625

Applicable designations: AMS 5599, AMS 5666, AMS 5837, ASTM B446, ASTM B475, DIN 2.4856

Associated specifications: UNS N06625

Type analysis

Single figures are nominal except where noted.

Nickel	Balance	**Chromium**	20.00–23.00 %	**Molybdenum**	8.00–10.00 %
Iron	Max 5.00 %	**Columbium + Tantalum**	3.15–4.15 %	**Cobalt**	Max 1.00 %
Manganese	Max 0.50 %	**Silicon**	Max 0.50 %	**Aluminum**	Max 0.40 %
Titanium	Max 0.40 %	**Carbon**	Max 0.10 %	**Phosphorus**	Max 0.015 %
Sulfur	Max 0.015 %				

Forms manufactured

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

Description

625 is a nonmagnetic, corrosion- and oxidation-resistant, nickel-base alloy. Its outstanding strength and toughness in the temperature range cryogenic to 2000°F (1093°C) are derived primarily from the solid solution effects of the refractory metals, columbium and molybdenum, in a nickel-chromium matrix. The alloy has excellent fatigue strength and stress-corrosion cracking resistance to chloride ions.

Key Properties:

- Nonmagnetic
- Corrosion- and oxidation-resistant
- Outstanding strength and toughness at cryogenic to 2000°F

Markets:

- All

Applications:

- Heat shields
- Gas turbine engine ducting
- Furnace hardware
- Chemical plant hardware
- Combustion liners and spray bars
- Special seawater applications

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> 625

Corrosion resistance

625 has withstood many corrosive environments. In alkaline, salt water, fresh water, neutral salts, and in the air, almost no attack occurs. The nickel and chromium provide resistance to oxidizing environments. Nickel and molybdenum provide for resistance to nonoxidizing atmospheres. Pitting and crevice corrosion are prevented by molybdenum. Niobium stabilizes the alloy against sensitization during welding. Chloride stress-corrosion cracking resistance is excellent. The alloy resists scaling and oxidation at high temperatures.

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	Excellent	**Acetic Acid**	Excellent
Sodium Hydroxide	Excellent	**Salt Spray (NaCl)**	Excellent
Sea Water	Excellent	**Sour Oil/Gas**	Excellent
Humidity	Excellent		

Physical properties

PROPERTY	At or From	English Units	Metric Units
DENSITY	—	0.3050 lb/in^3	—
MEAN SPECIFIC HEAT	—	0.09800 Btu/lb/°F	—
MEAN COEFFICIENT OF THERMAL EXPANSION (CTE)	200°F (93°C)	7.1 x 10^{-6} in/in/°F	12.8 x 10^{-6} length/length/°C
	400°F (204°C)	7.3 x 10^{-6} in/in/°F	13.1 x 10^{-6} length/length/°C
	600°F (316°C)	7.4 x 10^{-6} in/in/°F	13.3 x 10^{-6} length/length/°C
	800°F (427°C)	7.6 x 10^{-6} in/in/°F	13.7 x 10^{-6} length/length/°C
	1000°F (538°C)	7.8 x 10^{-6} in/in/°F	14.0 x 10^{-6} length/length/°C
	1200°F (649°C)	8.2 x 10^{-6} in/in/°F	14.8 x 10^{-6} length/length/°C
	1400°F (760°C)	8.5 x 10^{-6} in/in/°F	15.3 x 10^{-6} length/length/°C
	1600°F (871°C)	8.8 x 10^{-6} in/in/°F	15.8 x 10^{-6} length/length/°C
	1700°F (927°C)	9.0 x 10^{-6} in/in/°F	16.2 x 10^{-6} length/length/°C

> 625

THERMAL CONDUCTIVITY HEAT TREATED AT 2100°F (1149°C) FOR 1 HOUR	-250°F (-157°C)	50 Btu·in/ft^2·hr·°F	7.2 W/m·K
	-200°F (-129°C)	52 Btu·in/ft^2·hr·°F	7.5 W/m·K
	-100°F (-73°C)	58 Btu·in/ft^2·hr·°F	8.4 W/m·K
	0°F (-18°C)	64 Btu·in/ft^2·hr·°F	9.2 W/m·K
	70°F (21°C)	68 Btu·in/ft^2·hr·°F	9.8 W/m·K
	100°F (38°C)	70 Btu·in/ft^2·hr·°F	10.1 W/m·K
	200°F (93°C)	75 Btu·in/ft^2·hr·°F	10.8 W/m·K
	400°F (204°C)	87 Btu·in/ft^2·hr·°F	12.5 W/m·K
	600°F (316°C)	98 Btu·in/ft^2·hr·°F	14.1 W/m·K
	800°F (427°C)	109 Btu·in/ft^2·hr·°F	15.7 W/m·K
	1000°F (538°C)	121 Btu·in/ft^2·hr·°F	17.5 W/m·K
	1200°F (649°C)	132 Btu·in/ft^2·hr·°F	19.0 W/m·K
	1400°F (760°C)	144 Btu·in/ft^2·hr·°F	20.8 W/m·K
	1600°F (871°C)	158 Btu·in/ft^2·hr·°F	22.8 W/m·K
	1800°F (982°C)	175 Btu·in/ft^2·hr·°F	25.2 W/m·K
POISSON'S RATIO	70°F (21°C)	0.308	—
	200°F (93°C)	0.310	—
	400°F (204°C)	0.312	—
	600°F (316°C)	0.313	—
	800°F (427°C)	0.312	—
	1000°F (538°C)	0.321	—
	1200°F (649°C)	0.328	—
	1400°F (760°C)	0.329	—
ELASTIC MODULUS (E)	70°F (21°C)	29.8 x 10^3 ksi	205 x 10^3 MPa
	200°F (93°C)	29.2 x 10^3 ksi	201 x 10^3 MPa
	400°F (204°C)	28.4 x 10^3 ksi	196 x 10^3 MPa
	600°F (316°C)	27.5 x 10^3 ksi	190 x 10^3 MPa
	800°F (427°C)	26.6 x 10^3 ksi	183 x 10^3 MPa
	1000°F (538°C)	25.6 x 10^3 ksi	177 x 10^3 MPa
	1200°F (649°C)	24.4 x 10^3 ksi	168 x 10^3 MPa
	1400°F (760°C)	23.1 x 10^3 ksi	159 x 10^3 MPa
MODULUS OF RIGIDITY (G)	70°F (21°C)	11.4 x 10^3 ksi	79 x 10^3 MPa
	200°F (93°C)	11.2 x 10^3 ksi	77 x 10^3 MPa
	400°F (204°C)	10.8 x 10^3 ksi	74 x 10^3 MPa
	600°F (316°C)	10.5 x 10^3 ksi	72 x 10^3 MPa
	800°F (427°C)	10.1 x 10^3 ksi	70 x 10^3 MPa
	1000°F (538°C)	9.7 x 10^3 ksi	67 x 10^3 MPa
	1200°F (649°C)	9.2 x 10^3 ksi	63 x 10^3 MPa
	1400°F (760°C)	8.7 x 10^3 ksi	60 x 10^3 MPa
	1600°F (871°C)	8.2 x 10^3 ksi	57 x 10^3 MPa

> 625

ELECTRICAL RESISTIVITY	70°F (21°C)	776 ohm-cir-mil/ft	1290 microohm·mm
	100°F (38°C)	780 ohm-cir-mil/ft	1300 microohm·mm
	200°F (93°C)	794 ohm-cir-mil/ft	1320 microohm·mm
	400°F (204°C)	806 ohm-cir-mil/ft	1340 microohm·mm
	600°F (316°C)	812 ohm-cir-mil/ft	1350 microohm·mm
	800°F (427°C)	818 ohm-cir-mil/ft	1360 microohm·mm
	1000°F (538°C)	830 ohm-cir-mil/ft	1380 microohm·mm
	1200°F (649°C)	830 ohm-cir-mil/ft	1380 microohm·mm
	1400°F (760°C)	824 ohm-cir-mil/ft	1370 microohm·mm
	1600°F (871°C)	818 ohm-cir-mil/ft	1360 microohm·mm
	1800°F (982°C)	812 ohm-cir-mil/ft	1350 microohm·mm
	2000°F (1093°C)	806 ohm-cir-mil/ft	1340 microohm·mm
CURIE TEMPERATURE	—	< -320°F	-196°C
MELTING RANGE	—	2350–2460°F	1288–1349°C

Magnetic properties

MAGNETIC PERMEABILITY (200 Oe)	1.0006 Mu

Typical mechanical properties

CREEP STRENGTH

HIGH SOLUTION ANNEALED MATERIAL													
TEST TEMPERATURE		STRESS TO PRODUCE THE INDICATED PLASTIC STRAIN AT											
		1% IN 100 HRS		5% IN 100 HRS		1% IN 1,000 HRS		5% IN 1,000 HRS		1% IN 10,000 HRS		5% IN 10,000 HRS	
°F	°C	psi	MPa	psi	MPa	psi	MPa	psi	MPa	psi	MPa	psi	MPa
1200	649	52,000	359	55,000	379	38,000	262	45,000	310	27,500	190	31,000	214
1300	704	31,000	214	36,000	248	22,500	155	26,000	179	16,500	114	18,000	124
1400	760	17,500	121	22,500	155	13,000	90	16,000	110	8,500	59	11,500	79
1500	816	9,500	66	14,000	97	6,500	45	9,000	62	4,500	31	6,500	45
1600	871	5,500	38	7,500	52	3,500	24	5,500	38	2,500	17	4,000	28

> 625

EFFECT OF ANNEALING TEMPERATURE

HOT ROLLED ROD									
ANNEALING TEMP, 1 HR		0.2% YIELD STRENGTH		ULTIMATE TENSILE STRENGTH		ELONGATION IN 2 IN (50.8 MM)	REDUCTION OF AREA	HARDNESS
°F	°C	psi	MPa	psi	MPa	%	%	HRB
As-rolled		92,000	634	147,500	1017	46.0	55.3	98
1400	760	90,800	626	145,500	1003	43.0	49.5	101
1500	816	85,000	586	143,500	989	42.0	45.7	101
1600	871	87,200	601	145,500	1003	39.0	41.5	101
1700	927	86,000	593	147,000	1014	40.0	48.0	103
1800	982	83,600	576	143,500	989	44.0	48.0	101
1850	1010	78,600	542	142,500	983	46.0	53.0	99
1900	1038	66,300	457	142,500	983	49.0	51.5	95
2000	1093	52,500	362	124,000	855	64.0	62.5	93
2100	1149	50,000	345	116,000	800	62.0	61.0	89
2200	1204	48,000	331	116,500	803	72.0	61.3	88

ELEVATED TEMPERATURE TENSILE PROPERTIES

HOT ROLLED, SOLUTION ANNEALED ROD 2150°F (1177°C)						
TEST TEMPERATURE		0.2% YIELD STRENGTH		ULTIMATE TENSILE STRENGTH		ELONGATION
°F	°C	psi	MPa	psi	MPa	%
400	204	43,000	296	116,500	803	57.0
600	316	40,000	276	112,500	776	58.0
800	427	37,000	255	109,500	755	60.0
1000	538	35,000	241	106,500	734	62.0
1200	649	37,000	255	104,000	717	71.0
1400	760	40,000	276	75,000	517	91.0
1600	871	32,000	221	38,000	262	110.0
1800	982	16,000	110	18,000	124	120.0

LOW SOLUTION ANNEAL						
TEST TEMPERATURE		0.2% YIELD STRENGTH		ULTIMATE TENSILE STRENGTH		ELONGATION
°F	°C	psi	MPa	psi	MPa	%
400	204	66,000	455	134,000	924	45.0
600	316	63,000	434	132,000	910	42.5
800	427	61,000	421	131,500	907	45.0
1000	538	60,500	417	130,000	896	48.0
1200	649	60,000	414	119,000	820	34.0
1400	760	58,500	403	78,000	538	59.0
1600	871	39,000	269	40,000	276	117.5
1800	982	17,000	117	17,000	117	143.0

> 625

KEYHOLE CHARPY IMPACT ENERGY

HOT ROLLED STOCK								
TEST TEMPERATURE		ORIENTATION	IMPACT STRENGTH					
°F	°C	psi	ft·lb			J		
85	29	Longitudinal	48	49	50	65	66	68
		Transverse	46	49	51.5	62	66	70
-110	-79	Longitudinal	39	44	49	53	60	66
		Transverse	39	42	44	53	57	60
-320	-196	Longitudinal	35	35	35.5	47	47	48
		Transverse	31	32	36	42	43	49

ROOM TEMPERATURE TENSILE PROPERTIES

AS-DRAWN WIRE ANNEALED AT 2150°F (1177°C), 5 MIN, AIR COOLED							
WIRE DIAMETER		COLD REDUCTION	0.2% YIELD STRENGTH		ULTIMATE TENSILE STRENGTH		ELONGATION IN 10 IN (0.25 M)
IN	MM	%	psi	MPa	psi	MPa	%
0.397	10.08	0	61,500	83	138,000	187	52.3
0.036	0.91	19	153,250	208	174,500	237	17.5
0.0318	0.808	37	205,000	278	220,000	298	2.0
0.0285	0.724	49	218,000	296	246,000	334	2.0
0.0253	0.643	60	253,000	343	269,000	365	2.4
0.0226	0.574	68	242,000	328	283,000	384	2.2
0.020	0.51	75	251,000	340	293,000	397	2.0
0.0179	0.455	80	220,000	298	295,250	400	3.8
0.0159	0.404	84	250,500	340	303,000	411	3.4
0.0142	0.361	87	252,750	343	306,000	415	3.0
0.0126	0.320	90	269,000	365	316,250	429	2.6
0.0111	0.282	92	264,000	358	316,000	428	2.3
0.0099	0.251	94	274,500	372	322,250	437	3.0

HOT ROLLED, LOW SOLUTION ANNEALED BAR, EXPOSED 100 HRS AT INDICATED TEMPERATURES						
EXPOSURE TEMPERATURE		0.2% YIELD STRENGTH		ULTIMATE TENSILE STRENGTH		ELONGATION
°F	°C	psi	MPa	psi	MPa	%
1200	649	121,000	834	170,000	1172	35.0
1300	704	106,000	731	159,500	1100	35.0
1400	760	91,000	627	148,000	1020	35.5
1500	816	82,000	565	145,000	1000	37.0
1600	871	81,000	558	143,500	989	38.0
1700	927	74,000	510	135,000	931	43.0
1800	982	51,000	352	129,000	889	54.0

> 625

ROTATING BEAM FATIGUE STRENGTH

BAR STOCK

CONDITION, 1 HR, AC		TEST TEMPERATURE		STRESS FOR CYCLES TO FAIL							
				10^5		10^6		10^7		10^8	
°F	°C	°F	°C	psi	MPa	psi	MPa	psi	MPa	psi	MPa
As-rolled		R.T.	R.T.	133,000	917	104,000	717	100,000	689	100,000	689
1800	982	R.T.	R.T.	—	—	96,000	662	92,000	634	90,000	621
1800	982	800	427	—	—	96,000	662	92,000	634	90,000	621
1800	982	1000	538	91,000	627	87,000	600	84,000	579	81,000	558
1800	982	1200	649	80,000	552	76,000	524	72,000	496	69,000	475
1800	982	1400	760	—	—	65,000	448	57,000	393	57,000	393
1800	982	1600	871	—	—	36,000	248	24,000	165	12,000	83
2150	1177	R.T.	R.T.	72,000	496	68,000	469	68,000	469	68,000	469
2150	1177	800	427	69,000	476	67,000	462	66,000	455	66,000	455
2150	1177	1000	538	64,000	441	63,000	434	63,000	434	63,000	434
2150	1177	1200	649	58,000	400	57,000	393	57,000	393	57,000	393
2150	1177	1400	760	49,000	338	47,000	324	45,000	310	45,000	310
2150	1177	1600	871	—	—	39,000	269	33,000	228	27,000	186

RUPTURE STRENGTH

HIGH SOLUTION ANNEALED MATERIAL

TEST TEMPERATURE		STRESS TO PRODUCE RUPTURE AT THE INDICATED TIME									
		10 HRS		100 HRS		1,000 HRS		10,000 HRS		100,000 HRS	
°F	°C	psi	MPa	psi	MPa	psi	MPa	psi	MPa	psi	MPa
1200	649	75,000	517	60,000	414	53,000	365	40,000	276	31,000	214
1300	704	59,000	407	45,000	310	35,000	241	27,000	186	21,000	145
1400	760	40,000	276	30,000	207	22,000	152	17,000	117	13,000	90
1500	816	28,000	193	19,000	131	14,000	97	9,000	62	6,000	41
1600	871	17,000	117	12,000	83	7,500	52	5,000	34	3,500	24

Note: The notch bar (K_t 3.25) life is greater than the smooth bar life.

LOW SOLUTION ANNEALED MATERIAL

TEST TEMPERATURE		STRESS TO PRODUCE RUPTURE AT THE INDICATED TIME							
		10 HRS		100 HRS		1,000 HRS		10,000 HRS	
°F	°C	psi	MPa	psi	MPa	psi	MPa	psi	MPa
1200	649	—	—	75,000	517	58,500	403	42,500	293
1300	704	64,000	441	47,500	328	34,500	238	22,500	155
1400	760	40,000	276	28,000	193	18,000	124	12,000	83
1500	816	25,000	172	15,000	103	—	—	—	—

Note: The notch bar (K_t 3.25) life is greater than the smooth bar life.

> 625

TYPICAL ROOM TEMPERATURE TENSILE PROPERTIES

ROD AND BAR

CONDITION	0.2% YIELD STRENGTH		ULTIMATE TENSILE STRENGTH		ELONGATION IN 2 IN (50.8 MM)	REDUCTION OF AREA
	psi	MPa	psi	MPa	%	%
As-rolled	60,000/110,000	414/758	120,000/160,000	827/1103	30/60	40/60
Low solution anneal	60,000/95,000	414/655	120,000/150,000	827/1034	30/60	40/60
High solution anneal	42,000/60,000	290/414	105,000/130,000	724/896	40/65	60/90

STRIP

CONDITION	0.2% YIELD STRENGTH		ULTIMATE TENSILE STRENGTH		ELONGATION IN 2 IN (50.8 MM)	REDUCTION OF AREA
	psi	MPa	psi	MPa	%	%
Low solution anneal	60,000/75,000	414/517	120,000/140,000	827/965	30/55	—

Heat treatment

625 has three basic heat treatments:

1. High solution anneal	2000/2200°F (1093/1204°C), air quench or faster.
2. Low solution anneal	1700/1900°F (927/1038°C), air quench or faster.
3. Stress relieve	1650°F (899°C), air quench.

The time at the above temperatures depends on volume and section thickness. Strip, for example, would require shorter times than large sections. Temperatures for treatments No. 1 and No. 2 are generally held for 0.5 to 1 hour, 1 to 4 hours for treatment No. 3.

Treatment No. 1 is not commonly used for applications below 1500°F (816°C). It is generally used above 1500°F (816°C) and where resistance to creep is important. The high solution anneal is also used to develop the maximum softness for mill processing operations, such as cold rolling or drawing.

Treatment No. 2 is the most used treatment and develops an optimum combination of tensile and rupture properties from ambient temperatures to 1900°F (1038°C). Ductility and toughness at cryogenic temperatures are also very good.

Treatment No. 3 is recommended for applications below 1200°F (649°C) when maximum fatigue, hardness, tensile, and yield strength properties are desired. Ductility and toughness at cryogenic temperatures are excellent. When a fine grain size is desired for fatigue, tensile, and yield strengths up to 1500°F (816°C), treatment No. 3 is sometimes used.

> 625

Workability

Hot working	Hot working may be done at 2100°F (1149°C) maximum furnace temperature. Care should be exercised to avoid frictional heat build-up, which can result in overheating, exceeding 2100°F (1149°C). 625 becomes very stiff at temperatures below 1850°F (1010°C). Work pieces that fall below this temperature should be reheated. Uniform reductions are recommended to avoid the formation of a duplex grain structure. Approximately 15/20% reduction is recommended for finishing.
Cold working	625 can be cold formed by standard methods. When the material becomes too stiff from cold working, ductility can be restored by process anneals.
Weldability	Welding can be accomplished by the gas-shielded processes using a tungsten electrode or a consumable electrode. Postweld heat treatments of the weld are not necessary to maintain corrosion resistance. Heavy restrained sections can be welded, and the weld's mechanical properties follow the same trends as base metal properties. Standard practices such as clean surfaces, good joint alignment, U-joints for thicker sections, etc. should be followed.
Machinablility	Low cutting speeds, rigid tools and work piece, heavy equipment, ample coolant, and positive feeds are general recommendations.
Additional machinability notes	Carbide tools should have smaller angles than high-speed tools and operating speeds can be higher. A sulfur-base cutting fluid is recommended. Thoroughly clean work piece after machining to prevent surface contamination during subsequent heat treating. Chlorine additives would be an alternative.

> 625

EFFECT OF COLD WORK

STRIP ANNEALED AT 1865°F (1019°C) BEFORE COLD WORKING

STRIP THICKNESS		0.2% YIELD STRENGTH		ULTIMATE TENSILE STRENGTH		ELONGATION IN 2 IN (50.8 MM)	REDUCTION OF AREA	HARDNESS
IN	MM	psi	MPa	psi	MPa	%	%	HRC
0.113	2.87	67,000	462	136,000	938	46.2	Annealed	97 (HRB)
0.100	2.54	104,000	717	148,000	1020	37.0	11	29
0.090	2.29	137,000	945	163,000	1124	20.0	20	36
0.083	2.11	158,000	1089	178,000	1227	11.8	26	38
0.074	1.88	193,000	1331	200,000	1379	7.8	34	47
0.070	1.78	198,000	1365	209,000	1441	5.3	38	43
0.0615	1.56	210,000	1448	214,000	1475	4.6	46	44
0.0567	1.44	219,000	1510	223,000	1538	4.1	50	45
0.050	1.27	218,000	1503	230,000	1586	4.0	56	45
0.0452	1.15	228,000	1572	233,000	1606	4.3	60	45
0.0431	1.095	233,000	1606	238,000	1641	3.8	61	46
0.0414	1.052	230,000	1586	236,000	1627	3.1	64	46

HIGH-SPEED CUTTING TOOLS FOR LATHE TURNING OPERATIONS

ANGLE	ROUGHING	FINISHING
Back rake	0°	8°
Positive side rake	—	14–18°
End clearance	6°	8°
End cutting edge	6°	25°
Side cutting edge	—	Up to 45°

CUTTING SPEEDS FOR HIGH-SPEED STEELS

OPERATION	SPEED		FEED	
	SFPM	M/S	IPR	MM/REV
Turning	12–20	0.06/0.10	0.010	0.25
Drilling (0.500 in/12.70 mm)	10–12	0.05/0.06	0.006/0.010	0.15/0.25
Tapping	5–10	0.03/0.05	—	—
Milling	10–20	0.05/0.10	—	—
Reaming	8–10	0.04/0.05	—	—

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> 625

Descaling (cleaning)

Sodium hydride baths are necessary to descale this alloy. After the sodium hydride treatment, the material should be immersed in a sulfuric acid bath 165°F (74°C) for approximately 3 minutes. A 25-minute immersion in a nitric-hydrofluoric bath 145°F (63°C) is then necessary. Rinse. Sulfuric solution: 16% by weight, H2S04. Nitric solution: 8% HNO3 by weight and 3% HF by weight. Acid etching for macro-inspection: Expose material electrolytically to a 3-to-1 HCl to $HN0_3$ solution, saturated with $CuCl_2$ at a current density of 0.645 amp/in^2 (25.4 A/m).

For additional information, please contact your nearest sales office:

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