MONEL® nickel-copper alloy R-405 (UNS N04405) is the free-machining grade of alloy 400. Its greater sulfur content enhances machinability. It has essentially the same corrosion resistance and physical properties as alloy 400, but a slightly different range of mechanical properties. Alloy R-405 is used chiefly for automatic-screw-machine stock and is not generally recommended for other applications. The composition is shown in Table 1.

Thermal expansion of alloy R-405 is shown in Table 2. The values for physical constants and other thermal properties of MONEL alloy 400 may be used for MONEL alloy R-405 and are shown in Tables 3 and 4.

Table 1 - Limiting Chemical Composition, %, of MONEL Alloy R-405

Nickel (plus Cobalt)	63.0 min.
Carbon	0.3 max.
Manganese	2.0 max.
Iron	2.5 max.
Sulfur	0.025-0.060
Silicon	0.5 max.
Copper	28.0 - 34.0

Table 2 - Thermal Expansion of MONEL Alloy R-405

Temperature, °F	Mean Linear Expansion, [a] in./in./°F x 10^{-6}
200	7.6
400	8.4
600	8.7
800	9.0
1000	9.2
1200	9.4
1400	9.7
1600	9.9
1700	10.0
1800	10.1
2000	10.4

[a] Between 70°F and temperature shown.

Table 3 - Physical Constants of MONEL Alloy 400 [a]

Density, g/cm³	8.80
lb/in.³	0.318
Melting Range, °F	2370-2460
°C	1300-1350
Modulus of Elasticity, 10^3 ksi	
Tension	26.0
Compression	26.0
Torsion	9.5
Poisson's Ratio	0.32
Curie Temperature, °F	70-120
°C	21-49

[a] These values also apply to MONEL alloy R-405, the free-machining version of MONEL alloy 400.

Table 4 - Thermal Properties of MONEL Alloy 400

Temperature		Mean Linear Expansion[b]		Thermal Conductivity[a]		Specific Heat[a]		Electrical Resistivity[a,c]	
°F	°C	in/in/°F x 10^{-6}	µm/m•°C	Btu-in/h/ft²/°F	W/m•°C	Btu/lb/°F	J/kg•°C	ohm-circ mil/ft	µΩ•m
-320	-200	-	-	-	-	-	-	205	0.360
-300	-180	6.1	11.1	113	16.5	0.050	223	-	-
-200	-130	6.4	11.4	130	18.2	0.078	320	-	-
-100	-70	6.7	12.1	139	19.8	0.088	378	-	-
70	21	-	-	151	22.0	0.102	427	307	0.511
200	100	7.7	14.2	167	24.0	0.105	445	322	0.537
400	200	8.6	15.2	193	26.9	0.110	459	337	0.559
600	300	8.8	15.7	215	30.1	0.114	470	346	0.574
800	400	8.9	16.1	238	33.4	-	-	355	0.587
1000	500	9.1	16.3	264	36.5	-	-	367	0.603
1200	600	9.3	16.6	287	39.4	-	-	379	0.620
1400	700	9.6	17.0	311	42.4	-	-	391	0.639
1600	800	9.8	17.4	335[d]	45.5[d]	-	-	403	0.658
1800	900	10.0[d]	17.7	360[d]	48.8[d]	-	-	415	0.675
2000	1000	10.3[d]	18.1[d]	-	-	-	-	427	0.692

[a] These values also apply to MONEL alloy R-405, the free-machining version of MONEL alloy 400.
[b] Annealed material. Between 70°F (21°C) and temperature shown.
[c] Annealed material.
[d] Extrapolated.

MONEL® alloy R-405

Mechanical Properties

The ranges of nominal mechanical properties of MONEL alloy R-405 rod and bar are shown in Table 5.

Fatigue strength of alloy R-405 in various conditions is shown in Table 6. Toughness of the material is shown by the impact data in Tables 7, 8 and 9. The tension and torsion data are from Catlin and Mudge. Table 10 gives compressive properties found for the alloy.

Alloy R-405 is approved as a material of construction under Section VIII (Pressure Vessels - Division 1) of the ASME Boiler and Pressure Vessel Code and in Section III, Nuclear Vessels, of the Code.

Table 7 - Impact Strength[a] of MONEL Alloy R-405 Rod

Condition	Impact Strength, ft-lb	
	Izod	Charpy U Notch
Hot-Rolled	96	187
Cold-Drawn	99	140
Annealed	120+	196

[a] Tested at room temperature. None of the specimens was completely fractured.

Table 5 - Nominal Mechanical Property Ranges of MONEL Alloy R-405 Rod and Bar [a]

Condition	Tensile Strength, ksi	Yield Strength (0.2% Offset), ksi	Elongation, %	Hardness	
				Brinell (3000 kg)	Rockwell B
Annealed	70 - 85	25 - 40	50 - 35	110 - 140	60 - 76
Hot-Finished	75 - 90	35 - 60	45 - 30	130 - 170	72 - 86
Cold-Drawn, As-Drawn	85 - 115	50 - 105	35 - 15	160 - 245	85 - 23C

[a] The ranges shown are composites for various product sizes and therefore are not suitable for specification purposes.

Table 6 - Fatigue Strength of MONEL Alloy R-405 Rod [a]

Condition	Fatigue Strength (10^8 Cycles), ksi	Tensile Strength, ksi	Ratio, Fatigue Strength/ Tensile Strength
Annealed	30.0	75.5	0.40
Hot-Rolled	36.0	80.0	0.45
Cold-Drawn, As-Drawn	36.5	90.5	0.40
Cold-Drawn, Stress-Equalized[b]	40.0	95.0	0.42

[a] Rotating-beam tests of polished specimens in air at room temperature and 10,000 rpm.
[b] 525°F/3 hr.

Table 8 - Tension Impact Strength of MONEL Alloy R-405 Rod

Condition	Tension Impact			Tensile Properties				
	Impact Strength, [a] ft-lb	Elongation in 3.54 in., %	Reduction of Area, %	Tensile Strength, ksi	Yield Strength (0.2% Offset), ksi	Elongation in 2 in., %	Reduction of Area, %	Hardness, Brinell (3000 kg)
Cold-Drawn 24%, Stress-Relieved	90	17.0	64.7	83.15	74.35	28.0	66.6	180
Annealed 1450°F/3 hr	148	35.0	69.1	73.35	28.00	44.5	70.1	116

[a] Specimens completely broken.

Table 9 - Charpy Torsion Impact Strength of MONEL Alloy R-405 Rod

Temper	Impact Strength		Angle of Twist, [a] degree	Hardness, Brinell (3000 kg)
	ft-lb	ft-lb/sq in.		
Hot-Rolled	30	606	100.5	121
Cold-Drawn 24%, Stress-Relieved	34	687	100.5	180
Annealed 1450°F/3 hr	30	606	102.0	116

[a] Gage length about 3/16 in.

Table 10 - Compressive Properties of MONEL Alloy R-405 Rod

Temper	Compression		Tension			
	Yield Strength (0.01% Offset), ksi	Yield Strength (0.2% Offset), ksi	Tensile Strength, ksi	Yield Strength (0.01% Offset), ksi	Yield Strength (0.2% Offset), ksi	Elongation, %
Hot-Rolled	26.0	34.0	76.0	33.0	36.0	39.5
Cold-Drawn[a]	51.0	66.0	83.0	62.0	74.0	28.0
Annealed[b]	23.0	26.0	73.0	25.0	28.0	44.5

[a] Stress-equalized at 525°F after cold drawing.
[b] Cold-drawn + 1450°F/3 hr, F.C.

Working Instructions

MONEL alloy R-405 is fabricated, pickled and heat-treated by the same procedures as for alloy 400. The alloy is not recommended for forging.

Machining

MONEL alloy R-405 was especially developed for good machinability and is recommended for use with automatic screw machines. The nickel-copper sulfides resulting from the sulfur in its composition act as chip breakers. Because of these inclusions the surface finish of the alloy is not as smooth as that of MONEL alloy 400.

Some results obtained in actual production runs in commercial screw machines are shown in the publication "Machining" on the Special Metals Corporation website, www.yttzhj.com.

Joining

MONEL alloy R-405 may be joined by standard welding, brazing and soldering techniques. In general, processes and procedures are the same as for MONEL alloy 400. More information on joining can be found in the SMC publication "Joining" on the website www.yttzhj.com.

Available Products and Specifications

MONEL alloy R-405 is designated UNS N04405 and is normally furnished only in the form of rod and bar. Standard sizes of these products are available from stock. Wire and specialty products are available from converters.

Applicable specifications are:

Bar and Rod: ASME SB-164, ASTM B-164, Federal QQ-N-281, SAE AMS 4674 & 7234, Military MIL-N-894, NACE MR-01-75.

Publication Number SMC-085