mm / 0.003"
Crevice corrosion rate per year	<0.02mm / 0.0008"	<0.025mm / 0.001"	<0.02mm / 0.0008"	0.5mm / 0.02"	0.5mm / 0.02"	0.025-0.13mm / 0.001-0.005"	0.025-0.13mm / 0.001-0.005"	0.15mm / 0.006"	0.5mm / 0.020"	0.05mm / 0.002"	0.25mm / 0.010"	0.5mm / 0.02"
Selective Phase Corrosion per year	None	None	None	0.5-1.0mm / 0.02-0.04"	1.1mm (0.04") typical 1.4mm (0.055") observed	None	None	0.15mm / 0.006"	None	None	None	1.1mm (0.04") typical 1.4mm (0.055") observed
Impingement resistance limit m/second	3.7m/s (12ft/ sec.)	3.7m/s (12ft/ sec.)	6-8m/s (20-26ft/ sec.)	4.3m/s (14ft/sec.)	4.3m/s (14ft/sec.)	4.6m/s (15ft/ sec.)	3.7m/s (12ft/sec.)	3.05m/s (10ft/ sec.)	>9.1m/s (>30ft/ sec.)	>9.1m/s (>30ft/ sec.)	>9.1m/s (>30ft/sec.)	4.3m/s (14ft/ sec.)
Corrosion Potential in Seawater V_{sce}	-0.18	-0.19	-0.18	-0.19	-0.19	-0.18	-0.20	-0.24	-0.12	-0.12	-0.08	-0.19
Marine bio-fouling resistance	Highly resistant	Highly resistant	Highly resistant	Partially resistant	Partially resistant	Resistant	Highly resistant	Partially resistant	Not resistant	Not resistant	Not resistant	Not resistant