JACQUET

Alloy 400

Alloy 400 - Nickel-Base Alloy

(UNS N04400)

INTRODUCTION

Alloy 400 (UNS N04400) is a ductile nickel-copper alloy with resistance to a variety of corrosive conditions. The alloy is most frequently applied in a range of environments ranging from mildly oxidizing through neutral and to moderately reducing conditions. An additional application area of the material is in marine environments and other nonoxidizing chloride solutions.

The alloy has a long history of use as a corrosion resistant material, dating back to the early twentieth century when it was developed as an attempt to use a high copper content nickel ore. The nickel and copper contents of the ore were in the approximate ratio which is now formally specified for the alloy.

As with commercially pure nickel, the Alloy 400 is low in strength in the annealed condition.
For this reason, a variety of tempers are used which have the effect of increasing the strength level of the material.

PRODUCT FORMS

Alloy 400 alloy is available in plate, sheet, strip and long product forms.

SPECIFICATIONS & CERTIFICATES

The following widely published specifications are applicable to the Alloy 400 alloy.

Product Form	Specification			
	ASTM	ASME	AMS	Federal or Military
Plate, Sheet and Strip	B 127	SB 127	4544	QQ-N-281
Seamless Pipe and/or Tube	B 163 B165	SB 163 SB 165	4574	Mil-T-1368 Mil-T-23520
Rod, Bar and Forgins	B164 B564	SB 164 SB 564	4675	Mil-T-24106 QQ-N-281
Wire	-	-	4730 4731	QQ-N-281

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TYPICAL COMPOSITION

Element	Percent
Carbon	0.10
Manganese	0.50
Phosphorus	0.005
Sulfur	0.005
Silicon	0.25
Aluminum	0.02
Nickel + Cobalt	Balance*
Copper	32.0
Iron	1.0
*By difference - For material furnished to QQ-N-281, lead, tin and zinc are each typically <0.003.	

PHYSICAL PROPERTIES

Density

0.319 lb/in^3

8.83 g/cm^3

Specific Gravity

8.83

Magnetic Permeability

In the annealed condition the alloy is often moderately to faintly magnetic at room temperature. The Curie temperature of the material is close to room temperature. Above the Curie temperature, the material is nonmagnetic. The Curie temperature is influenced by minor composition variations, so some heats of material will be magnetic at room temperature and others will not.

Specific Heat

Room temperature values

0.10 Btu/lb - °F

430 Joules/kg•K

Electrical Resistivity

51.0 Microhm - cm

Linear Coefficient of Thermal Expansion			
Average from 70°F (21°C) to °F (°C)		10-6/°F	10-6/°C
200	(93)	7.7	13.9
400	(204)	8.6	15.5
600	(316)	8.8	15.8
800	(427)	8.9	16.0
1000	(538)	9.1	16.4

Thermal Conductivity			
Temperature		BTU•ft/h•ft²•°F	W/m•K
°F	°C		
200	(93)	14.0	24.1
400	(204)	16.1	27.8
600	(316)	18.9	31.0
800	(427)	19.8	34.3
1000	(538)	22.0	38.1

CORROSION RESISTANCE

The Alloy 400 is more resistant than commercially pure nickel (UNS N02200) to corrosion under reducing conditions, and more resistant than refined copper alloys under oxidizing conditions.

Alloy 400 is not useful in highly oxidizing acids such as nitric or nitrous acids.

In moderately reducing acids, neutral or alkaline solutions, Alloy 400 alloy may be considered for use. The alloy is resistant to most alkalies, salts, organic substances and atmospheric conditions. The alloy is a consideration for cooler alkaline caustic conditions, although high temperature, high stress and high concentrations of caustic have produced caustic stress corrosion cracking in the material. The alloy is used in reducing acids like sulfuric and hydrochloric, especially in the absence of aeration and oxidizing species. The alloy is exceptionally resistant to chloride stress corrosion cracking.

Application in waters, including sea and brackish water is a major use of the material.

The alloy is attacked in sulfur-bearing gases above about 700°F (371°C) and molten sulfur attacks the alloy at temperatures over about 500°F (260°C).

MECHANICAL PROPERTIES

The following are typical room temperature mechanical properties of Alloy 400.

The lowest strength and most ductile condition are the annealed condition with typical properties as shown below.

Properties Applicable to Plate, Sheet and Strip			
Yield Strength psi (MPa)	Ultimate Tensile Strength psi (MPa)	Elongation percent in 2" (51mm)	Elastic Modulus (E) psi (GPa)
35,000 (240)	75,000 (520)	45	$26x10^6$ (180)

Material furnished in the as hot rolled condition is somewhat stronger as indicated below.

Properties Applicable to Plate			
Yield Strength psi (MPa)	Ultimate Tensile Strength psi (MPa)	Elongation percent in 2" (51mm)	Elastic Modulus (E) psi (GPa)
45,000 (310)	80,000 (550)	30	$26x10^6$ (180)

The highest strength and least ductile condition is in the heavily cold rolled condition with typical properties as indicated below.

Properties Applicable to Sheet and Strip (Plated is not Funished in This Condition)			
Yield Strength psi (MPa)	Ultimate Tensile Strength psi (MPa)	Elongation percent in 2" (51mm)	Elastic Modulus (E) psi (GPa)
95,000 (650)	110,000 (760)	5	$26x10^6$ (180)

Charpy V-Notch impact values for all of these conditions ranged from 100 to 240 ft-lbs (135 to 325 Joules) at room temperature.

Short Time Elevated Temperature Properties

The following table illustrates the short time high temperature tensile properties of the Alloy 400 ™ alloy in the annealed condition. Creep resistance should be considered above about 650°F (343°C).

Test Temperature °F (°C)	0.2% Offset Yield Strength psi (MPa)	Ultimate Tensile Strength psi (MPa)	Percent Elongation
70 (21)	31,000 (215)	82,000 (565)	48
200 (93)	30,000 (205)	80,000 (550)	47
400 (204)	26,000 (180)	75,000 (520)	45
600 (316)	25,000 (175)	73,000 (505)	46
800 (427)	23,000 (160)	70,000 (480)	48
1000 (538)	21,000 (145)	53,000 (370)	40

FORMABILITY

The Alloy 400 exhibits excellent cold forming characteristics normally associated with chromium nickel stainless steels. The alloy has a lower work hardening rate than Types 301 or 304 stainless steel and can be used in multiple draws forming operations where relatively large amounts of deformation occur between anneals.

WELDABILITY

Alloy 400 may be joined by a variety of processes including gas tungsten-arc, gas metal-arc and shielded metal-arc processes. In all of these processes thorough cleaning of the joint area is necessary to avoid embrittlement from such sources as lubricants and paints. The material must be free of scale for best welding.

Welding procedures for Alloy 400 are similar to those used for austenitic stainless steels. Neither preheating, nor post-weld heat treatment are generally required. Joint design is similar to that used for austenitic stainless steels with two exceptions. The first is the need to accommodate the sluggish nature of the molten weld metal, necessitating a joint design sufficiently open to allow full filler wire access to fill the joint. The second is the high thermal conductivity and purity of the material which makes weld penetration lower than in austenitic stainless steels.

HEAT TREATMENT

The anneal cycle conducted on the Alloy 400 is typically in the 1400 to 1800°F (760 to 980°C) range for short times at temperature. The purpose is to soften the material after forming operations while maintaining a relatively fine grain size.

Annealing should be done in an atmosphere as free of sulfur compounds as possible since sulfur will embrittle the material in extended exposure time at the anneal temperature range.

A low temperature stress relief may be conducted on cold deformed material by heating to approximately 575°F (300°C) for 1 to 3 hours.

A large percentage of the Alloy 400 is put into service without final heat treatment. This is done to increase the strength of the material.

COMMON APPLICATIONS

- Feedwater and steam generator tubes in power plants
- Brine heater and recompression evaporator in saltworks
- Sulfuric and hydrofluoric acid alkylation
- Heat exchangers in the chemical industry
- Plating components for mineral oil distillation plants
- Splash zone lining on offshore platforms
- Impellers and pump shafts in marine technology
- Refining plants for the production of nuclear fuel
- Pumps and valves in production lines for tetrachlorethylene (perchlorethylene) and chlorinated plastics
- Heating tubes for monoethanolamine (MEA)
- Sour-gas resistant components for oil and gas production