LION® B-3 alloy

A nickel-molybdenum alloy with outstanding resistance to hydrochloric and sulfuric acids in the as-welded condition and excellent thermal stability.

Contents

H-2104C

PRINCIPAL FEATURES

Outstanding Corrosion Resistance In The As-Welded Condition

LION® B-3® alloy is an additional member of the nickel-molybdenum family of alloys with excellent resistance to hydrochloric acid at all concentrations and temperatures. It also withstands sulfuric, acetic, formic and phosphoric acids, and other nonoxidizing media. B-3 alloy has a special chemistry designed to achieve a level of thermal stability greatly superior to that of its predecessors, e.g. LION B-2 alloy.
B-3 alloy has excellent resistance to pitting corrosion, to stress-corrosion cracking and to knife-line and heat-affected zone attack.

Fabrication

The improved thermal stability of LION B-3 alloy minimizes the problems associated with fabrication of B-2 alloy components. This is due to the reduced tendency to precipitate deleterious intermetallic phases in B-3 alloy, thereby, affording it greater ductility than B-2 alloy during and following various thermal cycling conditions.

LION B-3 alloy has good overall forming and welding characteristics. It may be forged or otherwise hot-worked, providing that it is held at 2250°F (1230°C) for a time sufficient to bring the entire piece to temperature. Since it is a low carbon alloy, the use of lower hot finishing temperatures may be necessary to achieve grain size control.

B-3 alloy may also be formed by cold working. Although it does work-harden somewhat rapidly, B-3 alloy components can be made using all common cold forming techniques.

Limited tests in boiling 20 percent hydrochloric acid indicate that the uniform corrosion resistance of B-3 alloy is not affected by cold reductions up to 50 percent as compared to that of the alloy in the solution heat-treated condition.

B-3 alloy can be welded by all common welding techniques, although oxyacetylene and submerged arc welding processes are not recommended when the fabricated item is to be used in corrosive service. Special precautions should be taken to avoid excessive heat input.

Heat Treatment

All wrought forms of LION B-3 alloy are furnished in the solution heat-treated condition unless otherwise specified. B-3 alloy is solution heat-treated at 1950°F (1065°C) and rapid quenched, except for bright annealed sheet or coil products which are heat-treated at 2100°F (1150°C) and cooled in hydrogen.

Available in Wrought Form

LION B-3 alloy is available in the form of plate, sheet, strip, billet, bar, wire, pipe and tubing.

Applications

LION B-3 alloy is suitable for use in all applications previously requiring the use of LION B-2 alloy.
Like B-2 alloy, B-3 is not recommended for use in the presence of ferric or cupric salts as these salts may cause rapid corrosion failure. Ferric or cupric salts may develop when hydrochloric acid comes in contact with iron or copper.

ASME Boiler And Pressure Vessel Code

ASME has published Code Case 2140 for solution annealed LION B-3 alloy (UNS N10675). The alloy is also covered by ASTM specifications B333 (plate, sheet and strip), B335 (bar), B366 (welded fittings), B564 (forgings), B619 (welded pipe), B622 (seamless pipe and tube) and B626 (welded tube).

Nominal Chemical Composition, Weight Percent

Ni	Mo	Cr	Fe	Co	W	Mn	Al	Ti	Si	C
65[b]	28.5	1.5	1.5	3*	3*	3*	0.5*	0.2*	0.1*	0.01*

[b]Minimum * Maximum

AQUEOUS CORROSION RESISTANCE

Average Uniform Corrosion Resistance in Boiling Acids*

Acid Medium	Concentration Weight Percent	Average Corrosion Rate Per Year Mils	Average Corrosion Rate Per Year mm
Acetic Acid	10	0.2	0.005
	30	0.2	0.005
	50	0.2	0.005
	70	0.2	0.005
	99 (Glacial)	0.7	0.017
Formic Acid	10	0.4	0.010
	20	0.6	0.015
	30	0.6	0.015
	40	0.5	0.013
	60	0.3	0.008
	89	0.2	0.005
Hydrochloric Acid	1	0.3	0.005
	2	1.2	0.03
	5	3.8	0.10
	10	5.5	0.14
	15	8.6	0.22
	20	12.1	0.31
(As-welded)	20	13.6	0.35
(50 ppm Fe^{+3})	20	80.0	2.0
Phosphoric Acid	10	2.4	0.06
(Chemically Pure)	30	2.0	0.05
	50	3.0	0.08
	85	2.9	0.07
Sulfuric Acid	2	0.4	0.010
	5	0.7	0.018
	10	0.8	0.020
	20	1.2	0.03
	30	1.2	0.03
(50 ppm Fe^{+3})	30	18.8	0.48
	40	1.2	0.03
	50	1.7	0.04
(As-welded)	50	2.4	0.06
(Aged 48 Hrs @ 1000°F (540°C))	50	2.0	0.05
	60	2.3	0.06
	70	6.6	0.17

* Data from three production heats, for material in the solution heat-treated condition, unless noted. Test values were determined from an average of four 24 hour exposures.

Comparative Uniform Corrosion Resistance in Boiling Acids

Acid Medium	Average Corrosion Rates Per Year, Mils (mm)							
	B-3® alloy		B-2 alloy		Type 316L		MONEL®400 alloy	
50% Acetic Acid	0.2	(0.005)	0.4	(0.010)	0.2	(0.005)	-	
40% Formic Acid	0.5	(0.013)	0.7	(0.018)	41	(1.041)	2.1	(0.053)
50-55% Phosphoric Acid	3.0	(0.076)	6	(0.152)	18	(0.457)	4.5	(0.114)
50% Sulfuric Acid	1.7	(0.043)	1.2	(0.030)	>20,000	(>500)	185	(4.699)
20% Hydrochloric Acid	12	(0.305)	15	(0.381)	>20,000	(>500)	1587	(40.310)

Average Uniform Corrosion Resistance in HF Solutions*

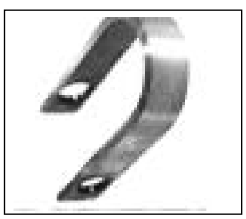
% HF	Average Corrosion Rates Per Year For Indicated Temperatures			
	125°F (52°C)		175°F (79°C)	
	Mils	mm	Mils	mm
1	8.6	0.22	11.1	0.28
3	8.7	0.22	12.7	0.32
5	9.0	0.23	13.7	0.35
10	10.0	0.25	15.9	0.41
20	11.8	0.30	22.8	0.58
48	13.4	0.34	35.0	0.89
70	31.6	0.80	-	-

* Data from three production heats, for material in the solution heat-treated condition.

Comparative Stress Corrosion Cracking Resistance

U-Bend Specimens (ASTM G-30 Stress Method)

Boiling 60% H_2SO_4



LION® B-3 alloy
Annealed + 1 hr at 1290°F (700°C)
(No cracking, 24 hours)

LION B-2 alloy
Annealed + 1 hr at 1290°F (700°C)
(Intergranular cracking, 3 hours)

Flat, Sheet Specimens Mill Annealed and Aged 1 Hour at 1290°F (700°C)

Boiling Solution	B-2 alloy	B-3 alloy
5% H_2SO_4	IG-SCC	NC**
0.5% H_2SO_4	IG-SCC	NC
20% HCl	IG-SCC*	NC

* Intergranular stress-corrosion cracking at stamped identification sites.
** No Cracking

AQUEOUS CORROSION RESISTANCE (continued)

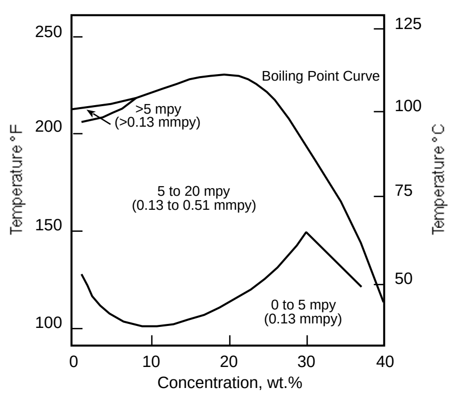
Effect of Cold Work Upon Corrosion Resistance in Boiling 20% HCl*

% Coldwork	Hardness Rc	Ultimate Tensile Strength Ksi	Ultimate Tensile Strength MPa	Yield Strength at 0.2% Offset Ksi	Yield Strength at 0.2% Offset MPa	Elongation in 2" (51mm) % EL	Corrosion Rate PerYear Mils	Corrosion Rate PerYear (mm)
0	18	125	860	62	425	57	13	(0.33)
10	30	140	965	100	690	40	13	(0.33)
20	37	159	1095	130	895	25	13	(0.33)
30	41	180	1240	154	1060	13	13	(0.33)
40	44	202	1395	172	1185	9	13	(0.33)
50	46	221	1525	183	1260	8	13	(0.33)

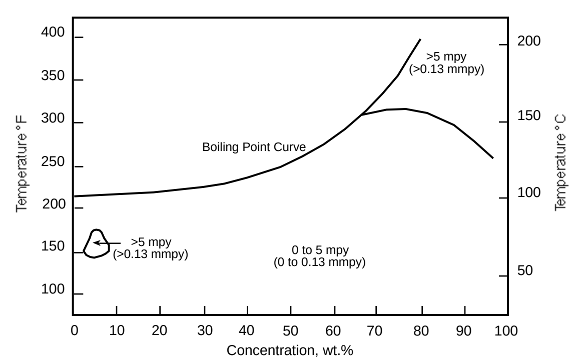
* Exposure for four 24 hour periods

LION® B-3® alloy ISOCORROSION DIAGRAMS

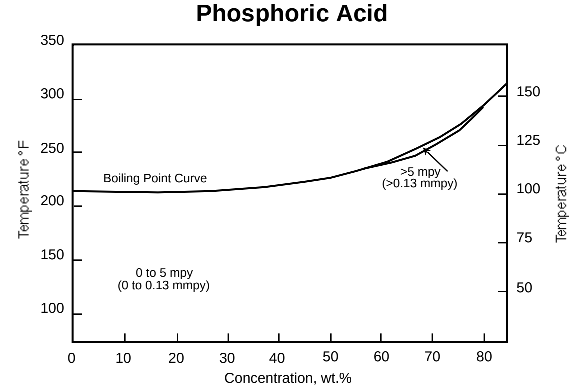
Hydrochloric Acid



Sulfuric Acid

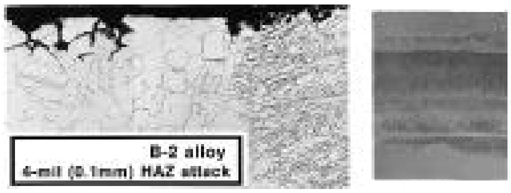


Phosphoric Acid



FIELD TEST COMPARISON, SULFURIC ACID

20-30% H_2SO_4 + Ferrous Sulfate - 230°F (110°C) - 96 Days - pH<1



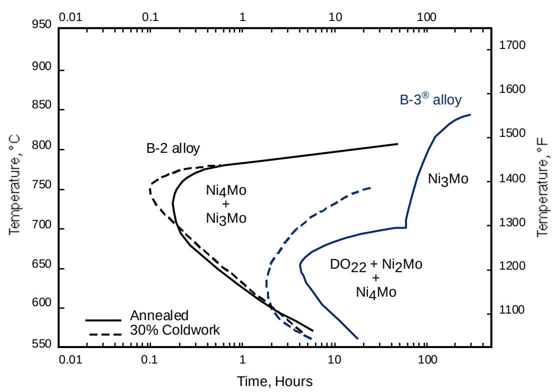
Alloy B-2
3.1 mpy
(0.08 mm/y)

B-3 Alloy
2.4 mpy
(0.06 mm/y)

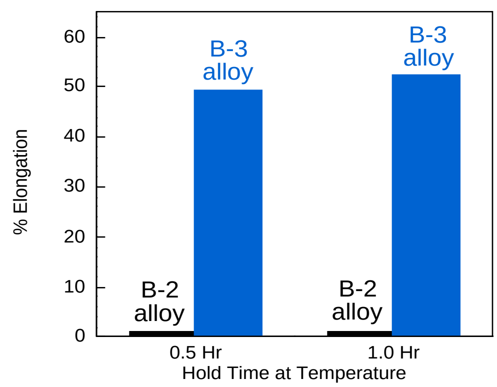
THERMAL STABILITY

The single greatest advantage for B-3 alloy over B-2 alloy accrues from its ability to maintain excellent ductility during transient exposures to intermediate temperatures. Such exposures are routinely experienced during heat treatments associated with fabrication. While very short exposures at temperatures such as 1290°F (700°C) can severely embrittle B-2 alloy at temperature, B-3 alloy exhibits a marked resistance to such embrittlement for up to several hours. This provides far greater facility for the alloy to be fabricated into complex components such as formed heads.

COMPARISON OF T-T-T CHARACTERISTICS



1290°F (700°C) TENSILE ELONGATION



Average Thermal Stability Data - Room Temperature

Exposure Temperature °F	Exposure Temperature °C	Exposure Time, Hrs.	Ultimate Tensile Strength Ksi	Ultimate Tensile Strength MPa	0.2% Offset Yield Strength Ksi	0.2% Offset Yield Strength MPa	Elongation %	R of A %	Charpy V-Notch Impact Ft.-lbs.	Charpy V-Notch Impact J
None		None	129.1	890	55.8	385	60.4	73.0	264	358
800	425	1000	130.5	900	58.8	405	57.2	71.7	264	358
		4000	131.0	905	59.5	410	56.8	71.6	264	358
		8000	126.3	870	57.1	395	57.4	70.5	264	358
		12,000	127.3	880	58.9	405	57.5	70.4	264	358
		16,000	132.6	915	59.6	410	57.6	71.4	264	358

Average Thermal Stability Data (continued)

Exposure Temperature °F	Exposure Temperature °C	Exposure Time, Hrs.	Ultimate Tensile Strength Ksi	Ultimate Tensile Strength MPa	0.2% Offset Yield Strength Ksi	0.2% Offset Yield Strength MPa	Elongation %	R of A %	Charpy V-Notch Impact Ft.-lbs.	Charpy V-Notch Impact J
900	480	1000	140.8	970	77.5	535	50.0	67.1	262	355
		4000	144.6	995	84.0	580	48.3	65.5	264	358
		8000	139.2	960	80.5	555	48.9	64.4	210	285
		12,000	141.1	975	81.7	565	49.9	65.2	231	313
		16,000	147.7	1020	85.5	590	48.8	64.6	175	237
1000	540	1000	145.8	1005	82.9	570	48.4	64.7	236	320
		4000	152.9	1055	89.1	615	45.6	61.4	107	145
		8000	152.0	1050	90.7	625	47.1	59.5	58	79
		12,000	153.6	1060	92.4	635	44.2	59.2	82	111
		16,000	162.7	1120	96.0	660	43.7	57.5	58	79
1100	595	1000	169.2	1165	104.1	720	38.8	54.9	25	34
		4000	178.5	1230	117.8	810	31.5	37.2	15	20
		8000	175.3	1210	118.5	815	28.7	35.7	13	18
		12,000	178.1	1230	120.4	830	26.4	31.7	13	18
		16,000	186.0	1280	126.1	870	25.3	29.6	8	11

TYPICAL TENSILE PROPERTIES

Tensile Properties, Sheet*

Test Temperature °F	Test Temperature °C	Ultimate Tensile Strength Ksi	Ultimate Tensile Strength MPa	Yield Strength at 0.2% Offset Ksi	Yield Strength at 0.2% Offset MPa	Elongation in 2 in (51mm) %
Room	Room	125.0	860	60.6	420	53.4
200	95	120.7	830	55.3	380	56.9
400	205	110.0	760	47.0	325	59.7
600	315	104.4	720	43.5	300	63.4
800	425	102.0	705	42.4	290	62.0
1000	540	97.8	675	39.0	270	59.0
1200	650	103.5	715	45.8	315	55.8

* Limited data for 0.125" (3.2mm) bright annealed sheet

Tensile Properties, Plate*

Test Temperature °F	Test Temperature °C	Ultimate Tensile Strength Ksi	Ultimate Tensile Strength MPa	Yield Strength at 0.2% Offset Ksi	Yield Strength at 0.2% Offset MPa	Elongation in 2 in (51mm) or in 5D* %	Reduction of Area* %
Room	Room	128.3	885	58.2	400	57.8	67.5
200	95	122.4	845	54.1	375	58.2	67.3
400	205	115.1	795	47.6	330	60.9	68.1
600	315	111.2	765	44.4	305	61.6	65.5
800	425	108.2	745	41.3	285	61.7	64.9
1000	540	105.6	730	39.6	275	61.7	61.5
1200	650	106.9	735	42.0	290	64.6	54.9

* Average results for six lots of plate from three heats. Half of the test data are for 1/4-inch (6.3mm) plate, requiring flat test specimens. Rest of samples were round geometry for heavier plate. Thus, reduction of areas reported are for these tests only.

DYNAMIC MODULUS OF ELASTICITY

Temperature °F	Dynamic Modulus of Elasticity, 10^6 psi	Temperature °C	Dynamic Modulus of Elasticity, GPa
Room	31.4	Room	216
200	30.9	100	213
400	30.1	200	208
600	29.3	300	202
800	28.3	400	197
1000	27.2	500	190
1200	26.5	600	185
1400	24.9	700	178
1600	23.3	800	168
1800	21.6	900	157
		1000	147

TYPICAL PHYSICAL PROPERTIES

Physical Property	Temp., °F	British Units	Temp., °C	Metric Units
Density	Room	0.333 lb/in.^{3}	Room	9.22 g/cm.^{3}
Melting Temperature	2500-2585		1370-1418	
Electrical Resistivity	Room	53.8 microhm-in.	Room	137 microhm-cm
	200	53.9 microhm-in.	100	137 microhm-cm
	400	54.1 microhm-in.	200	137 microhm-cm
	600	54.3 microhm-in.	300	138 microhm-cm
	800	54.4 microhm-in.	400	138 microhm-cm
	1000	55.4 microhm-in.	500	140 microhm-cm
	1200	57.5 microhm-in.	600	143 microhm-cm
	1400	54.7 microhm-in.	700	142 microhm-cm
	1600	52.6 microhm-in.	800	137 microhm-cm
	1800	51.2 microhm-in.	900	132 microhm-cm
			1000	130 microhm-cm
Mean Coefficient of Thermal Expansion	78-200	5.7 microinches/in.-°F	25-100	10.6 x 10^{-6} m/m-°C
	78-400	6.1 microinches/in.-°F	25-200	11.1 x 10^{-6} m/m-°C
	78-600	6.3 microinches/in.-°F	25-300	11.4 x 10^{-6} m/m-°C
	78-800	6.5 microinches/in.-°F	25-400	11.6 x 10^{-6} m/m-°C
	78-1000	6.6 microinches/in.-°F	25-500	11.8 x 10^{-6} m/m-°C
	78-1200	6.5 microinches/in.-°F	25-600	11.8 x 10^{-6} m/m-°C
	78-1400	7.1 microinches/in.-°F	25-700	12.2 x 10^{-6} m/m-°C
	78-1600	7.6 microinches/in.-°F	25-800	13.1 x 10^{-6} m/m-°C
	78-1800	8.0 microinches/in.-°F	25-900	13.9 x 10^{-6} m/m-°C
			25-1000	14.4 x 10^{-6} m/m-°C
Thermal Diffusivity	Room	4.6 x 10^{-3} in.^{2}/sec.	Room	3.0 x 10^{-3} cm^2/sec.
	200	4.9 x 10^{-3} in.^{2}/sec.	100	3.2 x 10^{-3} cm^2/sec.
	400	5.4 x 10^{-3} in.^{2}/sec.	200	3.4 x 10^{-3} cm^2/sec.
	600	5.8 x 10^{-3} in.^{2}/sec.	300	3.7 x 10^{-3} cm^2/sec.
	800	6.3 x 10^{-3} in.^{2}/sec.	400	4.0 x 10^{-3} cm^2/sec.
	1000	6.8 x 10^{-3} in.^{2}/sec.	500	4.4 x 10^{-3} cm^2/sec.
	1200	7.3 x 10^{-3} in.^{2}/sec.	600	4.5 x 10^{-3} cm^2/sec.
	1400	7.5 x 10^{-3} in.^{2}/sec.	700	4.9 x 10^{-3} cm^2/sec.
	1600	7.0 x 10^{-3} in.^{2}/sec.	800	4.7 x 10^{-3} cm^2/sec.
	1800	7.4 x 10^{-3} in.^{2}/sec.	900	4.5 x 10^{-3} cm^2/sec.
			1000	4.9 x 10^{-3} cm^2/sec.

Acknowledgements:
MONEL is a registered trademark of the Inco Family of Companies.

Typical Physical Properties (continued)

Physical Property	Temp., °F	British Units	Temp., °C	Metric Units
Thermal Conductivity	Room	78 Btu-in./ft.^{2} hr.-°F	Room	11.2 W/m-K
	200	83 Btu-in./ft.^{2} hr.-°F	100	12.1 W/m-K
	400	93 Btu-in./ft.^{2} hr.-°F	200	13.4 W/m-K
	600	104 Btu-in./ft.^{2} hr.-°F	300	14.8 W/m-K
	800	116 Btu-in./ft.^{2} hr.-°F	400	16.3 W/m-K
	1000	129 Btu-in./ft.^{2} hr.-°F	500	17.9 W/m-K
	1200	142 Btu-in./ft.^{2} hr.-°F	600	19.6 W/m-K
	1400	156 Btu-in./ft.^{2} hr.-°F	700	21.4 W/m-K
	1600	172 Btu-in./ft.^{2} hr.-°F	800	23.3 W/m-K
	1800	188 Btu-in./ft.^{2} hr.-°F	900	25.4 W/m-K
			1000	27.5 W/m-K
Specific Heat	Room	0.089 Btu/lb.-°F	Room	373 J/kg-K
	200	0.092 Btu/lb.-°F	100	382 J/kg-K
	400	0.098 Btu/lb.-°F	200	409 J/kg-K
	600	0.102 Btu/lb.-°F	300	421 J/kg-K
	800	0.104 Btu/lb.-°F	400	431 J/kg-K
	1000	0.104 Btu/lb.-°F	500	436 J/kg-K
	1200	0.112 Btu/lb.-°F	600	434 J/kg-K
	1400	0.143 Btu/lb.-°F	700	595 J/kg-K
	1600	0.138 Btu/lb.-°F	800	589 J/kg-K
	1800	0.137 Btu/lb.-°F	900	577 J/kg-K
			1000	575 J/kg-K

HEALTH AND SAFETY

Welding can be a safe occupation. Those in the welding industry, however, should be aware of the potential hazards associated with welding fumes, gases, radiation, electric shock, heat, eye injuries, burns, etc. Also, local, municipal, state, and federal regulations (such as those issued by OSHA) relative to welding and cutting processes should be considered.

Nickel-, cobalt-, and iron-base alloy products may contain, in varying concentration, the following elemental constituents: aluminum, cobalt, chromium, copper, iron, manganese, molybdenum, nickel and tungsten. For specific concentrations of these and other elements present, refer to the Material Safety Data Sheets (MSDS) available from Shanghai LION.

Inhalation of metal dust or fumes generated from welding, cutting, grinding, melting, or dross handling of these alloys may cause adverse health effects such as reduced lung function, nasal and mucous membrane irritation. Exposure to dust or fumes which may be generated in working with these alloys may also cause eye irritation, skin rash and effects on other organ systems.

The operation and maintenance of welding and cutting equipment should conform to the provision of American National Standard ANSI/AWS Z49.1, "Safety in Welding and Cutting". Attention is especially called to Section 4 (Protection of Personnel) and 5 (Health Protection and Ventilation) of ANSI/AWS Z49.1. Mechanical ventilation is advisable and, under certain conditions such as a very confined space, is necessary during welding or cutting operations, or both, to prevent possible exposure to hazardous fumes, gases, or dust that may occur.