HIGH TEMPERATURE CERAMIC ADHESIVES & PASTES

Technical Bulletin A2

A 2

Aremco's high temperature ceramic adhesives are unique inorganic formulations for bonding and sealing ceramics, metals, quartz, graphites, textiles and composite materials used in design, process and maintenance applications to 3200 °F. These advanced materials, which exhibit high thermal and electrical resistance, enable engineers to solve problems that were impossible previously using conventional epoxies and other organic-based products.

TYPICAL APPLICATIONS

Electrical

- *Ballast Resistors*
- *Fiberoptics*
- *Gas Ignitors*
- *Halogen Lamps*
- *Resistance Heaters*
- *Rheostats*

Mechanical

- *Catalytic Converters*
- *Ceramic-to-Ceramic*
- *Gasketing/Textiles*
- *Radiant Heaters*
- *Refractory Insulation*
- *Sagger Plates*
- *Threadlocking*
- *Carbon/Graphite Parts*

Sensors & Instruments

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

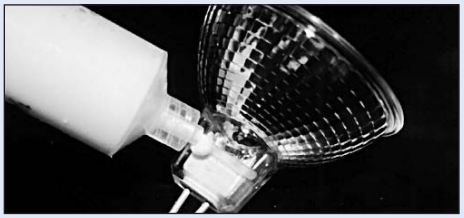
FEATURES

P/N	Filler	General Features	Bonding*	Principal Use
503	Alumina	High Fired Strength	C-C	Dense Ceramics
552		Good Adhesion to Metals	C-C, C-M	Low CTE Metals, SOFC's
569		Sets @ RT, Good Filler	C-C, C-M	Probes, Sensors
600		Ceramic Fiber-Reinforced	C-C	Refractory Repair
671		High Adhesive Strength	C-C, C-M, M-M	Textiles, Threadlocking
835M 835MB		High Strength, Good Filler	C-C, C-M	Halogen Lamps
813A		Fiber-Reinforced Sealer	C-C, C-M	Tundish Nozzles
865	Aluminum Nitride	High Thermal Conductivity	C-C, C-M	Probes, Sensors
668	Alumina-Silica	Sets @ RT, Good Filler	C-C, C-M	Oxygen Sensors
677			C-C, C-M	Induction Coils
690	Boron Nitride	Good Fired Strength	C-C	Boron Nitride
551RN	Graphite	High Adhesive Strength	Graphite, Carbon	Structures, Molds
669		Ceramic Fiber-Reinforced		
571	Magnesium Oxide	Dielectric, High Strength	C-M, M-M	Heaters, Sensors
618N	Silica	Low CTE, Good Strength	C-C, Quartz	Tubes, Vessels, Sensors
516	Zirconia	Dielectric, Moisture Resistant	C-C, C-M, M-M	Thermocouples
685N		Bonds Plated Metals to Ceramic	C-M	Heaters, Ignitors, Gasketing
835		Fiber-Reinforced, Sets @ RT	C-C, C-M	Halogen Lamps
885		Bonds and Coats Zirconia, High Strength	C-C	Zirconia, SOFC's
890	Silicon Carbide	Bonds SiC and Graphite Parts	C-C, Graphite	High Vacuum Fixtures

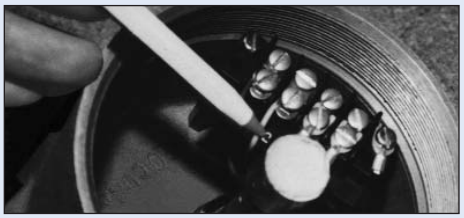
*C-C = Ceramic-to-Ceramic C-M = Ceramic-to-Metal M-M = Metal-to-Metal

Aremco's ceramic adhesives are easy-to-use, one- and two-component systems which air dry in 1-2 hours and are ready for use following a 200 to 700 °F cure. These materials are mostly water-based and do not outgas after curing. They are also environmentally safe, non-flammable materials which contain no volatile organic compounds.

Ceramabond™ 569 coats and encapsulates flex heater on quartz reservoir.



Ceramabond™ 835 bonds halogen bulb.



Ceramabond™ 571 bonds and coats gas sensor.

Graphi-Bond™ 669 bonds graphite fixture.

Ceramabond™ 571 coats high temperature filter.

Pyro-Putty™ 677 insulates induction heating coil.

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Rev. 1/09

HIGH TEMPERATURE CERAMIC ADHESIVE & PASTE PROPERTIES

Product No.		503	552	569	600	671	813A	835M ⑥	668	677	865	690	551RN ①	669	571	618N	890	516	685N	835	885
Trade Name		Ceramabond	Ceramabond	Ceramabond	Pyro-Putty	Ceramabond	Ceramabond	Ceramabond	Ceramabond	Pyro-Putty	Ceramabond	Ceramabond	Graphi-Bond	Graphi-Bond	Ceramabond	Ceramabond	Ceramabond	Ultra-Temp	Ceramabond	Ceramabond	Ultra-Temp
Major Constituent		Alumina							Alumina-Silica		Aluminum Nitride ④	Boron Nitride	Graphite		Magnesium Oxide	Silica	Silicon Carbide	Zirconia			
Maximum Temperature °F (°C)		3000 (1650)	3000 (1650)	3000 (1650)	2500 (1371)	3200 (1760)	3000 (1650)	3000 (1650)	2500 (1371)	2400 (1316)	3000 (1650)	1560 (850) ③ 2700 (1482)	5400 (2985)	2500	3200 (1760)	3000 (1650)	2500 (1371)	3200 (1760)	2500 (1371)	3000 (1650)	3200
CTE, in/in/°F x 10-6 (°C)		4.0 (7.2)	4.3 (7.7)	4.2 (7.6)	4.2 (7.6)	4.1 (7.4)	4.0 (7.2)	4.0 (7.2)	4.0 (7.2)	4.1 (7.4)	1.5 (2.7)	2.0 (3.6)	4.1 (7.4)	4.2 (7.6)	7.0 (12.6)	.33 (.59)	2.4 (4.4)	4.1 (7.4)	4.5 (8.1)	4.0 (7.2)	4.0 (7.2)
Volume Resistivity, ohm-cm @ RT (@ 1000 °F)		10^9 (10^5)	10^8 (10^4)	10^9 (10^5)	10^9 (10^5)	10^8 (10^4)	10^9 (10^5)	10^9 (10^5)	10^8 (10^4)	10^9 (10^5)	10^{15} (10^{10})	10^{15} (10^9)	NA (NA)	NA (NA)	10^9 (10^5)	10^9 (10^5)	NA	10^8 (10^4)	10^9 (10^5)	10^9 (10^5)	10^8 (10^4)
Dielectric Strength, volts per mil @ RT (@ 1000 °F)		253 (240)	250 (80)	256 (100)	200 (80)	250 (97)	250 (80)	245 (95)	245 (95)	200 (100)	500 (300)	500 (300)	NA (NA)	NA (NA)	255 (100)	200 (180)	NA	250 (80)	200 (150)	200 (100)	250 (80)
Torque Strength, ft-lbs ②		5.6	6.7	6.0	8.3	24.0	18.5	8.5	10.6	6.3	8.3	NA	9.5	2.1	21.6	5.2	10.5	8.6	9.0	7.5	8.0
Moisture Resistance ⑤		Good	Excellent	Excellent	Good	Excellent	Excellent	Good	Excellent	Excellent	Excellent	Good	Excellent	Excellent	Excellent	Excellent	Good	Good	Excellent	Good	Good
Alkali Resistance ⑤		Fair	Good	Good	Good	Excellent	Excellent	Excellent	Excellent	Good	Good	Good	Good	Good	Good	Good	Good	Excellent	Good	Good	Good
Acid Resistance ⑤		Excellent	Good	Excellent	Fair	Good	Good	Good	Good	Good	Good	Good	Good	Good	Fair	Good	Good	Good	Good	Good	Good
Handling	**No. Components** ①	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1
Handling	**Mix Ratio,** powder:liquid	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.5:1	N/A	N/A	N/A	N/A	N/A	N/A
Handling	**Viscosity,** cP	43,000	62,000	Paste	Paste	84,000	Paste	35,000	Paste	43,000	62,000	Paste	Paste	Paste	60,000	34,000	49,000	83,000	75,000	Paste	Paste
Handling	**Specific Gravity,** gms/cc	2.50	2.07	2.30	2.16	2.24	2.18	2.41	2.09	2.17	2.01	1.40	1.56	1.58	1.50	1.60	2.18	2.24	1.85	2.41	2.99
Curing	**Air Set,** hours	<1	1-4	1-4	2-4	1-4	4	2	1	1-4	1-4	1-4	1-4	1-4	1-4	1-4	<1	1-4	2-3	<1	<1
Curing	**Heat Cure,** °F, hrs	200, 2 500, 2 700, 2	200, 2 500, 2	200, 2	200, 3	200, 2	200, 3 or 24/RT	200, 2	200, 1-5	200, 2	200, 2	200, 2 500, 2 700, 2	265, 4 500, 2	200, 2	200, 2	200, 2 500, 2 700, 2	200, 2 500, 2 700, 2	200, 2 500, 2 700, 2	200, 3	200, 2	500, 2
Color		White	White	White	White	White	White	White	White	Off White	Gray	White	Black	Black	Beige	Light Gray	Gray	Tan	Tan	Tan	Tan
Shelf Life, Months		6	6	6	6	6	3	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Storage, °F		40-90	40-90	40-90	40-90	40-90	40-90	40-90	40-90	40-90	40-90	40-90	40	40-90	40-90	40-90	40-90	40-90	40-90	40-90	40-90

Reference Notes

① Graphi-Bond™ 551-RN is recommended for reducing atmospheres only. For international shipments, order two-part system, Graphi-Bond™ 551-RN-X, to extend shelf life.
② This test is performed after curing for 5 hours @ 200 °F.
③ Ceramabond™ 690 operates to 1560 °F in an oxidizing atmosphere or to 2700 °F in a vacuum/inert atmosphere.
④ Thermal conductivity of monolithic Aluminum Nitride is ~170 W/m-°K (1388 BTU-in/hr-ft²-°F)
⑤ Properties after firing above 700 °F.
⑥ A two-part variation of 835M named 835MB is also available. It is particularly good for bonding ceramics-to-quartz.

Abbreviations N/A – Not Applicable

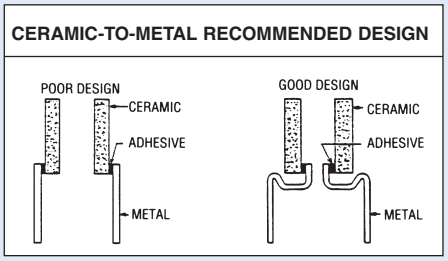
General Notes

❶ Ceramabond™ 503, 552, 569 and 571 can also be formulated using high purity, fine grain 1-5 micron ceramic powders. Add "-VFG" to the part number (eg. 503-VFG). Contact Aremco for special pricing.
❷ Custom formulations using cordierite, mullite and other powders are available.
❸ In some cases, specialty pigments in green, black and other colors are available upon request.
❹ All ceramic adhesives except 551-RN contain no volatile organic compounds (VOC's).

DESIGN GUIDELINES

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

Coefficient of Thermal Expansion



Due to the thermal shock implicit in most ceramic adhesives 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 ceramic adhesive in tension, since the metal expands faster than the ceramic. The "good" design allows for this thermal mismatch and loads the adhesive in compression, offering higher reliability.

Glue Line Thickness

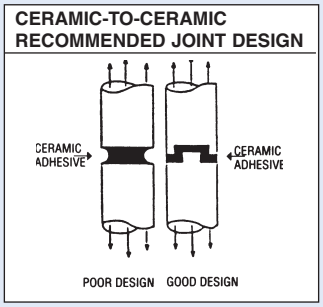
The clearance between mating parts at operating temperature should be 2-8 mils (50–200 microns). Less than 2 mils will prevent uniform adhesion, and greater than 8 mils will often result in cohesive shear failure within the adhesive.

Operating Environment

Ceramic adhesives offer excellent electrical, thermal and chemical resistance. In addition, ceramic adhesives, in contrast to organic-based materials, will not outgas under high vacuum. All operating conditions such as temperature, thermal cycling, humidity, corrosion and electrical requirements should be considered before selecting a ceramic adhesive.

Joint Design

Since ceramic adhesives exhibit relatively poor tensile and shear strength, it is desirable to design a joint that will distribute the mechanical stress. A glue line with greater surface area, such as a tongue-and-groove joint, should be used to reduce joint stress and increase mechanical strength.



Ceramic Adhesive Limitations

Ceramic adhesives are somewhat brittle and may be affected by dynamic conditions such as vibration and mechanical shock. Expansion joints can be used to relieve stress. Adding ceramic cloth at the interface is also useful.

High Vacuum Applications

Ceramic adhesives can be used under high vacuum conditions without outgassing. However, vacuum seals are difficult to produce unless the adhesive joint is sealed with a glass or glass-like coating. Refer to Technical Bulletin A5 for Aremco-Seal™ 617 and 850 glass sealants; refer to Technical Bulletin A11 for Cerama-Bind™ high temperature inorganic binders.

APPLICATION PROCEDURES

Follow the guidelines below for applying Aremco's high temperature adhesives. Make sure to read specific application instructions on container before use.

Surface Preparation

Clean surfaces thoroughly prior to application. Extremely smooth surfaces are difficult to bond and should be roughened whenever possible. Porous substrates tend to absorb the adhesive binders and should be pre-coated with an adhesive thinner. Product thinners are designated by adding a "-T" to the part number (eg. 503-T).

Mixing

High temperature adhesives tend to settle in the container and should be mixed thoroughly and slowly to avoid air entrapment. Reduce viscosity as desired using the appropriate product thinner by up to 15% by weight. Two-component systems should be mixed according to the following ***weight ratios:***

Ceramabond™ 571	1.5 : 1	Powder to Liquid
Graphi-Bond™ 551RN-Exp	83 : 17	Powder to Liquid

Note that Graphi-Bond™ 551RN-Exp is the export version of 551RN. This product is shipped as a two-component adhesive due to shelf life considerations.

Application

Apply adhesive to each surface in a thin coat using a brush, spatula or dispenser. Wet the surface thoroughly to ensure good adhesion. Maintain a uniform glue line thickness of 2-8 mils. Apply even pressure (clamp if possible), and wipe away excess material before drying.

A graded adhesive joint is recommended when bonding components which have a gross difference in coefficient of thermal expansion (CTE). First coat each substrate with the adhesive that best matches its CTE, then use a third adhesive with an intermediate CTE to bond the parts together.

Example: Bond nickel to silica by pre-coating the nickel with Ceramabond™ 571 and the silica with Ceramabond™ 618N. Allow each substrate to air dry and cure at 200 °F for 1-2 hours. Apply Ceramabond™ 552 as an intermediate adhesive and follow standard instructions in the *Curing* section.

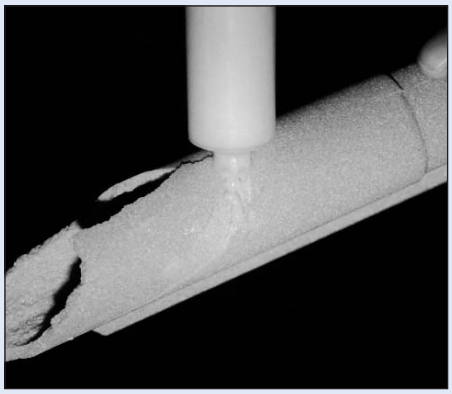
When it is necessary to use an adhesive alternatively as a coating, and several applications are required, allow the substrate to air dry for 1-2 hours before applying a second coat. A 200 °F cure for 1-2 hours is recommended for each successive coat to avoid blistering.

Curing

In general all products should be air set for 1-4 hours, then heat cured at 200 °F (93 °C) for 1-4 hours minimum. Ceramabond™ 503, 516, 618N, 690, 885, and 890 will not dry at room temperature and should be step cured at 200 °F (93 °C), 500 °F (260 °C), and 700 °F (372 °C) for 1-2 hours at each temperature. Graphi-Bond™ 551-RN must be cured at 265° F (130 °C) for 4 hours and 500 °F (260 °C) for 2 hours to develop maximum strength. Blistering may occur if the glue line is too thick or heating too rapid. Refer to specific product labels for detailed instructions.

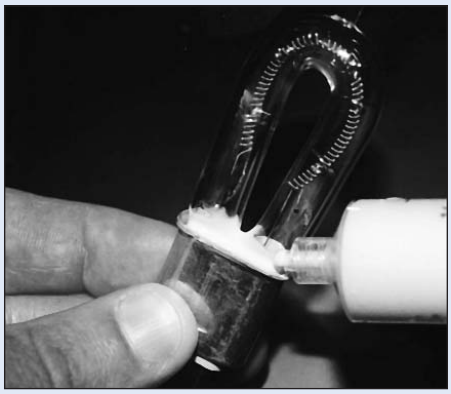
Safety

Read Material Safety Data Sheet carefully before use. All products except Graphi-Bond™ 551-RN can be washed from the skin with mild soap and warm water. Prolonged skin contact should be avoided to prevent irritation. If any material contacts the eyes, flush continuously with water or neutralizing solutions, then consult a physician immediately.



Ceramabond™ 503 repairs sand core.

Pyro-Putty™ 600 bonds insulation rope.



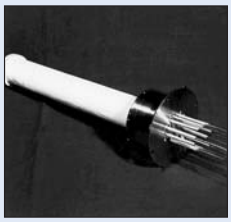
Ceramabond™ 835 bonds high intensity bulb.

CERAMIC ADHESIVE SELECTOR CHART

	MATERIAL	CTE X 10^{-6} in/in/ °F (°C)	503	516	551-RN	552	569	571	600	618N	668	669	671	677	685N	690	813A	835	835M	865	885	890
CERAMICS	ALUMINA (96%)	4.4 (7.9)	•	X		X	X	X	•		•		•		X		•		•			
	ALUMINUM NITRIDE	1.5 (2.7)					•			X	X					X	•	X	X	•		
	BERYLLIA (95%)	4.1 (7.4)	•	X		X	X	X					•				X		X			
	BORON CARBIDE	2.6 (4.6)					•			X	•											
	BORON NITRIDE	4.2 (3.8)	•			X							•			•	X		X			
	CERAMIC TEXTILES	—	•										•		X							
	CORDIERITE	1.1 (1.9)								•					X	X	X					
	GLASS (Borosilicate)	1.8 (3.2)	•							•					X	•		•				
	GLASS BONDED MICA	5.8 (10.4)						X							X		X	X	X			
	GRAPHITE	4.3 (7.7)	X	X	•							•										X
	MACOR®	5.2 (9.4)					X	X			X				X		X	X	X			
	MULLITE	3.0 (5.4)	•				X								X							
	QUARTZ	0.3 (.56)	X				X			•						X		•				
	SAPPHIRE	4.2 (7.6)	•						•		X		•									
	SILICON CARBIDE	2.9 (5.2)	•													X				X		•
	SILICON NITRIDE	1.8 (3.2)								X						X				X		
	STEATITE	4.0 (7.2)	•	X		X	X								X		X	X	X			
	ZIRCONIA			•											•			•			•	
	ZIRCONIA SILICATE			•											•			•			•	
	REFRACTORIES	—					•		•		•		•				•	•	X		•	
METALS	ALUMINUM	15.0 (27.0)						•							X			X				
	BRASS	10.2 (18.4)						•						•	X			X				
	CAST IRON	5.9 (10.6)		X		X	X	•					•		X							
	COPPER	9.3 (16.7)						•						•								
	INCONEL	6.4 (11.5)		X		X	•	X														
	MOLYBDENUM	2.9 (5.2)		X		X	•			X										X		
	NICKEL	7.2 (12.9)		X		X	X	•			X				X		X		X			
	NICKEL-IRON	2.6 (4.7)		X		•	X	X			X						X		X			
	PLATINUM	4.9 (8.8)	X													X						
	SILICON	1.6 (2.9)	X	•		X	X									X						
	SILVER	10.6 (19.1)						•														
	S/S (300 SERIES)	9.6 (17.3)		X		X	X	•			X		•		X		X					
	S/S (400 SERIES)	6.2 (16.6)						•					•		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					
	TITANIUM	5.8 (10.4)					X	•			X											
	TUNGSTEN	2.5 (4.5)		X		X	•			X	X					X	X			X		

• Preferred Product For This Application
X Applicable Product For This Application

Ceramabond™ 503 bonds Pt/40Rh heater wire on an alumina core. This assembly is part of a hi-temp process furnace used aboard the space shuttle.



Ceramabond™ 503 coats the entire heater assembly and provides oxidation and corrosion protection 1700 °C.

Refer to Price List for availability of sample kits and complete order information.