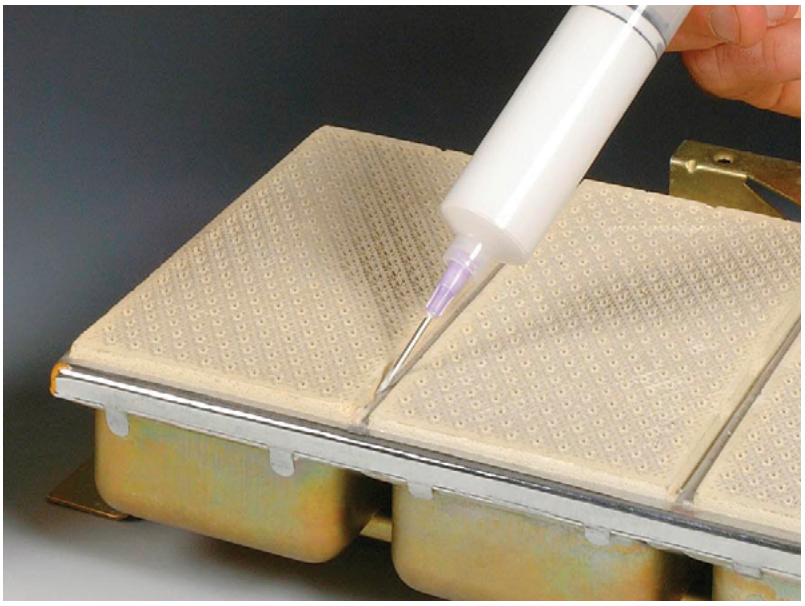
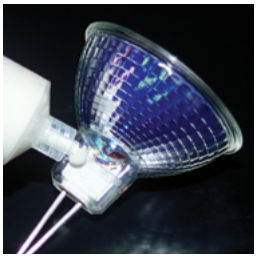
HIGH TEMPERATURE CERAMIC & GRAPHITE ADHESIVES

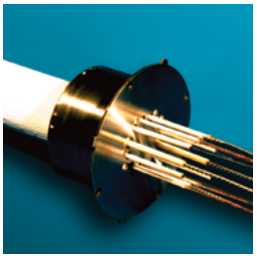
Technical Bulletin A2



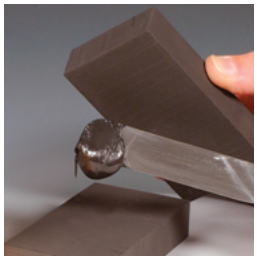
Ceramabond™ 685-N bonds infrared heater.



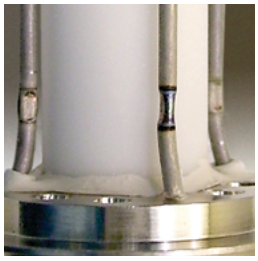
Ceramabond™ 835-M bonds halogen lamp.



Ceramabond™ 503 coats heater used to 1700 °C.



Graphi-Bond™ 551-RN bonds graphite blocks.



Ultra-Temp™ 516 seals heater assembly.

Aremco's high temperature ceramic and graphite adhesives are unique formulations for bonding, potting and sealing ceramics, composites, graphite, metals, quartz, and semiconductors for applications to 3200 °F (1760 °C).

Part No.	Filler	Bonding*	Principal Use
503	Al_2O_3	C–C	Dense Ceramics; Alumina-to-Alumina
552		C–C, C–M	Solid Oxide Fuel Cells; Low CTE Metals
569		C–C, C–M, Quartz	Probes, Sensors, Resistors, Igniters, Heaters
670		C–C, C–M	Ceramic Textiles, Thread-Locking
671		C–C, C–M, M–M	Ceramic Textiles, Thread-Locking
835-M		C–C, C–M, Quartz	Halogen Lamps
835-MB		C–C, C–M, Quartz	Halogen Lamps
865	AlN	C–C, C–M	Probes & Sensors; Thermal Conductivity
600-N	$Al_2O_3 – SiO_2$	C–C, C–M	Refractory Repair
668		C–C, C–M	Oxygen Sensors, Heaters
551-RN	Graphite	Graphite, Carbon	Reducing/Vacuum Atmosphere
669		Graphite	Oxidizing Atmosphere
571	MgO	C–M, M–M	Heaters, Induction Coils, Sensors
632	Mica	Mica	Mica Heaters
618-N	SiO_2	C–C, Quartz	Porous Ceramics, Quartz Tubes & Vessels
516	ZrO_2	C–C, C–M	Thermocouples, Semiconductor Wafers
685-N		C–C, C–M	Gasketing, Heaters, Igniters
835		C–C, C–M	Halogen Lamps
885		C–C	Zirconia, Solid Oxide Fuel Cells
890	SiC	C–C	Crucibles, Heaters, Sagger Plates

*C–C = Ceramic-to-Ceramic C–M = Ceramic-to-Metal M–M = Metal-to-Metal

TYPICAL APPLICATIONS

Electrical

- Halogen Lamps
- Heaters
- Igniters
- Fiberoptics
- Resistors
- Solid Oxide Fuel Cells

Instruments & Sensors

- Gas Chromatographs
- High Vacuum Components
- Liquid Metal Inclusion Counters
- Mass Spectrometers
- Oxygen Analyzers
- Strain Gauges
- Semiconductors
- Temperature Probes

Mechanical

- Ceramic Honeycombs
- Ceramic Textiles
- Graphite Blocks
- Refractory Insulation
- Sagger Plates
- Thread-Locking

HIGH TEMPERATURE CERAMIC & GRAPHITE ADHESIVES PROPERTIES

Part Number		503	552	569	670	671	835-M	835-MB	600-N	668	865
Tradename		Ceramabond™									
Major Constituent		Al_2O_3							$Al_2O_3 – SiO_2$		AlN
Color		White	White	White	White	White	White	White	Tan	White	Gray
Temperature Limit, °F (°C)		3000 (1650)	3000 (1650)	3000 (1650)	3000 (1650)	3200 (1760)	3000 (1650)	3000 (1650)	3000 (1650)	2500 (1371)	3000 (1650)
No. Components		1	1	1	1	1	1	2	1	1	1
Viscosity, cP		50,000–90,000	53,000–73,000	Paste	2,500–5,000	40,000–80,000	30,000–40,000	40,000–80,000	5,000–15,000	40,000–80,000	Paste
Specific Gravity, g/cc		2.35–2.55	1.90–2.20	2.15–2.30	1.80–1.95	2.05–2.15	2.35–2.45	2.00–2.15	2.00–2.05	2.20–2.40	1.95–2.15
CTE, in/in/°F × 10^{-6} (°C)		4.0 (7.2)	4.3 (7.7)	4.2 (7.6)	4.3 (7.7)	4.3 (7.7)	4.0 (7.2)	3.8 (6.8)	3.0 (5.4)	4.0 (7.2)	1.5 (2.7)
Handling	**Mix Ratio,** powder:liquid	NA	NA	NA	NA	NA	NA	100 : 60–80	NA	NA	NA
Handling	**Thinner**	503-T	552-T	569-T	670-T	671-T	835-M-T	835-MB-T	600-T	668-T	865-T
Handling	**Solvent**	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water
Handling	**Application Temperature,** °F	50–90	50–90	50–90	50–90	50–90	50–90	50–90	50–90	50–90	50–90
Handling	**Storage Temperature,** °F	40–90	40–90	40–90	40–90	40–90	40–90	40–90	40–90	40–90	40–90
Handling	**Shelf Life,** months	6	6	6	6	6	6	6	6	6	6
Curing	**Air Set,** hrs	≤ 1	1–4	1–4	1–4	1–4	1–4	1–4	1–4	1	1–4
Curing	**Heat Cure,** °F, hrs	200, 2 + 500, 2 + 700, 2	200, 2 + 500, 2	200, 2	200, 2	200, 2	200, 2	200, 2 + 350, 2 + 500, 2	200, 2 + 350, 1	200, 1–4	200, 2 + 350, 2 + 500, 2
Dielectric Strength, volts/mil @ RT		171	173	138	142	182	163	202	203	118	187
Torque Strength, ft-lbs[1]		60	52	38	60	57	63	27	14	38	27
Moisture Resistance[2]		Good	Excellent	Excellent	Excellent	Excellent	Good	Good	Excellent	Excellent	Excellent
Alkali Resistance[2]		Fair	Good	Good	Good	Excellent	Excellent	Excellent	Good	Excellent	Good
Acid Resistance[2]		Excellent	Good	Excellent	Good	Good	Good	Good	Good	Good	Good

Footnotes
[1] Tested using a torque wrench after bonding a pre-oxidized ½"–13 nut and bolt and final curing at 1000 °F.
[2] Properties were evaluated after curing at 700 °F for 2 hours.

General Notes
[1] All adhesives except 551-RN contain no volatile organic compounds (VOCs).
[2] Special pigments available upon request.
[3] Some adhesives including 503, 516, 552, 569, 571, 618-N, and 890 can be formulated using 1–5 micron ceramic powders. Add "-VFG" to the part number (eg. 503-VFG) and contact Aremco for special pricing.

Abbreviations
NA Not Applicable
NM Not Measured

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HIGH TEMPERATURE CERAMIC & GRAPHITE ADHESIVES PROPERTIES

Part Number		551-RN[3,4]	669	571[5]	632	618-N	890[6]	516	685-N	835	885[6]
Tradename		Graphi-Bond™		Ceramabond™							
Major Constituent		Graphite		MgO	Mica	SiO_2	SiC	$ZrO_2 – ZrSiO_4$			
Color		Black	Black	Off-White	Tan	Off-White	Blue-Gray	Tan	Tan	Tan	Tan
Temperature Limit, °F (°C)		5400 (2985)	1400 (760)	3200 (1760)	2300 (1260)	3000 (1650)	3000 (1650)	3200 (1760)	3000 (1650)	3000 (1650)	3200 (1760)
No. Components		1	1	2	1	1	1	1	1	1	1
Viscosity, cP		Paste	20,000–40,000	20,000–90,000	10,000–25,000	40,000–60,000	35,000–55,000	40,000–70,000	5,000–20,000	20,000–40,000	10,000–20,000
Specific Gravity, g/cc		1.45–1.50	1.45–1.50	1.90–2.20	1.45–1.50	1.80–1.90	1.70–1.75	2.15–2.30	1.85–1.95	2.25–2.35	2.65–2.70
CTE, in/in/°F × 10^{-6} (°C)		4.1 (7.4)	4.2 (7.6)	7.0 (12.6)	4.7 (8.5)	.33 (.59)	2.4 (4.4)	4.1 (7.4)	4.5 (8.1)	4.0 (7.2)	4.0 (7.2)
Handling	**Mix Ratio,** powder:liquid	NA	NA	1.0:1.0, 1.5:1.0	NA	NA	NA	NA	NA	NA	NA
Handling	**Thinner**	Ethanol	669-T	571-T	632-T	618-N-T	890-T	516-T	685-N-T	835-T	885-T
Handling	**Solvent**	Ethanol	Water	Water	Water	Water	Water	Water	Water	Water	Water
Handling	**Application Temperature,** °F	40–90	50–90	50–90	50–90	50–90	50–90	50–90	50–90	50–90	50–90
Handling	**Storage Temperature,** °F	30–75	40–90	40–90	40–90	40–90	40–90	40–90	40–90	40–90	40–90
Handling	**Shelf Life,** months	6	6	6	6	6	6	6	6	6	6
Curing	**Air Set,** hrs	1–4	1–4	1–4	1–4	1–4	≤1	1–4	1–4	≤1	≤1
Curing	**Heat Cure,** °F, hrs	265, 4 + 500, 2	200, 2	200, 2	200, 2 + 500, 2	200, 2 + 500, 2 + 700, 2	200, 2 + 500, 2 + 700, 2	200, 2 + 500, 2 + 700, 2	200, 2	200,2	200, 2 + 500, 2 + 700, 2
Dielectric Strength, volts/mil @ RT		75	105	91	150	156	73	188	176	111	105
Torque Strength, ft-lbs[1]		30	26	22	2	77	40	50	35	50	40
Moisture Resistance[2]		Excellent	Excellent	Excellent	Good	Excellent	Good	Good	Excellent	Good	Good
Alkali Resistance[2]		Good	Good	Good	Good	Good	Good	Excellent	Good	Good	Good
Acid Resistance[2]		Good	Good	Fair	Good	Good	Good	Good	Good	Good	Good

Footnotes

[1] Tested using a torque wrench after bonding a pre-oxidized ½"–13 nut and bolt and final curing at 1000 °F.
[2] Properties were evaluated after curing at 700 °F for 2 hours.
[3] Graphi-Bond™ 551-RN is also offered in a two-part, resin and powder, system called 551-RN-X for international shipments of 1 gallon or more.
[4] Graphi-Bond™ 551-RN also demonstrates a lap-shear strength of 770 psi.
[5] Ceramabond™ 571 ranges for viscosity and specific gravity reflect a powder-to-liquid mix ratio that ranges from 1-to-1 to 1.5-to-1.
[6] Ceramabond™ 885 and 890 are also available in high pH, silicate-bonded systems. Part numbers are 885-K and 890-K. Contact Aremco for special pricing.

General Notes

[1] All adhesives except 551-RN contain no volatile organic compounds (VOCs).
[2] Special pigments available upon request.
[3] Some adhesives including 503, 516, 552, 569, 571, 618-N, and 890 can be formulated using 1–5 micron ceramic powders. Add "-VFG" to the part number (eg. 503-VFG) and contact Aremco for special pricing.

Abbreviations

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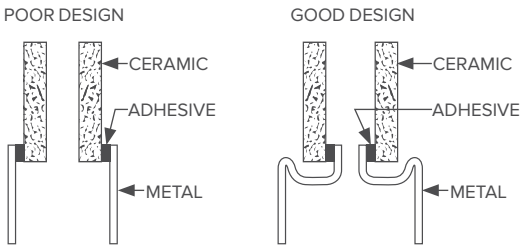
DESIGN GUIDELINES

General design criteria for bonding with ceramic and graphite adhesives are similar to those for epoxies and other organic adhesives. Main considerations include the coefficient of thermal expansion, joint design, glue line thickness, and operating environment.

Coefficient of Thermal Expansion

CERAMIC-TO-METAL RECOMMENDED DESIGN

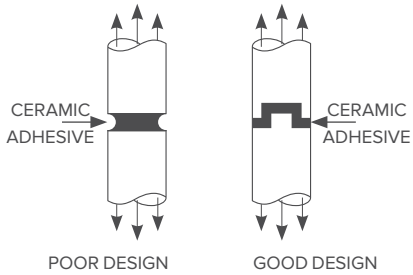


Due to the high thermal loading implicit in most ceramic adhesive applications, the joint design should account for the difference in the coefficient of thermal expansion between the adhesive and the components that are being joined. In the illustration above, note that the "poor" design loads the adhesive in tension since the metal expands faster than the ceramic. The "good" design allows for this thermal mismatch and loads the adhesion in compression, offering higher reliability.

Joint Design

Most adhesives offer relatively poor tensile-shear strength, so it is important to design a joint that will distribute the mechanical stress by maximizing the length of the glue line as shown in this illustration.

CERAMIC-TO-CERAMIC RECOMMENDED JOINT DESIGN



Glue Line Thickness

The clearance between mating parts at operating temperature should be 2–8 mils (50–200 microns). Less than 2 mils will prevent uniform adhesion; greater than 8 mils will often result in cohesive shear failure within the adhesive. A maximum depth of 0.25" is recommended when using a ceramic or graphite adhesive for a small potting application.

Operating Environment

These adhesives offer excellent chemical, electrical and ultra high thermal resistance, and do not outgas under high vacuum. The main limitations are (a) relatively low mechanical strength and (b) slight porosity after curing. Contact Aremco for suggestions about how to reduce porosity and produce gas-tight seals.

APPLICATION PROCEDURES

Surface Preparation

Smooth surfaces are difficult to bond and should be etched, abrasive blasted or oxidized, then cleaned thoroughly prior to application. Aremco's Corr-Prep™ CPR2000 is recommended for etching metals. Porous substrates should be pre-coated with a binder to prevent separation and absorption of the adhesive binder. Add a "-T" to the part number (eg. 503-T) to designate the product thinner.

Mixing

One-part adhesives tend to settle and should be mixed thoroughly prior to use. Refer to Tech Bulletin A12 for information about Aremco's Model 7000 Pneumatic Mixer. Mix ratios for two-part adhesives are shown in the Property Chart. Viscosity may be adjusted by thinning up to 20% by weight.

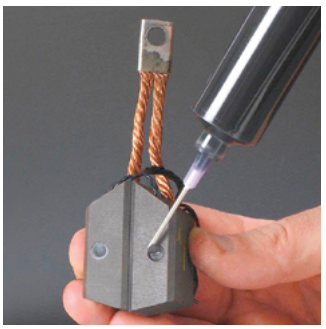
Application

Apply a thin coat of adhesive to each surface using a brush, spatula or dispenser. Using a clamp or similar tool, maintain a uniform glue line of 2–8 mils (200–500 microns) by applying even pressure across the assembly. Wipe away excess material prior to drying. Refer to Tech Bulletin A12 for optional dispensing tools.

Model 7000 Mixer

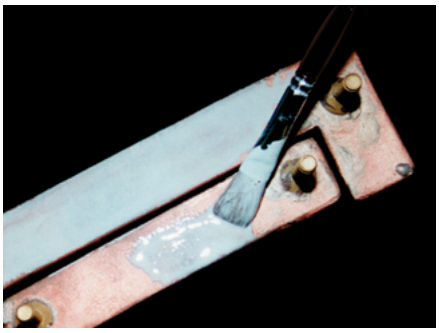
Curing

Refer to the Property Chart for specific curing instructions for each product.

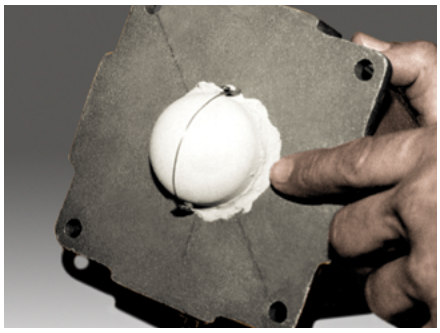


Graphi-Bond™ 551-RN seals sensor in carbon brushes.

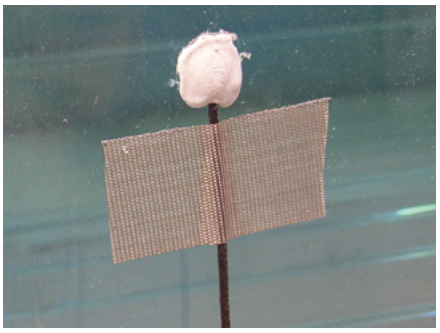
Ceramabond™ 569 bonds flex heater to quartz vessel.



Ceramabond™ 571 coats copper induction heater.

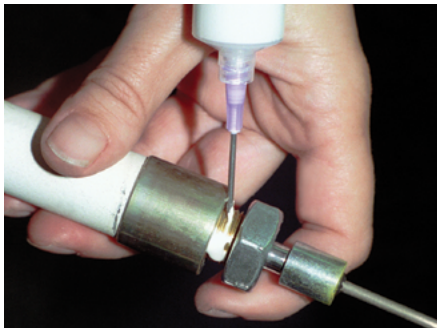


Ceramabond™ 571 coats oxygen sensor.



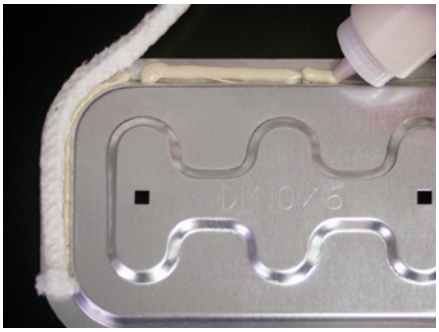
Ceramabond™ 571 bonds thermocouple to glass.

Ceramabond™ 618-N bonds porous ceramic filter elements.

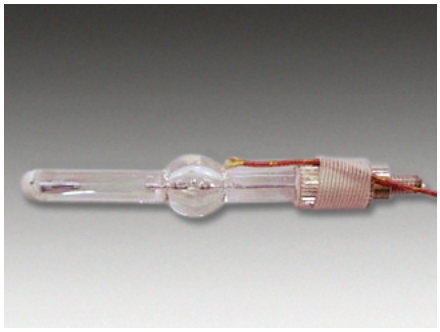


Ceramabond™ 671 used as a high temp threadlocker.

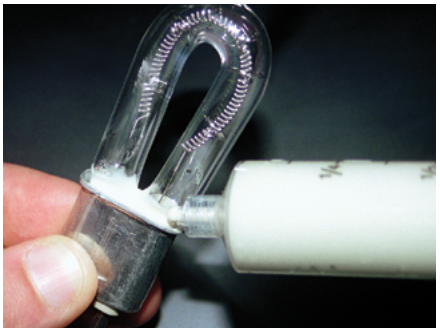
Ceramabond™ 503 repairs furnace saggar plate.



Ceramabond™ 685-N bonds ceramic gasket.



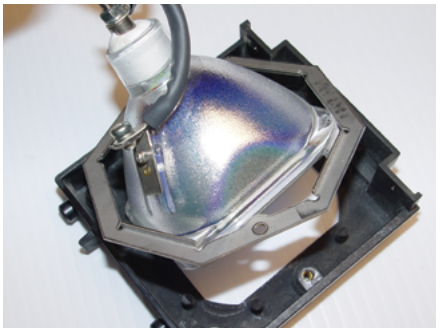
Ultra-Temp™ 516 bonds thermocouple to quartz tube.



Ceramabond™ 835 bonds halogen lamp.

Ceramabond™ 552 seals thermocouple in metal housing.

Ceramabond™ 835-M bonds cover to halogen lamp.



Ceramabond™ 835-M bonds halogen lamp.

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CERAMIC ADHESIVE SELECTOR CHART

	Material	CTE °F (°C)	503	552	569	670	671	835-M	835-MB	600-N	600-HV	668	865	551-RN	669	571	632	618-N	890	516	685-N	835	885
						Al_2O_3				$Al_2O_3 – SiO_2$			AlN	Graphite		MgO	Mica	SiO_2	SiC	$ZrO_2 – ZrSiO_4$			
CERAMICS	Alumina	4.4 (7.9)	•	•	•	•	•	•	•			x				x							
	Alumina-Silica	1.8 (3.2)								x	x	•											
	Aluminum Nitride	1.5 (2.7)											•					x					
	Beryllia	4.1 (7.4)	•	x	x	x	x	x												x	x	x	x
	Boron Carbide	2.6 (4.7)	x									x							x				
	Boron Nitride	4.2 (7.6)	x																				
	Borosilicate Glass	1.8 (3.2)	x															•					
	Calcium Silicate	3.0 (5.4)				•																	
	Ceramic Textile	–				•	x														x		
	Cordierite	1.1 (2.0)																•					
	Graphite	4.3 (7.7)	x											•	•				x				
	Macor	5.2 (9.4)		x	•	x	x	x				x				x	x						
	Mica	4.7 (8.5)															•						
	Mullite	3.0 (5.4)	x	x	x	x						•								x	x	x	
	Quartz	0.30 (0.54)	x		x			x	x			x						•				x	
	Refractory, Dense	–	•																•				x
	Refractory, Light Weight	–								•	•												
	Sapphire	4.2 (7.6)	•		x	x		x	x			x											
	Silica	0.31 (0.56)										x						•					
	Silicon Carbide	2.9 (5.2)	x																•				
	Silicon Nitride	1.8 (3.2)	x									x	x					x	x				
	Steatite	4.0 (7.2)		x	•		x	x	x			x									x	•	
	Zirconia	5.7 (10.3)																		x	x	x	•
	Zirconia Silicate	4.0 (7.2)																		•	•	•	x
METALS	Aluminum	15.0 (27.0)														•							
	Brass	10.2 (18.4)														•							
	Cast Iron	5.9 (10.6)		x	x	x	x	x				x				•	x				x		
	Copper	9.3 (16.7)														•							
	Inconel	6.4 (11.5)		x	x	x	x	x				x				•							
	Molybdenum	2.9 (5.2)		x	•	x	x	x				•								x	x	x	
	Nickel	7.2 (13.0)														•							
	Nickel-Iron	2.6 (4.7)		x	•	x	x	x				•								x	x	x	
	Platinum	4.9 (8.8)	•	x	x	x																	
	Silicon	1.6 (2.9)										x	x							x	x	x	
	Silver	10.6 (19.1)														x							
	Stainless (300 Series)	9.6 (17.3)										x				x							
	Stainless (400 Series)	6.2 (11.2)		x	x	x	x	x				x				•				x	x	x	
	Steel (1010)	6.5 (11.7)		x	x	x	x	x				x				•				x	x	x	
	Tantalum	3.9 (7.0)		x	x	x	x	x				•				x				x	x	x	
	Titanium	5.8 (10.4)		x	x	x	x	x				x				•				x	x	x	
	Tungsten	2.5 (4.5)		x	•	x	x	x				•								x	x	x	

• = Preferred, x = Applicable

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