JACQUET

ALLOY C276 DATA SHEET

UNS N10276

GENERAL PROPERTIES

Alloy C276 (UNS designation N10276) is a nickel-molybdenum-chromium-iron-tungsten alloy known for its corrosion resistance in a wide range of aggressive media. It is one of the most corrosion resistant alloys currently available. The high molybdenum content imparts resistance to localized corrosion such as pitting. The low carbon content minimizes carbide precipitation during welding to maintain resistance to intergranular attack in heat effected zones of weld joints. The alloy exhibits good high temperature strength and moderate oxidation resistance although the formation of embrittling high temperature precipitates will eventually occur.

The alloy is used extensively in the chemical processing, pollution control, pulp and paper and municipal waste treatment industries.

APPLICATIONS

CHEMICAL PROCESSING:

- Heat exchangers;
- Reaction vessels;
- Evaporators;
- Transfer piping.

POLLUTION CONTROL (FGD)

- Stack liners;
- Ducts;
- Dampers;
- Fans;
- Fan housings.

OTHER

- Pickling hooks;
- Pickling tanks.

STANDARDS

Product form	Specifications			
	ASTM	ASME	DIN	VdTÜV
Plate sheet and Strip	B575/B906	SB575/SB906	17750	400/12.98
Seamless, Pipe and Tubing	B622/B829	SB622/SB829	17751	400/12.98
Welded Pipe and Tubing	B626/B751 B619/B775	SB626/SB751 SB619/SB775	17751	400/12.98
Rod, Bar and Forgings	B462/B564/B574	SB564/SB574	17752/17753/17754	400/12.98

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CHEMICAL COMPOSITION

C	Mn	S	Si	Cr	Ni	Fe	Mo	Co	V	W	P
0.01 **max**	1.00 **max**	0.03 **max**	0.08 **max**	14.50→16.50	**Balance**	4.00→7.00	15.00→17.00	2.50 **max**	0.35 **max**	0.30→4.50	0.05 **max**

MECHANICAL PROPERTIES

Typical room temperature tensile properties for annealed material.

Yield Strength 0.2% Offset		Ultimate Tensile Strength		Elongation	Hardness
psi	MPa	psi	MPa	% in 2"	Rb minimum
50.3	347	107.4	741	67	89

Typical short time tensile properties as a function of temperature. Material tested was annealed to 2100 °F (1150 °C).

Temperature		Yield Strength 0.2% Offset		Tensile Strength		Elongation
°F	°C	Ksi	MPa	Ksi	MPa	% in 2"
−320	−198	82	565	140	965	45
150	101	70	480	130	895	50
70	21	60	415	115	790	50
200	93	55	380	105	725	50
400	204	50	345	103	710	50
600	316	46	315	98	675	55
800	427	42	290	95	665	60
1000	538	39	270	93	640	60

PHYSICAL PROPERTIES

Density

0.321 **lb/in**^{3}

8.89 **g/cm**^{3}

Magnetic Permeability

75 **°F,** 200 **oersted** 1.0002

Specific Heat

0.102 **Btu/lb-°F**

425 **J/kg-°K**

Specific Gravity

8.90

Melting Range

2415→2500 **°F**

1325→1370 **°C**

THERMAL PROPERTIES

Temperature		Linear coefficient of expansion		Thermal conductivity	
°F	°C	10^{-6} in/in/°F	10^{-6} cm/cm/°C	Btu/h-ft-°F	W/m-°K
−270	−168	–	–	4.2	7.3
−100	−73	–	–	5.0	8.7
70	21	–	–	5.9	10.2
200	93	6.2	11.2	6.4	11.0
400	204	6.7	12.0	7.5	13.0
600	316	7.1	12.8	8.7	15.1
800	427	7.3	13.2	9.8	17.0
1000	538	7.4	13.4	11.0	19.0

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ELEVATED TEMPERATURE DYNAMIC MODULUS PROPERTIES

Temperature	Young's Modulus	Shear Modulus	
°F	10^3 ksi	10^3 ksi	Poisson's ratio
70	31.30	11.81	0.33
100	31.18	11.75	0.33
200	30.77	11.57	0.33
300	30.35	11.40	0.33
400	29.92	11.23	0.33
500	29.42	11.05	0.33

IMPACT RESISTANCE

Temperature		Charpy V-Notch Impact Strength	
°F	°C	ft-lbs	Joules
−320	−198	180	245
70	21	240	325
392	200	240	325

CORROSION RESISTANCE

////**Alloy C276** is one of the most universally corrosion resistant materials available today. It is used in a variety of environments from moderately oxidizing to strong reducing conditions. The limiting factor when dealing with strong oxidizing environments is the low chromium content, which means that hot, concentrated nitric acid environments are NOT desirable. **Alloy C276** has exceptional resistance to sulfuric acid and hydrochloric acid, acid chlorides, solvents, formic and acetic acids, acetic anhydride, wet chlorine gas, hypochlorites and chlorine solutions. It also has excellent resistance to phosphoric acid at all temperature ranges below boiling and at concentrations lower than 65 %.

////**Alloy C276** exhibits excellent resistance to pitting, stress corrosion cracking and to oxidizing atmospheres up to 1 900 °F (1 038 °C). The alloy also has excellent resistance to corrosion by seawater especially under crevice conditions which induce attack in other commonly used materials.

////**Alloy C276** is especially effective in Scrubber (FGD) applications where it is able to withstand the higher chloride environments before the onset of localized corrosion.

////This alloy is also one of the top performing materials for use in oilfield applications, especially in the recovery and handling of “sour” natural gas, which contains hydrogen sulfide and carbon dioxide and chlorides. The high nickel, chromium and molybdenum content of **Alloy C276** make it extremely resistant to these environments.

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////GENERAL CORROSION DATA

	Corrosion Rates MPY (mm/a)						
	T316 Stainless steel		Al-6XN		Altemp 625	Alloy C276	
Test Environment (boiling)	Base Metal Sample	Welded Sample (0.080" thick)	Base Metal Sample	Welded Sample (0.047" thick)	Base Metal Sample	Base Metal Sample	Welded Sample (0.048" thick)
20% Acetic Acid	0.12(0.003)	0.12(0.003)	0.14(0.0036)	0.07(0.0018)	0.30(0.0076)	0.50(0.013)	0.24(0.006)
20% Formid Acid	10.92(0.277)	10.32(0.262)	4.55(0.116)	5.61(0.142)	5.0(0.13)	2.76(0.07)	1.92(0.049)
20% Oxalic Acid	40.08(1.02)	39.00(0.991)	10.92(0.277)	10.80(0.274)	6.0(0.15)	11.28(0.29)	10.20(0.259)
20% Phosphoric Acid	0.20(<0.01)	6.12(0.155)	0.26(0.007)	0.25(0.006)	0.36(0.01)	0.36(0.01)	0.24(0.006)
20% Sulfamic Acid	63.60(0.007)	62.16(1.58)	29.57(0.751)	14.98(0.381)	4.80(0.12)	2.64(0.07)	2.40(0.061)
20% Sulfuric Acid	636(16.2)	641(16.3)	84.4(2.14)	92.3(2.34)	25.3(064)	13.92(0.35)	19.80(0.503)
20% Sodium Bisulfate	41.64(1.06)	41.64(1.06)	23.96(0.609)	13.56(0.344)	3.96(0.10	2.64(0.07)	2.16(0.055)

////SIMULATED SCRUBBER (FGD) ENVIRONMENT CORROSION DATA

	Corrosion Rate MPY (mm/a)	
"Green Death Solution" (Boiling)	T316 Stainless steel	Alloy C276
7 % Sulfuric Acid, 3 % Hydrochloric Acid, 1 % Cupic Chloride, 1 % Ferric Chloride	Destroyed	26.5(0.67)

////CHLORIDE STRESS SOLUTION

Test Solution (Boiling)	Alloy Tested as U-Bend Samples Result and Test Time (Hours)			
	T316 Stainless steel	Al-6XN	Altemp 625	Alloy C276
42 % Magnesium Chloride	Fail (24 Hours)	Mixed (1 000 Hours)	Resist (1 000 Hours)	Resist (1 000 Hours)
33 % Lithium Chloride	Fail (100 Hours)	Resist (1 000 Hours)	Resist (1 000 Hours)	Resist (1 000 Hours)
26 % Sodium Chloride	Fail (300 Hours)	Resist (1 000 Hours)	Resist (1 000 Hours)	Resist (1 000 Hours)

////PITTING AND CREVICE CORROSION

The chrome, molybdenum and tungsten content of **Alloy C276** produces such a high level of pitting corrosion resistance that the alloy is considered inert to seawater and is used in many seawater, brine and high chloride environments.

	Temperature of Onset at Crevice Corrosion Attack in 10 % (Ferric Chloride - 6 % H_2O) solution per ASTM Procedure G-48	
Alloy	°F	°C
T316 Stainless steel	27	2.5
Al-6XN	113	45
Altemp 625	113	45
Alloy C276	140*	60*

*Generally considered beyond the stability of the Ferric Chloride Solution

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FORMABILITY

Alloy C276 is capable of being formed in the same manner as standard austenitic stainless steels. However, as the material is considerably stronger than conventional austenitic stainless steels, higher loads are required to cause the material to deform. During cold working, the material work hardens more rapidly than austenitic stainless steels. The combination of high initial strength and work hardening rate may necessitate the need for intermediate anneals if the cold deformation is extensive.

EFFECT OF COLD REDUCTION ON PROPERTIES OF PLATE ANNEALED AT 2150 °F (1177 °C)

Cold	Yield Strength (0.2 % Offset)		Tensile Strength		
Reduction (%)	psi	MPa	psi	MPa	Elongation (%)
0	60	415	115	790	50
10	90	620	129	890	40
20	125	860	145	1000	30
30	155	1070	168	1160	15
40	180	1240	194	1340	10
50	195	1345	210	1450	7

ELECTRICAL RESISTIVITY

Temperature °F		Temperature °C	
Temperature	ohm cmil/ft	Temperature	μΩ cm
−270	–	−168	–
−100	0	−73	–
0	–	20	–
77	739.2	25	122.9
100	–	100	123.7
200	743.8	200	124.5
400	749.3	300	125.7
600	757.7	400	126.0
800	760.3	500	127.7
1000	772.5	600	129.9
1200	781.5	700	129.7
1400	773.9	800	128.2
1600	768.3	900	127.4
1800	766.2	1000	127.1
2000	757.7	1100	–

HEAT TREATMENT

Alloy C276 mill products are furnished in the solution heat-treated condition. This requires the material to be heated to a range of 1900→2100 °F (1040→1150 °C) and rapidly cooled. For optimal corrosion resistance, **Alloy C276** should be cooled from solution heat-treatment temperatures to black in two minutes or less.

Stress relief heat treatments are not effective with this alloy and a full anneal should be conducted where stress relief heat treatment of other materials would be considered.

Material designated for heat treatment should be clean and free of grease, oils and other potential sources of carbon.

WELDING

////**Alloy C276** can be readily welded by conventional processes used for austenitic stainless steels. When choosing a welding method, those that minimize the degradation of corrosion resistance should be used. Gas tungsten-arc welding (GTAW), gas metal-arc (GMAW), shielded metal-arc (coated electrode) or resistance welding do minimal damage to the corrosion resistance of the heat affected zone. Oxyacetylene welding should not be used because of probable carbon contamination from the acetylene flame. Similarly, submerged arc fluxes containing carbon or silicon should not be used due to carbon pick-up. Minimum heat input consistent with suitable penetration should be used to avoid hot cracking.

////WELD JOINTS

Weld joint design should be determined by practices set forth in the ASME Boiler and Pressure Vessel Code.

////EDGE PREPARATION

The preferred way to achieve the correct profile for correct fit-up is by a method such a machining or waterjet cutting which will not work harden the edge the way that shearing will. Sheared edges should be ground back before welding to eliminate the work hardened area.

////WELD WIRE AND FILLER METAL

Wire, filler metal and electrodes are commercially available for welding **Alloy C276** to itself. For situations where it is necessary to join **Alloy C276** to materials such as other nickel alloys or stainless steels, and if the welds will be exposed to a corrosive environment, the welding products should be comparable in corrosion resistance to the more noble alloy.

POST-WELD HEAT TREATMENT

////For most corrosive service applications, **Alloy C276** can be used in the welded condition. For more severe environments, the material should be solution heat treated for optimum corrosion resistance.

DESCALING AND CLEANING

////A clean surface is required for **Alloy C276** to achieve optimal corrosion resistance.

////Surface oxides formed during annealing or welding deplete chromium very close to the scale-base metal interface. As such, acid treatments which remove surface metal under scaled surfaces are necessary for optimum corrosion resistance.

////The corrosion resistant properties of **Alloy C276** make descaling difficult. Stainless steel wire brushing or grit blasting is advisable, followed by immersion in a mixture of nitric and hydrofluoric acids and a through water rinse.