CARPENTER TECHNOLOGY

DATASHEET

AerMet® 360

Type analysis

Single figures are nominal except where noted.

Iron	Balance	**Cobalt**	17.0 %	**Nickel**	11.10 %
Molybdenum	2.35 %	**Chromium**	1.80 %	**Carbon**	0.34 %

Forms manufactured

Bar	**Hollow Bar**
Plate	**Ingot**
Billet	

Description

AerMet 360 is an alloy possessing ultra-high hardness and strength combined with good ductility and toughness. The alloy is designed for components requiring ultra-high strength and good fracture toughness.

Key Properties:

- High strength
- Ultra-high hardness
- Good fracture toughness

Markets:

- Aerospace
- Defense
- Energy

Applications:

- Hypersonics
- Structural members
- Ordnance
- Ballistic-tolerant components
- Armor
- Actuators
- Structural tubing
- Drive shafts

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Corrosion resistance

AerMet 360 has some environmental resistance, but it is not a stainless alloy.

Physical properties

PROPERTY	At or From	English Units	Metric Units
DENSITY	70°F	0.2880 lb/in^3	7972 kg/m^3
MEAN SPECIFIC HEAT	-45 (-43°C)	0.0967 Btu/lb/°F	404.9 J/kg·K
	-45 to -20°F (-43 to -29°C)	0.0987 Btu/lb/°F	413.2 J/kg·K
	-45 to 0°F (-43 to -18°C)	0.1001 Btu/lb/°F	419.1 J/kg·K
	-45 to 20°F (-43 to -7°C)	0.1014 Btu/lb/°F	424.5 J/kg·K
	-45 to 40°F (-43 to 4°C)	0.1027 Btu/lb/°F	430.0 J/kg·K
	-45 to 60°F (-43 to 16°C)	0.1038 Btu/lb/°F	434.6 J/kg·K
	-45 to 80°F (-43 to 27°C)	0.1049 Btu/lb/°F	439.2 J/kg·K
	-45 to 100°F (-43 to 38°C)	0.1058 Btu/lb/°F	443.0 J/kg·K
	-45 to 120°F (-43 to 49°C)	0.1068 Btu/lb/°F	447.2 J/kg·K
	-45 to 150°F (-43 to 66°C)	0.1080 Btu/lb/°F	452.2 J/kg·K
	70 to 200°F (21 to 93°C)	0.1101 Btu/lb/°F	461.0 J/kg·K
	70 to 300°F (21 to 149°C)	0.1137 Btu/lb/°F	476.0 J/kg·K
	70 to 400°F (21 to 204°C)	0.1172 Btu/lb/°F	490.7 J/kg·K
	70 to 500°F (21 to 260°C)	0.1212 Btu/lb/°F	507.4 J/kg·K
	70 to 600°F (21 to 316°C)	0.1260 Btu/lb/°F	527.5 J/kg·K
	70 to 700°F (21 to 371°C)	0.1309 Btu/lb/°F	548.1 J/kg·K
	70 to 800°F (21 to 427°C)	0.1359 Btu/lb/°F	569.0 J/kg·K
	70 to 900°F (21 to 482°C)	0.1486 Btu/lb/°F	622.2 J/kg·K
	70 to 1000°F (21 to 538°C)	0.1654 Btu/lb/°F	692.5 J/kg·K
	70 to 1100°F (21 to 593°C)	0.1567 Btu/lb/°F	656.1 J/kg·K
	70 to 1200°F (21 to 649°C)	0.1473 Btu/lb/°F	616.7 J/kg·K
	70 to 1300°F (21 to 704°C)	0.1806 Btu/lb/°F	756.1 J/kg·K
	70 to 1400°F (21 to 760°C)	0.2611 Btu/lb/°F	1093.2 J/kg·K
	70 to 1500°F (21 to 816°C)	0.2723 Btu/lb/°F	1140.1 J/kg·K
	70 to 1600°F (21 to 871°C)	0.1905 Btu/lb/°F	797.6 J/kg·K
	70 to 1700°F (21 to 927°C)	0.1375 Btu/lb/°F	575.7 J/kg·K
	70 to 1800°F (21 to 982°C)	0.1336 Btu/lb/°F	559.4 J/kg·K
	70 to 1900°F (21 to 1038°C)	0.1397 Btu/lb/°F	584.9 J/kg·K
	70 to 2000°F (21 to 1093°C)	0.1409 Btu/lb/°F	589.9 J/kg·K

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MEAN COEFFICIENT OF THERMAL EXPANSION

At or From	English Units	Metric Units
-45°F (-43°C)	4.9851 x 10^{-6} in/in/°F	8.9732 x 10^{-6} m/m/°C
-45 to -20°F (-43 to -29°C)	5.0654 x 10^{-6} in/in/°F	9.1177 x 10^{-6} m/m/°C
-45 to 0°F (-43 to -18°C)	5.0893 x 10^{-6} in/in/°F	9.1607 x 10^{-6} m/m/°C
-45 to 20°F (-43 to -7°C)	5.0658 x 10^{-6} in/in/°F	9.1184 x 10^{-6} m/m/°C
-45 to 40°F (-43 to 4°C)	4.9563 x 10^{-6} in/in/°F	8.9213 x 10^{-6} m/m/°C
-45 to 60°F (-43 to 16°C)	4.9909 x 10^{-6} in/in/°F	8.9836 x 10^{-6} m/m/°C
-45 to 80°F (-43 to 27°C)	5.7295 x 10^{-6} in/in/°F	10.3131 x 10^{-6} m/m/°C
-45 to 100°F (-43 to 38°C)	5.5321 x 10^{-6} in/in/°F	9.9578 x 10^{-6} m/m/°C
-45 to 120°F (-43 to 49°C)	5.4936 x 10^{-6} in/in/°F	9.8885 x 10^{-6} m/m/°C
-45 to 150°F (-43 to 66°C)	5.3470 x 10^{-6} in/in/°F	9.6246 x 10^{-6} m/m/°C
70 to 200°F (21 to 93°C)	5.4494 x 10^{-6} in/in/°F	9.8089 x 10^{-6} m/m/°C
70 to 300°F (21 to 149°C)	5.5742 x 10^{-6} in/in/°F	10.0336 x 10^{-6} m/m/°C
70 to 400°F (21 to 204°C)	5.6675 x 10^{-6} in/in/°F	10.2015 x 10^{-6} m/m/°C
70 to 500°F (21 to 260°C)	5.7521 x 10^{-6} in/in/°F	10.3538 x 10^{-6} m/m/°C
70 to 600°F (21 to 316°C)	5.8341 x 10^{-6} in/in/°F	10.5014 x 10^{-6} m/m/°C
70 to 700°F (21 to 371°C)	5.9199 x 10^{-6} in/in/°F	10.6558 x 10^{-6} m/m/°C
70 to 800°F (21 to 427°C)	6.0129 x 10^{-6} in/in/°F	10.8232 x 10^{-6} m/m/°C
70 to 900°F (21 to 482°C)	6.1027 x 10^{-6} in/in/°F	10.9849 x 10^{-6} m/m/°C
70 to 1000°F (21 to 538°C)	6.2006 x 10^{-6} in/in/°F	11.1611 x 10^{-6} m/m/°C
70 to 1100°F (21 to 593°C)	6.3078 x 10^{-6} in/in/°F	11.3540 x 10^{-6} m/m/°C
70 to 1200°F (21 to 649°C)	6.2421 x 10^{-6} in/in/°F	11.2358 x 10^{-6} m/m/°C
70 to 1300°F (21 to 704°C)	5.9383 x 10^{-6} in/in/°F	10.6889 x 10^{-6} m/m/°C
70 to 1400°F (21 to 760°C)	5.3970 x 10^{-6} in/in/°F	9.7146 x 10^{-6} m/m/°C
70 to 1500°F (21 to 816°C)	4.8024 x10^{-6} in/in/°F	8.6443 x 10^{-6} m/m/°C
70 to 1600°F (21 to 871°C)	4.5080 x10^{-6} in/in/°F	8.1144 x 10^{-6} m/m/°C
70 to 1700°F (21 to 927°C)	4.8094 x 10^{-6} in/in/°F	8.6569 x 10^{-6} m/m/°C
70 to 1800°F (21 to 982°C)	5.1672 x 10^{-6} in/in/°F	9.3010 x 10^{-6} m/m/°C
70 to 1900°F (21 to 1038°C)	5.4928 x 10^{-6} in/in/°F	9.8870 x 10^{-6} m/m/°C
70 to 2000°F (21 to 1093°C)	5.7847 x 10^{-6} in/in/°F	10.4125 x 10^{-6} m/m/°C

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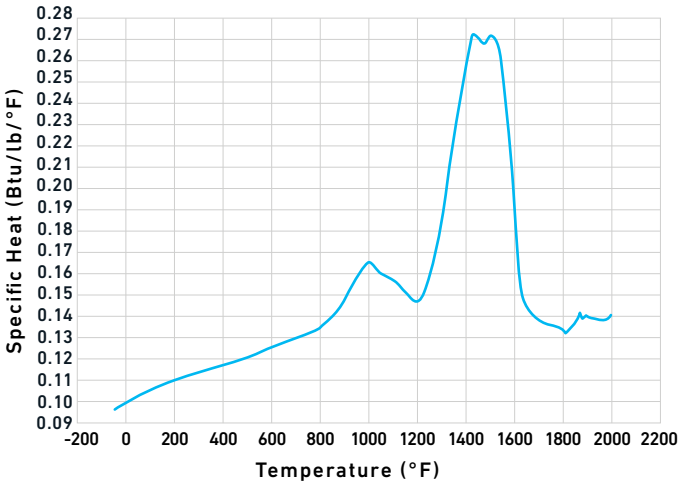
	At or From	English Units	Metric Units
THERMAL CONDUCTIVITY	-45°F (-43°C)	139.3814 Btu-in/hr/ft²/°F	20.0892 W/m·K
	-45°F to -20°F (-43 to -29°C)/	143.6757 Btu-in/hr/ft²/°F	20.7082 W/m·K
	-45°F to 0°F (-43 to -18°C)	147.2694 Btu-in/hr/ft²/°F	21.2261 W/m·K
	-45°F to 32°F (-43 to 0°C)	152.5322 Btu-in/hr/ft²/°F	21.9847 W/m·K
	-45°F to 50°F (-43 to 10°C)	155.3908 Btu-in/hr/ft²/°F	22.3967 W/m·K
	-45°F to 70°F (-43 to 21°C)	158.5153 Btu-in/hr/ft²/°F	22.8470 W/m·K
	-45°F to 125°F (-43 to 52°C)	165.9171 Btu-in/hr/ft²/°F	23.9139 W/m·K
	70 to 200°F (21 to 93°C)	173.9406 Btu-in/hr/ft²/°F	25.0703 W/m·K
	70 to 400°F (21 to 204°C)	189.3973 Btu-in/hr/ft²/°F	27.2981 W/m·K
	70 to 600°F (21 to 316°C)	203.9650 Btu-in/hr/ft²/°F	29.3978 W/m·K
	70 to 800°F (21 to 427°C)	213.3304 Btu-in/hr/ft²/°F	30.7476 W/m·K
	70 to 1000°F (21 to 538°C)	219.9819 Btu-in/hr/ft²/°F	31.7063 W/m·K
	70 to 1200°F (21 to 649°C)	224.7382 Btu-in/hr/ft²/°F	32.3918 W/m·K
	70 to 1400°F (21 to 760°C)	229.0322 Btu-in/hr/ft²/°F	33.0107 W/m·K
	70 to 1600°F (21 to 871°C)	230.3534 Btu-in/hr/ft²/°F	33.2012 W/m·K
	70 to 1800°F (21 to 982°C)	231.9388 Btu-in/hr/ft²/°F	33.4297 W/m·K
	70 to 2000°F (21 to 1093°C)	231.6746 Btu-in/hr/ft²/°F	33.3916 W/m·K
MODULUS OF ELASTICITY (E)	—	27.7 x 10³ ksi	191 x 10³ MPa
SOLIDUS (MEASURED BY DSC)	—	2604°F	1429°C

SPECIFIC HEAT FROM 0–2000°F



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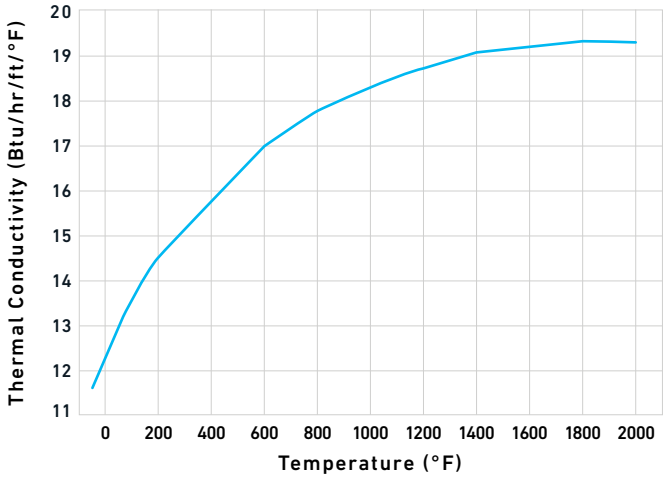
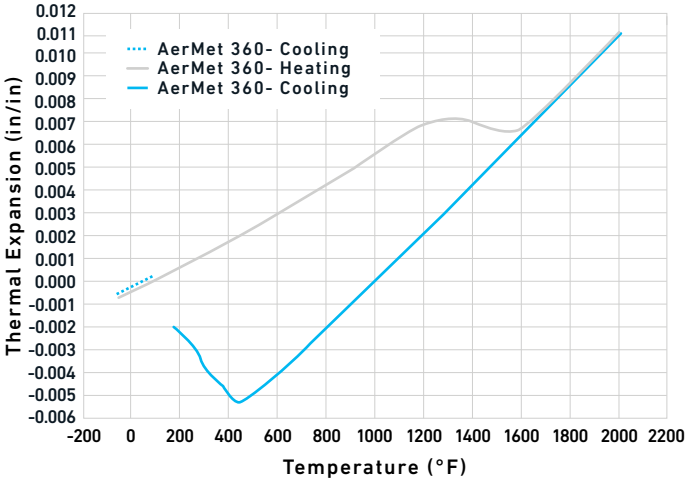
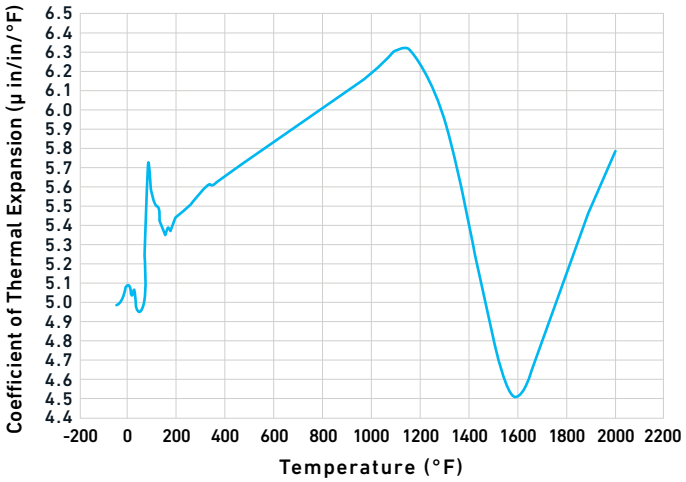
THERMAL CONDUCTIVITY FROM 0–2000°F



THERMAL EXPANSION FROM 0–2000°F



COEFFICIENT OF THERMAL EXPANSION FROM 0–2000°F



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Typical mechanical properties

FORM AND TREATMENT	ORIENTATION	0.2% YIELD STRENGTH		ULTIMATE TENSILE STRENGTH		ELONGATION IN 4D	REDUCTION OF AREA	FRACTURE TOUGHNESS	
		ksi	MPa	ksi	MPa	%	%	ksi√IN	MPa√M
Bar, 6.5–13.5 in. RD, 3.5h double age	Longitudinal	325.6	2244.9	369.6	2548.3	6.6	18.9	22.3	24.5
Bar, 6.5–13.5 in. RD, 3.5h double age	Transverse	322.6	2224.2	366.0	2523.5	5.3	14.3	23.4	25.7
Bar, 6.5–13.5 in. RD, 2.5h double age	Longitudinal	323.1	2227.7	374.2	2580.0	5.2	15	22.7	24.9
Bar, 6.5–13.5 in. RD, 2.5h double age	Transverse	322.4	2222.9	368.0	2537.3	3.8	8.6	20.6	22.6
Overaged	Longitudinal	156.0	1075.6	218.3	1505.1	8.5	17.6	—	—
Solution Treatment + Refrigeration	Longitudinal	226.3	1560.3	335.3	2311.8	9.4	27.4	—	—
Solution Treatment + Refrigeration	Transverse	229.5	1582.3	337.0	2323.5	9.4	26.7	—	—

FORM AND TREATMENT	ORIENTATION	CHARPY V-NOTCH		HARDNESS
		FT-LBS	J	HRC
Bar, 6.5–13.5 in. RD, 3.5h double age	Longitudinal	4.6	6.2	59
Bar, 6.5–13.5 in. RD, 3.5h double age	Transverse	4.3	5.8	59
Bar, 6.5–13.5 in. RD, 2.5h double age	Longitudinal	4.2	5.7	59
Bar, 6.5–13.5 in. RD, 2.5h double age	Transverse	4.0	5.4	59
Overaged	Longitudinal	7.2	9.8	44
Solution Treatment + Refrigeration	Longitudinal	12.6	17.1	56
Solution Treatment + Refrigeration	Transverse	13.1	17.8	56

3.5h double age: 1875°F (1024°C) 1h, AC to RT/ 1775°F (968°C) 1h, AC to RT/ -100°F (-73°C) 1h, AW to RT/ 900°F (482°C) 3.5 hours AC to RT/ -100°F (-73°C) 1h, AW to RT/ 900°F (482°C) 3.5 hours AC to RT/ -100°F (-73°C) 1h, AW to RT
2.5h double age: 1875°F (1024°C) 1h, AC to RT/ 1775°F (968°C) 1h, AC to RT/ -100°F (-73°C) 1h, AW to RT/ 900°F (482°C) 2.5 hours AC to RT/ -100°F (-73°C) 1h, AW to RT/ 900°F (482°C) 2.5 hours AC to RT/ -100°F (-73°C) 1h, AW to RT
Overaged: 1250°F (677°C) 16h, AC to RT
Solution Treatment + Refrigeration: 1775°F (968°C) 1h, AC to RT/ -100°F (-73°C) 1h, AW to RT

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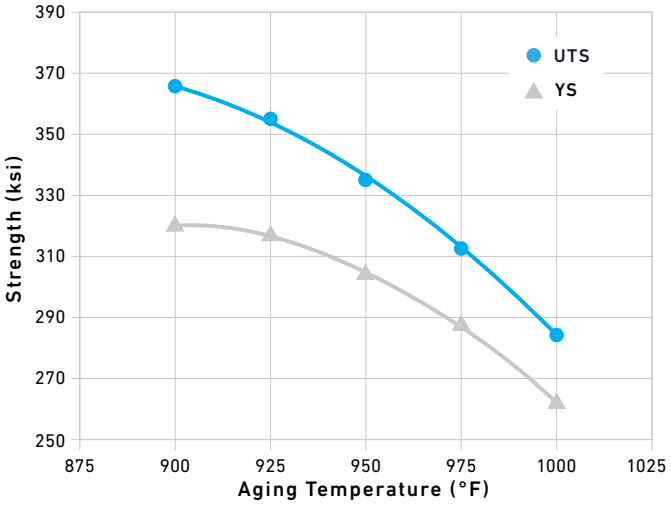
Aging study

AGING TEMP. (°F)	ULTIMATE TENSILE STRENGTH (ksi)	YIELD STRENGTH (ksi)	ELONGATION (%)	REDUCTION OF AREA (%)	CHARPY V-NOTCH (FT-LBS)
900	365.3	320.0	6.9	23.9	5.2
925	357.0	318.5	7.8	28.1	7.0
950	334.4	302.4	7.8	30.8	6.1
975	313.2	287.7	6.9	23.0	4.1
1000	285.0	261.3	5.7	12.9	3.2

Specimens heat treated: 1775°F (968°C) 1h, AC to RT/ -100°F (-73°C) 1h, AW to RT/ age at aging temp 3.5h, AC to RT/ -100°F (-73°C) 1h, AW to RT/ age at aging temp 3.5h, AC to RT/ -100°F (-73°C) 1h, AW to RT

EFFECT OF AGING TEMPERATURE ON TENSILE AND YIELD STRENGTHS



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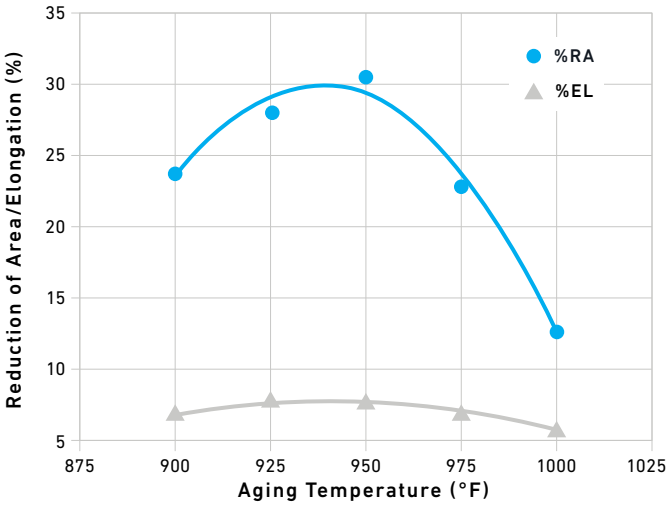
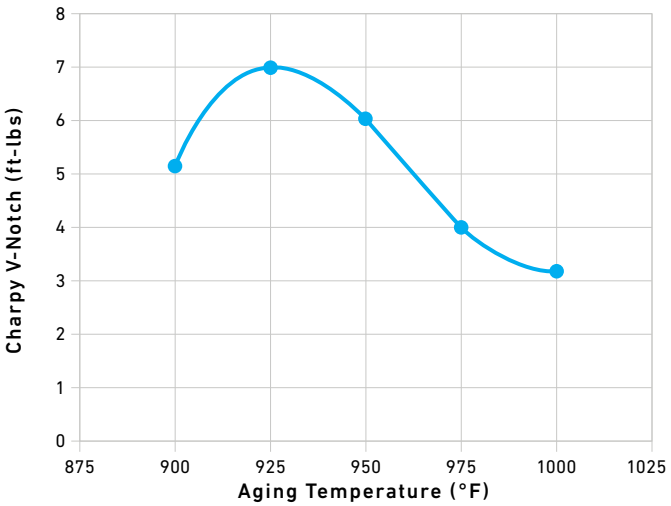
EFFECT OF AGING TEMPERATURE ON REDUCTION OF AREA AND ELONGATION



EFFECT OF AGING TEMPERATURE ON CHARPY V-NOTCH ENERGY



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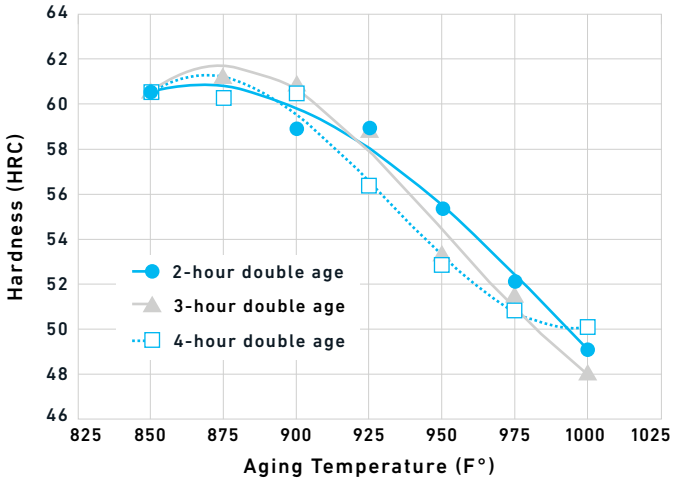
Hardness aging study

AGING TEMPERATURE (°F)	AGING TIME (HRS)	HRC
850	2	60.5
850	3	60.7
850	4	60.6
875	2	61.1
875	3	61.1
875	4	60.3
900	2	59.0
900	3	60.8
900	4	60.6
925	2	59.0
925	3	58.7
925	4	56.4
950	2	55.4
950	3	53.3
950	4	53.0
975	2	52.1
975	3	51.5
975	4	50.9
1000	2	49.1
1000	3	47.9
1000	4	50.2

Specimens heat treated: 1775°F (968°C) 1h, AC to RT/ -100°F (-73°C) 1h, AW to RT/ aged, AC to RT/ -100°F (-73°C) 1h, AW to RT/ aged, AC to RT/ -100°F (-73°C) 1h, AW to RT

HARDNESS AS A FUNCTION OF AGING TEMPERATURE



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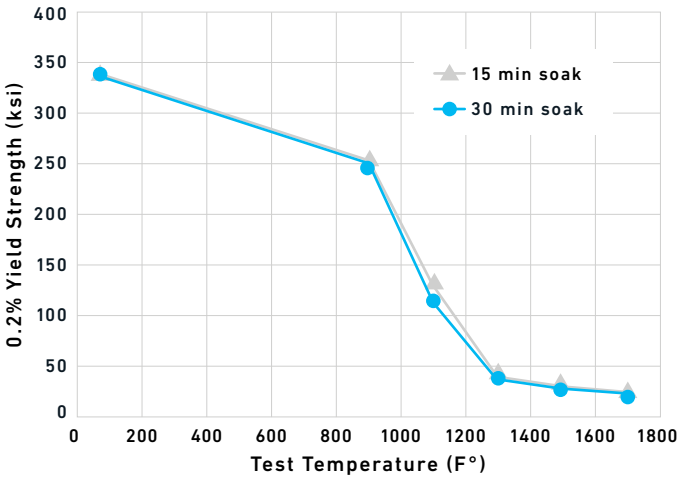
Elevated temperature compressive yield strength

COMPRESSIVE YIELD STRENGTH (KSI) (0.005 IN/IN/MIN)		
TEST TEMPERATURE (°F)	**15 MIN SOAK**	**30 MIN SOAK**
72	338.0	338.0
900	252.4	252.2
1100	129.5	113.3
1300	38.4	38.0
1500	29.5	25.8
1700	22.1	21.9

Specimens heat treated: 1875°F (1024°C) 1h, AC to RT/ 1775°F (968°C) 1h, AC to RT/ -100°F (-73°C) 1h, AW to RT/ 900°F (482°C) 3.5 hours AC to RT/ -100°F (-73°C) 1h, AW to RT/ 900°F (482°C) 3.5 hours AC to RT/ -100°F (-73°C) 1h, AW to RT

COMPRESSIVE YIELD STRENGTH AS A FUNCTION OF TEST TEMPERATURE



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Elevated temperature tensile testing

DURATION	TEMPERATURE (°F)	YIELD STRENGTH (ksi)	ULTIMATE TENSILE STRENGTH (ksi)	ELONGATION (%)	REDUCTION OF AREA (%)
15 min soak	72	326.1	372.7	6.3	15.5
	900	220.6	265.6	9.0	18.0
	1100	97.0	127.6	11.8	19.7
	1300	34.4	34.4	59.8	90.3
	1500	30.8	35.3	40.3	80.2
	1700	12.5	16.2	60.3	94.8
30 min soak	72	326.1	372.7	6.3	15.5
	900	221.1	266.8	7.3	19.0
	1100	97.3	135.7	7.7	13.7
	1300	36.5	58.3	46.0	70.0
	1500	31.5	39.7	30.7	71.2
	1700	14.7	19.3	56.0	83.5

Specimens heat treated: 1875°F (1024°C) 1h, AC to RT/ 1775°F (968°C) 1h, AC to RT/ -100°F (-73°C) 1h, AW to RT/ 900°F (482°C) 2.5 hours AC to RT/ -100°F (-73°C) 1h, AW to RT/ 900°F (482°C) 2.5 hours AC to RT/ -100°F (-73°C) 1h, AW to RT

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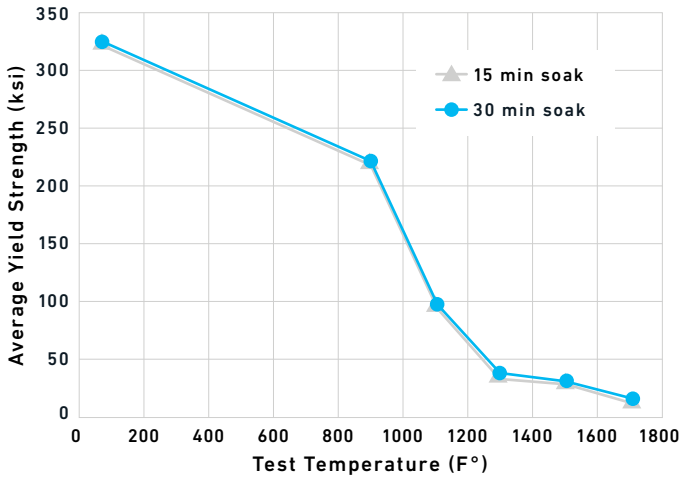
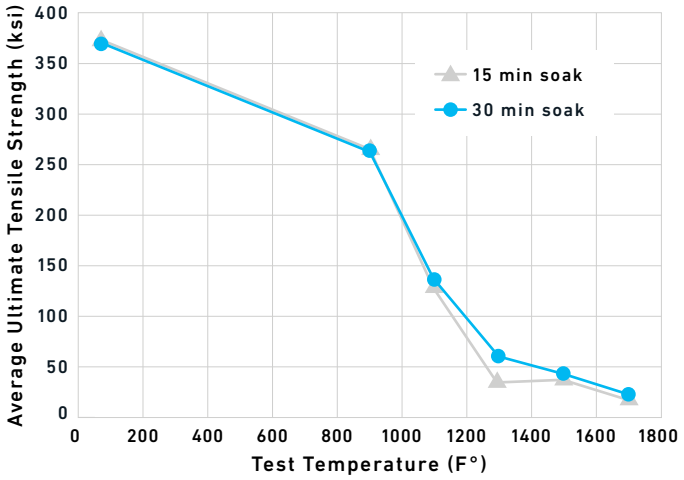
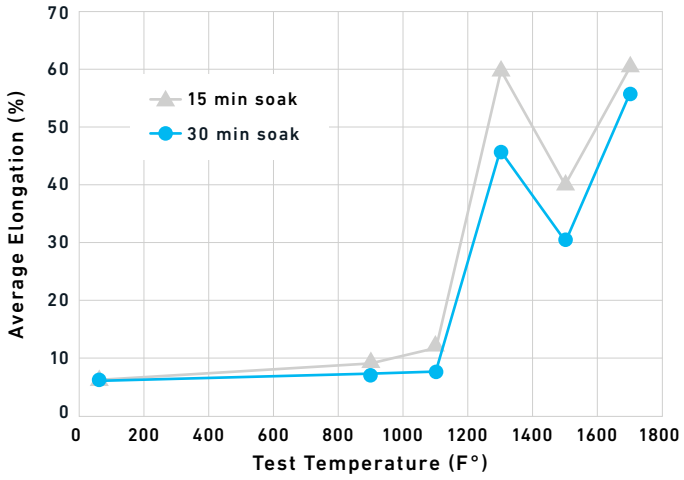
YIELD STRENGTH AS A FUNCTION OF TEST TEMPERATURE



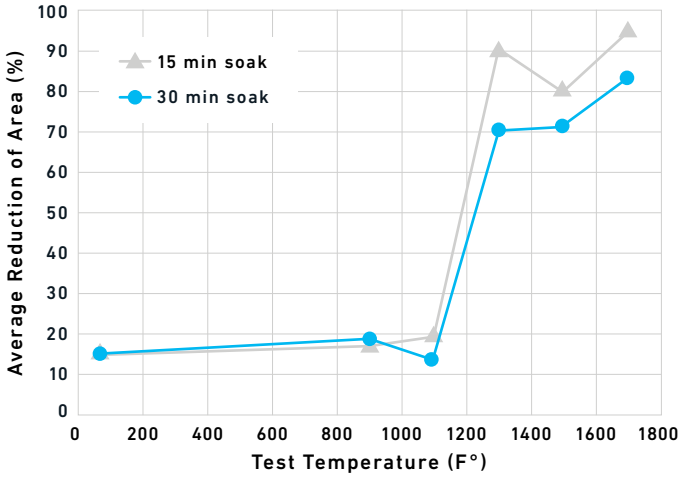
ULTIMATE TENSILE STRENGTH AS A FUNCTION OF TEST TEMPERATURE



ELONGATION AS A FUNCTION OF TEST TEMPERATURE



REDUCTION OF AREA AS A FUNCTION OF TEST TEMPERATURE



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Heat treatment

Annealing	AerMet 360 is softened by using a 1250°F (677°C) overage anneal for 16 hours. The optimum annealed hardness of 44 HRC maximum is obtained following this anneal.
Normalizing	AerMet 360 can be normalized by heating to 1875°F (1024°C) holding for 1 hour and air cooling to room temperature. Optimum softening for machining is obtained by following the 1875°F (1024°C) normalized with a 16 hour 1250°F (667°C) overage anneal.
Solution treatment	The solution treatment temperature range is 1775°F +/-25°F (°C +/-14°C) for 1 hour.
Quenching	Water quenching is not recommended. Proper quenching practice is essential for AerMet 360. The alloy should be cooled from the solution treatment temperature to 150°F (66°C) in 1 to 2 hours to develop optimum properties. Individual sections larger than 2 in. in diameter or 1 in. thick (plate) must be quenched with oil in order to obtain 150°F (66°C) in 1 to 2 hours. Individual sections up to 2 in. diameter or 1 in. thick (plate) will air cool to 150°F (66°C) in 1 to 2 hours. The cooling rate of the furnace load must be monitored by a thermocouple attached to the hottest spot in the load to insure that the 2 hour cool to 150°F (66°C) is obtained.
Cold Treatment	Following cooling to room temperature from the solution temperature, to obtain the full toughness capability, AerMet 360 should be cooled to -100°F (-73°C) and held for 1 hour. The parts can then be air warmed.
Stress relieving	Prior to straightening, a low temperature stress relief at 350/400°F (177/204°C) for 5 hours following the refrigeration operation will provide an optimal combination of ductility and yield strength for the mechanical straightening operation.
Tempering	The standard aging treatment for AerMet 360 is 900°F +/-10°F (482°C +/-6°C) for 3.5 hours followed by refrigeration at -100°F (-73°C) for 1 hour and a second aging cycle at 900°F +/-10°F (482°C +/-6°C) for 3.5 hours followed by refrigeration at -100°F (-73°C) for 1 hour. Final refrigeration is optional.

> AerMet 360

Workability

Forging	Primary breakdown forging of AerMet 360 should be done at a maximum starting temperature of 2250°F (1232°C). Finish forging should be done from 1800°F (982°C) with a finishing temperature below 1650°F (899°C) to optimize the final heat-treated properties. Following forging, the parts should be air cooled to room temperature and then overage annealed. Following the anneal, the forgings should be normalized to restore properties to the dead zone.
Weldability	AerMet 360 has been demonstrated to be weldable.

For additional information, please contact your nearest sales office:
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