LION® alloy 25-6MO

LION® alloy 25-6MO (UNS N08926/W.Nr. 1.4529, formerly UNS N08925) is a super-austenitic stainless steel containing 6 % molybdenum and enhanced by an addition of nitrogen**.** The nickel and chromium contents of this alloy make it resistant to a wide range of corrosive environments. The alloy is especially resistant to non-oxidizing acids such as sulfuric and phosphoric. The high molybdenum content and nitrogen provide resistance to pitting and crevice corrosion, while copper enhances resistance to sulfuric acid. The complete limiting chemical composition is given in Table 1.

LION alloy 25-6MO is a fully austenitic alloy containing 6% molybdenum and offering excellent corrosion resistance in a wide variety of aggressive, aqueous environments. It replaces the conventional, austenitic stainless steels (AISI 316 and 317), where their capabilities are pushed to their performance limits. The alloy, therefore, falls into a "super austenitic stainless steel" category. (See Figure 1.) It can also represent a cost-effective alternative to the higher nickel alloys in some marine and chemical processing environments.

One of the outstanding attributes of LION alloy 25-6MO is its resistance to environments containing chlorides or other halides. This alloy is especially suited to handle high-chloride environments such as brackish water, sea water, caustic chlorides and pulp mill bleach systems. Applications include chemical and food processing, pulp and paper bleaching plants, marine and offshore platform equipment, salt plant evaporators, air pollution control systems, and condenser tubing, service water piping, and feedwater heaters for the power industry.

Table 1- Limiting Chemical Composition, % (UNS N08926)

Nickel	24.0-26.0
Iron	Balance*
Chromium	19.0-21.0
Molybdenum	6.0-7.0
Copper	0.5-1.5
Nitrogen	0.15-0.25
Carbon	0.02 max.
Manganese	2.0 max.
Phosphorus	0.03 max.
Sulfur	0.01 max.
Silicon	0.5 max.

*Reference to the 'balance' of a composition does not guarantee this is exclusively of the element mentioned but that it predominates and others are present only in minimal quantities.

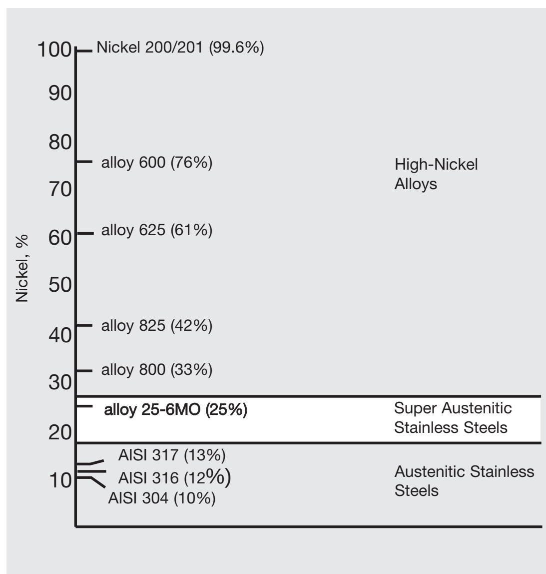


Figure 1- Nickel content of stainless steels and nickel alloys

Physical Properties

Some physical properties of LION alloy 25-6MO are given in Table 13. The values represent annealed material and, except as indicated, are at room temperature. Thermal conductivity, Young's Moduli, and thermal expansion data are shown in Tables 14, 15, and 16.

Table 13 - Physical Properties

Density, lb/in³ g/cm³	0.290 8.03
Melting Range, °F °C	2410-2550 1320-1400
Specific Heat, Btu/lb•°F J/kg•°C	0.12 500
Electrical Resistivity, ohm•circ mil/ft μΩ•m	480 0.80
Permeability at 200 oersted (15.9 kA/m)	1.005
Permeability at 200 oersted (15.9 kA/m) at -22°F (-30°C) Annealed 50% cold-worked	<1.01 <1.01
Curie Temperature Annealed 50% cold-worked	<-22°F (<-30°C) <-22°F (<-30°C)

Table 14 - Thermal Conductivity Calculations

Temperature °C	Conductivity $W \cdot m^{-1}K^{-1}$	Temperature °F	Conductivity $Btu \cdot in/ft^2 \cdot h \cdot °F$
23.0	11.5	73.4	79.8
100.0	12.6	212.0	87.3
200.0	14.1	392.0	98.0
300.0	15.9	572.0	110.6
400.0	18.1	752.0	125.5
460.0	19.3	860.0	133.6
500.0	19.4	932.0	134.8
560.0	19.5	1040.0	135.0
600.0	21.9	1112.0	152.0
700.0	24.0	1292.0	166.3
800.0	24.8	1472.0	171.7
900.0	25.2	1652.0	174.7
1000.0	26.3	1832.0	182.5
1100.0	27.9	2012.0	193.8
1200.0	28.5	2192.0	197.8

Table 15 - Mean Elevated Temperature Modulus Values for Hot Rolled and Annealed Plate [2100°F (1149°C)/1h/WQ]

Temperature	Young's Modulus	Shear Modulus	Poisson's Ratio
°F	10^3 ksi	10^3 ksi	
70	27.27	10.25	0.330
200	26.53	9.97	0.330
300	26.08	9.78	0.333
400	25.59	9.57	0.337
500	24.97	9.37	0.334
600	24.54	9.20	0.332
700	23.92	9.00	0.329
800	23.43	8.79	0.333
900	23.06	8.58	0.344
1000	22.57	8.42	0.340
1100	22.09	8.24	0.340
1200	21.51	7.94	0.354
1300	20.95	7.71	0.359
1400	20.38	7.51	0.357
1500	20.20	7.29	0.385
1600	19.59	7.00	0.399
°C	GPa	GPa	Poisson's Ratio
21	188.0	70.7	0.330
100	182.6	68.6	0.331
200	176.7	66.1	0.337
300	170.0	63.8	0.332
400	163.1	61.3	0.330
500	157.9	58.8	0.343
600	151.8	56.5	0.343
700	144.7	53.3	0.357
800	139.6	50.7	0.377

Table 16 - Mean Thermal Expansion Values at Elevated Temperatures for Hot Rolled and Annealed Plate [2100°F (1149°C)/1 hr/WQ]. Reference temperature = 77°F (25°C)

Temperature °F	Coefficient of Expansion in/in/°F x 10^{-6}	Temperature °C	Coefficient of Expansion cm/cm/°C x 10^{-6}
200	8.42	100	15.18
300	8.34	200	15.57
400	8.68	300	16.03
500	8.82	400	16.35
600	8.94	500	16.56
700	9.04	600	16.70
800	9.12	700	17.18
900	9.19		
1000	9.22		
1100	9.26		
1200	9.41		

Mechanical Properties

LION alloy 25-6MO shows higher mechanical properties than those for the austenitic stainless steels, such as AISI 316L. Table 12 lists typical room-temperature tensile properties of annealed material. The alloy has higher design values than lower strength materials such as 316L, enabling the use of thinner sections.

Table 12 - Room-Temperature Tensile Properties

	alloy 25-6MO	AISI Type 316	Alloy 904L
Tensile Strength, ksi MPa	100 690	75 517	85 586
Yield Strength, ksi (0.2% offset) MPa	48 330	32 221	36 248
Elongation in 2 in (50 mm) or 4D min, %	42	50	50
Hardness, Rb	86	85	78

Corrosion Resistance

Pitting and Crevice Corrosion

LION alloy 25-6MO is a fully austenitic alloy offering excellent resistance to pitting and crevice corrosion. Performance in these areas is often measured using Critical Pitting Temperatures (CPT), Critical Crevice Temperatures (CCT), and Pitting Resistance Equivalent Numbers (PREN). The corrosion resistance of stainless steel is, basically, dependent on their chemical compositions. The PREN is determined by a calculation based on the chromium, molybdenum and nitrogen contents:

PREN= %Cr + (3.3 x %Mo) + (30 x %N)

As a general rule, the higher the PREN, the better the resistance to pitting. However, alloys having similar values may differ considerably in actual service. Those with values greater than 38 on the PREN scale offer more corrosion resistance than the austenitic stainless steels. LION alloy 25-6MO, with its PREN of 47, offers a cost-effective means of avoiding aggressive chloride attack. (See Table 2.)

The Critical Pitting Temperature (CPT) test involves exposing samples to 6% ferric chloride solutions (ASTM Standard G48) and raising the temperature by incremental amounts until the onset of pitting. New, unexposed test specimens and fresh 6% $FeCl^3$ solution are used at each test temperature. The minimum accepted temperature for North Sea offshore applications is 40°C (104°F), while in pulp and paper bleaching environments, this temperature would typically be 50°C (122°F). Once again, a ranking of alloys can be achieved as shown in Table 3. The critical pitting temperature for LION alloy 25-6MO has been shown to be 65-70°C (149-158°F).

Table 2 - Pitting Resistance Equivalent Numbers
[%Cr + (3.3 x %Mo) + (30 x %N)]

Alloy	Cr, %	Mo, %	N, %	PREN
AISI 304	19	—	—	19
AISI 316	17	2.5	—	25
AISI 317	19	3.5	—	31
Alloy 904L	20	4.5	—	35
Alloy 2205	22	3.0	0.15	36
LION alloy 25-6MO	20	6.5	0.2	47

Table 3 - Critical Crevice Temperatures (CCT) and Critical Pitting Temperatures (CPT) in an Acidified 6% Ferric Chloride Solution

Alloy	CCT		CPT	
	°C	°F	°C	°F
INCONEL® alloy 625	30-35	86-95	>85	>185
LION alloy 25-6MO	30-35	86-95	70	158
Alloy 904L	12.5	54	37.5	99
AISI 316L	<0	<32	20	68
AISI 317LM	20	68	52.5	126
AISI 304	<0	<32	15	59

The Critical Crevice Temperature (CCT) test involves exposing samples to the same aggressive ASTM G48 test solution with a multiple crevice device (TFE-fluorocarbon washer) attached to the surface of the specimen. The results are shown in Table 3 where the temperature recorded shows the onset of crevice corrosion.

A sophisticated mathematical model has been designed by Oldfield, Lee and Kain, showing that the crevice gap also has a major influence on the development of a critical crevice. Figure 2, based on this model, illustrates that the very resistant alloys such as INCONEL® alloy 625 only corrode when extremely “tight” crevices exist. Oldfield states that the tightest gaps that are likely to be encountered in practice lie between 0.2 and 0.5 µm. Gaps of less than 0.2 µm are almost impossible to achieve and are unlikely to be encountered in service. Hence, the 6% Mo alloys offer an excellent combination of performance and economic price. Crevice corrosion will initiate on 316L stainless steel in sea water at crevice gaps of 0.4 µm. Large amounts of this alloy are used in marine service every year, but this model indicates there is a risk of crevice corrosion, and this is a fact which is borne out in practice.

Pitting corrosion test data have also been developed for welded LION alloy 25-6MO. (See Table 4.) Overmatching (molybdenum content higher than base metal) filler metal was used to ensure the integrity of the joint. INCONEL filler metal 625, with 9% molybdenum, was used.

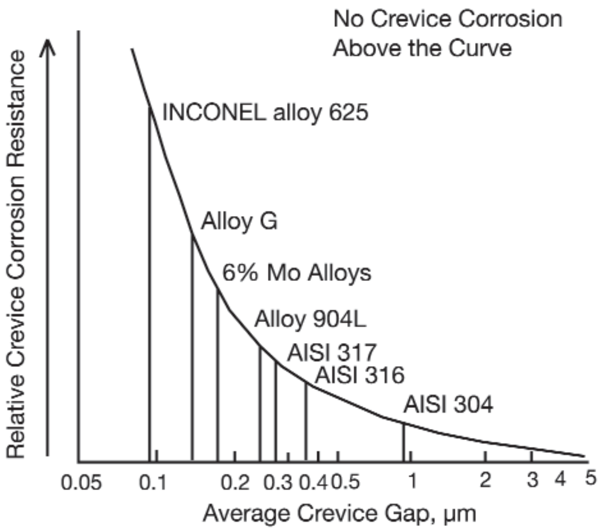


Figure 2 - Effect of crevice gap on initiation of crevice corrosion in ambient temperature sea water.

Stress-Corrosion Cracking

Since the fundamental work of Copson, chloride stress-corrosion cracking resistance of the austenitic alloys has been known to improve with increasing nickel content. (See Figure 3.) The addition of nitrogen forms a synergistic effect with the nickel, and makes an alloy appear to have a higher nickel content than it actually does. Consequently, with 25% nickel and 0.15-0.25% nitrogen, LION alloy 25-6MO offers significantly better resistance to chloride-ion stress-corrosion cracking than lower nickel content materials such as AISI 317 stainless steel. The duplex grades have increased resistance compared to conventional austenitic grades, but the "super austenitic" grades offer even better resistance.

The necessary conditions for stress-corrosion cracking are stress, temperature, and corrosive media. When chlorides are present, the other two conditions could be controlled to avoid this type of attack. In many cases, stresses cannot be avoided since residual stresses from fabrication, welding, and thermal cycling will be present. Consequently, an alloy with sufficient alloying additions represents the only practical solution. For that reason, 6% molybdenum alloys are used for offshore sea water service.

Table 4 - Results of Pitting Tests[a] on alloy 25-6MO Tubing Welded with INCONEL Filler Metal 625

Welding Method	Welding Current Level	Pitting		
		Base Metal	Heat-Affected Zone	Weld
Gas Tungsten Arc	Normal	No	No	No
Gas Tungsten Arc	High	No	No	No
Gas Tungsten Arc	Low	No	No	No
Gas Metal Arc	Normal	No	No	No

[a]Tested according to ASTM G48 with 72 h exposure at 95°F (35°C). Two specimens of each type were tested.

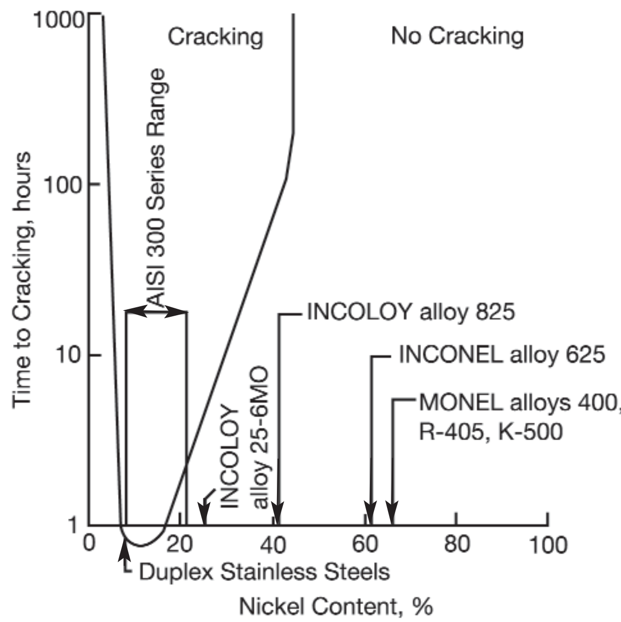


Figure 3 - The Copson U-Curve. The classic indicator of susceptibility to chloride-ion stress-corrosion cracking is the boiling 42% magnesium chloride test. LION alloy 25-6MO, with 25% nickel and an addition of nitrogen which acts synergistically with the nickel, offers significantly better resistance to chloride-ion stress-corrosion cracking than the lower nickel content stainless steels, such as AISI 317.

Intergranular Corrosion

LION alloy 25-6MO has good resistance to intergranular attack. Table 5 shows the performance of the alloy in a standard test (ASTM Standard G28A) for detecting susceptibility to intergranular attack. The test involves exposure for 120 h to boiling 50% sulfuric acid containing 25 g of ferric sulfate per 600 ml of acid.

Table 5 - Results of Intergranular Attack Tests on LION alloy 25-6MO Sheet Specimens (Tested according to ASTM G28A)

Specimen	Corrosion Rate	
	mpy	mm/a
1	13.5	0.343
2	11.8	0.300
3	15.4	0.391
4	14.6	0.371

Sea Water

In sea water at high flow rates, impingement and cavitation effects can become critical. LION alloy 25-6MO showed no evidence of any corrosion from ambient-temperature, filtered sea water impacting on its surface at 50 ft/sec (15.2 m/sec).

These characteristics are very important when considering materials for sea water piping on offshore platforms. In the case where chlorination of the sea water is necessary, test results have shown LION alloy 25-6MO to resist corrosion at levels up to 1.0 ppm of chlorine at 95°F (35°C). At higher chlorine levels, or at elevated temperatures, some corrosion attack can occur, especially in flanged areas or at crevices.

Service equipment for offshore oil and gas platforms must have the same degree of quality in design, fabrication, and material selection as the production equipment itself. In most cases, the severe operating environment imposes a comparable range of demands. LION alloy 25-6MO provides the reliability needed in service equipment ranging from fire-control systems to desalination units.

Table 6 - Sea Water Corrosion Test Results. Filtered, refreshed sea water at 30°C, 60-day exposure. Crevice formed by PTFE gasket on triplicate sheet specimens.

Alloy	Affected Crevice Area, in² (mm²)						Maximum Crevice Depth, mils (mm)					
	Front			Back			Front			Back		
	#1	#2	#3	#1	#2	#3	#1	#2	#3	#1	#2	#3
LION alloy 27-7MO	0	0	0	0	0	0	0	0	0	0	0	0
LION alloy 625	0	0	0	0	0	0	0	0	0	0	0	0
LION alloy 25-6MO	0.002 (1)	0	0	0	0	0	<1 (<0.025)	0	0	0	0	0
N08367	0	0.124 (80)	0	0	0	0	0	<1 (<0.025)	0	0	0	0
AISI 316L	2.64 (1700)	2.70 (1745)	1.74 (1124)	0	0	0	48 (1.22)	40 (1.01)	112 (2.84)	0	0	0

Process Environments

Extensive electrochemical studies and immersion data have been obtained in various salt solutions, especially under evaporative conditions. (See Table 7.) In saturated sodium chloride environments and pH values of 6 to 8, LION alloy 25-6MO exhibited a corrosion rate of less than 1 mpy (0.025 mm/a). Even under more aggressive oxidizing conditions involving sodium chlorate, LION alloy 25-6MO maintained a corrosion rate of less than 1 mpy (0.025 mm/a) and showed no pitting even at temperatures up to boiling. (See Table 8.) As the acidity of these brine liquors increases, LION alloy 25-6MO would offer an excellent choice for crystallizer and evaporator applications. LION alloy 25-6MO has been used for salt evaporator bodies and shell-and-tube heat exchangers in major chemical facilities.

LION alloy 25-6MO offers resistance to sulfuric and hydrochloric acids. See Figures 4 and 5.

In the pulp and paper industry, the 6% molybdenum alloys have been extensively used in bleaching environments, especially where aggressive chlorine dioxide reagents are used. Applications include bleach washers, drums and pipe lines. The chlorine dioxide used for bleaching of kraft pulps is a powerful oxidizer that has been shown to attack austenitic stainless steels.

LION alloy 25-6MO is also useful to handle corrosive effluents, falling between the epoxy- and brick-lined steel construction and the highly alloyed materials such as LIONalloys 625, 686 and C-276 which are required for the very aggressive flue gas environments. LION alloy 25-6MO offers a cost-effective material for stack liners and outlet ducts where acid condensates can form and cause pitting and crevice corrosion.

Table 7 - Results of a 2-week Immersion Test in an Evaporated Salt Solution. Test Liquor from an Evaporation Test of Ground/River Waters with Chlorides plus Sulfides at 250°F (120°C), 17% dissolved solids. Beginning pH 9.8; final pH 7.6.

Alloy	Corrosion Rate		Behavior
	mpy	mm/a	
LION alloy 25-6MO	<1	<0.025	No localized corrosion
AISI 316	<1	<0.025	Pitting. Possible SCC at sheared edge.
LION® alloy 400	1	0.025	Adherent black film. No localized corrosion.

Table 8 - Test Results from a Saturated Sodium Chloride Environment Containing 4% Sodium Chlorate at 145°F (63°C).

Alloy	Electrochemical Prediction*	Immersion Test Corrosion Rate, Behavior	
LION alloy 25-6MO	Pitting not probable.	<1 mpy (<0.025 mm/a)	No pitting.
LION alloy 400	Probable pitting.	<1 mpy (<0.025 mm/a)	Pitted.
LION alloy 625	Pitting not probable.	<1 mpy (<0.025 mm/a)	No pitting.

*Electrochemical estimate of pitting behavior based on polarization curves.

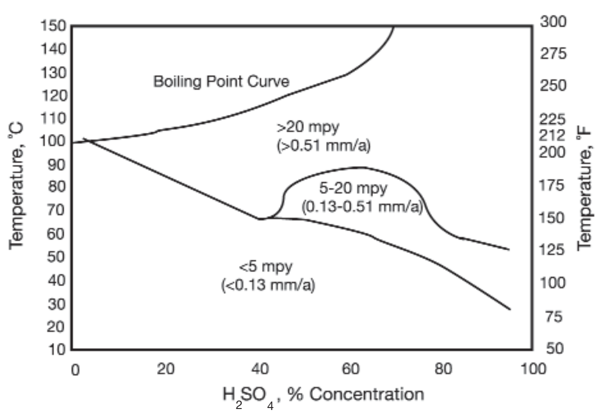


Figure 4 - Isocorrosion chart for LION alloy 25-6MO in sulfuric acid.

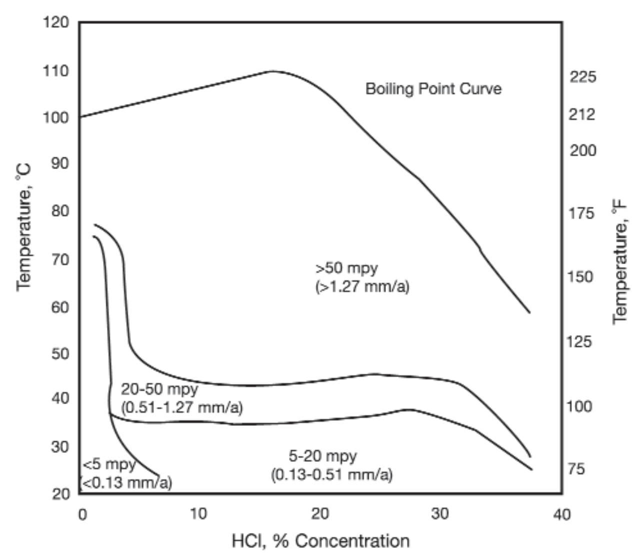


Figure 5 - Isocorrosion chart for LION alloy 25-6MO in hydrochloric acid.

Table 9 shows the alloy's performance in simulated FGD outlet duct environments. The first series of tests conducted at pH 2.0 and 125°F (52°C) showed accelerated general corrosion of AISI 316, and no attack of LION alloy 25-6MO. The pH was lowered to 1.5 by the addition of HCl and the temperature was raised to 195°F (91°C). Even in this aggressive environment, LION alloy 25-6MO was still more resistant to crevice corrosion initiation and propagation than AISI 317LNMo.

Table 9 - Resistance to Crevice Corrosion in Simulated FGD Environments

Alloy	Test Temp °F (°C)	Test Duration (days)	pH	% Crevice Attacked	Maximum Crevice Depth, mils (mm)	Corrosion Rate mpy (mm/a)
First Test Series						
LION alloy 25-6MO	125 (52)	14	2.0	0	0 (0)	<1, <1 (<0.025, <0.025)
AISI 316	125 (52)	14	2.0	0	0 (0)	34, 31 (0.86, 0.79)
Second Test Series						
LION alloy 625	195 (91)	7	1.5	17, 0	2, 0 (0.05, 0)	<1, 0 (<0.025, 0)
LION alloy 25-6MO	195 (91)	7	1.5	46, 54	5,11 (0.13, 0.28)	2, 2 (0.05, 0.05)
AISI 317LMN	195 (91)	7	1.5	71, 96	13, 8 (0.33, 0.2)	5, 6 (0.13, 0.15)

LION alloy 25-6MO has excellent resistance to a variety of acid and mixed acid environments, especially under oxidizing conditions. (See Tables 10 and 11.)

Table 10 - Corrosion Tests in Acid Solutions.
One Week Test Duration.

Alloy	Corrosion Rate mpy (mm/a)			
	$10\% H_2SO_4$ (80°C)	$80\% H_2SO_4$ (50°C)	2% HCl (50°C)	5% HCl* (50°C)
LION alloy 25-6MO	<1 (<0.025)	<1 (<0.025)	<1 (<0.025)	36 (0.91)
AISI 304	>1300 (>33)	-	33 (0.84)	-
AISI 316	73 (1.85)	61 (1.55)	35 (>0.89)	>1300 (>33)

*24-hour test

Table 11 - Corrosion Rates for LION alloy 25-6MO 0.125 in (3.2 mm) Sheet Evaluated in Acid Environments at Varied Exposure Temperatures for 192 Hours.

Environment	Temperature °C	Corrosion Rate	
		mpy	mm/a
0.2% HCl	Boiling	<0.10	<0.00
1.0% HCl	90	37.00	0.94
	70	0.02	<0.00
5.0% HCl	50	43.40	1.10
	30	10.60	0.27
$10.0\% H_2SO_4$	Boiling	10.40	0.26
	70	2.50	0.06
$60.0\% H_2SO_4$	70	9.40	0.24
	30	6.00	0.15
$95.0\% H_2SO_4$	50	18.90	0.48
	30	12.50	0.32
$85.0\% H_3PO_4$	90	0.24	0.01
$80.0\% HC_2H_3O_2$	Boiling	<0.10	<0.00

Microbiologically Influenced Corrosion (MIC)

Bacteria recognized as the agents of microbiologically influenced corrosion (MIC) live, thrive and multiply at pits, grain boundaries, weld undercuts, and inside the tube walls of pipes, heat exchanger tubing and other metallic structures associated with water. They come in a number of varieties but fall into two main classifications; anaerobic or reducing-type bacteria (sulfate-reducing and manganese-reducing), and pseudomonas, or oxygen consuming. This latter category is probably the most familiar in that it is a recognizable slime.

MIC can occur in a wide range of applications, especially where stagnant water conditions are present, where pipe systems are not properly flushed, where normally moving water stagnates at plant shutdowns, etc. The standard treatment is the injection of biocides into the water, chiefly chlorine derivatives. But the presence of free chlorine and the means of controlling it are all subject to variables which lessen the effectiveness of the treatment. Operating conditions, water temperatures, the climate of the region where the plant is located, available nutrient levels, available oxygen, evaporation, etc.; all can affect a chemical treatment and lead to a loss of biocide capability.

The susceptibility of the AISI 300 series of stainless steels to MIC has been well documented. One of the current research and testing programs to offer alternative and more resistant materials is focused on the investigation of alloys with a molybdenum content of 6% and higher. The University of Tennessee, Institute of Applied Microbiology carried out laboratory tests and field exposures at a nuclear generating site. The bacteria selected for laboratory tests were:

Pseudomonas Species: Obligate oxygen-consuming bacteria which are also characterized by the profuse quantities of extra-cellular polymers, or “slime”, that they produce. These organisms, perhaps the most ubiquitous, were isolated from nodules covering stainless steel weld leaks.

Acinetobacter Species: These bacteria have the ability to oxidize and precipitate ferrous iron in thermodynamically unfavorable conditions.

Bacillus Species: These obligately aerobic (oxygen-consuming) bacteria are characterized by having internal spores that can resist chemical and heat treatments of 212-250°F (100-121°C) for certain periods of time.

Sulfate-Reducing Bacteria (Desulfovibrio): The most cited bacteria involved in corrosion. These obligately anaerobic (cannot grow in the presence of oxygen) bacteria are protected from the oxygen by the growth of other organisms (such as Pseudomonas) on the surface biofilm. Under a mound of other bacteria, the sulfate-reducer not only exists but produces corrosive sulfide anions which accelerate the corrosion process.

Shigella Flexneri Strain A6F: This species, considered pathogenic and not generally used, has been shown to promote very fast crevice corrosion. The organism is characterized by a strong affinity for iron and production of organic acids.

The study concluded that in low total inorganic carbon, low chloride water, a slight increase in chromium, nickel and molybdenum from the 316L composition reduces the risk of MIC attack substantially. Further, iron base alloys, notably the 6%Mo austenitic stainless grades, are more resistant to MIC than 316 stainless steel. Additionally, in field testing of welded specimens in a fire protection system at a nuclear power station, types 304 and 316L stainless steels showed evidence of MIC after only 5 months’ exposure. Attack was in the form of rust deposits on the weld, heat affected zone and base metal, caused by iron oxidizing bacteria. Because of its resistance to MIC, LION alloy 25-6MO is being used in the waste-water piping systems of power plants.

Fabrication

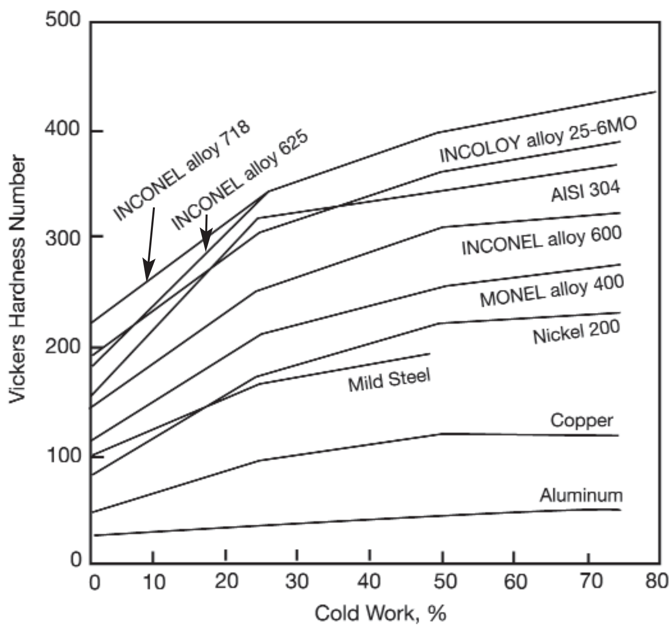
Hot working of LION alloy 25-6MO should be done in the 1800-2100°F (980-1150°C) temperature range. The alloy has good hot malleability, and large rounds or billets are readily forged into components such as valve bodies. Fittings and flanges have been hot pressed from plate stock.

The work hardening response is similar to that of LION alloy 800 and Type 304 stainless steel. A hardness comparison with other alloy systems is shown in Figure 6 where the hardness values are plotted as a function of the percentage cold work. Optimum ductility can be realized through an anneal at 2150°F (1175°C) although recrystallization of the grain structure can be achieved at lower temperatures.

Annealing has to be done with some caution, since all of the 6% molybdenum alloys have the tendency to suffer from catastrophic oxidation if processed under the wrong conditions. Stagnant oxidizing conditions must be avoided, particularly when heating the alloy above 1700°F (925°C). Attack can also occur at crevice points where flat rolled products are laid on flat surfaces or against one another, thereby resulting in differential furnace atmosphere conditions. Forced gas and air flows in the furnace are recommended. Cooling after annealing should be a rapid air cool or water quench.

Prolonged heating or cooling through the temperature range 950-1560°F (510-850°C) can cause precipitation of undesirable phases such as sigma, or some degree of sensitization, which may lead to intergranular attack or increased susceptibility to stress-corrosion cracking.

Figure 6 - The work-hardening rate for LION alloy 25-6MO is similar to that for AISI 304 stainless steel.



Machining

Machining characteristics of LION alloy 25-6MO are similar to those of other austenitic alloys. When using carbide insert tooling, rotating at 375 surface feet per minute (114 m/min) with a 0.15 in (0.4 mm) depth of cut, there was no difference in cutting characteristics between 316 stainless steel and LION alloy 25-6MO. When using high speed steel tooling, 316 stainless steel showed only a 20% improvement in tool life over LION alloy 25-6MO. This is probably due to the higher nickel content and increased strength of LION alloy 25-6MO. Consequently, LION alloy 25-6MO should be machined at slightly lower speeds than those used for stainless steel, using rigid tooling and optimum lubrication and cooling. Positive rake angles should be used with cemented carbide tooling. Cold-drawn, stress-relieved material is always preferred for machining, particularly when the smoothest finish is required. Work hardening characteristics of LION alloy 25-6MO are comparable to those of 304 stainless steel.

Although drilling tests showed 316 stainless steel easier to drill, LION alloy 25-6MO produced chips that broke better, allowing better chip control and lubrication. With the appropriate selection of tools, large tube sheets have been readily drilled.

Suggested specific machining parameters are as follows:

High Speed Steel						
Alloy	Speed		Depth of Cut		Feed	
	SFPM	m/min	in	mm	in/rev	mm/rev
AISI 316L	35	10.7	0.15	3.8	0.018	0.46
LION alloy 25-6MO	25	7.6	0.15	3.8	0.018	0.46
Carbide						
AISI 316L	375	114	0.15	3.8	0.018	0.46
LION alloy 25-6MO	350	107	0.15	3.8	0.018	0.46

Drilling with High-Speed Steel Tools				
Alloy	Speed		Feed	
	SFPM	m/min	in/rev	mm/rev
AISI 316L	30	9.1	0.005	0.03
LION alloy 25-6MO	25	7.6	0.005	0.03

Joining

LION alloy 25-6MO is readily weldable using conventional processes, such as gas tungsten arc welding (GTAW), gas metal arc welding (GMAW), shielded metal arc welding (SMAW), submerged arc welding (SAW) and plasma arc welding (PAW). Past corrosion studies have shown the 6% molybdenum alloys suffer a loss of corrosion resistance when autogeneously welded or welded with a matching composition filler metal. Higher molybdenum-containing (Mo >/= 9%), or overmatching filler metals (LIONfiller metal 625, LIONfiller metal C-276 or SONV-WELD® filler metal 686CPT®) should be specified. The equivalent welding electrodes are LION welding electrode 112, LIONwelding electrode C-276 or SONV-WELD welding electrode 686CPT. LION alloy 25-6MO can be joined to many types of austenitic or ferritic alloys with these welding products.

All welds should have a slightly larger root opening and included angle between 65° and 75° for V-joints compared to traditional austenitic stainless steels, allowing for improved torch access and lower base metal dilution. When using nickel base welding consumables to weld LION alloy 25-6MO, the torch should be manipulated aggressively, "puddling" within the weld joint to assure fusion to the base metal and previous weld passes. Ample, but not excessive, filler metal should be used to minimize the amount of base metal dilution, especially for the weld pass which will be exposed to the corrosive medium.

Welding procedures for LION alloy 25-6MO are significantly less demanding than those for the duplex stainless steels. Unlike the duplex stainless steels, which require a specific heat input (narrow welding parameter) range to maintain proper ferrite number for adequate mechanical and corrosion properties, LION alloy 25-6MO is fully austenitic, thus allowing for a wider heat input (wide welding parameter) range while maintaining adequate mechanical and corrosion properties. To minimize the amount of segregation which occurs in the fusion zone of the weld deposit, low heat input welding parameters should be incorporated into the welding process when possible to optimize the corrosion resistance of the weld. Inter-pass weld temperatures should not exceed 300°F (150°C) when joining thick sections.

Post-weld heat treatment is not required when overmatching filler metal is used. However, extensive testing has shown that a post-weld heat treatment at 2150°F/5 h/AC (1175°C) can improve the Critical Pitting Temperature (CPT) of the weld by as much as 18°F (10°C) for both autogeneous welds and those made with filler metal additions. Pickling after welding, with or without a post-weld solution anneal heat treatment, can further improve the CPT of the welded assembly. A post-weld pickle (nitric/hydrofluoric acid solution or paste) on the corrosive side of the welds for removing the heat tint, can *further* improve the corrosion resistance in bleaching environments. If pickling after welding is not possible, complete shielding on the corrosive side of the weld should be maintained to minimize the amount of heat tint.

For welding processes which require torch shielding gas, 100% argon is recommended, although, 100% helium and mixtures of argon/helium and argon/nitrogen can be used. Backing gases which can be used for shielding the opposing side of the material being welded are argon, helium, nitrogen or mixtures of these gases.

Table 17 - Typical Pulsed GMAW Parameters for 0.25 in (6.35 mm) Thicknesses at 120 Pulses Per Second[a]

Weld Pass	Current (amps)	Voltage (volts)	Background Voltage (volts)	Peak Current (amps)	Wire Feed Speed in/min (m/min)	Travel Speed in/min (m/min)
Root	180	25	21	400	430 (10.9)	19.5 (0.50)
Cap	180	25	21	400	430 (10.9)	22.5 (0.57)

[a]For Ni-Cr-Mo type filler metals 0.035 in (0.8 mm) diameter using argon shielding gas at 45 ft^3/h (1.3 m^3/h).

Table 18 - Typical Pulsed GTAW Parameters for 0.25 in (6.35 mm) Thicknesses [b]

Weld Pass	Current (amps)	Voltage (volts)	Wire Feed Speed		Travel Speed		Electrode Extension	
			in/min	(mm/min)	in/min	(mm/min)	in	(mm)
Root	100	9.5	10.0	(254)	2.0	(51)	0.25	(6.4)
2	125	11.0	7.3	(185)	2.9	(74)	0.25	(6.4)
Cap	125	11.0	8.3	(211)	3.2	(81)	0.25	(6.4)

[b]For Ni-Cr-Mo type filler metals 0.035 in (0.8 mm) diameter using argon shielding gas at 45 ft^3/h (1.3 m^3/h).

Table 19 - Typical SMAW Parameters for Ni-Cr-Mo Type Welding Electrodes

Electrode Diameter in (mm)	Currents (amps)	Voltage (volts)
3/32 (2.4)	40-65	24
1/8 (3.2)	65-90	25
5/32 (4.0)	90-125	26
3/16 (4.8)	125-160	26

Available Products and Specifications

Standard product forms are pipe, tube, sheet, strip, plate, round bar, forging stock and wire. The products are available in a wide range of sizes. Cold-rolled sheet and strip are produced to one-half ASTM/AMS thickness tolerances as standard practice.

Specifications for LION alloy 25-6MO (UNS N08926/W. Nr. 1.4529, formerly UNS N08925) include:

Plate, Sheet and Strip - ASTM B 625/ASME SB 625, ASTM A 240/ASME SB 240, ASTM B 480/ASME SB 480

Bar, Billet and Wire - ASTM B 649/ASME SB 649, ASTM B 472/ASME SB 472

Welded Pipe - ASTM B 673/ASME SB 673, ASTM B 775/ASME SB 775, ASTM B 804/ASME SB 804

Welded Tube - ASTM B 674/ASME SB 674, ASTM B 751/ASME SB 751

Seamless Pipe and Tube - ASTM B 677/ASME SB 677, ASTM B 829/ASME SB 829

ASME CODE CASES

ASME Code Case 2120
N-453 Welded pipe for Class 2 and Class 3
N-454 Wrought fittings for Class 2 and Class 3
N-455 Forged flanges and fittings for Class 2 and Class 3 construction

ASME Boiler and Pressure Vessel Code

LION alloy 25-6MO is approved under the Boiler and Pressure Vessel Code of the American Society of Mechanical Engineers. ASME Code Case 2120 (Ni-Fe-Cr-Mo-Cu-Low Carbon alloy N08926) defines the chemical composition, maximum allowable stress values, and the mechanical property requirements.