SPECIAL METALS

BRIGHTRAY® alloy B

A nickel-iron-chromium electrical-resistance alloy for use at operating temperatures up to 2010°F (1100°C). It contains rare-earth additions for increased oxidation resistance, especially under conditions of frequent switching or wide temperature fluctuations. The alloy has a relatively high temperature coefficient of resistance. Used for heating elements in domestic appliances and industrial equipment.

BRIGHTRAY® alloy C

A nickel-chromium electrical-resistance alloy for use at operating temperatures up to 2100°F (1150°C). It contains rare-earth additions for increased oxidation resistance, especially under conditions of frequent switching or wide temperature fluctuations. The alloy has a low temperature coefficient of resistance, making it suitable for control resistors. Used for heating elements in domestic appliances and industrial equipment.

Standard Product Forms

Sheet, strip and wire.

Wire.

Major Specifications

UNS N06004
DIN 17742
Werkstoff Nr. 2.4867

UNS N06003
Werkstoff Nr. 2.4869

Limiting Chemical Composition, %

Limiting[a]

Ni[b] .... 57.0 min.	Si ..... 0.75 – 1.6	S ..... 0.01 max.
Fe ... Remainder	Mn ..... 1.0 max.	
Cr ..... 14 – 18	C ..... 0.15 max.	

[a]As in UNS N06004. Also contains rare-earth additions. [b]Plus Co.

Limiting[a]

Ni[b] .... Remainder	Fe ..... 1.0 max.	S ..... 0.01 max.
Cr ..... 19 – 21	Mn ..... 1.0 max.	
Si ..... 0.75 – 1.6	C ..... 0.15 max.	

[a]As in N06003. Also contains rare-earth additions. [b]Plus Co.

Physical Constants and Thermal Properties

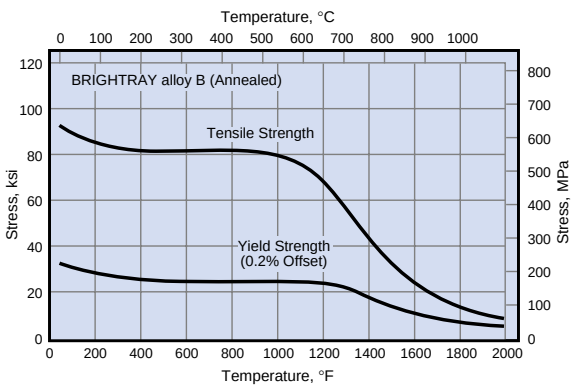
Density, lb/in^3	0.302
g/cm^3	8.36
Melting Range, °F	2550 – 2590
°C	1400 – 1420
Specific Heat, Btu/lb • °F	0.110
J/kg • °C	461
Permeability at 200 Oersted (15.9 kA/m)	1.68
Coefficient of Expansion, 68 – 212°F, 10^{-6} in/in • °F	6.9
20 – 100°C, µm/m • °C	12.5
Electrical Resistivity, ohm • circ mil/ft	662
µΩ • m	1.10
Temp. Coefficient of Resistance, 68 – 932°F, 10^{-6} ohm/ohm • °F	100
20 – 500°C, µΩ/Ω • °C	180

Density, lb/in^3	0.308
g/cm^3	8.53
Melting Range, °F	2520 – 2550
°C	1380 – 1400
Specific Heat, Btu/lb • °F	0.100
J/kg • °C	419
Permeability at 200 Oersted (15.9 kA/m)	1.0005
Coefficient of Expansion, 68 – 212°F, 10^{-6} in/in • °F	6.9
20 – 100°C, µm/m • °C	12.5
Electrical Resistivity, ohm • circ mil/ft	650
µΩ • m	1.08
Temp. Coefficient of Resistance, 68 – 932°F, 10^{-6} ohm/ohm • °F	78
20 – 500°C, µΩ/Ω • °C	140

Typical Mechanical Properties

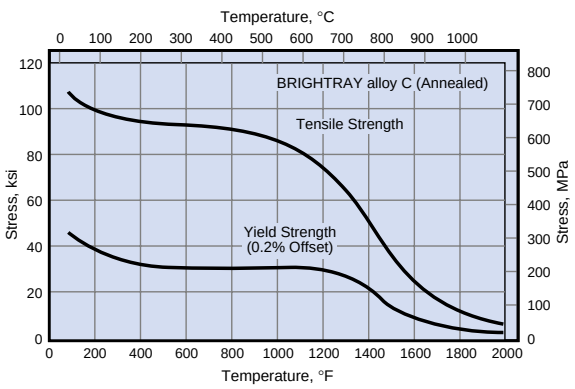
(Annealed)

Tensile Strength, ksi	90
MPa	620
Yield Strength (0.2% Offset), ksi	30
MPa	210



(Annealed)

Tensile Strength, ksi	110
MPa	760
Yield Strength (0.2% Offset), ksi	48
MPa	330



SPECIAL METALS

BRIGHTRAY® alloy F

A nickel-iron-chromium electrical-resistance alloy for use at temperatures up to 1920°F (1050°C) under continuous operating conditions. Its high iron content and relatively low level of nickel make it particularly resistant to internal oxidation in atmospheres that alternate between oxidizing and reducing or carburizing. The alloy has a high temperature coefficient of resistance. Used for heating elements in industrial furnaces.

BRIGHTRAY® alloy S

A nickel-chromium electrical-resistance alloy for use at temperatures up to 2100°F (1150°C) under continuous operating conditions. It is similar to BRIGHTRAY alloy C but does not contain rare-earth additions. It has good resistance to oxidizing, neutral, and reducing atmospheres. The alloy has a low temperature coefficient of resistance. Used for heating elements in industrial furnaces.

Standard Product Forms

Sheet, strip and wire.

Strip and wire.

Major Specifications

None applicable.

UNS N06003
DIN 17742
Werkstoff Nr. 2.4869

Chemical Composition, %

Nominal

Ni 37.0	Cr 18.0	Mn 1.2
Fe 42.0	Si 2.3	C 0.05

Limiting

Ni[a] .. Remainder	S ..... 0.01 max.	C ..... 0.15 max.
Cr .. 19.0 – 21.0	Fe ..... 1.0 max.	
Si ... 0.75 – 1.75	Mn ..... 1.0 max.	

[a]Plus Co.

Physical Constants and Thermal Properties

Density, lb/in^3 ..... 0.286
g/cm^3 ..... 7.92

Melting Range, °F ..... 2430 – 2550
°C ..... 1330 – 1400

Specific Heat, Btu/lb • °F 0.107
J/kg • °C 450

Permeability at 200 Oersted (15.9 kA/m) 1.038

Coefficient of Expansion, 68 – 212°F, 10^{-6} in/in • °F ... 8.3
20 – 100°C, µm/m • °C 15.0

Electrical Resistivity, ohm • circ mil/ft 650
µΩ • m 1.08

Temp. Coefficient of Resistance,
68 – 932°F, 10^{-6} ohm/ohm • °F .. 160
20 – 500°C, µΩ/Ω • °C 290

Density, lb/in^3 ..... 0.305
g/cm^3 ..... 8.44

Melting Range, °F ..... 2550 – 2590
°C ..... 1400 – 1420

Specific Heat, Btu/lb • °F 0.100
J/kg • °C 419

Coefficient of Expansion, 68 – 212°F, 10^{-6} in/in • °F ... 6.9
20 – 100°C, µm/m • °C 12.5

Electrical Resistivity, ohm • circ mil/ft 662
µΩ • m 1.10

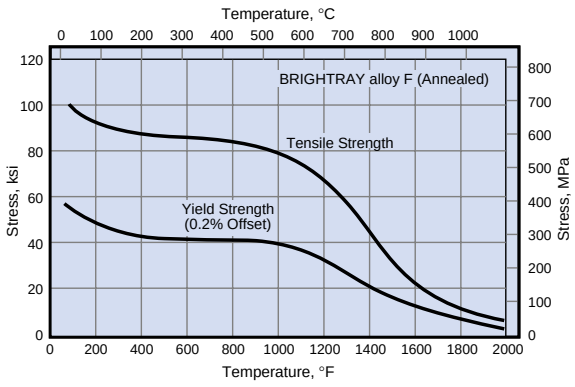
Temp. Coefficient of Resistance,
68 – 932°F, 10^{-6} ohm/ohm • °F 33
20 – 500°C, µΩ/Ω • °C 60

Typical Mechanical Properties

(Annealed)

Tensile Strength, ksi 100
MPa 690

Yield Strength (0.2% Offset), ksi 54
MPa 370



(Annealed)

Tensile Strength,	70°F, ksi	106.5
	20°C, MPa	734
	1110°F, ksi	72.8
	600°C, MPa	502
	1470°F, ksi	30.3
	800°C, MPa	209

BRIGHTRAY® alloy 35

A nickel-iron-chromium electrical-resistance alloy for use at operating temperatures up to 1920°F (1050°C). It is similar to BRIGHTRAY alloy F but with rare-earth additions for greater resistance to oxidation under conditions of frequent switching or wide temperature fluctuations. The alloy has a high temperature coefficient of resistance. Used for heating elements in domestic appliances and industrial equipment.

Standard Product Forms

Wire.

Major Specifications

None applicable.

Limiting Chemical Composition, %

Limiting[a]

Ni[b] ..... 34 – 37	Si ..... 1.0 – 3.0	S ..... 0.01 max.
Fe ... Remainder	Mn ..... 1.0 max.	
Cr ..... 18 – 21	C ..... 0.15 max.	

[a]Also contains rare-earth additions. [b]Plus Co.

Physical Constants and Thermal Properties

Density, lb/in^3 ..... 0.301
g/cm^3 ..... 8.33

Melting Range, °F ..... 2440 – 2520
°C ..... 1340 – 1380

Specific Heat, Btu/lb • °F 0.125
J/kg • °C 523

Permeability at 200 Oersted (15.9 kA/m) 1.026

Coefficient of Expansion, 68 – 212°F, 10^{-6} in/in • °F ... 7.2
20 – 100°C, µm/m • °C 12.9

Electrical Resistivity, ohm • circ mil/ft 614
µΩ • m 1.02

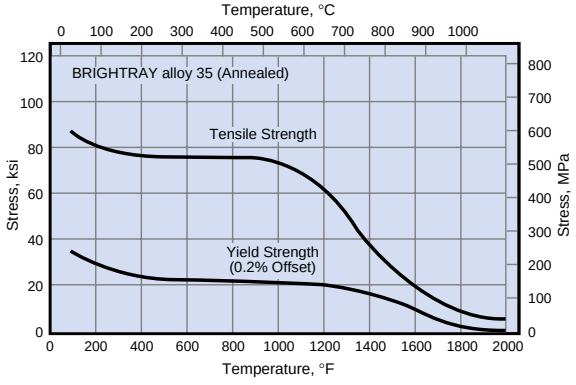
Temp. Coefficient of Resistance,
68 – 932°F, 10^{-6} ohm/ohm • °F .. 180
20 – 500°C, µΩ/Ω • °C 330

Typical Mechanical Properties

(Annealed)

Tensile Strength, ksi 88
MPa 610

Yield Strength (0.2% Offset), ksi 36
MPa 250



SPECIAL METALS

NILO® alloy 36

A nickel-iron low-expansion alloy containing 36% nickel. It maintains nearly constant dimensions over the range of normal atmospheric temperatures, and has a low coefficient of expansion from cryogenic temperatures to about 500°F (260°C). The alloy also retains good strength and toughness at cryogenic temperatures. Used for standards of length, measuring devices, laser components, bi-metal thermostat strip, thermostat rods, and tanks and piping for storing and transporting liquefied gases.

NILO® alloy 365

This alloy was developed to meet the demand by the aerospace industry for improved manufacture of durable, close-tolerance tooling for composite components. It is an age-hardenable, low-expansion alloy, strengthened by heat treatment to reach property levels well above those of conventional nickel-iron alloys. It is the first high-strength, low-expansion alloy produced specifically for tooling applications.

Standard Product Forms

Pipe, tube, sheet, plate, round bar, forging stock and wire.

Plate and round bar.

Major Specifications

UNS K93600
ASTM F 30
DIN 385, 1715
Werkstoff Nr. 1.3912

None applicable.

Limiting Chemical Composition, %

Ni ... 35.0 – 38.0	P .... 0.025 max.	Mo ... 0.50 max.
Fe ... Remainder	S .... 0.025 max.	Co ..... 1.0 max.
C ..... 0.10 max.	Si ..... 0.35 max.	
Mn ... 0.60 max.	Cr .... 0.50 max.	

Ni .. 40.0 – 46.0	S .... 0.012 max.	Co ..... 2.0 max.
Fe ... Remainder	Si ..... 0.60 max.	Al ..... .50 max.
C ..... 0.05 max.	Cr .... 0.50 max.	Ti ..... 1.15 – 1.8
Mn ..... 1.0 max.	Cu ... 0.60 max.	Nb ... 3.0 – 4.25

Physical Constants and Thermal Properties

Density, lb/in³ 0.293
g/cm³ 8.11

Melting Temperature (Approximate), °F 2610
°C 1430

Inflection Point, °F 430
°C 220

Thermal Conductivity, Btu • in/ft² • h • °F 69.3
W/m • °C 10.0

Coefficient of Expansion, 68 – 212°F, 10^{-6} in/in • °F ... 0.83
20 – 100°C, µm/m • °C 1.5
68 – 392°F, 10^{-6} in/in • °F 1.4
20 – 200°C, µm/m • °C 2.6

Electrical Resistivity, ohm • circ mil/ft 480
µΩ • m 0.800

Density, lb/in³ 0.293
g/cm³ 8.11

Melting Temperature (Approximate), °F ..... 2430 – 2570
°C ..... 1334 – 1409

Specific Heat, Btu/lb • °F 0.12
J/kg • °C 500

Curie Temperature, °F 515
°C 268

Thermal Conductivity[A], Btu • in/ft² • h • °F 86
W/m • °C 12.4

Coefficient of Expansion, 10^{-6} in/in • °F (µm/m • °C)
70 – 200°F (21 – 93°C) 2.35 (4.23)
70 – 250°F (21 – 121°C) 2.39 (4.30)
70 – 300°F (21 – 149°C) 2.40 (4.32)
70 – 400°F (21 – 204°C) 2.51 (4.52)
70 – 500°F (21 – 260°C) 2.69 (4.84)
70 – 600°F (21 – 316°C) 3.30 (5.94)

Electrical Resistivity[A], ohm • circ mil/ft 506
µΩ • m 0.840

Young's Modulus[A], 10^6 psi 23.1
GPa 160

[A]room temperature, as aged.

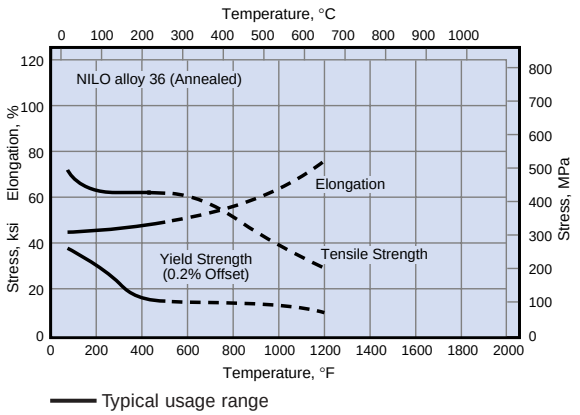
Typical Mechanical Properties

(Annealed)

Tensile Strength, ksi 71
MPa 490

Yield Strength (0.2% Offset), ksi 35
MPa 240

Elongation, % 42



(Precipitation Hardened)

Tensile Strength, ksi 184
MPa 1269

Yield Strength (0.2% Offset), ksi 146
MPa 1007

Elongation in 2" (50 mm), % 16

Reduction of Area, % 36

SPECIAL METALS

NILO® alloy 42

A nickel-iron controlled-expansion alloy containing 42% nickel. It has a low and nominally constant coefficient of thermal expansion from room temperature to about 570°F (300°C). Used for semiconductor lead frames in integrated circuits, bi-metal thermostat strip, thermostat rods, for ceramic-to-metal seals with alumina ceramics, and various glass-to-metal seals such as the core of copper-clad wire for sealing into glass envelopes of electric bulbs, radio valves, television tubes, and fluorescent lights.

NILO® alloy 475

A nickel-iron-chromium controlled-expansion alloy containing 47% nickel. It is designed to have thermal-expansion characteristics that closely match those of the soft glasses of the lead or soda-lime type up to their annealing temperatures. The alloy is a particularly good match with L92 glass. Used for various glass-to-metal seals and for anode-cavity caps in television tubes.

Standard Product Forms

Strip, plate and wire.

Strip.

Major Specifications

UNS K94100
ASTM F 29, F 30
DIN 385, 17745
Werkstoff Nr. 1.3917

DIN 17745
Werkstoff Nr. 2.4486

Chemical Composition, %

Limiting

Ni ..... 42[a]
Fe ... Remainder
C ..... 0.05 max.
Mn ... 0.80 max.
P .... 0.025 max.
S .... 0.025 max.
Si ..... 0.30 max.
Cr .... 0.25 max.
Al ..... 0.15 max.
Co ..... 1.0 max.

[a]Nominal value; adjusted to meet expansion requirements.

Nominal

Ni 47
Fe 48
Cr 4.8

Physical Constants and Thermal Properties

Density, lb/in^3 ..... 0.293
g/cm^3 ..... 8.11

Melting Temperature (Approximate), °F 2615
°C 1435

Inflection Point, °F 700
°C 370

Thermal Conductivity, Btu • in/ft^2 • h • °F 72.8
W/m • °C 10.5

Coefficient of Expansion, 68 – 212°F, 10^{-6} in/in • °F 2.9
20 – 100°C, µm/m • °C 5.3

68 – 572°F, 10^{-6} in/in • °F .. 2.5 – 3.6
20 – 300°C, µm/m • °C ..... 4.5 – 6.5

Electrical Resistivity, ohm • circ mil/ft 370
µΩ • m 0.610

Density, lb/in^3 ..... 0.296
g/cm^3 ..... 8.18

Melting Temperature (Approximate), °F 2640
°C 1450

Inflection Point, °F 680
°C 360

Thermal Conductivity, Btu • in/ft^2 • h • °F 87.4
W/m • °C 12.6

Coefficient of Expansion, 68 – 212°F, 10^{-6} in/in • °F 4.6
20 – 100°C, µm/m • °C 8.2

68 – 842°F, 10^{-6} in/in • °F .. 5.42 – 5.75
20 – 450°C, µm/m • °C .... 9.75 – 10.35

Electrical Resistivity, ohm • circ mil/ft 510
µΩ • m 0.850

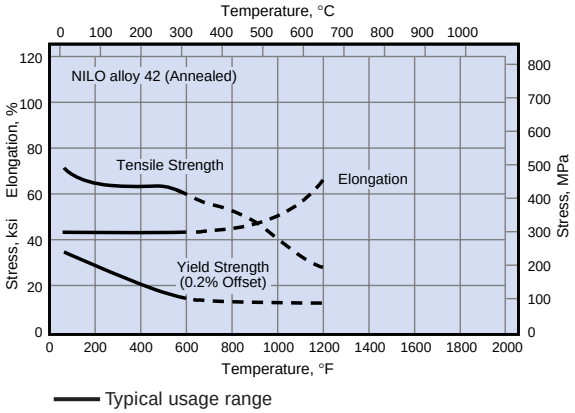
Typical Mechanical Properties

(Annealed)

Tensile Strength, ksi 71
MPa 490

Yield Strength (0.2% Offset), ksi 36
MPa 250

Elongation, % 43



(Annealed)

Tensile Strength, ksi 75
MPa 520

Yield Strength (0.2% Offset), ksi 26
MPa 180

Elongation, % 37

SPECIAL METALS

NILO® alloy 48

A nickel-iron controlled-expansion alloy containing 48% nickel. Its coefficient of thermal expansion is designed to match that of soft lead and soda-lime glasses. The alloy also has a high inflection point. Used for glass-to-metal seals in radio valves and incandescent electric light bulbs and for industrial thermostats that operate at temperatures up to 840°F (450°C).

NILO® alloy K

A nickel-iron-cobalt controlled-expansion alloy containing 29% nickel. Its coefficient of expansion, which decreases with rising temperature to the inflection point, matches the expansion rate of borosilicate glasses and alumina ceramics. Used for glass-to-metal seals in applications requiring high reliability or resistance to thermal shock. Examples are high-power transmitting valves, transistor leads and headers, integrated-circuit lead frames, and photography flash bulbs.

Standard Product Forms

Wire.

Tube, sheet and round bar.

Major Specifications

UNS K94800
ASTM F 30
DIN 17745
Werkstoff Nr. 1.3922, 1.3926, 1.3927

UNS K94610
ASTM F 15, F 29
SAE AMS 7726 – 7728
DIN 17745
Werkstoff Nr. 1.3981

Limiting Chemical Composition, %

Ni ..... 48[a]
Fe ... Remainder
C ..... 0.05 max.
Mn ... 0.80 max.
P .... 0.025 max.
S .... 0.025 max.
Si ..... 0.30 max.
Cr .... 0.25 max.
Al ..... 0.10 max.
Co ..... 1.0 max.

[a]Nominal value; adjusted to meet expansion requirements.

Ni ..... 29[a]
Fe ..... 53[a]
Co ..... 17[a]
C ..... 0.04 max.
Mn ... 0.50 max.
Si ..... 0.20 max.
Al ..... 0.10 max.
Cr .... 0.20 max.
Mg ... 0.10 max.
Zr ..... 0.10 max.
Ti ..... 0.10 max.
Cu ... 0.20 max.
Mo ... 0.20 max.

[a]Nominal value; adjusted to meet expansion requirements.

Physical Constants and Thermal Properties

Density, lb/in^3 ..... 0.296
g/cm^3 ..... 8.20

Melting Temperature (Approximate), °F 2640
°C 1450

Inflection Point, °F 860
°C 460

Thermal Conductivity, Btu • in/ft^2 • h • °F 116
W/m • °C 16.7

Coefficient of Expansion, 68 – 212°F, 10^{-6} in/in • °F 4.7
20 – 100°C, µm/m • °C 8.5
68 – 752°F, 10^{-6} in/in • °F .. 4.6 – 5.2
20 – 400°C, µm/m • °C ..... 8.3 – 9.3

Electrical Resistivity, ohm • circ mil/ft 280
µΩ • m 0.470

Density, lb/in^3 ..... 0.295
g/cm^3 ..... 8.16

Melting Temperature (Approximate), °F 2640
°C 1450

Inflection Point, °F 840
°C 450

Thermal Conductivity, Btu • in/ft^2 • h • °F 116
W/m • °C 16.7

Coefficient of Expansion, 68 – 212°F, 10^{-6} in/in • °F 3.3
20 – 100°C, µm/m • °C 6.0
68 – 752°F, 10^{-6} in/in • °F .. 2.6 – 2.9
20 – 400°C, µm/m • °C ..... 4.6 – 5.2

Electrical Resistivity, ohm • circ mil/ft 260
µΩ • m 0.430

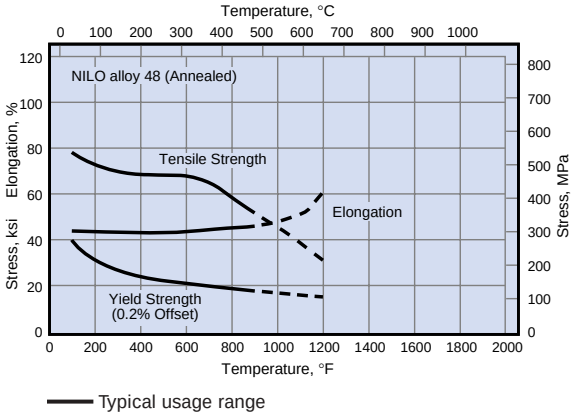
Typical Mechanical Properties

(Annealed)

Tensile Strength, ksi 75
MPa 520

Yield Strength (0.2% Offset), ksi 38
MPa 260

Elongation, % 43

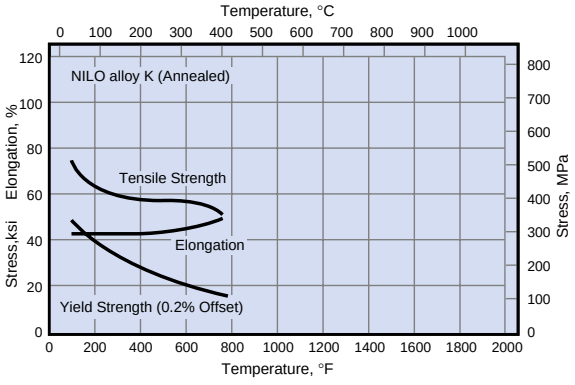


(Annealed)

Tensile Strength, ksi 75
MPa 520

Yield Strength (0.2% Offset), ksi 49
MPa 340

Elongation, % 42



SPECIAL METALS

FERRY® alloy

A copper-nickel alloy used mainly for its electrical properties. It has medium-range electrical resistivity and a very low temperature coefficient of resistance (TCR). The low TCR makes the alloy useful for wire-wound precision resistors having operating temperatures up to 750°F (400°C). A reproducible electromotive force against copper makes the alloy suitable for thermocouples and thermocouple compensating leads.

NILOMAG® alloy 77

A nickel-iron alloy with additions of copper and molybdenum. It is a low-loss, soft-magnetic alloy with a high initial permeability. The alloy is particularly useful for applications in which power requirements must be minimized. Used for transformers, inductors, magnetic amplifiers, switching cores, magnetic shields, tape-recorder heads, and memory storage devices.

Standard Product Forms

FERRY® alloy	NILOMAG® alloy 77
Strip and wire.	Sheet and strip.

Major Specifications

FERRY® alloy	NILOMAG® alloy 77
ASTM B 267 DIN 17644 Werkstoff Nr. 2.0842	None applicable.

Chemical Composition, %

FERRY® alloy

Limiting

Ni .... Remainder	Fe ..... 1.0 max.	Mn ..... 1.0 max.
Cu ..... 55.0[a]	C ..... 0.1 max.	Si ..... 0.5 max.

[a]Nominal.

NILOMAG® alloy 77

Nominal

Ni 77	Cu 5.0	C 0.02
Fe 13.5	Mo 4.2	

Physical Constants and Thermal Properties

FERRY® alloy

Density, lb/in³	0.321
g/cm³	8.89
Melting Range, °F	2230 – 2320
°C	1220 – 1270
Specific Heat, Btu/lb • °F	0.094
J/kg • °C	394
Temp. Coefficient of Resistance, 68 – 212°F, 10^{-6} ohm/ohm • °F	17
20 – 100°C, μΩ/Ω • °C	30
Coefficient of Expansion, 68 – 212°F, 10^{-6} in/in • °F	8.17
20 – 100°C, μm/m • °C	14.7
Thermal Conductivity, Btu • in/ft² • h • °F	155
W/m • °C	22.4
Electrical Resistivity, ohm • circ mil/ft	295
μΩ • m	0.490

NILOMAG® alloy 77

Density, lb/in³	0.317
g/cm³	8.77
Electrical Resistivity, ohm • circ mil/ft	360
μΩ • m	0.600
Curie Temperature, °F	750
°C	400
Initial Permeability	60 000
Maximum Permeability	300 000
Saturation Induction, T	0.63
Remanence, T	0.39
Coercivity, A/m	0.80

Typical Mechanical Properties

FERRY® alloy

(Annealed)

Tensile Strength, ksi	60
MPa	415
Yield Strength (0.5% Offset), ksi	21
MPa	145
Elongation, %	32

NILOMAG® alloy 77

(Annealed)

Tensile Strength, ksi	78
MPa	540
Hardness, HV	125

SPECIAL METALS

NI-SPAN-C® alloy 902

A nickel-iron-chromium alloy made precipitation hardenable by additions of aluminum and titanium. The titanium content also helps provide a controllable thermoelastic coefficient, which is the alloy's outstanding characteristic. The alloy can be processed to have a constant modulus of elasticity at temperatures from –50 to 150˚F (–45 to 65˚C). Used for precision springs, mechanical resonators, and other precision elastic components.

Waspaloy

Waspaloy is a nickel-base, age-hardenable superalloy with excellent high-temperature strength and good resistance to corrosion, notably to oxidation. It is used for aerospace and gas turbine engine components at service temperatures up to 1200˚F (650˚C) for critical rotating applications, and up to 1600˚F (870˚C) for other, less demanding, applications. Applications include compressor and rotor discs, shafts, spacers, seals, rings and casings, fasteners and other miscellaneous engine hardware, airframe assemblies and missile systems.

Standard Product Forms

Round bar.

Round bar, forging stock, extruded section and wire.

Major Specifications

UNS N09902
SAE AMS 5221, 5223, 5225

UNS N07001
ASTM B 637
Werkstoff Nr. 2.4654
ISO 9723 – 9725
SAE AMS 5544, 5704, 5706 – 5709, 5828, MAM 5706
AECMA Pr EN 2193 – 2195, 2406, 2958 – 2960, 3220

Limiting Chemical Composition, %

Limiting

Ni[a] . 41.0 – 43.5	Ti ..... 2.2 – 2.75	Mn ... 0.80 max.
Fe ... Remainder	Al ... 0.30 – 0.80	S ..... 0.04 max.
Cr .... 4.9 – 5.75	C ..... 0.06 max.	Si ..... 1.0 max.
		P ..... 0.04 max.

[a]Plus Co.

Limiting

Ni .... Remainder	Al ... 1.20 – 1.60	Cu ... 0.50 max.
Cr .. 18.0 – 21.0	Zr ... 0.02 – 0.12	S .... 0.030 max.
Co . 12.0 – 15.0	B . 0.003 – 0.01	Si ..... 0.75 max.
Mo . 3.50 – 5.00	C. . 0.02 – 0.10	Mn .... 1.00 max.
Ti ... 2.75 – 3.25	Fe .... 2.00 max.	P ..... 0.030 max.

Physical Constants and Thermal Properties

Density, lb/in³ 0.291
g/cm³ 8.05

Melting Range, °F ..... 2650 – 2700
°C ..... 1450 – 1480

Specific Heat, Btu/lb • °F 0.12
J/kg • °C 500

Curie Temperature, °F 380
°C 190

Young's Modulus, 10^6 psi ..... 24 – 29
GPa ..... 165 – 200

Modulus of Rigidity, 10^6 psi ..... 9 – 10
GPa ..... 62 – 69

Coefficient of Expansion, 70 – 200°F, 10^{-6} in/in • °F 4.2
20 – 93°C, µm/m • °C 7.6

Thermal Conductivity, Btu • in/ft² • h • °F 84
W/m • °C 12.1

Electrical Resistivity, ohm • circ mil/ft 611
µΩ • m 1.02

Density, lb/in³ 0.296
g/cm³ 8.19

Melting Range, °F ..... 2425 – 2475
°C ..... 1330 – 1360

Permeability at 200 Oersted (15.9 kA/m) 1.004

Coefficient of Expansion, 10^{-6} in/in • °F (µm/m • °C)

70 – 200°F (21 – 93°C) 6.8 (12.2)
70 – 1000°F (21 – 538°C) 7.7 (13.9)
70 – 2000°F (21 – 1093°C) 10.4 (18.7)

Electrical Resistivity[A], ohm • circ mil/ft 722
µΩ • m 1.20

Young's Modulus[A], 10^6 psi (GPa) 30.6 (211)

Hardness[A], HRC ..... 34 – 40

[A]Room temperature, as aged.

Typical Mechanical Properties

(Precipitation Hardened)

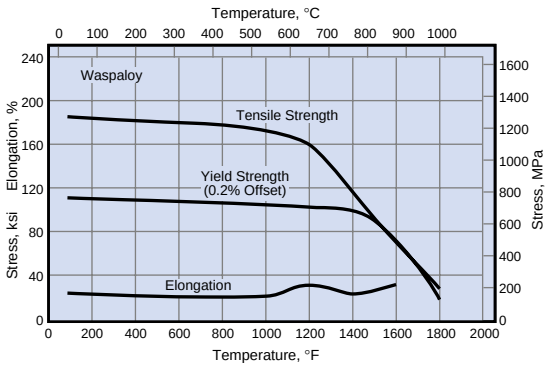
Tensile Strength, ksi 175
MPa 1210

Yield Strength (0.5% Offset), ksi 110
MPa 760

Elongation, % 25

(Precipitation Hardened)

Rupture Strength (1000 h)	ksi	MPa
1200°F / 649°C	89	615
1300°F / 704°C	65	450
1400°F / 760°C	42	290
1500°F / 816°C	26	180
1600°F / 870°C	16	110



SPECIAL METALS

UDIMET® alloy 188

A cobalt-base alloy with excellent high temperature strength and good oxidation resistance to 2000°F (1093°C). The high chromium level coupled with small additions of lanthanum produce an extremely tenacious and protective scale. The alloy also has good sulfidation resistance and excellent metallurgical stability displayed by its good ductility after prolonged exposure to elevated temperatures. Good fabricability and weldability combine to make the alloy useful in typical gas turbine applications such as combustors, flame holders, liners and transition ducts.

UDIMET® alloy L-605

A cobalt-base superalloy with good formability, high strength to 1500°F (816°C), and good oxidation resistance to 2000°F (1093°C). The alloy also has good sulfidation resistance and resistance to wear and galling. The alloy is used in the hot sections of aircraft and land based gas turbines in combustor liners and other applications requiring moderate strength and good oxidation resistance at high temperatures. The alloy can also be used in industrial furnace applications such as muffles / liners in high temperature kilns.

Standard Product Forms

Forging billet, bar, plate, and sheet.

Forging billet, bar, sheet, plate and wire.

Major Specifications

UNS R30188 AMS 5772
AMS 5608

UNS R30605 AMS 5759
AMS 5537

Chemical Composition, %

Limiting

C ... 0.05 – 0.15	Ni ... 20.0 – 24.0	Fe ..... 3.0 max.
Mn ... 1.25 max.	W ... 13.0 – 16.0	Co ..... Balance
Si ..... 0.2 – 0.5	La .. 0.02 – 0.12	B .... 0.015 max.
Cr .. 20.0 – 24.0		

Limiting

Ni ..... 9.0 – 11.0	Fe ..... 3.0 max.	C ... 0.05 – 0.15
Cr .. 19.0 – 21.0	Mn ..... 1.0 – 2.0	S ..... 0.03 max.
W ... 14.0 – 16.0	Si ..... 0.40 max.	Co ..... Balance

Physical Constants and Thermal Properties

Density, lb/in³ 0.330
g/cm³ 9.13

Melting Range, °F ..... 2375 – 2425
°C ..... 1300 – 1330

Specific Heat, Btu/lb • °F 0.097
J/kg • °C 405

Coefficient of Expansion, 70 – 200°F, 10^{-6} in/in • °F 6.6
21 – 93°C, µm/m • °C 11.9

Thermal Conductivity, Btu • in/ft² • h • °F 84
W/m • °C 12.1

Density, lb/in³ 0.330
g/cm³ 9.13

Melting Range, °F ..... 2425 – 2570
°C ..... 1330 – 1410

Specific Heat, Btu/lb • °F 0.092
J/kg • °C 385

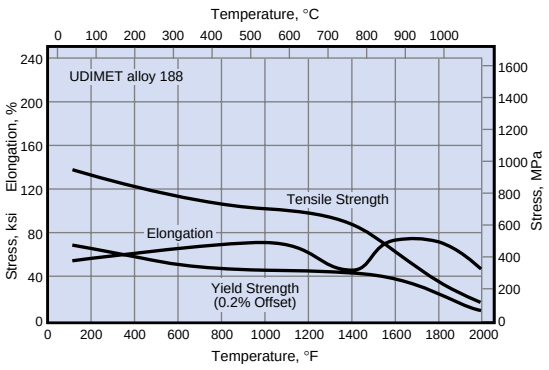
Coefficient of Expansion, 70 – 200°F, 10^{-6} in/in • °F .. 6.83
20 – 93°C, µm/m • °C 12.3

Thermal Conductivity, Btu • in/ft² • h • °F 65
W/m • °C 9.4

Typical Mechanical Properties

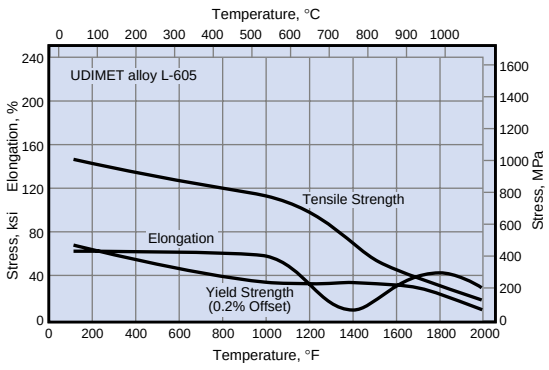
Rupture Strength (1000 hour)

	ksi	MPa
1300°F / 704°C	35	240
1400°F / 760°C	24	165
1500°F / 816°C	16	110
1600°F / 871°C	10	69
1700°F / 927°C	6	41
1800°F / 982°C	3	25
1900°F / 1038°C	2	15
2000°F / 1093°C	1	9



Rupture Strength (1000 hour)

	ksi	MPa
1200°F / 649°C	39	270
1300°F / 704°C	32	220
1400°F / 760°C	24	165
1500°F / 816°C	17	120
1600°F / 871°C	10	72
1700°F / 927°C	6	44
1800°F / 982°C	4	25



SPECIAL METALS

UDIMET® alloy 520

A precipitation hardenable nickel-base super-alloy with an exceptional combination of high temperature mechanical properties, corrosion resistance and forgeability characteristics. Developed for use in the 1400 – 1700°F (760 – 927°C) temperature range the alloy has excellent structural stability and unusually good fabricability. Primary application is blading for aircraft and land based gas turbines.

UDIMET® alloy 720

A nickel-base alloy solid solution strengthened with tungsten and molybdenum and precipitation hardened with titanium and aluminum. The alloy combines high strength with metallurgical stability as demonstrated by excellent impact strength retention after long exposures at elevated temperatures. Good oxidation and corrosion resistance combined with high strength make the alloy useful in gas turbine blade and disc applications.

Standard Product Forms

Forging bar.

Forging billet and bar.

Major Specifications

PDS 15125A1

EMS 55477 MSRR 7252 MTS 5013
EMS 73105 C50TF105

Chemical Composition, %

Limiting

C ... 0.02 – 0.06	Mo ..... 5.5 – 7.0	W ..... 0.8 – 1.2
Cr .. 18.0 – 20.0	Ti ..... 2.9 – 3.25	B .. .004 – 0.010
Co . 11.0 – 14.0	Al ..... 1.8 – 2.3	Ni ..... Balance

Limiting

Ni ..... Balance	W ... 1.00 – 1.50	C ... 0.01 – 0.02
Cr .. 15.5 – 16.5	Ti ... 4.75 – 5.25	Zr .. 0.025 – 0.05
Co .. 14.0 – 15.5	Al ... 2.25 – 2.75	B .... 0.01 – 0.02
Mo .. 2.75 – 3.25		

Physical Constants and Thermal Properties

Density, lb/in³ 0.297
g/cm³ 8.21

Melting Range, °F ..... 2300 – 2560
°C ..... 1260 – 1405

Density, lb/in³ 0.292
g/cm³ 8.08

Melting Range, °F ..... 2180 – 2440
°C ..... 1194 – 1338

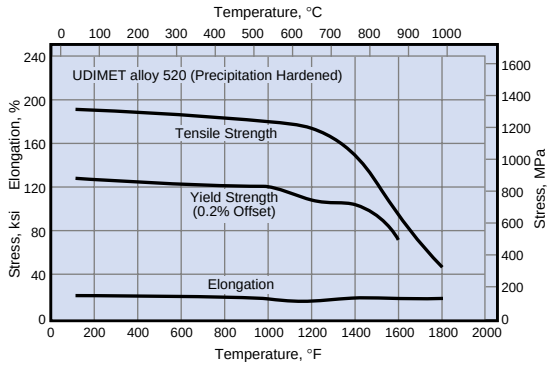
Coefficient of Expansion, 70 – 200°F, 10^{-6} in/in • °F 6.8
21 – 93°C, µm/m • °C 12.24

Typical Mechanical Properties

(Precipitation Hardened)

Rupture Strength (1000 hour)

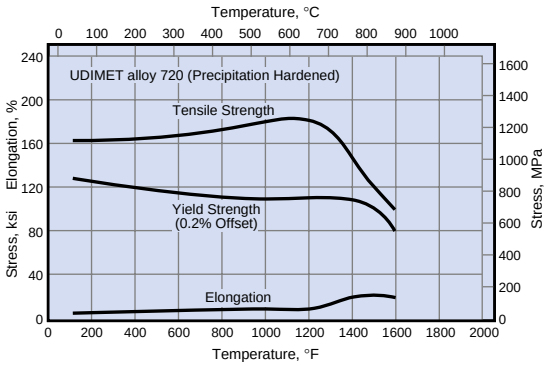
	ksi	MPa
1200°F / 649°C	85	585
1300°F / 704°C	69	475
1400°F / 760°C	50	345
1500°F / 816°C	33	230
1600°F / 871°C	22	150



(Precipitation Hardened)

Rupture Strength (1000 hour)

	ksi	MPa
1200°F / 649°C	102	700
1300°F / 704°C	73	500
1400°F / 760°C	70	480
1600°F / 871°C	32	219
1800°F / 982°C	10	68



SPECIAL METALS

UDIMET® alloy D-979

An iron-nickel alloy designed for turbine disc applications at temperatures up to 1200 – 1400°F (649 – 760°C). Hardened by a complex precipitation of intermetallic phases, the alloy combines corrosion resistance with excellent tensile and stress rupture strength.

UDIMET® alloy R41

A precipitation hardening nickel-chromium alloy containing significant amounts of cobalt and molybdenum along with lesser amounts of aluminum and titanium that exhibits extremely high room and elevated temperature mechanical properties. Excellent corrosion resistance and fabricability have led to wide usage in critical aircraft engine components such as nozzle partitions, turbine blades and wheels, combustion chamber liners and structural hardware.

Standard Product Forms

Forging billet and bar.

Forging billet, bar, sheet and plate.

Major Specifications

UNS N09979 AMS 5746

UNS N 07041 AMS 5712
AMS 5545 AMS 5713

Chemical Composition, %

Limiting

Cr .. 14.0 – 16.0
Fe ..... Balance
Mo ..... 3.0 – 4.5
W ..... 3.0 – 4.5
Ti ..... 2.7 – 3.3
Al ..... 0.75 – 1.3
Ni ... 42.0 – 48.0
C ..... 0.08 max.
Si ..... 0.75 max.
Mn ... 0.75 max.
B .... .008 – .016

Limiting

Ni ..... Balance
Cr .. 18.0 – 20.0
Co . 10.0 – 12.0
Mo ... 9.0 – 10.5
Al ... 1.40 – 1.80
Ti ..... 3.0 – 3.3
Fe ..... 5.0 max.
B ... .003 – .010
C ..... 0.12 max.

Physical Constants and Thermal Properties

Density, lb/in^3 ..... 0.296
g/cm^3 ..... 8.19

Melting Range, °F ..... 2225 – 2530
°C ..... 1220 – 1390

Coefficient of Expansion, 70 – 200°F, 10^{-6} in/in • °F ... 7.60
21 – 93°C, µm/m • °C 13.7

Thermal Conductivity, Btu • in/ft^2 • h • °F 87
W/m • °C 12.6

Density, lb/in^3 ..... 0.298
g/cm^3 ..... 8.25

Melting Range, °F ..... 2250 – 2535
°C ..... 1232 – 1391

Specific Heat, Btu/lb • °F 0.104
J/kg • K 435

Coefficient of Expansion, 70 – 200°F, 10^{-6} in/in • °F ... 6.63
21 – 93°C, µm/m • °C 11.9

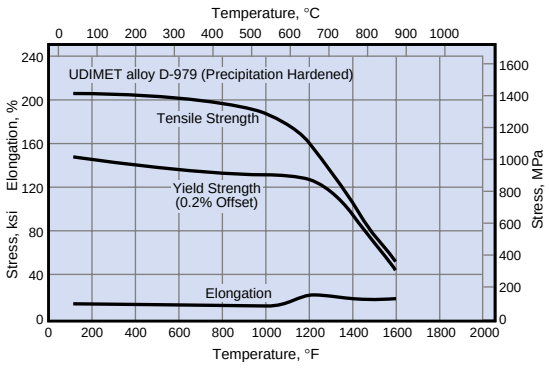
Thermal Conductivity, Btu • in/ft^2 • h • °F 62
W/m • °C 9.0

Typical Mechanical Properties

(Precipitation Hardened)

Rupture Strength (1000 hour)

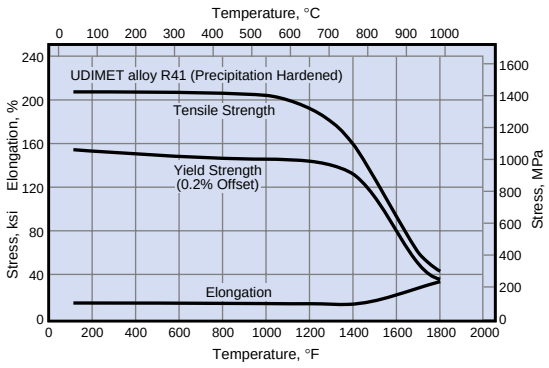
	ksi	MPa
1200°F / 649°C	75	515
1300°F / 704°C	55	380
1400°F / 760°C	36	250
1500°F / 816°C	21	145
1600°F / 871°C	10	69



(Precipitation Hardened)

Rupture Strength (1000 hour)

	ksi	MPa
1200°F / 649°C	102	705
1300°F / 704°C	80	550
1400°F / 760°C	50	345
1500°F / 816°C	29	200
1600°F / 871°C	17	117
1700°F / 927°C	11	76



SPECIAL METALS

UDIMAR® alloy 250

An age hardenable (maraging) iron-nickel steel combining ultra-high strength, toughness and resistance to crack propagation. The alloy is well suited to applications where heat treatment distortion and dimensional changes must be minimized and where high fracture toughness is required such as rocket motor casings, light aircraft landing gear, power shafts and low temperature tooling.

UDIMAR® alloy 300

An age hardenable (maraging) iron-nickel steel combining ultra-high strength and resistance to crack propagation. The alloy is well suited to applications where heat treatment distortion and dimensional changes must be minimized and where high fracture toughness is required such as rocket motor casings, light aircraft landing gear, power shafts and low temperature tooling.

Standard Product Forms

Forging billet and bar.

Forging billet and bar.

Major Specifications

UNS K92890
UNS K92940
AMS 6512

UNS K93120
AMS 6514

Chemical Composition, %

Limiting

C ..... 0.03 max.
Si ..... 0.10 max.
Mn ... 0.10 max.
S .... 0.010 max.
P .... 0.010 max.
Co ..... 7.0 – 8.5
Ni ... 17.0 – 19.0
Mo ..... 4.6 – 5.1
Ti ... 0.30 – 0.50
Al ... 0.05 – 0.15
Fe ..... Balance

Limiting

C ..... 0.03 max.
Si ..... 0.10 max.
Mn ... 0.10 max.
S .... 0.010 max.
P .... 0.010 max.
Co ..... 8.0 – 9.5
Ni ... 18.0 – 19.0
Mo ..... 4.6 – 5.2
Ti ... 0.55 – 0.80
Al ... 0.50 – 0.15
Fe ..... Balance

Physical Constants and Thermal Properties

Density, lb/in^3 ..... 0.290
g/cm^3 ..... 8.0

Melting Range, °F ..... 2600 – 2650
°C ..... 1427 – 1454

Specific Heat, Btu/lb • °F 0.07
J/kg • K 293

Permeability at 200 Oersted (15.9 kA/m) 77.5

Coefficient of Expansion, 70 – 200°F, 10^{-6} in/in • °F 5.4
21 – 93°C, µm/m • °C 9.72

Thermal Conductivity, Btu • in/ft^2 • h • °F 136
W/m • °C 19.6

Density, lb/in^3 ..... 0.290
g/cm^3 ..... 8.0

Melting Range, °F ..... 2600 – 2650
°C ..... 1427 – 1454

Specific Heat, Btu/lb • °F 0.08
J/kg • K 335

Permeability at 200 Oersted (15.9 kA/m) 77.5

Coefficient of Expansion, 70 – 200°F, 10^{-6} in/in • °F 4.8
21 – 93°C, µm/m • °C 8.64

Thermal Conductivity, Btu • in/ft^2 • h • °F 136
W/m • °C 19.6

Typical Mechanical Properties

	Solution Annealed 1500°F (816°C) 1 hr, AC	Solution Annealed plus aged 900°F (482°C) 3 hrs, AC
0.2% Yld, ksi	115	260
UTS, ksi	145	270
El, %	20	10
RA, %	70	60
Hardness, Rc	30	50

	Solution Annealed 1500°F (816°C) 1 hr, AC	Solution Annealed plus aged 900°F (482°C) 3 hrs, AC
0.2% Yld, ksi	120	280
UTS, ksi	150	290
El, %	16	8
RA, %	70	40
Hardness, Rc	30	52

General

The 18% nickel maraging steels offer a unique combination of properties not available from conventional low alloy ultra high strength steels. They offer high strength, high ductility and toughness, and resistance to crack propagation. Hardening is accomplished by a simple aging cycle of 3 hours at 900°F (482°C) followed by air cooling. UDIMAR alloy 250 provides through hardening without quenching, freedom from decarburization, minimal distortion during aging, good formability, machinability, and weldability and a low coefficient of thermal expansion.

The 18% nickel maraging steels offer a unique combination of properties not available from conventional low alloy ultra high strength steels. They offer high strength, high ductility and toughness, and resistance to crack propagation. Hardening is accomplished by a simple aging cycle of 3 hours at 900°F (482°C) followed by air cooling. UDIMAR alloy 300 provides through hardening without quenching, freedom from decarburization, minimal distortion during aging, good formability, machinability, and weldability and a low coefficient of thermal expansion.

INCOTHERM® alloy TD

A nickel-chromium alloy that was originally developed for thermocouple sheathing where high temperature corrosion resistance and strength are required without the use of elements that may cause thermocouple degradation over time, the alloy has now been identified for uses in other high temperature and heat-treating applications. This product has been tailored to provide improved oxidation resistance over stainless steels and higher nickel alloys at temperatures up to 2282˚F (1250˚C) and possibly beyond. The alloying additions improve oxide scale adherence and reduce the rate of mass change, allowing the alloy to show significant improvements over alloys currently being used in heat treating applications. INCOTHERM alloy TD has excellent resistance to nitridation up to 2151˚F (1177˚C). Lacking the alloying elements that form internal nitrides such as Nb or Al, the product exhibits freedom from microstructural degradation in nitrogen-based atmospheres. Because of this excellent resistance to nitridation, the alloy is being evaluated for use in powder metallurgy sintering furnace belts and other thermal processing applications as well as thermocouple sheathing.

Standard Product Forms

Strip, wire and tube

Major Specifications

–

Chemical Composition, %

Nominal

Cr 22	Fe ..... 1.0 max.	C ..... 0.05 max.
Ni ..... Balance	Mn ... 0.10 max.	Rare earth elements .. 0.05
Mo 3	Al ..... 0.10 max.	
Si 1.4		

Physical Constants and Thermal Properties

Density, lb/in^3 (g/cm^3) 0.308 (8.54)

Melting Range, °F (°C) ..... 2516 – 2552 (1380 – 1400)

Coefficient of Expansion, 10^{-6} in/in • °F (µm/m • °C)

70 – 932°F (21 – 500°C) 8.09 (14.56)
70 – 1112°F (21 – 600°C) 8.32 (14.98)
70 – 1292°F (21 – 700°C) 8.66 (15.59)
70 – 1472°F (21 – 800°C) 8.97 (16.15)
70 – 1652°F (21 – 900°C) 9.34 (16.81)
70 – 1832°F (21 – 1000°C) 9.61 (17.30)

Electrical Resistivity, ohm • circ mil/ft 698
µΩ • m 1.16

Typical Mechanical Properties

	RT	800˚C	900˚C	1000˚C	1100˚C	1200˚C	1250˚C
0.2% Yield Strength, MPa	405	177	75	39	20	10	8
Tensile Strength, MPa	799	279	131	88	59	37	29
Elongation, %	51	82	80	83	156	79	95

Shape Memory Alloys (Nitinol)

Nitinol is a family of specialty nickel / titanium alloys which exhibit unique shape memory and super-elastic characteristics. This class of materials may be formed into a product, bent or twisted into a different shape, and then easily returned to their original shape. Principal applications include a variety of medical grade devices, orthodontic wire, eyeglass frames, temperature control devices, clamping devices and cellular telephone antennas. For more information, contact our Shape Memory Alloys department at New Hartford, NY.
Phone: 315-798-2900 • Fax: 315-798-6860

Atomized Powder Products

In the most technologically advanced jet engines, the requirements for strength, high temperature corrosion resistance and toughness exceed the capabilities of conventional cast or wrought mill forms. Powder metallurgy superalloy products are used in military jet engines and the latest generation of large commercial jet engines. These alloys are manufactured using inert gas atomization to break up a molten metal stream into droplets, which rapidly solidify into metal powder particles. Superalloys produced in our Princeton, Kentucky facility are supplied as powder, hot isostatically pressed consolidated shapes or extruded billet and bar. For more information, contact our Atomized Powder Division in Princeton, KY.
Phone: 270-365-9551 • Fax: 270-365-5910