

TECHNICAL

ASPECTS OF

CERAMIC

FIBER

Ceramic

Fiber

Systems

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INTRODUCTION

Over the past 75 years, Thermal Ceramics has proven itself to be a world leader in solving problems for heat-intensive industries.

The refractory ceramic fiber manufactured by Thermal Ceramics is a highly versatile material. It can be spun or blown into bulk, air-laid into a blanket, folded into modules, formed into monolithic modules (Pyro-Bloc), converted into papers, boards, and shapes, die-cut into gaskets, twisted into yarns, woven into rope and cloth, and blended into liquid binders for coatings and cements. With this wide range of products, Thermal Ceramics can provide exactly the right product, or engineered system to fit your requirements. Thermal Ceramics has an experienced staff of refractory specialists to assist you in product selection, system design, and installation techniques.

Thermal Ceramics has enjoyed great success with its ceramic fiber products due to their cost-effectiveness and excellent insulating properties. They are lightweight and have low thermal conductivities, excellent resistance to thermal shock, outstanding electrical resistivity, and good acoustical properties. In addition, Enfil® engineered fibers provide excellent wear resistance and mechanical strength.

This Design and Installation Manual is intended to give the designers, installers, and users of Thermal Ceramics ceramic fiber products a broad range of information on how to select the most appropriate fiber system for a particular application, necessary design criteria, and how to correctly install the selected system.

PLEASE NOTE: This manual has been designed to easily accommodate new or revised information. Holders of the manual are advised to keep their address current with the Advertising and Sales Promotion Department at Thermal Ceramics in Augusta, Georgia. Any questions or comments regarding this manual should be addressed to your local Thermal Ceramics representative.

TECHNICAL ASPECTS OF CERAMIC FIBER

Several very important factors affect the choice of fiber and the type of ceramic fiber lining utilized in any particular design. This section will not cover actual design, but the properties and characteristics of ceramic fiber. The specific topics which will be discussed are:

- 1. Thermal Conductivity**
- 2. Effect of Shot Content on Thermal Conductivity**
- 3. Devitrification**
- 4. Shrinkage**
- 5. Velocity Resistance**
- 6. Effect of Reducing Atmospheres**
- 7. Chemical Attack**

1. THERMAL CONDUCTIVITY

Ceramic fiber is one of the most efficient high-temperature insulations available. A good understanding of thermal conductivity mechanisms will allow the design engineer to maximize the benefits of ceramic fiber linings in a variety of forms: wallpaper, board, blanket or weld-on modules. The three primary modes of heat transfer are conduction, radiation, and convection.

1.1 Conduction

Conductive heat transfer is actually comprised of two separate mechanisms. The majority of conduction takes place in gas between the fibers while solid conduction through the individual fiber and shot particles is found to be a minor mode of heat transfer. At low temperatures, conductive heat transfer is the primary heat transfer mechanism, as can be seen in Figure 1. As the temperature increases, conduction through gas and through solids will increase along with the radiative heat transfer.

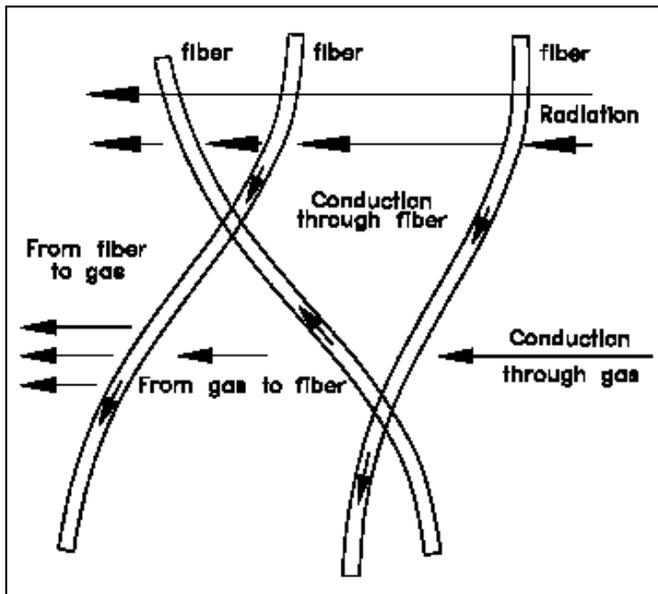


Figure 1 - Heat Transfer in R.C.F.

Figure 2 shows the relationship between gas conductivity, fiber conductivity, and radiation at higher temperatures. At elevated temperatures, radiative heat transfer becomes the primary mechanism.

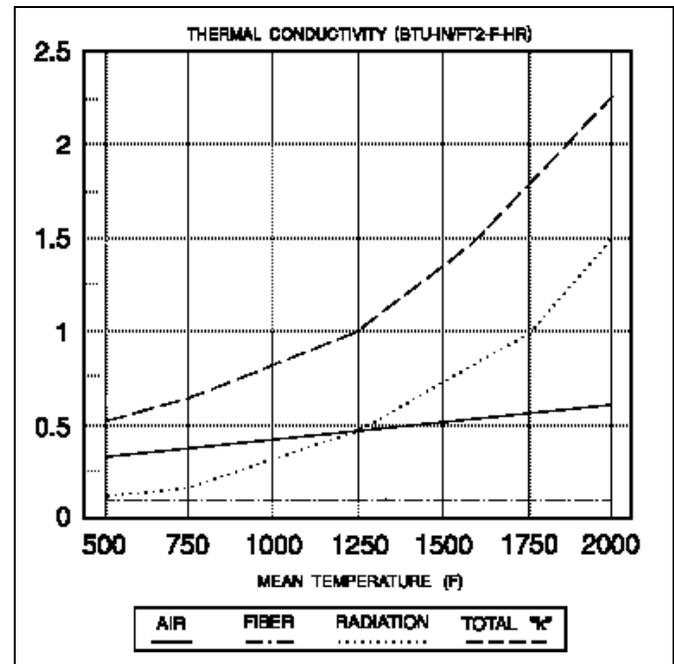


Figure 2 - Primary Heat Transfer Modes

1.2 Radiation

This is the primary high-temperature heat transfer mechanism for ceramic fibers and consists of two major parts: a) radiation that is not absorbed by the fibrous structure but is reflected and scattered, b) reradiation between fiber particles which is dependent upon the absorption and emittance of the fibers and the average difference in temperature (thermal distance) between two fibers. Radiant energy heat transfer is proportional to the difference of the 4th power of the absolute temperatures for the participating surfaces. This means simply that as temperature increases, the heat transfer due primarily to radiation transfer will rise quickly, becoming its dominant heat transfer mechanism.

1.3 Convection

Natural convective heat transfer is apparent only when individual air cells are relatively large (approximately 2mm). With cells smaller than this the natural air turbulence is nominal and convective heat transfer is insignificant. In ceramic fiber products, the mean effective pore size is small and the convective heat transfer is held to an absolute minimum. However, where forced gas flow and/or significant gas pressure exist, forced convection becomes a significant factor.

2. EFFECT OF SHOT CONTENT ON THERMAL CONDUCTIVITY

Within typically manufactured ranges, shot content will not directly influence thermal conductivity. It indirectly reduces the thermal performance simply by reducing the quantity of ceramic fiber in a given unit of volume, which is similar to, but less significant than, the effect of increased fiber diameter. The shot will act somewhat as a solid conductor and as a radiation blocker, but the effects are insignificant when compared to the effect that the reduced fiber quantity has on thermal conductivity. Where shot becomes important is in its relationship to bulk density (i.e., the more shot, the denser the product and the less fiber present in a given sample, and hence the higher the thermal conductivity). It is imperative when comparing shot content values that they only be compared when similar methods of determination are used. The two methods of measuring shot are water elutriation and ASTM C-892. The water elutriation method is the industry standard, but ASTM C-892 may be used as well.

2.1 Water Elutriation Method

This test method consists of two tests, the single tube (cup) and the four tube (cup) methods. Thermal Ceramics uses the single tube method for measuring shot content in blown ceramic fiber, and the four tube method for spun ceramic fiber. The two methods have evolved because of the difference in physical size between blown and spun ceramic fiber.

The single tube method requires a disenchantment chamber, an elutriation (separation) tube and a shot collection flask. The blown ceramic fiber is taken unfired and crushed, then introduced into the elutriation tube, where the fiber and shot are separated. The shot is then collected, dried, and screened to report typical data for +40, -40 x +100, -100 mesh screens and total content.

The four tube method requires four elutriation (separation) chambers. The spun ceramic fiber is fired and placed in a high shear mixing chamber to break up the fibers. The fiber and shot are then introduced into four elutriation tubes, each having a different water flow rate. The shot is classified by which tube it comes from, in ranges of +50 mesh, -50 x +100 mesh, -100 x +200 mesh, and -200 x +325 mesh. The collected material is dried and reported as total shot content.

A variation between the single and four tube methods is the fact that the four tube method gives lower percentage shot results. It is estimated that the four tube method will give

results between 6 and 15 percent lower than the single tube method. This is due to the measurement of fine shot particles not being as accurate in the four tube method.

2.2 ASTM C-892

This test method uses fired and crushed ceramic fiber which is then rubbed through standard screens. This method gives shot content as a cumulative weight, and is not normally used in the measurement of ceramic fiber shot content.

Variations in test procedures and methods will give different test results, therefore when comparing ceramic fiber shot contents it is important to know what measurement method was used.

3. DEVITRIFICATION

3.1 Standard Alumina-Silica Fibers

Ceramic fiber will generally exist in an amorphous state as produced. The kaolin or alumina-silica blend is melted, then supercooled; the fiber produced is in a vitreous or “glassy” state typical of melt-fiberization. The term amorphous is best defined as “lacking crystalline structure or definite molecular arrangement.” A characteristic of all glasses is the absence of crystalline structure. When glasses are formed, the liquid is rapidly quenched or “frozen” before the individual atoms or molecules can arrange themselves in a suitable crystalline structure. These molecules remain in the random orientation until sufficient energy is added to the system to promote rearrangement or restructuring to form crystalline products. This is, in essence what the term devitrification, or recrystallization means. In the case of kaolin fiber or synthetic alumina-silica fibers, the initial devitrification temperature is approximately 1750°-1800°F (950°-975°C).

The first recrystallization product is mullite. The mullite precipitates from the glassy matrix as a well-defined crystallite which can be seen in DTA curves and confirmed through X-ray diffraction. The second recrystallization product is α -cristobalite which begins to precipitate from the silicon-rich glassy matrix after an extended period of time at 2012°F (1100°C). As a rough rule of thumb the following time/temperature relationship can be used for α -cristobalite formation in alumina-silica fibers.

α-Cristobalite forms after:

4 months	(3000 hrs)	@ 2012°F (1100°C)
2 weeks	(300 hrs)	@ 2192°F (1200°C)
2 days	(50 hrs)	@ 2372°F (1300°C)

The long-term delayed onset of precipitation accounts for the lack of a high temperature peak for α -cristobalite in DTA analysis. This same phenomenon also accounts for the lack of α -cristobalite in the X-ray diffraction pattern of alumina-silica fiber fired to 2400°F. This is detailed in Table 1.

Temperature °F, (°C)	Mineralogy	Specific Gravity g/cc	% Volume of Solid Phase
<1796 (980)	100% Alumina-silica (A) (Kadin)	2.60	4.6
1796 - 2012	64% Mullite 36% Silica (A)	2.84	4.2
>2012 (1100)	64% Mullite 36% Cristobalite	2.88	4.1

Table 1 - Alumina-Silica Blanket Phase Changes

3.2 Alumina-Silica-Zirconia Fibers

This system acts very differently than the alumina-silica fiber system. The primary low-temperature form of the material is a homogeneous AZS glass which is stable up to a temperature of approximately 1800°-1830°F (980°-1000°C). The initial recrystallization consists of co-precipitation products of mullite and the tetragonal form of zirconia. The zirconia apparently stabilizes the glassy structure, accounting for a slight shift (|| 50°F (10°C) higher) in initial devitrification temperature when compared to alumina-silica fiber systems.

Secondary recrystallization occurs at approximately 2318°F (1270°C) as α -cristobalite begins to precipitate. DTA indicates a discrete precipitation range for this product very different than the precipitation mechanism for α -cristobalite in the alumina-silica system. The zirconia apparently may act as a mineralizer, promoting the precipitation of α -cristobalite within a finite temperature range.

The zirconia will eventually react with the silica-rich matrix and/or the cristobalite to form zircon at a temperature of approximately 2660°F (1460°C). These crystallographic changes are summarized in Table 2.

Temperature °F, (°C)	Mineralogy	Specific Gravity g/cc	% Volume of Solid Phase
<1796 (980)	100% Alumina-silica-zirconia	2.70	4.4
1796 - 2318 (980 - 1270)	45% Mullite 20% Zirconia (T) 35% Silica (A)	3.30	3.6
2318 - 2660 (1270 - 1460)	45% Mullite 20% Zirconia (T)	3.40	3.5
>2660 (1460)	45% Mullite 29% Zircon 26% Cristobalite	3.43	3.4

Notes: (A) - Amorphous form
(T) - Tetragonal form

Table 2 - Alumina-Silica-Zirconia Blanket Phase Changes

3.3 Summary

Devitrification and recrystallization are important in ceramic fiber systems for several reasons. First, as the crystals are formed, the ceramic fiber loses flexibility. As crystals grow, the product becomes stiff or thermally bonded. The second major consideration is that shrinkage is closely related to crystallization in ceramic fiber. Although devitrification contributes significantly to shrinkage, it is not the major contributing factor. Other mechanisms involving grain growth and fiber “curling” account for the majority of shrinkage in ceramic fiber systems. Ceramic fiber shrinkage is controllable. Several well-known design options are available so that with proper engineering and material choice, very suitable ceramic fiber linings can be designed for elevated temperatures.

Notes: (A) - Amorphous form
(T) - Tetragonal form

4. SHRINKAGE OF CERAMIC FIBER PRODUCTS

When ceramic fiber is heated it begins to shrink. This shrinkage determines the fiber’s ultimate use limit temperature. When furnace design engineers, maintenance workers, or process equipment operators decide to reline or upgrade their vessels, they need to consider the effects of shrinkage. Shrinkage of ceramic fiber is a continuous process, as detailed in Figure 3. The majority of shrinkage occurs within 24 hours of start-up as the fiber filaments adjust to their new environment. As the product is continually exposed to temperature it will continue to shrink as changes occur within the individual fiber particles themselves.

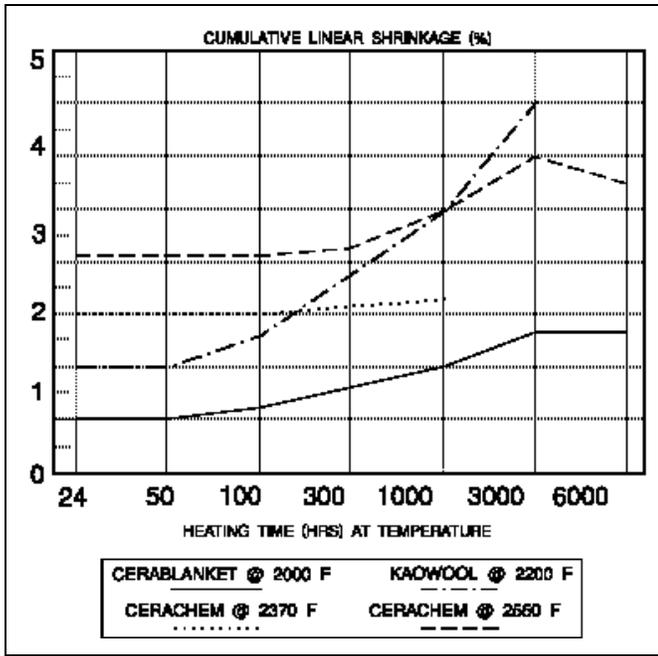


Figure 3 - R. C. F. Long-Term Linear Shrinkage

In designing furnace linings with ceramic fiber, several steps are taken to counteract this shrinkage and maximize lining life, depending on the lining system selected. Compression, short lengths of blanket, batten strips, parquet patterns, overlaps, and edge grain configuration are some of the ways shrinkage is minimized in ceramic fiber. By understanding the specific mechanisms which cause ceramic fiber to shrink, we can design better furnace linings which will provide a satisfactory life.

The shrinkage of ceramic fiber products is closely related to the following changes which occur as fiber is exposed to increasing temperature: relaxation of stress, devitrification and crystallization, grain growth, and ceramic fiber curling.

We will discuss each mechanism in detail and explain its interaction with the shrinkage of ceramic fiber. At low temperatures where the non-stress-relieved ceramic fiber remains amorphous or non-crystalline, virtually no shrinkage occurs. It is only when the fiber begins to relieve stress and to devitrify or change from a glassy (amorphous) state to a crystalline state that shrinkage begins.

4.1 Devitrification and Crystallization

As previously described, both alumina-silica and alumina-silica-zirconia fibers undergo several changes in crystal

structure as they reach higher and higher temperatures. As the material undergoes these transformations it also has concurrent changes in specific gravity. As the temperature is increased, the structure changes, and the individual fibers become denser as the maximum use limit is approached. The changes are summarized for both fiber types in tables 1 and 2.

The percent volume ratio of solid phase is simply a measure of the percentage of solids in a given volume of fiber and is defined as:

$$\text{Percent Volume of Solid Phase} = (\text{Bulk Density} / \text{Specific Gravity}) \times 100.$$

In a 8 pcf alumina-silica (kaolin) blanket only 4.6 percent is solid mass; the remainder is air. There simply is not enough solid mass available to contribute greatly to shrinkage. If individual fiber shrinkage or densification is not responsible for the shrinkage of ceramic fiber products, then what is? In the introduction we briefly mentioned that devitrification signals the onset of shrinkage by beginning a process called “curling” in the ceramic fiber.

Curling, or deformation of individual filaments of fiber, is the mechanism which accounts for a vast majority of shrinkage. To understand curling, we need to look at crystal grain growth and how it progresses with time and temperature.

4.2 Crystal Grain Growth

As the various mineralogical phases precipitate, finely divided crystalline structures form, which grow with time and temperature. Figure 4 shows how in standard alumina-silica (kaolin) blanket the crystal size of mullite and cristobalite change with both time and temperature. Mullite is the first precipitant and begins to form at temperature in excess of 1742°F (950°C). Mullite formation is not greatly time dependent; however, the initial crystal size is. These crystals grow with both time and temperature. At 2372°F (1300°C) individual crystals of mullite will be nearly four times the size they were at 2012°F (1100°C). Cristobalite begins to precipitate at temperatures in excess of 2012°F (1100°C) but varies with temperature. Thus the higher the temperature, the earlier the initial formation of cristobalite and the larger the individual crystal size will be. As the grains grow and approach the ultimate fiber diameter the individual filaments become weaker. This time-temperature relationship is responsible for:

- Weakening or brittleness of the fiber product over long periods of time.
- Continuation of shrinkage over time, reducing the effective fiber lengths, leading to long-term shrinkage shown in Figure 3.

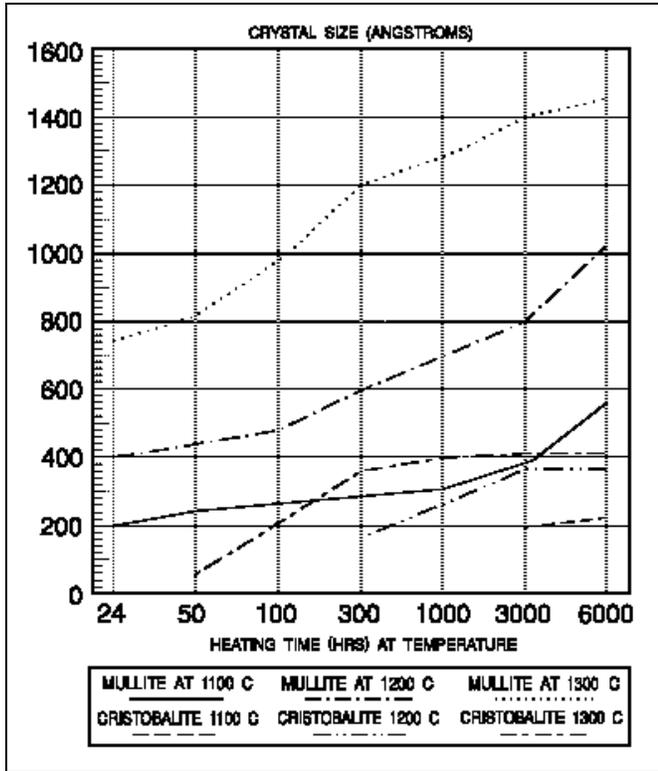


Figure 4 - Crystal Grain Growth in Alumina-Silicate R. C. F.

Crystal grain growth is also a major reason why the fibers “curl” and cause shrinkage thru nonhomogenous or dissimilar grain growth.

4.3 Ceramic Fiber Curling

When ceramic fiber is manufactured a wide range of filament sizes result. Individual filaments may change diameter, change direction, or contain any of a variety of imperfections in their amorphous state. As meltfiberized products rapidly cool to form the glassy structure, different stresses will develop along the length of the fiber. These dissimilar stresses will tend to relieve themselves at temperatures in excess of the devitrification temperature in a manner similar to annealing of metals. As these stresses are relieved at approximately 1000°F the fiber distorts, decreasing the effective fiber length. As crystallization progresses the fiber continues to distort and the effective length shortens with

time and temperature. Dissimilar grain growth can be attributed to both temperature and imperfections in crystal structure. This inconsistent growth is due in part to attempts of the fiber to relieve itself of stress through differential grain growth mechanisms because of slight thermal differences.

The initial precipitation products will form at those regions of highest stress (i.e., the outside radius of the fiber), and will form more slowly at the low stress locations along the inside radius of the fiber. This phenomenon initiates and promotes curling as a direct result of crystal formation and continued growth. Figure 5 illustrates this behavior with high stress, initial crystallization (region “A”) and lower stress, delayed crystallization (region “B”). These two mechanisms, initial crystallization to relieve stresses and crystal grain growth through time-temperature relationships, account for the majority of shrinkage in ceramic fiber products.

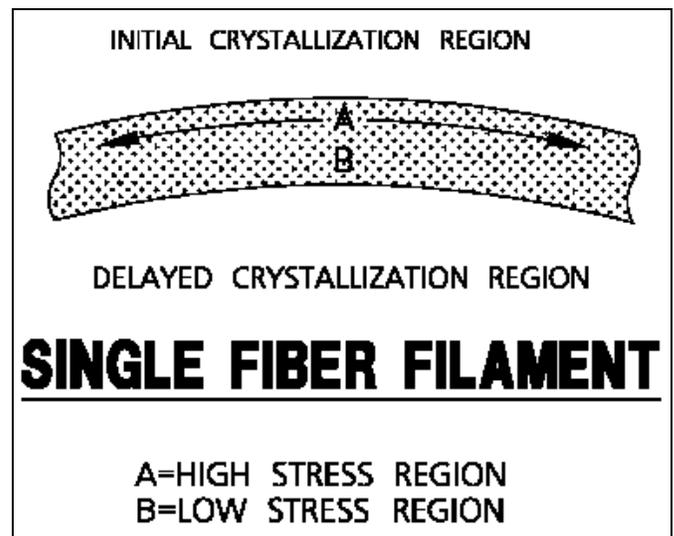


Figure 5 - Stress Induced Crystallization

5. VELOCITY RESISTANCE

One of the most common parameters which must be considered in the design of ceramic fiber linings is the ability of the lining to withstand furnace gas flow. Because of its inherent structure, it is sometimes necessary to modify furnace lining designs to accommodate high velocities. Velocity is generally measured in terms of feet per second (ft/s) or meters per second (m/s). It is important when discussing velocity whether it is referring to laminar flow or turbulent flow type patterns. Laminar flow is far less destructive to ceramic fiber linings than turbulent flow where the air “tumbles”, creating localized regions of high velocity in its flow pattern. When

turbulent flow occurs, such as in elbows, curves, or restrictions, special care must be exercised to adequately protect the ceramic fiber lining. A general guideline for turbulent flow regions is to utilize the next level of velocity resistance.

Beyond simple product choice, another alternative is to utilize coating systems which protect the hot face layer of fiber. The available coatings are colloidal suspensions of either silica or alumina and ceramic coatings which are sprayed on the surface of blankets, modules, and boards. The specific products, temperature use limits, and coverage rates are as follows:

Kaowool® Rigidizer	1800°F (982°C) 15 SF/Gal
Unikote® M	2400°F (1316°C) .81 Lb/SF
Unikote S	2800°F (1538°C) .81 Lb/SF

Blanket/Wallpaper	Ft	m/s
Blanket	50 - 70	15 - 21
Rigidized 8 pcf blanket	150	45
Wet Felt	250	75
Modules		
Pyro-Bloc®		
8#	100	30
10#	125	37
12#	150	45
15#	150	45
Pyro-Fold™, Uri-Bloc®, Z-Bloc®		
8#	125	37
9.3#	140	42
Modules treated with Unikote	175	53
Veneering Modules		
Unifelt® 3000	150	45
Unifelt XT	150	45
Board Products		
All Boards	250	75

Table 3 - Maximum Velocities for Laminar Flow Across the Surface of Ceramic Fiber

Note: Unikote M or S is not recommended for use on a blanket lining.

It is very important not to exceed the above temperature guidelines as very severe shrinkage of the fiber surface can occur. The ceramic coatings may offer resistance to specific forms of chemical attack.

6. EFFECT OF REDUCING ATMOSPHERES

Ceramic fiber is frequently used under reducing conditions. Carburizing, reforming, and vacuum furnaces provide a specialized set of conditions in which ceramic fiber must exist. Gaseous components such as H₂, CO, NH₃ and CH₄ are generally considered to be reducing in nature and can lead to changes in the ceramic fiber microstructure.

6.1 Reduction of Silica

Reducing atmospheres can lead to a reduction in silica (SiO₂) out of the glass phase or mullite. This vaporization of SiO₂ out of the glass phase or mullite in a vacuum can effect the recrystallization processes in alumina-silica and alumina-silica-zirconia fibers. The reduction of silica occurs as a function of temperature and dew point and is observed as a weight loss as gaseous SiO moves away from the hot face and condenses at colder areas of the lining. Several mechanisms can be involved with the reduction of silica in reducing atmospheres. They can involve reduction of SiO₂ to SiO, or with water vapor or steam present they form silicic acid hydrates such as Si(OH)₄ or Si₂O(OH)₆. The vaporization of SiO₂ increases with increasing H₂ content, with increased free SiO, and with increased temperature. Reduction of silica will begin to occur at 2100°F (1149°C) but will only become significant at temperatures above 2100°F (1149°C). A combination of hydrogen and nitrogen (H₂-N₂) atmospheres will more readily attack SiO₂ than will pure hydrogen atmospheres, and the presence of water vapor will accelerate the rate of reaction.

6.2 Reduction of Other Oxides

Reducing atmospheres can cause other refractory oxides to dissociate in manners similar to SiO₂. Figure 6 illustrates the effect of reducing atmospheres on iron oxide, titania, and even alumina. Generally titania and iron oxide are in small quantities in ceramic fiber, so reduction of these oxides produces little, if any effect in the performance of the fiber. Only under the most extreme conditions of temperature and low dew point can alumina be reduced, so it generally is of little concern.

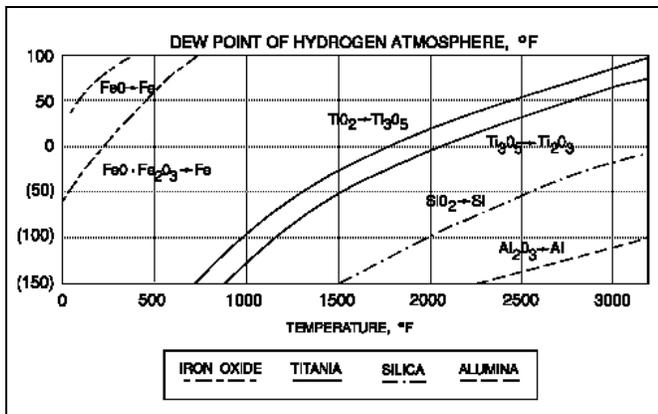


Figure 6 - Effect of Reducing Atmospheres on Refractory Oxides

7. CHEMICAL ATTACK

The resistance of ceramic fibers to corrosive environments can be one of the most confusing topics associated with fiber designs. This information will show how fiber behaves under chemical attack and hopefully be a useful reference. The easiest way to deal with this subject is to individually discuss several corrosive agents which are known to attack ceramic fiber. Environments addressed include fluorine and fluorine derivatives, vanadium and other heavy metals, phosphoric acid, and alkalis.

7.1 Fluorine and Its Derivatives

Without a doubt, fluorine is the most aggressive attacker of ceramic fiber. At temperatures below 212°F (100°C) reactions of fluorine and water vapor with ceramic fiber will lead to widespread destruction of the material. Even at relatively low concentrations, hydrogen fluoride (HF) appears to preferentially attack the alumina, forming AlF_3 and $\text{AlF}_3 \cdot \text{H}_2\text{O}$, causing massive destruction of the fiber structure. Hydrogen fluoride will also readily attack SiO_2 . In moderate temperature ranges (i.e., normal amorphous range up to 1800°F (982°C)), it appears that a fluorine-enriched environment may promote low-temperature recrystallization which, in turn, can lead to minor fiber destruction. At temperatures where significant recrystallization has occurred, the fluorine seems to form a reaction product on the surface of the fiber, which can lead to fiber structure alterations. A thin layer of “crusting” on the fiber surface should be evident. Fluorine attacks all forms of alumina-silicates, including mullite. After the fluorine attacks, it often out-gases, which makes it very difficult to determine the cause of failure.

7.2 Vanadium and Other Heavy Metals

Vanadium and other heavy metals, which are present in poorer quality fuel oils, when burned, attack ceramic fiber. The attack comes from vanadium pentoxide (V_2O_5) which at ambient temperatures is solid, but melts at a temperature of approximately 1280°F (693°C). The liquid slag is absorbed into the porous fiber and will chemically react with the alumina-silica system in refractory ceramic fiber. Once reacted, the slag will form a hard, crusty layer on the hot face. Over a period of time, this crust will break away from the unreacted portion of the ceramic fiber blanket, and the process will begin again on the freshly exposed fiber.

The rate of attack is dependent upon a number of factors which include concentration (ppm) of heavy metals, time, porosity of material, and temperature. There is no firm concentration limit below which attack will be minimized. Rather, it is the concentration of heavy metals over time which will determine refractory life. Vanadium pentoxide at temperatures above 1280°F (693°C) will attack fiber, but the rate is affected by the above parameters. Periodic replacement of hot face material will be required as attack builds up over time.

A word of warning: Vanadium pentoxide will attack ceramic fiber, but vanadium in the presence of alkalis forms much more aggressive slags that melt at very low temperatures, which causes the ceramic fiber to degrade much more quickly. Normally, fuels high in heavy metal content also contain alkalis.

7.3 Sulfur and Sulfuric Acid

Ceramic fiber has excellent resistance to sulfuric acid. Only minor disruption or reaction of the fiber can be expected, typically forming aluminum sulfate ($\text{Al}_2(\text{SO}_4)_3$) or alumina sulfate hydrates. This generally will not lead to fiber failures. Metal anchor corrosion is a serious concern, and steps should be taken to protect metal components with a bitumastic coating or stainless foil, or to keep the metal parts at a temperature above the dew point of sulfuric acid (generally 250-350°F (121-177°C)). Ceramic fiber in the presence of iron (Fe) and sulfuric acid (H_2SO_4) will form a ferro-alumina-silicate sulfate compound. This compound will “dissolve” the anchors and casing, converting the metal to a slate-like material.

Generally a yellowing of the surface of the fiber occurs. It appears that sulfur deposits on the surface of the fiber may

cause disruption during the recrystallization process at temperatures around 1800°F (982°C). This attack normally occurs in a discreet location on the hot face of the lining. The attack appears to cause the fiber to obtain a powdery consistency which, with mechanical action (vibrations) or gas velocities, can lead to a loss of hot face material. This gradual reduction of hot face material will expose fresh material which is susceptible to attack, and the process can regenerate itself. Only over long periods of time can this really become disruptive to the lining integrity. Periodic replacement of the hot face layer of blanket in wallpaper construction may be required. If using a modular form of ceramic fiber, a spray coating of Unikote may be considered.

7.4 Alkali Attack

Alkali attack on ceramic fiber appears to be largely time and temperature dependent. The alkalies form low melting compounds leading to profound shrinkage/sintering of fibers and ultimate lining failure. Components such as V_2O_5 , SO_3 , etc. amplify the destructive behavior leading to early fiber failure. Alkali attack usually occurs on the hot face layer of fiber where a crust or “slag” layer is formed. As more attack occurs, this eventually degrades the fiber and fresh fiber is exposed to attack.

7.5 Other Acids

Ceramic fiber is generally thought to be resistant to hydrochloric acid (HCl), acetic acid (CH_3COOH), and nitric acid (HNO_3). It is also resistant to phosphoric acid (H_3PO_4) at low temperatures; however, significant shrinkage of fiber occurs as complex alumino-phosphates are formed at higher temperatures. It is best to avoid the presence of phosphates at temperatures in excess of 1000°F (537°C).

Notice:

Some of the products described in this literature contain Refractory Ceramic Fiber (R.C.F.) and/or crystalline silica (cristobalite or quartz). Based on experimental animal data, the International Agency for Research on Cancer (IARC) has classified R.C.F., along with fibrous glasswool and mineral wool, as a possible human carcinogen (Group 2B) and respirable crystalline silica as a probable human carcinogen (Group 2A).

To reduce the potential risk of health effects, Thermal Ceramics recommends engineering controls and safe work practices be followed by product users. Contact the Thermal Ceramics Product Stewardship Group (1-800-722-5681) to request detailed information contained in its MSDSs and product literature and videos.

Amorphous: Having no definite crystalline structure or form.

Back-up Insulating Material: The layer or layers of insulating material that are located between the hot face insulating layer and the outer casing.

Blanket: A flexible unbonded ceramic fibrous insulating material of reasonably determinate dimensions.

Board: A substantially rigid or semi-rigid flat sheet produced by vacuum forming.

Bulk Fiber: Ceramic fibers in the "as-produced" state.

Butt Joint: A ceramic fiber wallpaper construction joint where edges of adjacent blankets meet.

Cold Face Temperature: Term used to denote the outside casing temperature.

Cristobalite: A crystalline phase of silica which will begin to form above 1800°F.

Devitrification: The phase transformation from glass to crystalline structure.

Edge-grain: The orientation of a fiber system in which strips of ceramic fiber blanket or felt are oriented perpendicular to the plane of the furnace casing.

Felt (Pressed): A flexible sheet product formed from ceramic fibers and bonded with an organic binder.

Continuous Use Limit: Long-term (continuous) temperature limit for a product installed as a lining. This temperature is based upon product shrinkage, specifically what is considered to be a "manageable" or "controllable" shrinkage. This term is not to be confused with temperature rating.

Heat Loss: The term used to denote the amount of heat being lost through a lining construction over time, measured in BTU/sq ft/min, (watts/sq in).

Heat Storage: The thermal property of a material wherein heat accumulates in the mass (which in refractories is a function primarily of the material's specific heat, mass, and temperature rise measured in BTU/lb/°F (Cal/g/°C)).

Heat Transfer: The study of heat flow mechanisms - conduction, convection, and radiation.

High Alumina Fiber: A ceramic fiber containing more than 90% alumina, giving a high use limit. Mullite fiber is also used in high temperature applications.

High Purity (HP) Fiber: A ceramic fiber produced from synthetic alumina and silica.

Hot Face Insulating Material: The layer of lining insulating material that has at least one surface exposed to the full temperature of the furnace gases.

Kaolin Fiber: A ceramic fiber produced from calcined kaolin.

Laminar Flow: The flow of a gas in which the gas stream moves in straight lines parallel to the direction of the flow.

Layered Lining Wallpaper: Lining that is composed of several layers and thicknesses of refractory ceramic fiber.

Linear Shrinkage: The amount of shrinkage which occurs along the length of a material after it has been subjected to elevated temperatures and then cooled - measured in percent of original pre-fired length.

Lock Washers: Washers used in conjunction with Kao-lok studs. They are slotted so that when pushed over the stud and then twisted 90° the washer is locked into place, other locking systems are available, such as cone anchors. Lock anchors come in ceramics or alloy metals to suit temperature requirements.

Maximum Temperature Rating: The temperature which is used by the industry as a loose classification of different grades of ceramic fiber. This is generally higher than the continuous use limit.

Module: A prefabricated unit which can be applied as a lining block to the inner face of a furnace structure.

Mortar/Cement: A ceramic-based adhesive for attaching ceramic fiber products to other surfaces.

Mullite: A crystalline phase of alumina-silica.

Overlap Construction: A construction technique used to accommodate shrinkage in ceramic fiber or to improve velocity resistance in which one edge of a blanket is lapped over an adjacent blanket edge by 4" to 12" and shares a common anchor stud and washer.

Paper: A roll product produced from ceramic fibers and organic binders on conventional paper-making machinery.

Parquet: A method of installing modular edge-grained forms of ceramic fiber so that the edge grain of one module is perpendicular to the edge grain of the adjacent modules.

Rigidizing: The practice of applying an inorganic hardening agent to the surface of ceramic fiber (by spray or brush) in order to improve its velocity resistance.

R.C.F.: Refractory Ceramic Fiber.

Shingled Joint: A method of applying double layers of ceramic fiber blanket in such a way that half the width of each layer overlaps half the width of the adjacent layer.

Shot: A glassy material formed during fiberization.

Textile: Cloth, tape, sleeving, tubing, or other forms manufactured from ceramic fiber yarn.

Thermal Conductivity: The property of material to conduct heat - measured in BTU flow per hour through a square foot of area across one inch of thickness BTU•in/hr•ft•°F (w/m•C°).

Thermal Resistivity: The property of a material to resist the flow of heat; the reciprocal of thermal conductivity.

Thermal Shock: A failure mechanism wherein sudden changes in temperature bring sufficient thermal mechanical stress in a material to cause cracking or spalling. As a general rule, the thermal shock resistance of a material is greater as the strength and thermal conductivity of a material increase and as the thermal expansion and modulus of elasticity decrease.

Turbulent Flow: Fluid flow in which the velocity of a given stream of gas changes constantly both in magnitude and direction.

Vacuum Forming: A method of producing molded shapes and flat board by converting fibers into a slurry and vacuuming them onto a screen former.

Veneer: Layer of ceramic fiber in either blanket or module form which is attached to the hot face of a brick, module or monolithic lining.

Wallpaper Construction: The term used to describe a ceramic fiber lining construction technique where the blanket is installed on a wall like a roll of wallpaper.

- Notes -



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