

INCOLOY® alloy 27-7MO is an advanced super-austenitic stainless steel offering corrosion resistance in most environments superior to 6% molybdenum super-austenitic stainless steels. In many environments alloy 27-7MO offers resistance approaching that of much more highly alloyed and expensive materials such as INCONEL alloys 625, 622, and C-276.

Alloy 27-7MO products typically contain 27% nickel, 22% chromium, 7.2% molybdenum, and 0.34% nitrogen. Its limiting chemical composition is presented in Table 1. The alloy's content of nickel and nitrogen produce a stable austenitic structure. By virtue of its content of molybdenum, chromium, and nitrogen, alloy 27-7MO offers excellent resistance to pitting and crevice corrosion. The nickel, nitrogen, and molybdenum provide resistance to reducing media while a high content of chromium offers resistance to oxidizing media. Alloy 27-7MO performs well in mixed acid environments, especially those containing oxidizing and reducing acids. The alloy's contents of nickel and nitrogen result in resistance to stress corrosion cracking and attack by caustic media. Alloy 27-7MO offers excellent resistance to corrosion in seawater and brine. It is resistant to the aggressive media encountered in air pollution control systems such as flue gas desulfurization equipment for high-sulfur coal-fired electric power utilities.

Applications for INCOLOY alloy 27-7MO are found in the pollution control, power, marine, chemical processing, pulp and paper and oil and gas industries. The alloy offers a unique combination of corrosion resistance, high strength and ease of fabrication at an economical price. Alloy 27-7MO is available in standard product forms including plate, sheet, rod, bar, wire rod, pipe, tube, and forging stock.

Table 1 - Limiting Chemical Composition, wt %

Nickel	26.0-28.0
Chromium.....	20.5-23.0
Molybdenum	6.5-8.0
Copper	0.5-1.5
Nitrogen.....	0.3-0.4
Iron	Balance*
Manganese	3.00 max.
Phosphorus	0.03 max.
Sulfur	0.01 max.
Silicon	0.5 max.
Carbon.....	0.020 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.

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Mechanical Properties

INCOLOY alloy 27-7MO exhibits an optimum combination of strength and ductility. Typical mechanical properties of alloy 27-7MO products are compared with those of similar alloys in Table 2. Alloy 27-7MO is normally supplied in the annealed condition.

Table 2 - Typical Mechanical Properties at Room Temperature

Alloy	Ultimate Tensile Strength, ksi	Yield Strength (0.2%), ksi	Elongation, %	Hardness Rockwell 'B'
INCOLOY alloy 25-6MO	95	45	42	90
INCOLOY alloy 27-7MO	120	60	50	95
INCONEL alloy 625	125	68	50	95
INCONEL alloy C-276	105	50	60	88

Corrosion Resistance

Pitting Resistance Equivalency Number - A means of comparing the corrosion resistance of alloys is by their Pitting Resistance Equivalency Number or 'PREN'. Alloys exhibiting higher PREN values are generally found to be more corrosion resistant than those with lower PREN values. The PREN can be calculated by several different equations based upon the chemical composition of the alloys. Some equations are applicable to stainless steels while others are better applied to nickel-based alloys. The equation used here is generally accepted as being applicable to a wide range of alloy compositions. When comparing alloys by their PREN it is absolutely necessary that the same equation be used for all materials to be compared. Comparing alloys by PRENs generated from different equations will give erroneous results. For more information on the use of PRENs to compare the corrosion resistance of materials, refer to the Special Metals publication, "High Performance Alloys for Resistance to Aqueous Corrosion" or visit the Special Metals website, www.specialmetals.com.

PRENs for alloy 27-7MO and similar materials are seen in Table 3. Based on these values of PREN, alloy 27-7MO would be predicted to offer significantly better corrosion resistance than alloy 25-6MO (and similar grades of super-austenitic stainless steel) and even superior performance to alloy 625, a significantly more highly alloyed (and costly) material. Alloy 27-7MO's resistance approaches that of alloy C-276.



INCOLOY® alloy 27-7MO

Table 3 - Pitting Resistance Equivalency Numbers (PREN)*

Alloy	% Ni	% Cr	% Mo	% Nb	% W	% N	PREN
INCOLOY alloy 25-6MO	25	20	6.5	0	0	0.20	35.8
INCOLOY alloy 27-7MO	27	22	7.2	0	0	0.34	43.0
INCONEL alloy 625	62	22	9	3.5	0	0	40.8
INCONEL alloy C-276	58	16	16	0	3.5	0	45.2

*PREN = %Cr + 1.5 (%Mo + %W + %Nb) + 30 (%N)

Critical Pitting Temperatures and Critical Crevice Corrosion Temperatures

Alloys may also be ranked by the threshold temperature at which they begin to be attacked in a given medium. Samples may be directly exposed to the medium which may induce pitting, or a crevice device may be attached which may induce crevice corrosion. The samples are exposed at increasing temperatures until corrosive attack occurs. The lowest temperature at which measurable corrosion takes place is defined as the Critical Pitting Temperature (CPT) or Critical Crevice Temperature (CCT), depending on whether or not a crevice device is attached to the sample. One test method is ASTM G48. Method C is a pitting test while Method D is a crevice corrosion test. The maximum test temperature is 85°C (185°F) as the test solution becomes unstable at higher temperatures. For procedural details, the reader is directed to the test procedure published by ASTM.

CPT and CCT values for some alloys are presented in Table 4. It is seen that alloy 27-7MO exhibits higher values than alloys 25-6MO and 625 and approaches those of alloy C-276.

Table 4 - CPT and CCT per ASTM G48 Test Methods C and D

Alloy	Critical Pitting Temperature		Critical Crevice Temperature	
	°C	°F	°C	°F
INCOLOY alloy 25-6MO	70	158	35	95
INCOLOY alloy 27-7MO	>85	>185	45	113
INCONEL alloy 625	>85	>185	35	95
INCONEL alloy C-276	>85	>185	50	122

Critical corrosion temperatures (CPT and CCT) for an alloy can be determined in essentially any corrosive aqueous medium. "Green Death" is a well known aggressive medium that is often used to evaluate the corrosion resistance of nickel-chromium-molybdenum alloys. It is composed of 11.9% H₂SO₄ + 1.3% HCl + 1% FeCl₃ + CuCl₂.

Table 5 - CPT and CCT determined in "Green Death" solution

Alloy	Critical Pitting Temperature		Critical Crevice Temperature	
	°C	°F	°C	°F
INCOLOY alloy 25-6MO	60	140	50	122
INCOLOY alloy 27-7MO	75	167	60	140
INCONEL alloy C-276	>Boiling	>Boiling	90	194

When tested by ASTM G 28, Method A, INCOLOY alloy 27-7MO wrought products exhibit a typical corrosion rate of 15 mpy.

Resistance to Corrosion by Seawater

Nickel-chromium alloys and austenitic and super-austenitic stainless steels containing molybdenum are well known for their resistance to corrosion in seawater and marine environments. A test program conducted at the LaQue Center for Corrosion Technology in Wrightsville Beach, North Carolina (a laboratory well known for marine corrosion testing) produced data showing that INCOLOY alloy 27-7MO offers corrosion-resistance superior to many of the corrosion-resistant alloys commonly used in marine service. Samples of sheet to which Teflon crevice devices were attached were exposed to flowing natural seawater at 30°C for 60 days. Results of the tests are reported in Table 6.

Table 6 - Crevice Corrosion in Seawater

Sample Material	PREN* of Test Material	Maximum Area Attacked (sq. mm)	Maximum Depth of Attack (mm)
316L Stainless Steel	21.2	1745	2.84
Super-Austenitic Stainless Steel (N08637)	37.0	80	0.01
INCOLOY alloy 27-7MO	41.6	0	0
INCONEL alloy 625	40.2	0	0
INCONEL alloy C-276	45.2	1	0.02

*PREN = %Cr + 1.5 (%Mo + %W + %Nb) + 30 (%N)

Table 7 - Corrosion Resistance in Acids, mpy(mm/a)

Test Media	Temperature, °C (°F)	INCOLOY Alloy 27-7MO	INCOLOY Alloy 25-6MO	UNS S31254	UNS N08367	INCONEL Alloy 625	INCONEL Alloy C-276
5% HCl	50 (122)	<0.1 (<0.0025)	38 (0.97)	51 (1.30)	46 (1.17)	<0.1 (0.0025)	0.5 (0.013)
95% H ₂ SO ₄	50 (122)	14 (0.36)	18 (0.46)	26 (0.66)	22 (0.56)	48 (1.22)	0.1 (0.0025)
10% H ₂ SO ₄ + 2% HCl	50 (122)	<0.1 (<0.0025)	43 (1.09)	38 (0.97)	46 (1.17)	<0.1 (0.0025)	<0.1 (<0.0025)

Resistance to Corrosion by Acids

The molybdenum content of alloy 27-7MO imparts resistance to reducing acids while the alloy's content of chromium results in resistance to oxidizing acids. With its balanced composition the alloy offers resistance to mixed acid environments. Thus, alloy 27-7MO is particularly useful for service in chemical processing and wet scrubbing systems for air pollution control.

Alloy 27-7MO and other materials were tested in hydrochloric acid (HCl), sulfuric acid (H₂SO₄), and a mixed acid solution. Results of those tests are reported in Table 7.

Resistance to Corrosion in Flue Gas Desulfurization Service

Components for service in flue gas desulfurization (FGD) systems for removal of sulfur dioxide from high sulfur coal-fired electric power utilities are exposed to very aggressive conditions. The environment inside the scrubbers is typically sulfuric acid at very low pH (1 or less) containing significant concentrations of halide ions (chlorides and fluorides) at temperatures up to 80°C (176°F).

To determine the performance of alloy 27-7MO and similar alloys, test specimens were exposed to a test solution that has been used to rank materials for FGD service. The solution contained 60% H₂SO₄ + 2.5% HCl + 0.2% HF + 0.5% flyash at 80°C (176°F). The test duration was one week. The resulting corrosion rates of the materials tested are reported in Table 8.

Table 8 - Corrosion Rates in a Simulated FGD Environment (60% H₂SO₄ + 2.5% HCl + 0.2% HF + 0.5% Flyash at 80°C)

Test Material	Corrosion Rate, mpy (mm/a)
INCOLOY alloy 25-6MO	199 (5.08)
INCOLOY alloy 27-7MO	153 (3.91)
INCONEL alloy 625	187 (4.77)
Ni-Cr-Mo alloy UNS N06059	47 (1.20)
INCONEL alloy 622	40 (1.02)
INCONEL alloy C-276	28 (0.71)
INCONEL alloy 686	23 (0.58)

Fabrication

INCOLOY alloy 27-7MO is readily fabricated, formed, and joined utilizing conventional equipment, techniques, and products. Forming can either be hot or cold.

Alloy 27-7MO is best hot worked in the temperature range of 1800 to 2100°F (980 to 1150°C). Annealing is done at 2100°F (1150°C). Stagnant oxidizing conditions must be avoided, particularly when heating the alloy above 1700°F (925°C), to prevent catastrophic oxidation. For example, attack can occur at crevice points when flat rolled products are stacked or laid against each other in a heat treating furnace. Forced gas and air flow are recommended. Cooling after heat treatment should be by rapid air cool or water quench. Prolonged exposure to temperatures between 950 and 1560°F (510 to 850°C) during heating or cooling can cause precipitation of undesirable phases such as sigma. It can also cause sensitization which may lead to intergranular attack or increased susceptibility to stress corrosion cracking.

The work hardening rate of alloy 27-7MO is similar to that of INCONEL alloy 600 or grade 316 or 317 stainless steel (Figure 1). Equipment used to form austenitic (300 series) stainless steels and nickel-based alloys will normally be suitable for forming alloy 27-7MO. The effect of cold work on the mechanical properties of INCOLOY alloy 27-7MO and similar products is shown in Table 9. Additional information on fabrication is available in the Special Metals publication, "Fabricating" or on the Special Metals website, www.specialmetals.com.

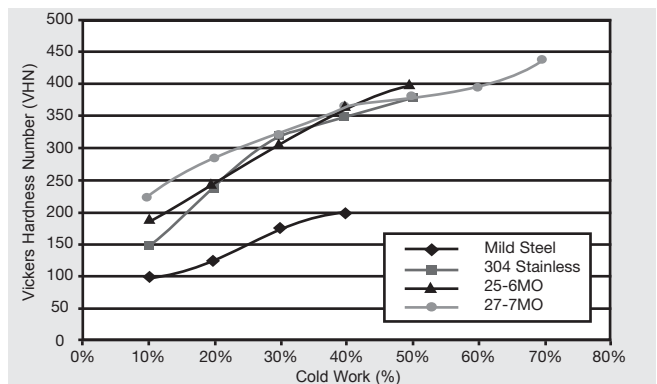


Figure 1. Effect of cold work on hardness.

Table 9 - Typical Room Temperature Mechanical Properties of Cold Worked Sheet

Cold Work, %	Tensile Strength, ksi (MPa)	0.2% Yield Strength, ksi (MPa)	Elongation, %
0	119 (820)	64 (441)	50
25	169 (1165)	149 (1027)	17
50	203 (1400)	188 (1296)	8
75	220 (1517)	200 (1379)	5

Welding

INCOLOY alloy 27-7MO products are readily joined using conventional welding processes such as gas tungsten-arc (GTAW), gas metal-arc (GMAW), shielded metal-arc (SMAW), submerged arc (SAW), and plasma arc (PAW). Alloy 27-7MO (like other super-austenitic alloys) suffers a loss of corrosion resistance when autogenously welded or when welded with matching composition filler metal. Thus, overmatching composition welding products (i.e., those with higher molybdenum content) such as INCONEL Filler Metals 622, C-276, and 686CPT and INCONEL Welding Electrodes 122 and C-276 and INCO-WELD Welding Electrode 686CPT are used. INCONEL Filler Metal 622 and INCONEL Welding Electrode 122 are considered optimum for joining the alloy to itself or to dissimilar materials. Maintaining low heat input will minimize elemental segregation in the fusion zone and optimize corrosion resistance. The interpass weld temperature should be limited to 300°F (150°C).

Post-weld heat treatment is not required when overmatching composition welding products are used. However, autogenous weldments should be post weld heat treated at 2000°F (1100°C) for 5 minutes and air cooled or water quenched. This heat treatment will generally somewhat improve the corrosion resistance of products welded with filler metal as well. Pickling after welding or heat treatment is also generally effective in optimizing corrosion resistance. Removal of heat tint on the back of the welded component is often beneficial in improving corrosion resistance.

Additional information on joining nickel alloys and stainless steels is available in the Special Metals publication, "Joining" or on the Special Metals website, www.specialmetals.com.

Machining

The machining characteristics of alloy 27-7MO are similar to those of other austenitic alloys. Products are readily machined in the annealed condition. Detailed information on machining alloy 27-7MO is available in the Special Metals publication, "Machining" or on the Special Metals website, www.specialmetals.com.

Available Products and Specifications

INCOLOY alloy 27-7MO is available in standard product forms - plate, sheet, strip, rod, bar, seamless pipes and tubes, wire rod and forging stock.

Application to ASTM for product specifications is being made. Until these specifications are issued, the buyer may reference specifications for INCOLOY alloy 25-6MO for commercial information. Contact Special Metals for assistance.

U.S.A.

Special Metals Corporation
 3200 Riverside Drive
 Huntington, WV 25705-1771
 Phone +1 (304) 526-5100
 +1 (800) 334-4626
 Fax +1 (304) 526-5643

4317 Middle Settlement Road
 New Hartford, NY 13413-5392
 Phone +1 (315) 798-2900
 +1 (800) 334-8351
 Fax +1 (315) 798-2016

United Kingdom

Special Metals Wiggin Ltd.
 Holmer Road
 Hereford HR4 9SL England
 Phone +44 (0) 1432 382200
 Fax +44 (0) 1432 264030

