ALLOY Data

Carpenter MP35N Alloy

Identification

UNS Number

• R30035

Type Analysis

Carbon (Maximum)	0.03 %	**Manganese (Maximum)**	0.15 %
Phosphorus (Maximum)	0.015 %	**Sulfur (Maximum)**	0.010 %
Silicon (Maximum)	0.15 %	**Chromium**	19.00 to 21.00 %
Nickel	33.00 to 37.00 %	**Molybdenum**	9.00 to 10.50 %
Cobalt	Balance	**Titanium (Maximum)**	1.00 %
Boron	0.010 %	**Iron (Maximum)**	1.00 %

General Information

Description

Carpenter MP35N* alloy is a nonmagnetic, nickel-cobalt-chromium-molybdenum alloy possessing a unique combination of ultrahigh tensile strength (up to 300 ksi [2068 MPa]), good ductility and toughness, and excellent corrosion resistance. In addition, this alloy displays exceptional resistance to sulfidation, high temperature oxidation, and hydrogen embrittlement.

The unique properties of MP35N alloy are developed through work hardening, phase transformation and aging. If the alloy is used in the fully work hardened condition, service temperatures up to 750°F (399°C) are suggested.

MP35N alloy is normally produced by vacuum induction melting (VIM), followed vacuum arc remelting (VAR).

* MP35N is a trademark of SPS Technologies, Inc. MP is a registered trademark of SPS Technologies, Inc.

Applications

Because of its unique combination of properties, MP35N alloy has been used in a wide variety of applications.

MP35N alloy has been used in fasteners, springs, nonmagnetic electrical components and instrument parts in medical, seawater, oil and gas well, and chemical and food processing environments.

Corrosion Resistance

MP35N alloy possesses excellent resistance to sulfidation, high temperature oxidation, hydrogen embrittlement, saline solutions and most mineral acids.

This alloy features exceptional resistance to stress corrosion cracking at very high strength levels under severe environmental conditions that can crack most conventional alloys. It is also highly resistant to other forms of localized attack, such as pitting and crevice corrosion.

In seawater environments, this alloy is virtually immune to general, crevice and stress corrosion, regardless of strength level or process condition.

MP35N alloy is an extremely noble metal. This can result in galvanic corrosion when electrically coupled with more active metals such as carbon steel, Type 316 stainless, or K-Monel.**

MP35N alloy is included in NACE MR-01-75*** to a maximum hardness of Rockwell C35 (maximum hardness of Rockwell C48 in specific cold reduced plus aged conditions). This material requirement lists sulfide stress cracking resistant materials for exposure to sour environments, such as in gas and oil well service.

**Monel is a trademark of the Special Metals Corporation group of companies.
***NACE Standard MR-01-75 Material Requirement -
Sulfide Stress Cracking Resistant Metallic Material for Oil Field Equipment, 1980 Revision and May 1981 Supplement.

Important Note: *The following 5-level rating scale is intended for comparative purposes only. Corrosion testing is recommended; factors which affect corrosion resistance include temperature, concentration, pH, impurities, aeration, velocity, crevices, deposits, metallurgical condition, stress, surface finish and dissimilar metal contact.*

Nitric Acid	Good	Sulfuric Acid	Good
Phosphoric Acid	Good	Acetic Acid	Excellent
Sodium Hydroxide	Good	Salt Spray (NaCl)	Excellent
Sea Water	Excellent	Sour Oil/Gas	Excellent
Humidity	Excellent		

Properties

Physical Properties

Specific Gravity

--	8.43	

Density

--	0.3040	lb/in³

Mean Coefficient of Thermal Expansion

70.00 °F, 200.0 °F	7.10	x 10^{-6} in/in/°F
70.00 °F, 400.0 °F	7.60	x 10^{-6} in/in/°F
70.00 °F, 600.0 °F	8.20	x 10^{-6} in/in/°F
70.00 °F, 800.0 °F	8.30	x 10^{-6} in/in/°F
70.00 °F, 1000.0 °F	8.70	x 10^{-6} in/in/°F

Mean coefficient of thermal expansion

Temperature		10^{-6}/°F	10^{-6}/°C
70°F to	21°C to		
200	93	7.1	12.8
400	204	7.6	13.7
600	316	8.2	14.8
800	427	8.3	14.9
1000	538	8.7	15.7

Thermal Conductivity

-300 °F	45.00	BTU-in/hr/ft²/°F
-100 °F	63.00	BTU-in/hr/ft²/°F
70 °F	78.00	BTU-in/hr/ft²/°F
200 °F	88.00	BTU-in/hr/ft²/°F
400 °F	104.0	BTU-in/hr/ft²/°F
600 °F	118.0	BTU-in/hr/ft²/°F
800 °F	133.0	BTU-in/hr/ft²/°F
1000 °F	148.0	BTU-in/hr/ft²/°F
1200 °F	162.0	BTU-in/hr/ft²/°F

Thermal conductivity

Temperature °F	Temperature °C	Btu-in/ft² • hr • °F	W/m • K
-300	-184	45	6.5
-100	- 73	63	9.1
70	21	78	11.2
200	93	88	12.7
400	204	104	15.0
600	316	118	17.0
800	427	133	19.2
1000	538	148	21.3
1200	649	162	23.4

Modulus of Elasticity (E)

79 °F, Annealed	33.8 x 10 ^{3} ksi
450 °F, Annealed	31.3 x 10 ^{3} ksi
900 °F, Annealed	29.2 x 10 ^{3} ksi
79 °F, Cold Worked and Aged	34.1 x 10 ^{3} ksi
450 °F, Cold Worked and Aged	31.8 x 10 ^{3} ksi
900 °F, Cold Worked and Aged	29.2 x 10 ^{3} ksi

Modulus of elasticity

Temperature		Annealed		Cold Worked and Aged	
°F	°C	ksi x 10³	MPa x 10³	ksi x 10³	MPa x 10³
78	26	33.76	232.8	34.05	234.8
450	232	31.33	216.0	31.76	219.0
900	482	29.15	201.0	29.19	201.3

Modulus of Rigidity (G)

78.0 °F, Annealed	12.1 x 10 ^{3} ksi
450 °F, Annealed	11.3 x 10 ^{3} ksi
900 °F, Annealed	10.2 x 10 ^{3} ksi
78.0 °F, Cold Worked and Aged	11.7 x 10 ^{3} ksi
450 °F, Cold Worked and Aged	10.8 x 10 ^{3} ksi
900 °F, Cold Worked and Aged	9.83 x 10 ^{3} ksi

Electrical Resistivity

-300 °F	593.0 ohm-cir-mil/ft
-100 °F	608.0 ohm-cir-mil/ft
70.0 °F	621.0 ohm-cir-mil/ft
200 °F	632.0 ohm-cir-mil/ft
400 °F	648.0 ohm-cir-mil/ft
600 °F	664.0 ohm-cir-mil/ft
800 °F	679.0 ohm-cir-mil/ft
1000 °F	694.0 ohm-cir-mil/ft
1200 °F	709.0 ohm-cir-mil/ft

Electrical resistivity

Temperature		ohms c/mf	microhm-mm
°F	°C		
-300	-184	593	986
-100	- 73	608	1011
70	21	621	1033
200	93	632	1051
400	204	648	1078
600	316	664	1104
800	427	679	1129
1000	538	694	1154
1200	649	709	1179

Melting Range

--	2400.000 to 2625.000 °F

Shear modulus

Temperature		Annealed		Cold Worked and Aged	
°F	°C	ksi x 10^3	MPa x 10^3	ksi x 10^3	MPa x 10^3
78	26	12.09	83.36	11.74	80.95
450	232	11.29	77.84	10.84	74.74
900	482	10.24	70.60	9.83	67.78

Magnetic Properties

Magnetic Permeability

-319.0 °F	1.0014 Mu
-220.0 °F	1.0012 Mu
-99.00 °F	1.0010 Mu
-17.00 °F	1.0010 Mu
77.00 °F	1.0009 Mu
246.0 °F	1.0009 Mu

Magnetic Permeability at Various Temperatures — Carpenter MP35N Alloy

Temperature		Magnetic Permeability
°F	°C	
-319	-195	1.0014
-220	-140	1.0012
- 99	- 73	1.0010
- 17	- 27	1.0010
77	25	1.0009
246	119	1.0009

Typical Mechanical Properties

Charpy V-Notch Impact Strength — Carpenter MP35N Alloy
280 ksi (1931 MPa) Strength Level

Condition	Test Temperature		Impact Strength	
	°F	°C	ft-lb	J
Cold Drawn 49% and Aged 1200°F (649°C) 4 Hrs./A.C.	75 -100 -200 -320 -423	24 - 73 -129 -196 -253	18.9 17.1 15.3 16.1 13.5	25.6 23.2 20.7 21.8 18.3

Room Temperature R.R. Moore Bending Fatigue Strength — Carpenter MP35N Alloy

Condition	Stress for Cycles to Failure					
	10^6		10^7		10^8	
	ksi	MPa	ksi	MPa	ksi	MPa
Cold Drawn and Aged to 220 ksi (1517 MPa) Strength Level	100	689	90	620	88	606
Cold Drawn and Aged to 265 ksi (1827 MPa) Strength Level	108	744	99	682	97	668

Smooth Stress Rupture Properties — Carpenter MP35N Alloy

Condition	Test Temperature		Stress for Rupture in:					
			10 hours		200 hours		1000 hours	
	°F	°C	ksi	MPa	ksi	MPa	ksi	MPa
220 ksi (1517 MPa) Strength Level	1000 1100 1200	538 593 649	187 165 133	1288 1137 916	167 133 93	1151 916 641	138 96 —	951 661 —
265 ksi (1827 MPa) Strength Level	1000 1100 1200	538 593 649	209 177 137	1440 1219 944	179 138 93	1233 951 641	143 96 —	985 661 —

Typical Room and Elevated Temperature Tensile Properties — Carpenter MP35N Alloy
Aged 1050°F (565°C) 4 hours, air cooled

Condition	Test Temperature		Ultimate Tensile Strength		0.2% Yield Strength		% Elongation	% Reduction of Area
	°F	°C	ksi	MPa	ksi	MPa		
0.750" (19.05 mm) Dia. Cold Drawn 33% to 0.611" (15.52 mm) Dia.	Room		227	1565	217	1496	14.2	60
	300	149	200	1397	190	1310	13.9	59
	400	204	193	1331	186	1282	13.5	58
	500	260	190	1310	181	1248	13.0	57
	600	316	184	1269	177	1220	13.0	55
	700	371	186	1282	176	1214	13.0	51
	800	426	187	1289	176	1214	12.5	47
1.240" (31.5 mm) Dia. Cold Drawn 53% to 0.850" (21.59 mm) Dia.	Room		294	2027	285	1965	10.0	46
	300	149	266	1834	255	1758	8.0	45
	400	204	260	1793	248	1710	8.0	44
	500	260	253	1744	241	1662	8.0	43
	600	316	250	1724	236	1627	8.0	41
	700	371	245	1689	230	1586	7.0	22
	800	426	240	1655	225	1551	4.0	8

Typical Room Temperature Tensile Properties — Carpenter MP35N Alloy

% Cold Reduction	Ultimate Tensile Strength		0.2% Yield Strength		% Elongation	% Reduction of Area	Hardness Rockwell C
	ksi	MPa	ksi	MPa			
Work Strengthened							
0	135	931	60	414	70	70	8
15	155	1069	118	814	41	70	29
25	170	1172	150	1034	28	65	34
35	194	1336	154	1062	22	67	42
45	228	1572	189	1303	17	62	47
55	265	1827	205	1413	12	50	47
65	280	1931	235	1620	11	49	50
Work Strengthened + Aged 1000°F (538°C) 4 Hrs., Air Cooled							
0	135	931	60	414	68	77	7
15	158	1089	125	862	39	70	33
25	186	1282	175	1207	24	65	39
35	203	1400	195	1344	21	62	43
45	257	1772	251	1731	12	52	46
53	300	2068	290	1999	10	48	50

Heat Treatment

Annealing

MP35N alloy should be annealed at 1900/2000°F (1038/1093°C) for one to four hours, followed by air cooling.

Age

After work hardening, MP35N alloy can be aged in the temperature range of 800/1200°F (427/649°C) for increased strength. The alloy will respond to aging only if first work strengthened. No increase in strength will result from aging annealed material.

For optimum mechanical properties, cold worked MP35N alloy should be aged at 1000/1100°F (538/593°C) for 4 hours, then air cooled.

Relevant specification requirements should be consulted prior to any heat treating operations.

Workability

Hot Working

MP35N alloy should be forged from approximately 2150°F (1177°C). To prevent surface tearing, deformation should not be continued below approximately 1600°F (871°C). MP35N alloy forges and rolls similarly to Carpenter Waspaloy alloy or Pyromet® alloy 718.

Cold Working

The strength levels developed by MP35N alloy are primarily the result of mechanical working. Mechanical working can take the form of either cold or warm working. In warm working, temperatures should be kept below 800°F (427°C).

Work hardening can be accomplished by drawing, rolling, extruding, forging, swaging or a combination of these methods.

Both strength and hardness increase in a nearly linear manner with percent cold work. As expected, ductility decreases with increasing percent cold work; however, even with large amounts of deformation, excellent ductility is retained.

When determining the strength level developed, working operations which deform the metal similarly can be considered additive. Thus, all work strengthening need not be performed at the mill. Some working can be done when the part is formed into its final shape.

Machinability

MP35N alloy is difficult to machine in any heat treated condition. Machinability studies have shown that this alloy possesses machining characteristics superior to those of Waspaloy, a widely used standard for nickel-cobalt-chromium-base alloy machinability. Machining parameters for MP35N alloy are similar to those used for Waspaloy alloy.

Weldability

MP35N alloy can be successfully TIG welded. In general, welding properties are similar to those of Type 304 stainless; similar preparations and precautions should be employed.

The welding parameters should be adjusted to ensure that the heat input per pass is low. Approximately one-half to two-thirds of the heat input used to weld maraging steel and Type 304 stainless should be used.

From TIG welding studies, joint efficiency was found highest if the material is welded in the annealed condition. If a filler metal is required, a matching composition should be used.

Other Information

Applicable Specifications

- AMS 5758
- AMS 5845
- AMS 5844
- ANSI/ASTM F562

Forms Manufactured

- Bar-Rounds
- Strip
- Wire-Rod
- Billet
- Wire

Technical Articles

- Unique Properties Required of Alloys for the Medical and Dental Products Industry