REFRACTORIES FOR EVERY USE

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Refractories for Every Use

Temperature limits for refractories are moving upward but maximum output per unit of cost still rules choice.

Although the refractories industry is a comparatively small one, it is critical because nearly all other industries depend on it. Refractories contain our heating processes, and their characteristics to a large degree determine the types of heating operations we can perform satisfactorily and economically. Without proper refractories we would be without steel production, steam generation, glass manufacture, portland cement, many chemicals—to mention only a few.

There is no ideal refractory for all applications. Choice of the most economical one in any case depends on a number of factors. In some cases very expensive refractories costing several dollars per brick may give the lowest refractory cost per unit of output. At the other extreme, sometimes the lowest cost fireclay brick obtainable may be the most economical. Installed cost per unit of production over the life of the refractory is the proper criterion for choice in most cases, rather than f.o.b. price. However, the cost of shutdowns and unplanned outages must be considered as well.

Refractories need not only withstand their necessary operating temperature without melting or shrinking, but they must be satisfactory from several other standpoints. For example, consideration must be given to their compressive strength under heat, to their tendency to disintegrate in furnace atmospheres of CO or H_2, to their resistance to erosion from slags, corrosive vapors or mechanical abrasion, and to splitting or spalling owing to rapid heating and cooling cycles.

By far the greatest proportion of refractories is produced in the standard weight types formed as brick, as special shapes or as tile. In addition, the industry makes light-weight insulating refractories; refractory castables, which are refractory-base granules mixed with hydraulic cement; ramming mixtures for monolithic refractory linings; and special materials such as high-temperature ceramic coatings for metals, and the metal-ceramic combinations called cermets.

Refractories produced in the form of brick and tiles are summarized in Table I.

ALUMINA-SILICA REFRACTORIES

Fireclay Refractories—Fireclay refractories constitute the largest group of refractories produced. They are made largely from fireclays obtained from New Jersey, Kentucky, Pennsylvania, Ohio, and Missouri and are divided into four main groups, based partly on maximum service temperatures which they can withstand. These groupings are: (1) Low-duty fireclay brick; (2) intermediate fireclay brick; (3) high-duty fireclay brick; and (4) superduty fireclay brick.

Fireclay brick as a group are relatively cheap. They are used to some extent in almost every furnace structure built, where operating temperatures are within their temperature service range and where no special conditions of reducing furnace atmospheres or special problems are encountered. Their low cost makes them an economical material.

Alumina-Diaspore Fireclay Brick—These brick have a higher melting

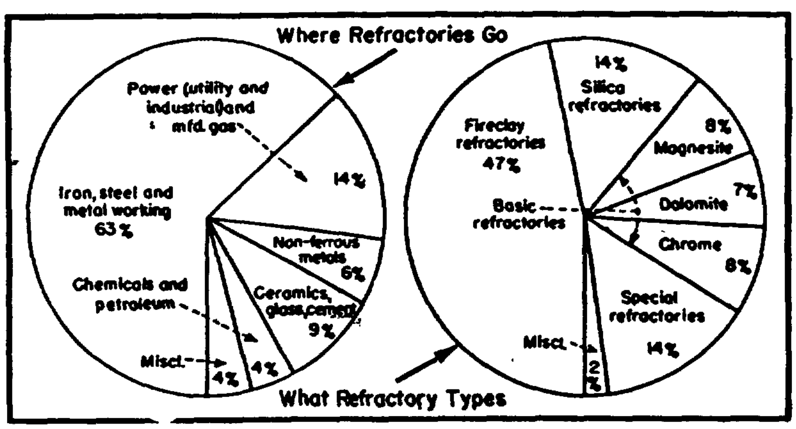

Fig. 1—REFRACTORIES by destination and types. The chart on the left shows how refractories use breaks down by industry groups. Chemical process industries include a part of the power group, a part of the non-ferrous metals group, the ceramic, chemical and petroleum groups. The chart on the right shows that fireclay refractories, including all clay brick as well as insulating refractories, mortars, plastics and castables, encompasses nearly half the total industry product. The special refractories include fused alumina, SiC, mullite, sillimanite, forsterite, zircon, carbon and other special refractories, and their non-brick forms.

Table I—Classification and Use Properties of Refractory Brick

Name	Composition, Percent	Melting Point, °F.	Normal Use Limit, °F.*	Approx. \$/M, 9-in. Equiv.	True Specific Gravity	Bulk Density, Lb./Ft.^{3}	Source
Alumina-Silica							
Fireclay base							
First quality	35–40 Al_2O_3 54–60 SiO_2	3,090–3,175	2,400–2,700	95	2.60–2.70	125–140	Fireclay
Semi-silica	70–80 SiO_2	2,940–3,060	2,400–2,700	100	2.40–2.45	125–140	Fireclay
Superduty	41–45 Al_2O_3 51–55 SiO_2	3,175–3,200	2,500–2,800	115	2.65–2.75	130–145	Flint fireclay
High burned superduty	41–45 Al_2O_3 51–55 SiO_2	3,175–3,200	2,500–2,800	155	2.65–2.75	130–145	Flint fireclay
50% alumina	50 Al_2O_3	3,200–3,245	2,500–2,800	160	2.75–2.85	130–145	Fireclay, diaspore, bauxite
60% alumina	60 Al_2O_3	3,245–3,310	2,700–2,900	200	2.90–3.05	130–145	Fireclay, diaspore, bauxite
70% alumina	70 Al_2O_3	3,290–3,335	2,700–2,900	235	3.15–3.25	135–150	Diaspore, bauxite
80% alumina	80 Al_2O_3	3,335–3,390	2,800–3,000	260	3.35–3.45	140–155	Diaspore, bauxite
90% alumina	90 Al_2O_3	3,390–3,425	2,800–3,200	1,175	3.55–3.65	172	Calcined alumina
Kyanite base	$Al_2O_3 \cdot SiO_2$ 58–68 Al_2O_3	3,250–3,300	2,800–3,000	500–680	3.00–3.06	140–150	Kyanite
Kaolin base (High-fired)	$Al_2O_3 \cdot 2SiO_2$ 44–45 Al_2O_3	3,190	2,800–2,900	170–335	2.65–2.75	135–145	Kaolin
Fused mullite base	$3Al_2O_3 \cdot 2SiO_2$ 72–75 Al_2O_3	3,325–3,350	2,900–3,200	685–1,370	3.08–3.25	150–160	Bauxite and synthetic
Silica							
Standard	SiO_2	3,142 (pure)	3,000	95–100	2.30–2.38	100–105	Quartz sand, ganister
Superduty	SiO_2	3,142 (pure)	3,000 plus	110	2.30–2.38	100–105	Quartz sand, ganister
Magnesite							
Burned	MgO plus SiO_2, Fe_2O_3, Cr_2O_3	5,070 (pure)	3,000–4,000	520	3.40–3.60	160–165	Magnesite, sea water, brines, brucite
Chemically bonded	MgO plus FeO, Cr_2O_3		2,900–3,100	465	3.60–3.80	170–175	Magnesite, sea water, brines, brucite
Chrome							
Burned	$FeO \cdot Cr_2O_3$ pure; plus some Al_2O_3, MgO, Fe_2O_3, SiO_2	3,540–3,990	2,800–3,200	430	3.60–4.10	185–190	Chromite ores
Chemically bonded	$FeO \cdot Cr_2O_3$ plus MgO	3,540–3,990	2,900–3,100	450–485	3.90–4.10	170–180	Chromite ores
Forsterite	$2MgO \cdot SiO_2$	3,461 (pure)	3,000	530	3.30–3.40	150–166	Olivine or synthetics
Silicon carbide	SiC	Dissociates at 4,082	2,800–3,200	1,520	3.19	155	Synthetic
Fused alumina	Al_2O_3	3,722 (pure)	3,400	2,000	3.70–3.90	175–195	Bauxite
Zircon	$ZrO \cdot SiO_2$	4,532 (pure)	3,400	1,210	4.70	206	Zircon sands
Zirconia (Stabilized)	ZrO_2	4,870 (pure)	4,300	9,430	5.75	275	Zircon sands
Carbon (Graphite)	C	6,330	4,000 (reduc. atm.)	1,600	2.25	137	Carbon

* Note: "Normal-use-limit" temperatures are approximate only because service conditions sometimes will change allowable temperatures by several hundred degrees. Such conditions may include heavily reducing atmospheres and unusual loading.

point and an alumina content which varies from 50 to 70 percent. As a class, they are used much less than the ordinary fireclay brick because of their higher price. They are used only where their higher use limit and melting point, and in some cases resistance to slag, make them a more economical selection. One important use of the 70 percent alumina type is in the linings of rotary cement kilns.

Special Alumina-Silica Refractories—In this classification we have the sillimanite and mullite types usually made from kyanite with an over-all alumina percentage between 58 and 65 percent. These bricks are considerably more expensive than the alumina-diaspore class and are used where the service temperature of this latter group is exceeded.

In this classification are also the kaolin base refractories which are made from relatively pure china clay which has been heated to very high temperatures to render it volume stable at high application temperatures.

Also in this group are mullite refractories which have a true mullite composition with an alumina content of approximately 75 percent. These brick are usually made from electrically fused mullite grain, with a bond which also develops theoretical mullite compositions on firing. These brick have extrêmely good compressive strength under load at high temperatures. They resist rapid heating and cooling cycles, and are resistant to certain types of slag attack. They are volume stable at higher temperatures than the refractories previously listed.

SILICA REFRACTORIES

Silica refractories are the second largest group of refractories produced and large quantities of them are used by the steel and glass industries. They are made from crushed sandstone or quartzite, bonded with a small amount of lime water. Silica brick have the advantages of being relatively low priced and have good load bearing capacity at high temperatures close to their melting point. Because of their thermal expansion characteristics they have poor resistance to rapid heating and cooling and for that reason are used primarily in furnaces where the temperature is held constant for long periods of time.

Recently a new development in silica refractories has been made, known as the superduty silica brands. This superduty silica brick is one in which the total alumina content is lower than in the normal brands and as a result it has a somewhat higher use limit than the standard silica refractories.

MAGNESITE REFRACTORIES

Magnesite refractories are produced from calcined magnesite rock or from calcined magnesium carbonate recovered from sea water. In the heating process the CO_2 contained in the magnesium carbonate of the starting material is driven off to form MgO. The MgO granules are then bonded, sometimes with the addition of chrome ore, to form bricks and shapes. Some of these are fired to high temperatures as in the case of other refractories and some are chemically bonded by a process which requires no firing. Magnesite brick are used mainly where they are in contact with basic slags. These brick are considerably more expensive than fireclay brick and for that reason are used where the cheaper fireclay brick will not give an economical life.

There is also a type of electrically fused MgO refractory produced from nearly pure magnesia which has a higher use limit than normal magnesite brick, suitable for use at very high temperatures.

CHROME REFRACTORIES

Chrome refractories are produced from natural chrome ore and, like magnesite, can be made either as fired or as chemically bonded brick. The chemically bonded structures always contain some MgO additions. Chrome brick is relatively neutral chemically and does not react at moderately high temperatures with silica, magnesite, or alumina refractories. For that reason it is often used as a separator in furnace constructions between two refractories which would react with each other if allowed to come into contact.

FORSTERITE REFRACTORIES

Forsterite refractories are usually made from olivine rock to which some MgO has been added to adjust the composition ratio to $2MgO \cdot SiO_2$. Forsterite refractories can also be made by synthetic mixtures of MgO and SiO_2. These refractories are made only as a fired refractory and are reported to be particularly good against the attack of alkali vapors at high temperatures.

SILICON CARBIDE REFRACTORIES

Silicon carbide is an electric furnace product used primarily as an abrasive and is known under trade names such as Carborundum and Crystolon. When this material is produced in refractory shapes it provides a very high rate of heat conduction, approximately 10 times that of fireclay brick. (See Fig. 2. Due to its hardness it is sometimes used where mechanical abrasion

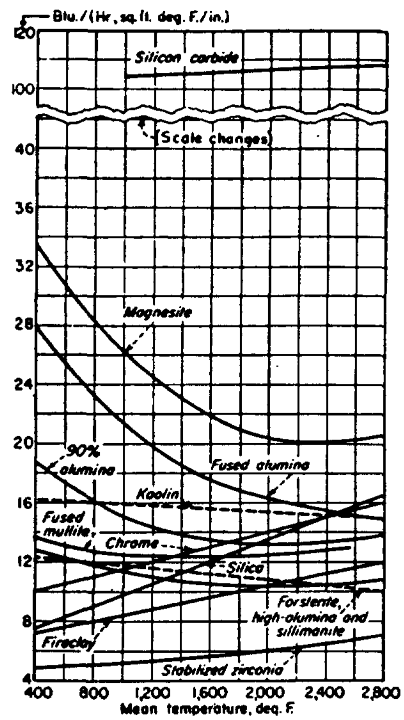

Fig. 2 — REFRACTORY BRICK show widely varying thermal conductivities. (Data from various sources; values vary considerably depending on test method.)

is severe and also where it is exposed to certain types of slag. Its property of high heat conduction, however, is probably its outstanding physical characteristic and for this reason it is used widely for muffles and various air-cooled furnace and recuperator constructions.

FUSED ALUMINA REFRACTORIES

Fused alumina is another electric furnace product whose primary use is in abrasives. When compounded into refractory shapes it also has a high heat conduction, but considerably lower than silicon carbide. Its heat flow is approximately 2.5 times that of ordinary fireclay brick. It is also used for muffles and air cooled sections and replaces silicon carbide where the latter is unsatisfactory for other reasons. It has a very high use limit in both oxidizing and reducing atmospheres and it is used where extreme temperature levels rule out other materials.

ZIRCON REFRACTORIES

Zircon refractories are made mainly from the natural mineral zircon which is often found concentrated in certain beach sands. It has a high melting point and use limit and is resistant to some types of siliceous slags.

ZIRCONIA REFRACTORIES

These refractories are made from purified zirconium oxide with small additions of lime, magnesia, or other ingredients to render it stable in volume. Pure unstabilized zirconium oxide inverts on cooling from the high temperature form to a low temperature form with a considerable volume change which is sufficient to cause cracking and disintegration. The stabilized structure retains the high temperature form on cooling without undergoing a change in volume. These refractories have a very high melting point and use limit and are employed where extreme temperatures are encountered. An interesting physical property is that even at extremely high temperatures the thermal conductivity is low so that the heat flow through a furnace section is relatively low. These refractories are relatively high priced and can be justified economically only for extreme use.

CARBON REFRACTORIES

Carbon (graphite) refractories are produced by heating a mixture of tar and coke. The refractories in brick or block form have been used in blast furnaces and in some other industries. They are limited to applications where the furnace operates reducing.

INSULATING FIREBRICK

Insulating firebrick are produced mainly from clays which are mixed with some type of combustible material such as sawdust. When fired, the combustible material burns out, leaving a highly porous refractory structure. These light-weight products can be used as the exposed lining in the furnace chamber in the same way as other refractories. They are made in several grades, the lowest grade being suitable for temperatures of 1,600 deg. F., and the highest temperature grade being satisfactory at 3,000 deg. F. The weight per brick ranges between 1.25 and 4 lb. as contrasted to 8 lb. for a standard firebrick.

It is the low weight of these refractories which makes them of importance. The time necessary to raise a cold furnace to operating temperature is proportional to the weight of the furnace lining, assuming equal fuel inputs to the structure. Likewise,

Table II—Classification of Insulating Firebrick

Type *	Composition, Percent	Normal Use Limit, °F.†	Approx. $/M, 9-in. Equiv.	Bulk Density, Lb./Ft.^{3}
Group 16	15–37 Al_2O_3, 30–60 SiO_2 plus TiO_2, Fe_2O_3, Alk.	1,600	115	21–37
Group 20	26–38 Al_2O_3, 45–61 SiO_2 plus TiO_2, Fe_2O_3, Alk.	2,000	125	26–45
Group 23	25–42 Al_2O_3, 45–67 SiO_2 plus TiO_2, Fe_2O_3, Alk.	2,300	150	27–47
Group 26	40–46 Al_2O_3, 47–55 SiO_2 plus TiO_2, Fe_2O_3, Alk.	2,600	195	43–64
Group 28	45–53 Al_2O_3, 42–52 SiO_2 plus TiO_2, Fe_2O_3, Alk.	2,800	260	45–65
Others	45 Al_2O_3	2,900	285	52
	65 Al_2O_3	3,000	480	69
	90 Al_2O_3	3,250	750	81

* Group number is std. A.S.T.M. classification, indicating normal use limit (×100).
† See note under Table I.

Table III—Classification of Refractory Castables

(Refractory aggregates plus hydraulic cement)

Name, Standard Types	Composition	Normal Use Limit, °F.*	Approx. Cost, $/T., CL	Bulk Density, Installed & Fired, Lb./Ft.^{3}
Alumina-Silica				
Fireclay type	Al_2O_3, SiO_2 plus CaO, Fe_2O_3, TiO_2, Alk.	2,400–2,700	60–75	100–140
Superduty type	Al_2O_3, SiO_2 plus CaO, Fe_2O_3, TiO_2, Alk.	2,700–3,000	100–170	100–140
Chrome	$FeO \cdot Cr_2O_3$ plus Al_2O_3, CaO, SiO_2	2,700–3,100	90–150	160–190
Insulating Types				
Expanded mica	....	1,600–1,800	....	40–60
Diatomaceous base	SiO_2 plus Al_2O_3, impurities	1,800–2,000	....	55–70
Bloated clay base	Al_2O_3, SiO_2 plus CaO, Fe_2O_3, TiO_2, Alk.	2,000	....	70–100
Porous refractory base	Al_2O_3, SiO_2 plus CaO, Fe_2O_3, TiO_2, Alk.	2,000–2,500	90–130	50–90

* See note under Table I.

Table IV—Classification of Refractory Plastics and Ramming Mixes

Name	Composition	Melting Point, °F.	Normal Use Limit, °F.*	Approx. Cost, $/T., CL	Bulk Density, Installed & Fired, Lb./Ft.^{3}
Alumina-Silica					
Fireclay base	Al_2O_3, SiO_2, plus Fe_2O_3, TiO_2, Alk.	2,850–3,100	2,500–2,700	50–70	125–140
Superduty base	Al_2O_3, SiO_2, plus Fe_2O_3, TiO_2, Alk.	....	2,700–3,000	60–80	130–140
Kyanite base	$Al_2O_3 \cdot SiO_2$, plus Fe_2O_3, TiO_2, Alk.	....	3,000–3,100	150–175	140–150
Fused mullite base	$3Al_2O_3 \cdot 2SiO_2$ plus Fe_2O_3, TiO_2, Alk.	....	3,000–3,200	175	150–160
Silica	SiO_2	3,142 (pure)	2,800–3,000	......	100–105
Magnesite					
Grain	MgO	5,070 (pure)	2,900–3,100	70–100	150–160
Mixtures	....	....	....	......	145–165
Dolomite	$CaO \cdot MgO \cdot 2CO_2$	4,650–5,070 (pure)	2,900–3,100	......	....
Chrome	$FeO \cdot Cr_2O_3$ plus Al_2O_3, MgO	3,765 (pure)	2,900–3,100	95–110	180–200
Silicon carbide	SiC	Dissociates at 4,082	2,800–3,150	......	150–170
Fused alumina	Al_2O_3	3,722 (pure)	2,900–3,400	......	175–195
Zircon	$ZrO \cdot SiO_2$	4,532 (pure)	3,200	......	205
Zirconia (Stabilized)	ZrO	4,870 (pure)	3,800	......	275

* See note under Table I.

the time necessary to cool the furnace structure down is proportional to the weight. In actual practice it is not uncommon to effect fuel reductions of 30-65 percent in a cyclic heating process when insulating firebrick are substituted for standard refractories.

The high porosity of insulating firebrick also gives them a low heat flow, the thermal conductivity being roughly proportional to their weight as shown in Fig. 3. This means that for continuous heating operations, thin wall sections can be used having the same heat flow as more massive firebrick sections backed up by insulation.

Insulating firebrick have application limitations, however, and are confined to heating operations where there are conditions of clean heat, freedom from mechanical abrasion, and freedom from slag. It is largely because porous structures are unsatisfactory when subjected to slag that insulating firebrick are made from alumina-silica compositions, since the better slag resisting properties of magnesite, chrome or similar materials would have little advantage in a sponge-like texture.

REFRACTORY CASTABLES

Refractory castables are concretes, similar to structural concrete except that the sand and gravel of structural concrete is replaced by a carefully prepared and sized aggregate of crushed refractory material. The cement used is usually the same as in structural concrete, being portland or high-alumina cement. More recently, a more refractory cement composed of nearly pure lime and alumina in the

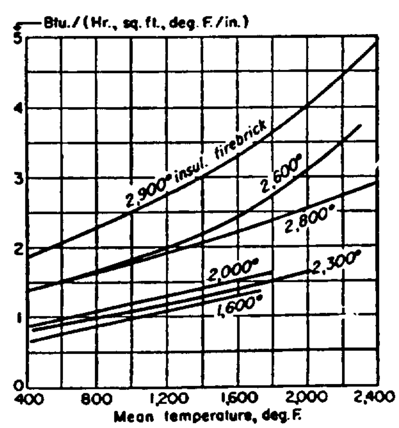

Fig. 3—INSULATING FIREBRICK have thermal conductivities much below most standard weight refractories. (Data on one maker's products.)

ratio of $3CaO \cdot 5Al_2O_3$ has been used. With alumina-silica base aggregates, castables are available for service temperatures from 2,400 deg. F. to temperatures somewhat above 3,000 deg. F. The alumina-silica base castables constitute the bulk of the market, although special castables are made with chrome, fused alumina and other bases.

Just as in the case of preformed refractories, there is a class of lightweight castables made by using a porous aggregate. The advantages of light weight in a castable are the same as in the case of insulating firebrick.

At the present time, the general use of castables is being extended considerably due to their low cost of installation. Refractory concrete is mixed and placed in a manner similar to structural concrete, and is a desirable material to use in areas where skilled brickmasons are hard to obtain. When the proper grade is selected for a given application, a castable will provide a volume stable monolithic lining in many instances giving equal or better service life than a lining of regular brickwork.

PLASTIC AND RAMMING REFRACTORIES

There is another group of refractory products known as plastic refractories or ramming mixes. These compositions are generally composed of clays or other binders mixed with crushed refractory aggregate and tempered with water to bring the mixture to proper working consistency. The plastic or ramming mix is installed by pounding or ramming into place, and for this reason the installation costs are usually somewhat higher than for a similar castable installation.

Plastic or ramming mixtures are made in alumina-silica compositions with temperature use limits ranging from 2,500 to over 3,000 deg. F. There are also compositions using fused alumina, chrome ore, magnesite, periclase, silicon carbide, and other refractory base aggregates.

REFRACTORY MORTARS

Many types of mortars are produced for laying up or jointing preformed refractory brick. There are two main types, those which develop their bond strength only when heated to temperature in the furnace— known as "heat setting" mortars—and those which develop a high bond on drying, called "air setting" mortars. Both types have their applications, and the best guide is to follow the recommendation of the manufacturer supplying the brick used with the mortar.

METAL-CERAMIC COMBINATIONS

Various combinations of ceramic materials have been used as coatings on metals, including parts for nuclear reactors and heat-resistant components for both jet-propulsion and reciprocating aircraft engines. These coatings can be used to impart chemical inertness at high and low temperatures to the metal, and have good thermal shock resistance and low porosity. Ceramic-coated low-alloy steels can replace the higher alloyed strategic materials. These coatings reduce oxidation and inter-granular corrosion of the base metal up to a temperature of 1,900 deg. F. Although the better coatings contain a considerable portion of strategic material in their composition, the thinness of the coating together with the substitution of lower alloy content steels represent a considerable over-all saving in strategic materials. The U. S. Bureau of Standards and several industrial concerns have done considerable work in developing this type of material. Many of these mixtures consist essentially of an enameling frit of alumina and silica with additions of metallic oxides such as chromium and cobalt.

Another approach to metal-ceramic combinations which has spurred considerable research in recent years is the class of cermets. This work has been prompted by the scarcity of high-temperature metals requiring strategic materials. Cermets are mechanical and chemical combinations of metals and ceramics whose properties in the combined state differ from those of either component. Ceramic materials themselves are limited by low tensile strength and thermal shock resistance, whereas metals have good tensile and shock-resistant properties, but lose rapidly with increase in temperature. Cermets attempt to blend the desirable properties of both, securing the advantages of improved thermal shock resistance, wear resistance and mechanical strength at elevated temperatures, compared with ceramics. Also they have a higher strength-to-weight ratio than ordinary refractories. They can be formed by methods similar to those used in powder metallurgy. Usually, the ceramic components are refractory oxides, carbides and nitrides, while such metal components as chromium, nickel, molybdenum and titanium are used. Hence such materials are costly, and many of the available types require strategic materials.

Table V—Refractory Compounds with Reported Melting Points Above 4,000 Deg. F.

Material	Formula	M.P., °F.
Oxides		
Beryllium oxide (Bromellite)	BeO	4,580
Calcium oxide (Lime)	CaO	4,650
Cerium oxide	CeO_2	4,710
Chromium oxide	Cr_2O_3	4,410
Hafnium oxide	HfO_2	5,090
Lanthium oxide	La_2O_3	4,208
Magnesium oxide (Periclase)	MgO	5,070
Strontium oxide	SrO	4,410
Thorium oxide	ThO_2	5,520
Yttrium oxide	Y_2O_3	4,370
Zirconium oxide	ZrO_2	4,870
Silicates		
Zirconium silicate (Zircon)	$ZrO_2 \cdot SiO_2$	4,532
Nitrides		
Boron nitride	BN	5,432
Hafnium nitride	HfN	5,970
Scandium nitride	ScN	4,800
Tantalum nitride	TaN	6,080
Titanium nitride	TiN	5,250
Zirconium nitride	ZrN	5,340
Borides		
Hafnium boride	HfB	5,549
Tungsten boride	WB_2	5,288
Zirconium boride	ZrB_2	5,414
Carbides		
Boron carbide	B_4C	4,230
Calcium carbide	CaC_2	4,170
Columbium carbide	CbC	6,330
Hafnium carbide	HfC	7,530
Molybdenum carbide	Mo_2C	4,320
Silicon carbide	SiC	4,890
Tantalum carbide	TaC	7,020
Thorium carbide	ThC_2	5,020
Titanium carbide	TiC	5,670
Tungsten carbide	WC	5,036
Uranium carbide	UC	4,350
Vanadium carbide	VC	5,130
Zirconium carbide	ZrC	6,380
Zirconates		
Barium zirconate	$BaO \cdot ZrO_2$	4,748
Calcium zirconate	$CaO \cdot ZrO_2$	4,262
Strontium zirconate	$SrO \cdot ZrO_2$	>5,072
Thorium zirconate	$ThO_2 \cdot ZrO_2$	5,072

SPECIAL REFRACTORIES

The refractory products which have been described above constitute the bulk of refractories which are in commercial production and are readily available. In addition to these products, there are many other refractory materials which have been used only on limited or small-scale applications. To give a picture of the possibilities of these materials a list has been made in Table V of materials having melting points reported to be in excess of 4,000 deg. F. These might well be termed the refractories of the future, since if processes are carried out at higher and higher temperature levels, refractories for furnace constructions may be drawn from this list or from other untested materials of similar characteristics.

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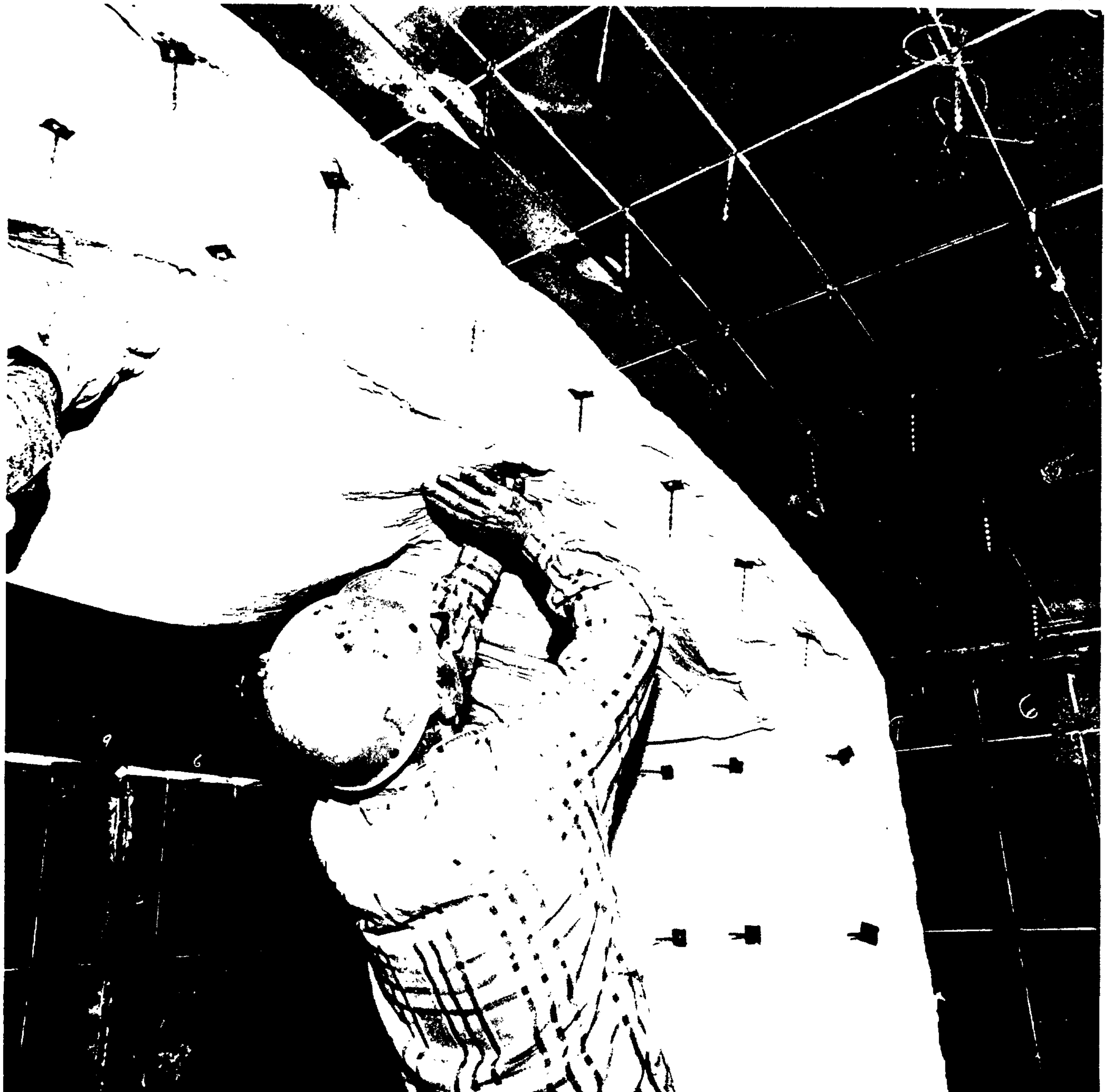


Kaowool® Ceramic Fiber: A Star Is Born

Babcock & Wilcox

Kaowool® a star is born

Already installed in 5,000 different furnaces across the globe, B & W's "miracle" fiber is currently in white hot demand. The ceramic blanket's energy conservation talents, low thermal conductivity, resistance to thermal shock and ease of installation have sparked interest and sales in metal making plants throughout the country.

"Greater than the tread of mighty armies is an idea whose time has come."—Victor Hugo.
"I'd rather have a market than a mill"—Early U.S. Steel sales executive.

There, quotation fans, is a double-nutshell description of the current status of Kaowool, Babcock & Wilcox's ceramic fiber.

The coming of Kaowool's time clocked-in with the advent of the energy crisis, when demand for the now familiar insulating refractory material created a market bigger than existing plant capacity could comfortably meet.

"There's no question that we were caught with excess of demand over capacity in the fall of '73," says Thomas R. Tate, B&W Refractories Division market group manager. "We had been shipping at 95 percent of our rated capacity when demand suddenly exploded as fuel supplies started tightening up. We immediately began expanding on a world-wide basis, adding 100 percent to the capacity of our main manufacturing plant in Puerto Rico and enlarging our other plants in Augusta, Georgia, Burlington, Ontario, England, Belgium and Japan. We even made plans to add a plant in Brazil."

What caused this sudden spurt of capacity expansion within the company that pioneered a way to convert kaolin clay into fibers that could be matted and made into flexible blankets to replace conventional refractory bricks in a myriad of high-heat areas? Simply stated, it was the equally-sudden shortage of fossil fuels, whose scarcity made them hideously expensive in certain forms—even if they were available.

B&W's five-year plan

"Our expansion plans carry through 1979," Tate explains. "By then, we'll have just about quadrupled our 1973 capacity. The way we see it, whatever else happens to the economy—low auto sales, consumer resistance and so on—the outlook for fuel makes it almost certain that there will be no reduction in the demand for insulating refractory materials.

"Actually, going to Kaowool or a similar product is an investment people can't afford not to make," Tate contends, "because there's no question about fuel prices rising. Just in the last three or four years, No. 6 fuel oil in some areas has jumped from $0.53/ million BTU's to about $1.75, and there are government projections that show the price will hit $2.18 next year." "And you have high prices coupled with allocations, so saving fuel becomes a matter not only of saving money, but of just plain staying in business. If a company has an allocation of X number of million BTU's, it becomes a matter of shutting down or making its equipment operate in a manner that will allow it to keep going."

One steel mill Tate knows about has already linked its natural-gas usage to a computer because if the facility even exceeds its allocation in any 15 day period, it's hit with a heavy financial penalty.

"That company has begun using Kaowool in its reheat furnaces for economic reasons, if nothing else," he says.

What makes a ceramic fiber refractory material such a boon to the hard-pressed energy consumer engaged in preparing metals for reworking since this happens to be Kaowool's principal application?

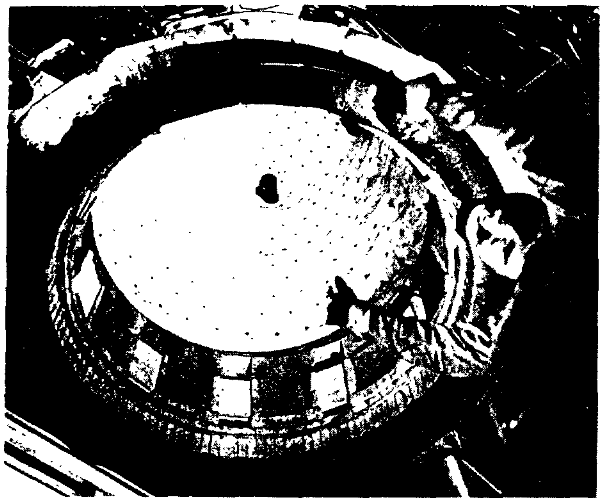
Low thermal conductivity is key

The answer, according to Tate, is low thermal conductivity coupled with ease of installation and maintenance, light weight and almost complete resistance to one of the bugaboos of nearly all other refractories—thermal shock.

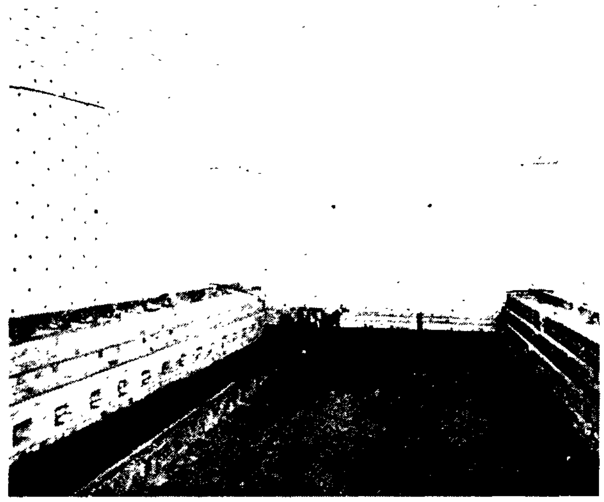
"When we first started marketing Kaowool seriously," Tate recalls, "we were stressing the installation and maintenance features over everything else because fuels were cheap and plentiful. But when the turnaround came in late 1973, we realized that the product was much more important to our customers as a means of encapsulating heat than for any other reason."

Almost everyone who bought Kaowool prior to 1974 to line such installations as heat-treating, normalizing, car-bottom, forging, stress-relieving, continuous tunnel-type and other furnaces did so because the material was easy to handle and install, Tate reports.

"Since the cost of using Kaowool was about the same as refractory bricks or castables," he continues, "the savings in fuel it provided were interesting, but not that important. Now, however, it's a different



A 4½-in. thick lining of Kaowool in this single stack annealing cover reportedly reduced heat storage in the cover to less than 20 percent of that with a brick lining, increased available inner volume and cut the lining weight in half



A popular use of Kaowool ceramic fiber insulation is in heat treating furnaces. Kaowool insulation is attached to furnace walls by means of threaded studs, speed clips, and nuts and washers

picture. Heat users almost have to go for it just to save on heating costs. There isn't much anybody can do about melting operations, because it's going to take a fixed number of BTU's per ton to do that in almost any system. But where savings can be made—in reheating, for example—the companies involved in metals production are going to have to find them. And reheating is one area where savings can be made.

Fuel-use research, a case study from Big Steel

Tate cites the case of one major integrated steel producer which established a special section in its research laboratory just to find ways of cutting fuel costs in its secondary operations. The firm was afraid that if it continued to spend money in ever-increasing amounts for energy it would soon lose out in the worldwide competition for its market share.

Searching for someone to head the section, the company went outside the industry for an engineer who "wouldn't know about all the things that couldn't be done," gave him a strong mandate to produce results, and turned him loose on the firm's steel plants.

One of the first items on this engineer's agenda was a five-zone reheat furnace at a midwestern mill.

"He invited B&W and other refractory manufacturers to help analyze the situation," Tate says. "Then he told us that he was going to take B&W's word on what we could do to help save energy in that furnace. Within four weeks, he had set up a monitoring system for the furnace, decided what materials—including Kaowool—he wanted to use, placed an order with us for $50,000 worth of materials, and had them installed.

"This was an extraordinary performance—getting operators to go along with a research engineer to install thermocouples in a furnace needed to keep production moving and getting the purchasing department to process a major order in almost record time. To me, it demonstrates that the company involved is not just paying lip service to the idea of saving fuel, but is seriously committed to making it work.

"We see this as the forerunner of similar departments in every major steel company in the country," Tate says. "Our own Tubular Products Division now has a combustion engineering department to supplement existing activities in this area. Using Kaowool in our own furnaces provides a convenient yardstick for predicting the results other customers can expect to get."

5,000 furnaces using Kaowool

Based on B&W's own experience and that of other companies that have applied it in some 5,000 different furnaces around the world, a newcomer to Kaowool can, according to Tate, look forward to some rather spectacular results.

"The first benefit he's going to receive," Tate reports, "is complete flexibility of furnace operations. The only limiting factor on how fast a user can heat up a Kaowool-lined furnace is the product being heated. Kaowool has such a low heat stroage characteristic that he won't have to pump BTU's into the furnace walls before the 'ware' starts to heat up. So once the furnace is turned on, he can put BTU No. 1 into the slab, coil or whatever else is being treated.

"Secondly, the user doesn't have to worry about keeping a furnace hot between cycles to avoid damaging the lining. A typical example would be a shop

You can pack it, wrap it, fit it or spray it on.

No matter how you install it, all of the 32 Kaowool ceramic fiber products help cut costs. In bulk form, Kaowool cuts joint packing costs 25% because its long fibers have greater resiliency. Gives greater recovery from compression.

Babcock & Wilcox has a full line of Kaowool products to cut the high cost of heat in temperatures up to 2300F. Even higher in some applications. Kaowool is lightweight. It resists shock, flame erosion, or wetting by molten aluminum and zinc. And it saves time and labor, too.

B&W Kaowool is Kaolin clay in wool form. Its fiber length averages 4 in. Some go as high as 10 in. These fibers, thoroughly interlaced in the production process, give Kaow[illegible] products unsurpassed strength without the addition of a binder system. And because it has no organic binder, Kaowool can't contaminate furnace atmospheres or emit offensive odors.

Check the picture and find the Kaowool form closest to your application. Then call or write your representative listed on the back. He'll help you figure the size, density and thickness requirements for your particular application.

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1. **Kaowool paper:** Produced from Kaowool ceramic fibers and processed on a papermaking machine. Thicknesses: 20 mil, 40 mil, and 80 mil. Density uncompressed 12-13 lb per cu ft. Recommended for use up to 2300F.

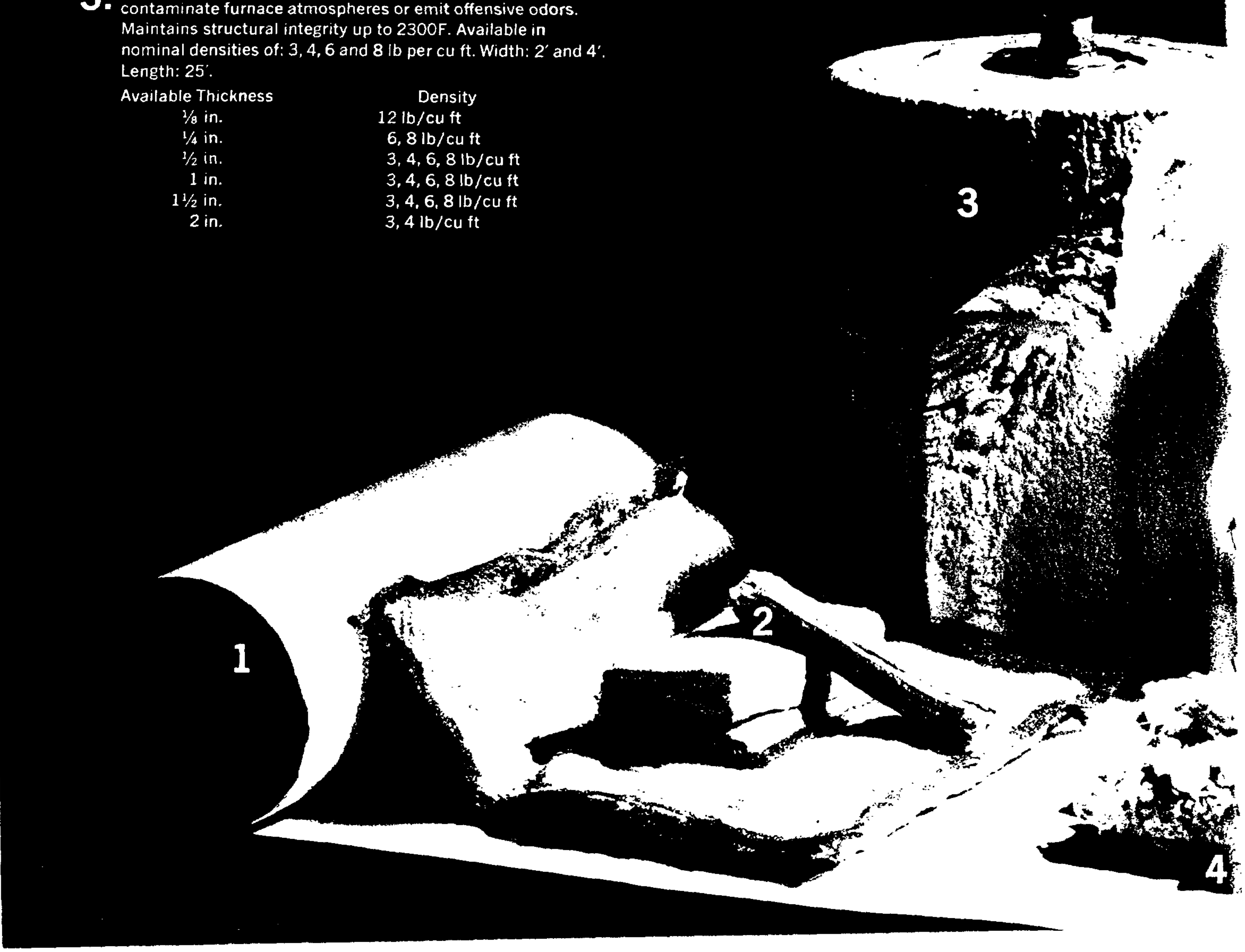
2. **Kaowool mesh enclosed:** Produced by covering ceramic fiber shapes with alloy wire mesh. Tufted with alloy buttons and tufting. The alloy wire mesh covering can provide resistance to corrosion at temperatures up to 2100F. Available in blanket, cable, wrap and strip. Special shapes and sizes are available.

3. **Kaowool blanket:** Contains no organic binder. Blanket will not contaminate furnace atmospheres or emit offensive odors. Maintains structural integrity up to 2300F. Available in nominal densities of: 3, 4, 6 and 8 lb per cu ft. Width: 2' and 4'. Length: 25'.

Available Thickness	Density
⅛ in.	12 lb/cu ft
¼ in.	6, 8 lb/cu ft
½ in.	3, 4, 6, 8 lb/cu ft
1 in.	3, 4, 6, 8 lb/cu ft
1½ in.	3, 4, 6, 8 lb/cu ft
2 in.	3, 4 lb/cu ft

4. **Kaowool bulk fiber:** Longer fibers offer greater resiliency, greater recovery from compression. Lightweight, low thermal conductivity. Easily packed to firm densities. Also available chopped or completely inorganic.

5. **Kaowool surface coatings:** Cement: Air-setting, and easy-to-use. Cement has excellent thermal shock resistance, and continuous exposure ability to 2300F. Rigidizer: A liquid binder used to increase hardness and erosion resistance of B&W Kaowool ceramic fiber.



6. **Kaowool strip:** The interlacing effect of longer fibers provides greater stability, high tensile strength and resiliency needed to withstand vibration and physical abuse. Available widths: 1" to 11". Thicknesses: ¼" to 2". Densities: 3, 4, 6, 8 lb per cu ft.

7. **Kaowool spray mix:** A lightweight high temperature ceramic fiber insulation designed for pneumatic gun placement. It is composed of Kaowool ceramic fiber and inorganic binders, which after being mixed with water at the spray gun nozzle, will adhere to the surface to be insulated.

8. **Kaowool vacuum formed shapes:** Produced from Kaowool ceramic fibers and a suitable binder system. Density averages 12 lb per cu ft. Practically any shape is available, including irregular hot tops, combustion chambers, tundishes, sprue liners and cones.

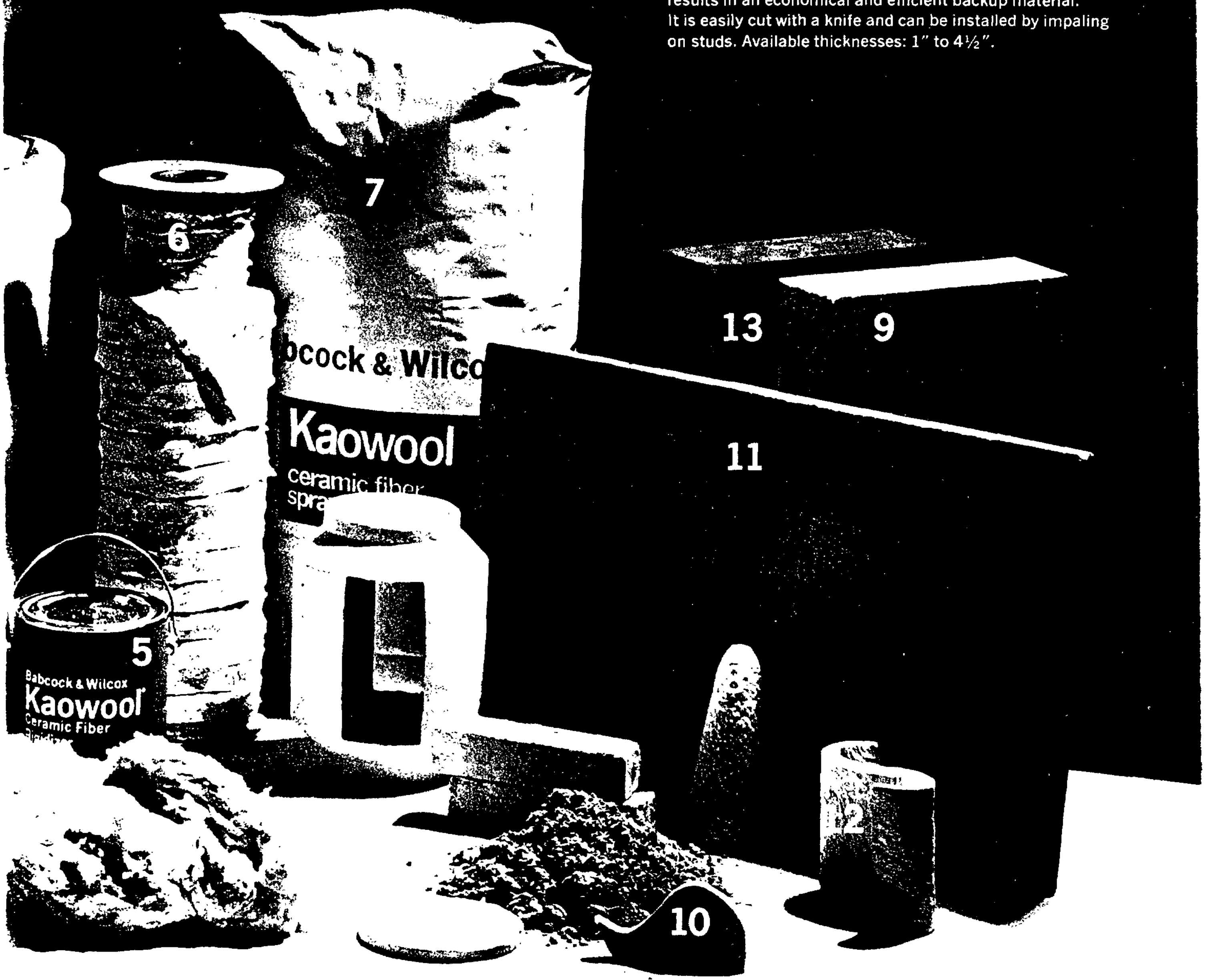
9. **Kaowool M board:** A vacuum formed board produced from Kaowool ceramic fibers having very good handling and structural strength. Surface can be rigidized for molten metal contact applications. It can be easily cut for easy field installation.

10. **Kaowool die-cut shapes:** Made to design specifications from blanket, paper or wire mesh enclosed. Simplifies job of installing insulation around odd-size openings and shapes. Kaowool die-cut shapes are available in the same thicknesses and densities as Kaowool blanket or paper.

11. **Kaowool block and expansion joint board:** Formed from Kaowool ceramic fibers under controlled conditions. A strong durable refractory block extremely resistant to thermal shock. It can be quickly cut to fit and studded for easy installation. Kaowool expansion joint board allows quicker and more uniform firebrick constructions using expansion joints.

12. **Kaowool wet felt:** Made from Kaowool ceramic fiber blanket. Pliable, moist. Packed in plastic bags. Easily formed in place. Air dries. No pins or straps required. Available in 2' x 3' sheets in thicknesses of ⅛" to 1". Special sizes available upon request.

13. **Block insulation (mineral fiber):** A resilient mineral fiber block, formed and cut to precise tolerances. The block has high breaking strength and low thermal conductivity, which results in an economical and efficient backup material. It is easily cut with a knife and can be installed by impaling on studs. Available thicknesses: 1" to 4½".



that works five days and is shut down for two. Normally, the operator would have to idle his furnaces at about 800 F for the weekend to eliminate possible thermal shock at start up. With Kaowool linings, these same furnaces can be shut off completely Friday night and fired again on Monday with no damage or wasted energy."

Because its thermal conductivity is so low, a customer can take advantage of Kaowool in two ways—reducing fuel usage while maintaining existing production levels or increasing output with no corresponding hike in energy consumption.

Reducing fuel usage

To illustrate the first contention, Tate cited the case of a Pittsburgh area steel mill that decided to give Kaowool a try in its nine car-bottom annealing furnaces in an effort to offset a 45 percent increase in fuel costs mated to a 15 percent reduction in allotments.

Originally designed to be lined with 4½ in. of insulating fire brick and 9 in. of dense firebrick, each car was given a 4½ in. course of dense fire brick on the hearth and around the car-pier bases, plus a 3 in. blanket of 4 lb. density Kaowool topped by a 1 in. blanket of 8 lb. density.

The change produced the following before-and-after heat-flow factors at 1,500 F operations:

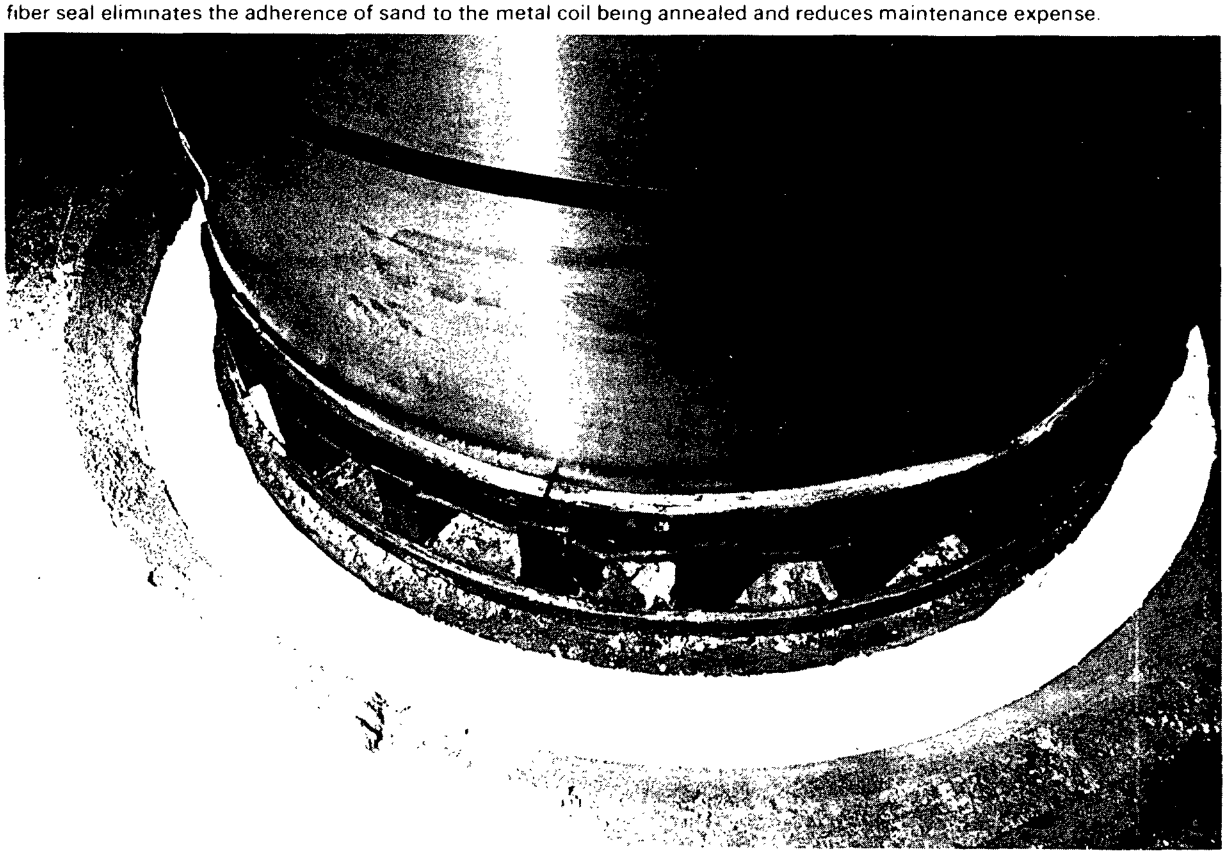
Heat loss—440 BTU/sq ft/hr before, 250 after.
Heat storage—11,820 BTU/sq ft before, 2,080 after.
Cold-face temperature—253 F before, 195 F after.

In addition, the mill reduced its cycle time approximately 15 min., allowing it to cycle one additional load every eight hrs. This was accompanied by a "significant" reduction in the fuel cost on a per-ton basis, and delivery of a more uniformly annealed product.

In addition, it used to take two bricklayers and a helper two or three days to reline a car deck; the job can now be completed by laborers in less than four hrs.

In a non-metals application, Tate relates the case of a construction-brick producer in the Birmingham, Alabama area, who decided to veneer the inner faces of the 25 in. thick refractory walls of his beehive kilns with 2 in. blankets of Kaowool and found himself producing "twice as many bricks per hour with the same amount of fuel because the material keeps the heat in the kiln and out of the walls."

A bottom-edge seal of Kaowool ceramic fiber for annealing furnace covers can eliminate problems associated with the use of sand for such seals, according to Babcock & Wilcox, manufacturer of the material. The resilient kaolin-clay-base fiber seal eliminates the adherence of sand to the metal coil being annealed and reduces maintenance expense.



Furnace design could change

In this regard, Tate believes Kaowool may revolutionize furnace design. "For years," he says, "people have been building furnaces out of refractory brick, making them as big as houses to provide sufficient heat resistance and structural strength. Now, they can make them smaller without sacrificing a thing in the way of capacity or insulating qualities."

Partly, this claim is based on Kaowool's light weight in relation to its thermal conductivity, which Tate says is the "lowest of any product on the market for handling temperatures in the 2,000 F range."

Kaowool can also, according to Tate, provide the user with advantages that aren't as readily identified on the bottom line as lower fuel consumption and reduced installation and maintenance costs, since these benefits fall into the realm of employee comfort and safety.

Reduction of temperatures at the cold face of a furnace makes it less of a hazard to people who must work in close proximity to it, to say nothing of reducing ambient temperatures in the shop.

Kaowool can also be put to use as a sound insulating material as well as a heat encapsulator. One Midwestern steel mill is meeting Occupational Safety and Health Act requirements for soundproof pulpits in areas where ear protection is indicated by constructing two such units with a 2 in. layer of Kaowool sandwiched between a steel-plate outside wall and an expanded metal inner surface. Tate reports that the ceramic fiber blankets are cheaper than polyurethane foam and are fireproof, to boot.

Fiber earns a safe bill of health

Further, working with Kaowool poses no known health hazards—either to the people who make it or those who use it.

"Ceramic fibers are quite different from other refractory fibers such as asbestos," Tate explains. "We've been monitoring the possible effects of working with Kaowool for the past 10 years and we're happy to report there is no toxicity.

"In fact, many of the applications Kaowool has been put to in the last year or so have been strictly replacements for asbestos because of the restrictions on the use of that material."

Despite the good qualities he lists for Kaowool, Tate acknowledges that it can't solve every problem that might arise in a metals plant.

For example, B&W thought it had found the perfect way, in Kaowool, to reduce the weight of brick-lined soaking pit covers. Based on early limited successes, it had proved an estimable product for sealing such covers because of its compressability. But when B&W had devised a Kaowool system for lining the entire cover and convinced several steel companies to test it, the embarrassing discovery was made that when exposed to iron oxide at temperatures above 2,400 F, the soaking pit atmosphere fluxed the ceramic fibers and left them blackened and hanging in tatters in about eight days.

The company hasn't given up entirely on the idea, however. "We are producing a new grade with 60 to 63 percent alumina compared to the original half alumina, half silica formula that may be able to handle temperatures up to 2,600 F in the presence of iron oxide," Tate reports. "The cost will be about 60 percent higher than the old product, but if it works, it could be the most exciting new thing soaking pit operators have seen for a long time; they'd really love to have it."

As noted earlier, the softness of Kaowool, the very property that lets it shrug off the damaging effects of sudden temperature changes, obviates its use in areas where it would be subjected to physical wear and tear. Gas velocities over 50 ft/sec are also Kaowool bugaboos, although B&W has developed a special Kaowool board or block that can withstand velocities nearly twice that level.

Future once in doubt

Seemingly destiny's child in the 1970's, Kaowool nearly wound up an infant-mortality statistic 30 years earlier.

Here's the way Tate describes the product's birth and early tribulations:

"Kaowool was originally developed during World War II when our people discovered that if they melted kaolin clay and then hit it with steam or a high-speed air it would attenuate into fibers 4 to 10 in. long that could be collected and formed into blankets. It was an interesting, wooly material that our researcher knew had good insulating properties, but because B&W was not familiar with marketing insulating fiber, it was put aside.

"The product stayed on the shelf until 1950, when two of our competitors, in effect, jointly rediscovered it by combining silica and alumina, melting the blended material and blowing it into fibers. When their combined sales reached $1 million/yr by 1960, B&W realized that there was a strong demand for ceramic-fiber insulation and started an intensive development program that began paying off by 1965. In less than five years, Kaowool had taken over the top spot in the market, a position it still holds logging the major portion of total sales, mostly because we have concentrated on proving its value to heavy industry, especially steel."

With non-ferrous industries such as aluminum, copper and brass, chemical process and petroleum refining coming on strong as Kaowool converts, Tate is convinced that B&W's main concern will be keeping production abreast of demand.

For more information contact your nearest B&W sales office or The Babcock & Wilcox Company, Refractories Division, Augusta, Georgia 30903

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