Specification Sheet: Alloy C276
(UNS N10276) W. Nr. 2.4819

A Nickel-Molybdenum-Chromium Alloy with Excellent Corrosion Resistance in both Oxidizing and Reducing Environments

Alloy C276 (UNS N10276) is an austenitic nickel-molybdenum-chromium alloy with a small addition of tungsten. It is one of the premier corrosion resistant materials available for process industries. Alloy C276 has excellent corrosion resistance in both oxidizing and reducing environments.

The combination of the high molybdenum and chromium content, along with the addition of tungsten, make Alloy C276 highly resistant to chloride stress corrosion cracking, pitting, crevice corrosion and general corrosion.

Alloy C276 can operate in oxidizing atmospheres up to 1900°F (1038°C), however, the alloy lacks sufficient chromium content to operate successfully in the most strongly oxidizing environments like hot, concentrated nitric acid.

The low carbon content of Alloy C276 enables the alloy to be utilized in the as-welded condition. It cannot be hardened by heat treatment, but can be hardened by cold working. The alloy has a higher work-hardening rate than the austenitic stainless steels which should be taken into consideration.

Alloy C276 can be easily welded and processed utilizing standard shop fabrication practices for austenitic stainless steels and nickel based alloys.

Standards

ASTM ..... B 575

ASME ..... SB 575

Applications

- Air Pollution Control—flue gas desulfurization systems – stack liners, absorbers, ducts, dampers, stack gas re-heaters and fans
- Chemical Processing—heat exchangers, pressure vessels, tanks, evaporators, piping, flanges and fittings, pumps and valves
- Oil and Gas Production—sour gas service components
- Pharmaceutical Production—reactor vessels, piping, flanges and fittings, pumps and valves
- Pulp and Paper—bleaching vessels and digestors
- Waste Treatment—incinerators for toxic, industrial and municipal waste

Chemical Analysis

Weight % (all values are maximum unless a range is otherwise indicated)

Nickel	Balance	**Manganese**	1.0
Molybdenum	15.0 min.–17.0 max.	**Carbon**	0.01
Chromium	14.5 min.–16.5 max.	**Vanadium**	0.35
Iron	4.0 min.–7.0 max.	**Phosphorous**	0.04
Tungsten	3.0 min.–4.5 max.	**Sulfur**	0.03
Cobalt	2.5	**Silicon**	0.08

Physical Properties

Density
0.321 lbs/in^3
8.89 g/cm^3

Specific Heat
0.102 BTU/lb-°F @ 70°F
427 J/kg-°C @ 20°C

Modulus of Elasticity
29.8 x 10^6 psi
205.0 GPa

Thermal Conductivity 212°F (100°C)
67.9 BTU-in/ft^2-hr-°F
9.8 W/m-°C

Melting Range
2415–2500°F
1325–1370°C

Electrical Resistivity
51 Microhm-in at 75°F
1.30 Microhm-cm at 24°C

Mean Coefficient of Thermal Expansion

Temperature Range			
°F	°C	in/in °F	cm/cm °C
200	93	6.8 x 10^{-6}	12.24 x 10^{-6}
400	204	7.0 x 10^{-6}	12.60 x 10^{-6}
600	316	7.2 x 10^{-6}	12.96 x 10^{-6}
800	427	7.4 x 10^{-6}	13.32 x 10^{-6}

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Mechanical Properties

Typical Values at 68°F (20°C)

Yield Strength 0.2% Offset		Ultimate Tensile Strength		Elongation in 2 in.	Hardness
psi	(MPa)	psi	(MPa)	%	(max.)
41,000	283	100,000	690	40	100 Rockwell B

Corrosion Resistance

Alloy C276 is one of the premier corrosion resistant materials that performs exceptionally well in both oxidizing and reducing environments. It resists chloride stress corrosion cracking, pitting, crevice and general corrosion. The alloy is also resistant to carbide precipitation during welding enabling it to be utilized in the as-welded condition.

In chemical processing applications, the alloy has exceptional resistance to sulfuric, hydrochloric, formic, acetic and phosphoric acids. Alloy C276 performs well in environments containing acid chlorides, solvents and acetic anhydride, The alloy is one of the few grades that withstands wet chlorine gas, hypochlorite and chlorine dioxide solutions.

Alloy C276 is highly resistant to concentrated solutions of oxidizing salts including iron and copper chloride. It also performs well in seawater, especially under crevice conditions where other frequently used alloys such as stainless steel, Alloy 400 and Alloy 625 fail.

The operating conditions of flue gas desulfurization systems offer a challenging environment for corrosion resistant materials. Scrubber liquors and gas condensates often contain chlorides. Alloy C276 has been shown to withstand higher chloride levels than other grades before the onset of localized corrosion in these systems.

Alloy C276 is used extensively in the recovery and processing of sour natural gas which contains hydrogen sulfide along with carbon dioxide and chlorides. Carbon and alloy steels cannot withstand this corrosive environment. They are subject to failure by sulfide stress cracking or stress corrosion cracking. The rich chemistry of Alloy C276 makes it resistant to sour environments even at high temperatures in deep wells.

Corrosion Tests* in Hydrogen Fluoride Gas.
Test Duration, 36 Hours. Temperature 932–1112°F (500–600°C)

MATERIAL	Corrosion Rate, mpy (mm/a)	Comments
Alloy C-276	0.3 (0.01)	Iridescent tarnish film
Alloy 600	0.7 (0.02)	Iridescent tarnish film
Nickel 200	9 (0.23)	Black film
Nickel 201	14 (0.36)	Black film
Alloy 400	13 (0.33)	Adherent dark film
Alloy K-500	16 (0.41)	Adherent dark film
70/30 Copper-Nickel	16 (0.41)	Adherent dark film

** 7 lb HF per hour at 4 psig was passed through a laboratory furnace for hydroflourination of metal oxides.*

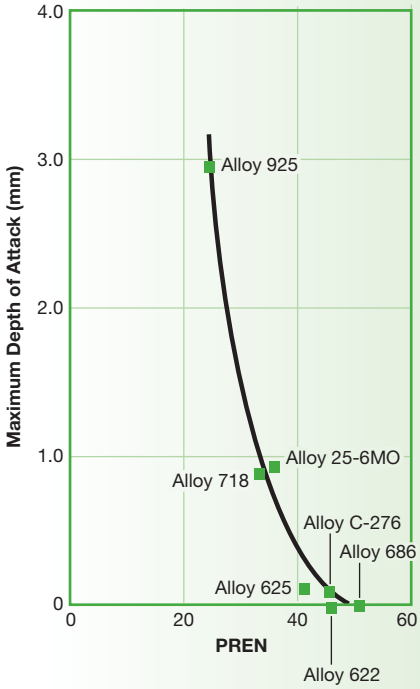
Maximum Pitting or Crevice Attack, mils (MM), in FGD Scrubber Slurry[a]

Alloy	Quencher	Absorber	Absorber Outlet	Outlet Duct	Bypass Duct
316L Stainless Steel	22 (0.56)	21 (0.53)	35 (0.89)[b]	35 (0.89)[b]	12 (0.30)
317LM Stainless Steel	20 (0.51)	22 (0.56)	29 (0.74)	33 (0.84)	29 (0.74)
Alloy 825	15 (0.38)	33 (0.84)	39 (0.99)	50 (1.27)[b]	10 (0.25)
Alloy 625	<2 (<0.05)	10 (0.25)	11 (0.28)	7 (0.18)	nil
Alloy C-276	nil	nil	<2 (<0.05)	nil	nil

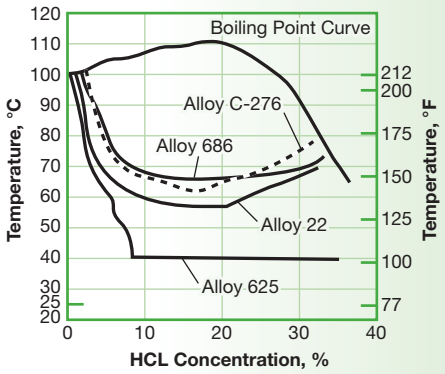
[a] *6-month exposure at 126°F (62°C), pH 5.5, 5000 ppm chlorides.*
[b] *Perforated.*

Maximum depth of attack by crevice corrosion after exposure to quiescent seawater at 85°F (29°C) for 180 days as a function of PREN*

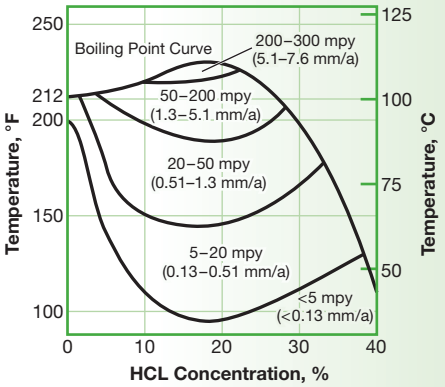
**PREN = % Cr + 1.5 (% Mo + % W = % Nb) + 30 (% N)*



Corrosion resistance in hydrochloric acid. The isocorrosion curves show tempatures and concentrations above which the corrosion rate exceeds 0.5 mm/a (20 mpy).



Iso-corrosion chart for Alloy C-276 in hydrochloric acid.

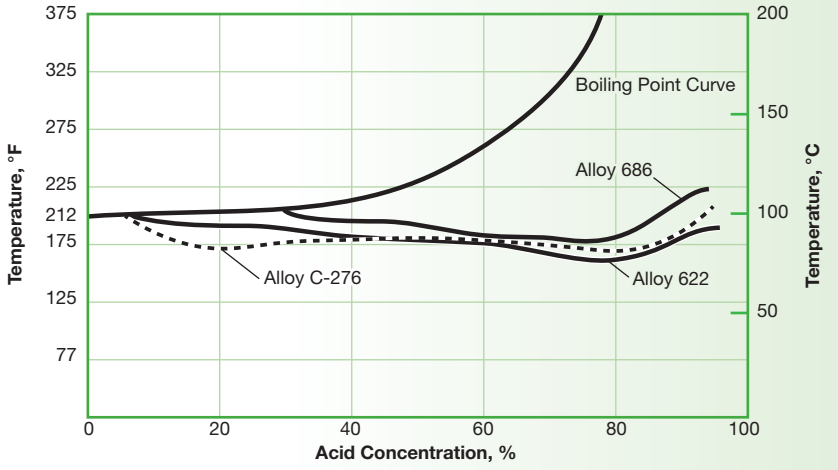


Pitting Resistance Equivalency Numbers (PREN)* for Corrosion-Resistant Alloys

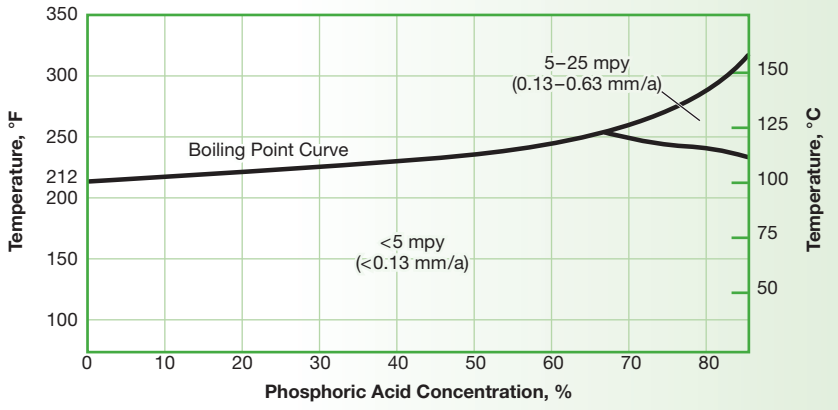
ALLOY	Ni	Cr	Mo	W	Nb	N	PREN
316 Stainless Steel	12	17	2.2	—	—	—	20.4
317 Stainless Steel	13	18	3.8	—	—	—	23.7
Alloy 825	42	21.5	3	—	—	—	26.0
Alloy G-3	44	22	7	—	—	—	32.5
Alloy 25-6MO	25	20	6.5	—	—	0.20	35.8
Alloy 625	62	22	9	—	3.5	—	40.8
Alloy C-276	58	16	16	3.5	—	—	45.2
Alloy 622	60	20.5	14	3.5	—	—	46.8
Alloy 686	58	20.5	16.3	3.5	—	—	50.8

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

Comparitive behavior of Ni-CR-MO alloys in sulfuric acid. The iso-corrosion lines indicate a corrosion rate of 20 mpy (0.51 mm/a).



Iso-corrosion chart for Alloy C-276 in phosphoric acid.



Fabrication Data

Alloy C276 can be easily welded and processed utilizing standard shop fabrication practices for austenitic stainless steels and nickel based alloys.

Hot Forming

The hot-working temperature range for Alloy C276 is 1600–2250°F (870–1230°C). The alloy should be water quenched after hot working. Heat treatment is recommended after hot working to ensure maximum corrosion resistance.

Cold Forming

Alloy C276 should be in the annealed condition for cold working. The alloy has a higher work-hardening rate than the austenitic stainless steels which should be taken into consideration. An in-process anneal may be necessary with a high degree of cold working. If the alloy undergoes greater than 15% deformation during cold working, a solution anneal may be necessary.

Welding

Alloy C276 can be readily welded by most standard processes including GTAW (TIG), PLASMA, GMAW (MIG/MAG) and SMAW (MMA). A post weld heat treatment is not necessary. Brushing with a stainless steel wire brush after welding will remove the heat tint and produce a surface area that does not require additional pickling.

Machining

Alloy C276 should preferably be machined in the annealed condition. Since Alloy C276 is prone to work–hardening, only low cutting speeds should be used and the cutting tool should be engaged at all times. Adequate cut depth is necessary to assure avoiding contact with the previously formed work-hardened zone.

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