CARPENTER TECHNOLOGY

DATASHEET

MP35N

Applicable specifications: AMS 5758, AMS 5844, AMS 5845, ANSI/ASTM F562

Associated specifications: UNS R30035

Type analysis

Single figures are nominal except where noted.

Cobalt	Balance	**Nickel**	33.00–37.00 %	**Chromium**	19.00–21.00 %
Molybdenum	9.00–10.50 %	**Iron**	Max 1.00 %	**Titanium**	Max 1.00 %
Manganese	Max 0.15 %	**Silicon**	Max 0.15 %	**Carbon**	Max 0.025 %
Boron	Max 0.015 %	**Phosphorus**	Max 0.015 %	**Sulfur**	Max 0.010 %

Forms manufactured

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

Description

MP35N is a nonmagnetic, nickel-cobalt-chromium-molybdenum alloy possessing a unique combination of ultra-high 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 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 is produced by vacuum induction melting (VIM), followed vacuum arc remelting (VAR).

Key Properties:

- Ultra-high tensile strength
- Ductility and toughness
- Excellent corrosion resistance

Markets:

- Aerospace
- Industrial
- Energy
- Medical

Applications:

- Fasteners
- Springs
- Instrument parts
- Nonmagnetic electrical components

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Corrosion resistance

MP35N 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 which 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 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.[1]

MP35N is included in NACE MR-01-75 to a maximum hardness of 35 HRC (maximum hardness of 51 HRC 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.

For additional oil and gas corrosion resistance information, please see the MP35N white paper at CarpenterTechnology.com/Resources.

IMPORTANT NOTE:
The following 4-level rating scale is intended for comparative purposes only. Corrosion testing is recommended; factors that 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		

[1]Monel is a trademark of the Special Metals Corporation group of companies.

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Physical properties

PROPERTY	At or From	English Units	Metric Units
SPECIFIC GRAVITY	—	8.43	8.43
DENSITY	—	0.308 lb/in^3	8525 kg/m^3
MEAN CTE	70 to 200°F (21 to 93°C)	7.10 x 10^{-6} in/in/°F	12.8 x 10^{-6} length/length/°C
	70 to 400°F (21 to 204°C)	7.60 x 10^{-6} in/in/°F	13.7 x 10^{-6} length/length/°C
	70 to 600°F (21 to 316°C)	8.20 x 10^{-6} in/in/°F	14.8 x 10^{-6} length/length/°C
	70 to 800°F (21 to 427°C)	8.30 x 10^{-6} in/in/°F	14.9 x 10^{-6} length/length/°C
	70 to 1000°F (21 to 538°C)	8.70 x 10^{-6} in/in/°F	15.7 x 10^{-6} length/length/°C
THERMAL CONDUCTIVITY	-300°F (184°C)	45.00 Btu-in/hr/ft^2/°F	6.5 W/m·K
	-100°F (-73°C)	63.00 Btu-in/hr/ft^2/°F	9.1 W/m·K
	70°F (21°C)	78.00 Btu-in/hr/ft^2/°F	11.2 W/m·K
	200°F (93°C)	88.00 Btu-in/hr/ft^2/°F	12.7 W/m·K
	400°F (204°C)	104.0 Btu-in/hr/ft^2/°F	15.0 W/m·K
	600°F (316°C)	118.0 Btu-in/hr/ft^2/°F	17.0 W/m·K
	800°F (427°C)	133.0 Btu-in/hr/ft^2/°F	19.2 W/m·K
	1000°F (538°C)	148.0 Btu-in/hr/ft^2/°F	21.3 W/m·K
	1200°F (649°C)	162.0 Btu-in/hr/ft^2/°F	23.4 W/m·K
ELASTIC MODULUS	78°F (26°C), Annealed	33.76 x 10^3 ksi	232.8 x 10^3 MPa
	450°F (232°C), Annealed	31.33 x 10^3 ksi	216.0 x 10^3 MPa
	900°F (482°C), Annealed	29.15 x 10^3 ksi	201.0 x 10^3 MPa
	78°F (26°C), Cold Wrkd+Aged	34.05 x 10^3 ksi	234.8 x 10^3 MPa
	450°F (232°C), Cold Wrkd+Aged	31.76 x 10^3 ksi	219.0 x 10^3 MPa
	900°F (482°C), Cold Wrkd+Aged	29.19 x 10^3 ksi	201.3 x 10^3 MPa
RIGIDITY MODULUS	78°F (26°C), Annealed	12.1 x 10^3 ksi	83.43 x 10^3 MPa
	450°F (232°C), Annealed	11.3 x 10^3 ksi	77.91 x 10^3 MPa
	900°F (482°C), Annealed	10.2 x 10^3 ksi	70.33 x 10^3 MPa
	78°F (26°C), Cold Wrkd+Aged	11.7 x 10^3 ksi	80.67 x 10^3 MPa
	450°F (232°C), Cold Wrkd+Aged	10.8 x 10^3 ksi	74.46 x 10^3 MPa
	900°F (482°C), Cold Wrkd+Aged	9.83 x 10^3 ksi	67.78 x 10^3 MPa
SHEAR MODULUS	78°F (26°C), Annealed	12.09 x 10^3 ksi	83.36 x 10^3 MPa
	450°F (232°C), Annealed	11.29 x 10^3 ksi	77.84 x 10^3 MPa
	900°F (482°C), Annealed	10.24 x 10^3 ksi	70.60 x 10^3 MPa
	78°F (26°C), Cold Wrkd+Aged	11.74 x 10^3 ksi	80.95 x 10^3 MPa
	450°F (232°C), Cold Wrkd+Aged	10.84 x 10^3 ksi	74.74 x 10^3 MPa
	900°F (482°C), Cold Wrkd+Aged	9.83 x 10^3 ksi	67.78 x 10^3 MPa

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ELECTRICAL RESISTIVITY	-300°F (-184°C)	593.0 ohm-cir-mil/ft	986 microohm·cm
	-100°F (-73°C)	608.0 ohm-cir-mil/ft	1011 microohm·cm
	70°F (21°C)	621.0 ohm-cir-mil/ft	1033 microohm·cm
	200°F (93°C)	632.0 ohm-cir-mil/ft	1051 microohm·cm
	400°F (204°C)	648.0 ohm-cir-mil/ft	1078 microohm·cm
	600 °F (316°C)	664.0 ohm-cir-mil/ft	1104 microohm·cm
	800°F (427°C)	679.0 ohm-cir-mil/ft	1129 microohm·cm
	1000°F (538°C)	694.0 ohm-cir-mil/ft	1154 microohm·cm
	1200°F (649°C)	709.0 ohm-cir-mil/ft	1179 microohm·cm
MELTING RANGE	—	2400 to 2630°F	1316 to 1443°C

Magnetic properties

MAGNETIC PERMEABILITY AT VARIOUS TEMPERATURES

TEMPERATURE		MAGNETIC PERMEABILITY
°F	°C	μ
-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

CONDITION	TEST TEMPERATURE		CHARPY V-NOTCH IMPACT STRENGTH	
	°F	°C	FT-LB	J
Work strengthened and aged to 280 ksi (1931 MPa) strength level	75	24	18.9	25.6
	-100	-73	17.1	23.2
	-200	-129	15.3	20.7
	-320	-196	16.1	21.8
	-423	-253	13.5	18.3

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ROOM TEMPERATURE R.R. MOORE BENDING FATIGUE STRENGTH

CONDITION	STRESS FOR CYCLES TO FAILURE					
	10^5		10^7		10^9	
	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

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	538	187	1288	167	1151	138	951
	1100	593	165	1137	133	916	96	661
	1200	649	133	916	93	641	—	—
265 ksi (1827 MPa) strength level	1000	538	209	1440	179	1233	143	985
	1100	593	177	1219	138	951	96	661
	1200	649	137	944	93	641	—	—

TYPICAL ROOM AND ELEVATED TEMPERATURE TENSILE PROPERTIES — AGED 1050°F (565°C) 4 HOURS, AIR COOLED

CONDITION	TEST TEMPERATURE		0.2% YIELD STRENGTH		ULTIMATE TENSILE STRENGTH		ELONGATION	REDUCTION OF AREA
	°F	°C	ksi	MPa	ksi	MPa	%	%
0.850 in (21.59 mm) diameter bar work strengthened and aged per AMS 5845	Room		285	1965	294	2027	10.0	46
	300	149	255	1758	266	1834	8.0	45
	400	204	248	1710	260	1793	8.0	44
	500	260	241	1662	253	1744	8.0	43
	600	316	236	1627	250	1724	8.0	41
	700	371	230	1586	245	1689	7.0	22
	800	426	225	1551	240	1655	4.0	8

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TYPICAL ROOM TEMPERATURE TENSILE PROPERTIES

CONDITION	COLD REDUCTION	0.2% YIELD STRENGTH		ULTIMATE TENSILE STRENGTH		ELONGATION	REDUCTION OF AREA	HARDNESS
	%	ksi	MPa	ksi	MPa	%	%	HRC
Work strengthened	0	60	414	135	931	70	70	8
	15	118	814	155	1069	41	70	29
	25	150	1034	170	1172	28	65	34
	35	154	1062	194	1336	22	67	42
	45	189	1303	228	1572	17	62	47
	55	205	1413	265	1827	12	50	47
	65	235	1620	280	1931	11	49	50
Work strengthened and aged 1000°F (538°C) 4 hours, air cooled	0	60	414	135	931	68	77	7
	15	125	862	158	1089	39	70	33
	25	175	1207	186	1282	24	65	39
	35	195	1344	203	1400	21	62	43
	45	251	1731	257	1772	12	52	46
	53	290	1999	300	2068	10	48	50

Heat treatment

Annealing	MP35N should be annealed at 1900/1950°F (1038/1066°C) for 1 to 4 hours, followed by air cooling.
Age	After work hardening, MP35N can be aged in the temperature range of 1000/1200°F (538/649°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 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.

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Workability

Hot Working	MP35N should be forged from approximately 2100°F (1149°C). To prevent surface tearing, deformation should not be continued below approximately 1600°F (871°C). MP35N forges and rolls similarly to Waspaloy or Pyromet® 718.
Cold Working	The strength levels developed by MP35N 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, pilgering, and flowforming, 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 that 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 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 are similar to those used for Waspaloy.
Weldability	MP35N can be successfully TIG welded. In general, welding properties are similar to those of Type 304 stainless; similar preparations and precautions should be employed. 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. While welding MP35N is possible and in many cases necessary, the act of welding may remove the material's ability to age harden. MP35N requires mechanical stress (cold work) in conjunction with thermal processes to achieve age hardening. Welding would remove any prior cold work that would exist in and near the heat affected zone.

For additional information, please contact your nearest sales office:
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