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*

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

*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™ 671 high temperature threadlocker.

Ceramabond™ 835 bonds halogen bulb.

Graphi-Bond™ 669 bonds graphite fixture.

Ceramabond™ 685 bonds gas ignitor.

Ceramabond™ 503 repairs mullite saggar.

Pyro-Putty™ 677 insulates induction heating coil.

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Rev. 1/08

HIGH TEMPERATURE CERAMIC ADHESIVE & PASTE PROPERTIES

Product No.		503	552	569	600	671	813A	835M [7]	668	677	618N	551RN [1]	669	516	685N	835	885	571	690	865
Trade Name		Ceramabond	Ceramabond	Ceramabond	Pyro-Putty	Ceramabond	Ceramabond	Ceramabond	Ceramabond	Pyro-Putty	Ceramabond	Graphi-Bond	Graphi-Bond	Ultra-Temp	Ceramabond	Ceramabond	Ultra-Temp	Ceramabond	Ceramabond	Ceramabond
Major Constituent		Alumina							Alumina-Silica		Silica	Graphite		Zirconia				Magnesium Oxide	Boron Nitride	Aluminum [5] Nitride
Maximum Temperature °F (°C)		3000 (1650)	3000 (1650)	3000 (1650)	2500 (1371)	3200 (1760)	3000 (1650)	3000 (1650)	2500 (1371)	2400 (1316)	3000 (1650)	5400 [2] (2985)	2500 (1371)	3200 (1760)	2500 (1371)	3000 (1650)	3200 (1760)	3200 (1760)	1560 (850) [4] 2700 (1482)	3000 (1650)
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)	.33 (.59)	4.1 (7.4)	4.2 (7.6)	4.1 (7.4)	4.5 (8.1)	4.0 (7.2)	4.0 (7.2)	7.0 (12.6)	2.0 (3.6)	1.5 (2.7)
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)	10^9 (10^5)	NA (NA)	NA (NA)	10^8 (10^4)	10^9 (10^5)	10^9 (10^5)	10^8 (10^4)	10^9 (10^5)	10^{15} (10^9)	10^{15} (10^{10})
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)	200 (180)	NA (NA)	NA (NA)	250 (80)	200 (150)	200 (100)	250 (80)	255 (100)	500 (300)	500 (300)
Torque Strength, ft-lbs [3]		5.6	6.7	6.0	8.3	24.0	18.5	8.5	10.6	6.3	5.2	9.5	2.1	8.6	9.0	7.5	8.0	21.6	NA	8.3
Moisture Resistance [6]		Good	Excellent	Excellent	Good	Excellent	Excellent	Good	Excellent	Excellent	Excellent	Excellent	Excellent	Good	Excellent	Good	Good	Excellent	Good	Excellent
Alkali Resistance [6]		Fair	Good	Good	Good	Excellent	Excellent	Excellent	Excellent	Good	Good	Good	Good	Excellent	Good	Good	Good	Good	Good	Good
Acid Resistance [6]		Excellent	Good	Excellent	Fair	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Fair	Good	Good
Handling	**No. Components** [1]	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1
Handling	**Mix Ratio,** powder:liquid [2]	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	N/A	N/A	N/A	1.5:1	N/A	N/A
Handling	**Viscosity,** cps [3]	43,000	62,000	Paste	Paste	84,000	Paste	35,000	Paste	43,000	34,000	Paste	Paste	83,000	75,000	Paste	Paste	60,000	Paste	62,000
Handling	**Specific Gravity,** gms/cc	2.50	2.07	2.30	2.16	2.24	2.18	2.41	2.09	2.17	1.60	1.56	1.58	2.24	1.85	2.41	2.99	1.50	1.40	2.01
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	2-3	<1	<1	1-4	1-4	1-4
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, 2 500, 2 700, 2	265, 4 500, 2	200, 2	200, 2 500, 2 700, 2	200, 3	200, 2	200, 2 500, 2 700, 2	200, 2	200, 2 500, 2 700, 2	200, 2
Color		White	White	White	White	White	White	White	White	Off White	Light Gray	Black	Black	Tan	Tan	Tan	Tan	Beige	White	Gray
Shelf Life, Months		6	6	6	6	6	3	6	6	6	6	6	6	6	3	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	40-90	40-90	40-90	40-90	40-90	40-90	40-90	40-90

Reference Notes

① Graphi-Bond™ 551-RN is exported only as a 2-component system due to shelf life considerations. Order 551-RN-Exp.
② Graphi-Bond™ 551-RN temperature limit is for reducing atmospheres only.
③ This test is performed after curing for 5 hours @ 200 °F.
④ Ceramabond™ 690 operates to 1560 °F in an oxidizing atmosphere or to 2700 °F in a vacuum/inert atmosphere.
⑤ Thermal conductivity standard for aluminum nitride is 200 W/m-°K (1388 BTU-in/hr-ft^2-°F)
⑥ Properties after firing above 700 °F.
⑦ 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

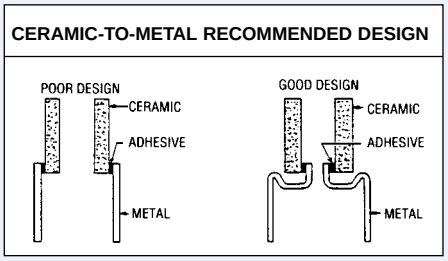
General Notes

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

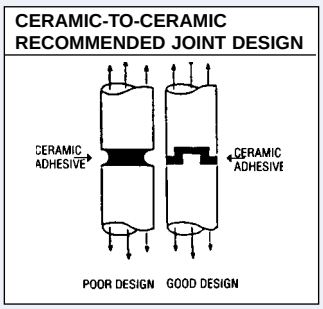
The clearance between mating parts at operating temperature should be 2-8 mils (50–200 microns). Less than 2 mils will prevent uniform adhesion, and greater than 8 mils will often result in cohesive shear failure within the adhesive.

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.

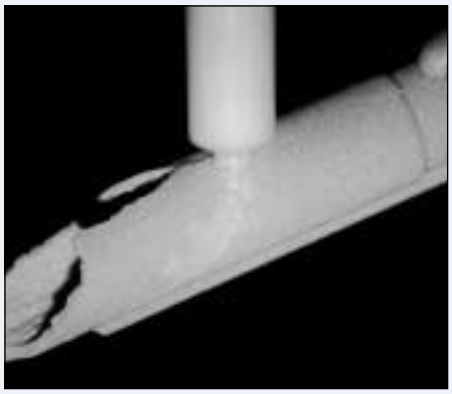
When it is necessary to use an adhesive alternatively as a coating, and several applications are required, allow the substrate to air dry for 1-2 hours before applying a second coat. A 200 °F cure for 1-2 hours is recommended for each successive coat to avoid blistering.

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 and 690 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 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
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	•							•									
	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.

Aremco Products makes no warranty express or implied concerning the use of this product.
The user assumes all risk of use or handling whether or not in accordance with directions or suggestions, or used singly or in combination with other products.

AP-2

HI-TEMPERATURE CERAMIC ADHESIVES

APPLICATION PROCEDURES
For Bulletin No. M2

CERAMABOND™ 503, 551-R, 552, 569, 571, 618, 632, 633, 668, 670, 671 ULTRA-TEMP™ 516 AND GRAPHI-BOND™ 669

A) SURFACE PREPARATION AND APPLICATION:

1) All surfaces to be bonded or coated should be free of dirt, grease or oil. When possible roughen surfaces. Porous substrates will absorb the liquid binders so it is recommended to impregnate the surface with the appropriate thinner before using the adhesive. Thinner may be ordered by adding a "–T" to the product number (eg. 503–T).

2) Mix the adhesive thoroughly prior to use. Stir slowly to avoid air entrapment. Ceramabond™ 571 is a two component system with a mix ratio of 1 part liquid to 1.5 parts powder by weight.

3) Apply adhesive to each surface in a thin coat using a brush, spatula, spray gun or dispenser. Wet the surface thoroughly to ensure good adhesion.

4) The glue line thickness should be held between .002" and .010". Keep the glue line as uniform as possible to obtain good adhesion. Pressure should be applied and maintained until drying is complete. Do not repeatably squeeze assembly as this will cause air to be drawn into the glue line, thereby weakening the bond.

5) Immediately press the surfaces together maintaining a uniform glue line. Fixture if necessary. Wipe away excess before drying.

6) When applied as a coating, if repeat coats are necessary, spray substrate and allow it to air dry before applying the second coat. An oven dry at 200 °F is recommended before applying a third coat. This will avoid blistering during final cure. (See Section B).

B) CURING SCHEDULE:

All products require a heat cure. For Ceramabond™ 569 it is recommended but not required. Follow the schedule below.

1) Air set 1 to 4 hours depending upon the substrate size. The larger the part the longer the required air set.

2) Place part in oven at 200 °F for 1 to 4 hours. This will remove moisture gradually increasing the density and strength of the adhesive.

3) For maximum adhesion and moisture resistance raise temperature to 500 °F and hold for 1 hour. Note: This is a necessity for Ceramabond™ 503 to maintain integrity in humid envionments.

C) BONDING SUBSTRATES WITH DISSIMILAR COEFFICIENTS OF THERMAL EXPANSION

1) If materials have gross differences in CTE, then a graded adhesive line should be formed. First select an adhesive that best matches the CTE of each substrate. Coat each substrate with the best adhesive then use a third material with an intermediate CTE to bond the parts together.

2) Example: To bond nickel to silica, coat the nickel with Ceramabond™ 571 and the silica with the Ceramabond™ 618. Allow each substrate to air dry and cure at 200 °F. Apply Ceramabond™ 552 as the intermediate adhesive. Press parts firmly together and cure according to Section B.

D) SAFETY PRECAUTIONS:

1) Prolonged skin contact should be avoided due to possible irritation.

2) All products can be washed from skin with a mild soap and water in the uncured state.

3) If any material contacts eyes, flush continuously with water or neutralizing solutions; then consult a physician immediately.

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株式会社ニラコ

セラマボンド　503、552、569、571、618、671、
超高温用　516、グラファイボンド 669、551-R、551-A
□・・・弊社取扱商品

A）表面の前処理、塗布

1）接合または接着剤を塗布する面の汚れ、グリース、オイル等はすべて取り除いてください。表面が粗い場合、多孔性材料である場合は液体の接着剤を吸収しやすいので、これを防ぐため水または適当な希釈液で表面を湿らせることをお勧めします。（例：503 ですと 503 用の希釈液（503T）を使用してください。）

2）接着剤を十分混ぜあわせてください。この際、過度の撹拌は空気進入の原因になり接着強度が弱くなりますので注意してください。
＊(セラマボンド 571)は重量比で液体 1 に対し粉末 1.5 の割合で混合してください。

3）へら、ブラシ、スプレーなどを使用して面に塗布してください。十分な接着力がでるよう表面を十分湿らせてください。

4）接合部分の接着剤は均一、かつ 0.025～0.25mm になるようにしてください。また、十分に乾燥するまでしっかりとおさえて動かないようにしてください。この際、繰り返して、押しつけると空気が接着層に入り接着力が弱くなる原因となりますので注意してください。

5）均一な接着層を保つため、必要であればただちに固定物で圧力をかけてください。余剰物はふき取ってください。

6）コーティングとして使用するために重ね塗りが必要な場合は、まずスプレーを使って表面に塗布し、空気乾燥させた後に 2 度目のコーティングに取りかかって下さい。更に、3 度目のコーティングの前に 93℃で 1-2 時間オーブン乾燥させることをお勧めします。この作業によって気泡の発生を防ぐことができます。（セクション B も参照）

B）乾燥、熱処理

通常、すべて熱処理が必要です。（ただし、セラマボンド 569 に関してはこの作業を行うことが望ましいとされていますが必須ではありません。）

＊セラマボンド 569、671、571

1）1～4 時間　空気乾燥。（時間は接着面の面積により異なり、面積が広いほど長く時間をかけます。）

2）2 時間　93℃で熱処理。これは徐々に湿気を取り除くことで、密度と接着強度を増加させるために行います。

3）接着力を最大限に発揮させるためには、更に、温度を 371℃まで上昇させこれを 1 時間保つようにします。

＊セラマボンド　552

1）1～4 時間　空気乾燥。

2）2 時間　93℃で熱処理。

3）2 時間　260℃で熱処理。

＊セラマボンド 503、516、618

1）1～4 時間　空気乾燥。（503 は 1 時間弱。）

2）2 時間　93℃で熱処理。これは徐々に湿気を取り除くことで、密度と接着強度を増加させるために行います。

3）2 時間　260℃で熱処理。

4）2 時間　372℃で熱処理。

湿気ある環境で完全な状態を維持すために以上の作業は欠かせません。

＊グラファイボンド 551R

1)　1～4 時間　空気乾燥。

2）4 時間　　130℃で熱処理。

＊グラファイボンド 551A

1）1～4 時間　　空気乾燥。

2）2 時間　　93℃で熱処理。

3）2 時間　　260℃で熱処理。