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Closed Cell Foamed Borosilicate Glass Block Lining System

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A foamed borosilicate glass block lining system is the first major innovation in inorganic, acid/corrosion resistant lining materials in over half a century. It is composed of borosilicate glass foamed to 12 lb/ft^3 density with completely closed cells and cut into blocks providing excellent chemical and thermal resistance. It is lighter than other types of linings, easy to install and does not support combustion. Table 17-1 lists the chemical composition of the block.

Table 17-1: Chemical Composition of Foamed Borosilicate Glass Block

Silica	80%
Boric oxide	18%
Potassium oxide	2%

The lining system may be used to protect metal, concrete or FRP substrates from deterioration caused by both chemicals and temperature. Applicable to exposures in the chemical processing, metallurgical, petrochemical, pulp and paper, waste incineration and power generation industries, among others, it can be used to replace or to augment conventional masonry or cementitious monolithic organic linings.

*Throughout this paper, when mention is made of "glass block" or other similar designation, in order to shorten the title, only the subject *closed cell foamed borosilicate glass block* is referred to. There are available plain blocks of glass which have no insulating effect, and blocks of foamed glass that are *not* closed cell, or are *not* borosilicates. Only those block made of *borosilicate* glass, foamed in a *closed cell* (and, hence, liquid and gas-tight) form, will meet the physical and chemical standards of the subject material.

Some specific applications have been in air pollution control equipment such as wet limestone flue gas desulfurization (FGD) scrubbers, baghouses, quench chambers and inlet/outlet ductwork; carbon steel liners of concrete chimneys and breechings; FRP stack linings; linings for steel or concrete covers of molten sulfur pits, pickling tanks and acid storage tanks; petrochemical furnace and heater linings; and acid process vessel linings.

Installed alone as a semi-refractory material, the foamed borosilicate glass block lining withstands hot face temperatures up to 960°F. It may also be used with refractory, chemical-resistant masonry or monolithic internal linings at temperatures above 960°F providing a unique combination of corrosion protection and heat conservation with little added weight and a lesser overall lining thickness. The foamed glass block may also be fabricated into nozzles, T-sections, elbows, liner inserts and other custom shapes.

This foamed borosilicate glass block lining system combines the desired properties of a number of other lining systems into one. Its features are:

Chemical Resistance—The completely closed-cell, foamed borosilicate glass block is resistant to weak bases, all organic and almost all inorganic acids. It is not resistant to hydrofluoric acid, acid fluorides or strong alkalies.

Closed-Cell Structure—The closed-cell nature of the block renders it virtually impermeable to penetration of harsh chemicals. With permeability, capillarity and absorption at practically zero, contact with liquids results in surface wetting of the block lining only. Since the membrane behind it rarely will come in direct contact with the operating chemicals, its life is extended.

Wide Temperature Range—The block lining system has high resistance to low-temperature acid condensates and process chemicals and the thermal resistance to withstand high-temperature corrosive gases or concentrated acid condensates at temperatures above the limits of most organic lining materials. This characteristic is unique among lining materials and allows such a block lining to be used in applications with widely fluctuating temperatures and acidic conditions.

Low Coefficient of Thermal Expansion—A low coefficient of thermal expansion of $1.6 \times 10^{-6}/°F$ allows the block to withstand the wide range of temperatures without spalling. It is resistant to upset or bypass operations where thermal shock can damage or destroy other lining materials and the insulation it provides protects the support structure itself from such damage.

Low Thermal Conductivity—Two inches of foamed borosilicate glass block has 5.7 times the insulation power of 2½" of conventional acid-resistant brick; therefore 2" of block provides the thermal insulation equivalent of about 12" of brick, even under the longest exposures to completely acidic liquid operating conditions. This attribute results in a thinner overall lining, reduces energy costs to keep a vessel at a required temperature and substantially reduces the temperature at the surface of the membrane giving longer membrane life. Figure 17-1 shows the thermal gradient for various thicknesses of the block.

In process vessels, the foamed glass block can be substituted for several courses of acid brick. A brick facing over the block serves both to protect the block against abrasion from mechanical abuse and to lower the temperature at the face of the block when operating temperatures exceed the limits of the block. In both cases, the block installed over a membrane and beneath brick reduces the amount of brick required and thereby cuts installation time and costs.

Due to its excellent insulating power, the block eliminates the need for external insulation, usually accompanied by high maintenance costs, on process equipment. The outside surface of the equipment remains cooler and heat losses are minimized.

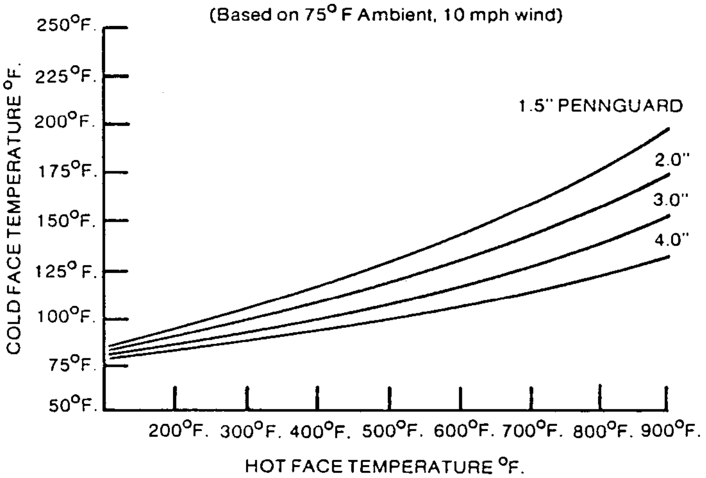

Figure 17-1: Temperature gradient for various thicknesses of foamed borosilicate glass block.

Low Density and Installed Thickness—Low density of 12 lb/ft^3 and a thin installed thickness relative to acid-resistant brickwork, adds only 3 lb/ft^2 to the support structure. This feature increases design flexibility, reduces steel shell and structural support costs and permits the construction of tall, free-standing structures.

INSTALLATION METHODS

The integrity of any lining system depends not only on the quality of the material used but also on the quality of the actual installation. Therefore, an experienced specialty contractor is required to ensure a high-quality installation. Typically, a masonry contractor experienced in the special handling of acid-resistant brickwork construction will have the expertise to follow the block supplier's application instructions.

Blocks are normally 9" x 6" and supplied in thicknesses of 1", 1½", 2" and 2½" to meet the requirements of a variety of applications. The thickness of the block for a particular application is determined by the hot face temperature or operating temperature. The thermal gradient is calculated to ensure that the membrane or substrate does not experience temperatures beyond its recommended limit.

The primary requirement for a high-quality lining system is a properly prepared substrate. First, the uniformity of the flatness of a rectangular substrate or the roundness of a curved substrate should be verified. Small irregularities can be marked and the block can be easily cut to minimize the deviation and ensure full contact of the block.

Carbon steel substrates must be sandblasted to a near-white metal finish (SSPC-SP10 or NACE #2) and maintained at least 5°F above the acid dewpoint during installation. Concrete surfaces must be free of any imperfections such as blow holes or honeycombing. Old concrete must be free of oil, grease or chemical contamination.

Both carbon steel and concrete substrates must be clean and dry and maintained above 50°F during the installation. Preparation of alloy steel, FRP or organic-coated surfaces must be specified by the block supplier.

Bonding Systems

There are two different bonding systems employed with the block: a urethane asphalt adhesive/membrane or a special inorganic silica-based mortar. The choice depends on mechanical considerations and on the chemical and thermal environment.

Urethane Asphalt Adhesive/Membrane: A urethane asphalt elastomer serves as both an adhesive and a membrane to protect the substrate. It is a two-component material which bonds the blocks to each other and to carbon steel, alloy steel, concrete or other organic linings and also functions as a moisture and chemical-resistant barrier (or membrane) between the block and the substrate.

Generally, the adhesive/membrane is resistant to organic and inorganic acids, bases and salts in solution at various concentrations and temperatures (within the recommended range). The actual chemical resistance may depend on the specific environment of the application. The adhesive/membrane is not resistant to strong acids or petroleum-derived compounds though the block by itself is resistant to them. In such exposures, the compatible mortar must be used.

The adhesive/membrane forms an elastomeric bond that serves as a mechanical and thermal stress relieving mechanism by absorbing vibration and any stresses of expansion and contraction thus reducing the probability of lining cracks. It remains elastomeric at temperatures as low as -40°F to as high as 180°F continuous at the hot face of the adhesive/membrane line behind the block.

At continuous operating temperatures above 180°F and up to 400°F, the adhesive/membrane in the joints between the block will char to different depths through the joint. Because of the block's low thermal conductivity, if properly designed, the bottom of the joint and back joint, serving as a membrane, will be at 180°F or below and remain elastomeric. The glasslike char that forms retains the integrity of the lining. It also retains chemical resistance and, although the top of the block is "frozen" in place at the charred portion of the joint, the small block size prevents large stresses from being created that would crack the block.

To install the block with adhesive/membrane on properly prepared substrates, the adhesive/membrane is applied to the substrate at a minimum 1/16" thickness with a trowel. The adhesive/membrane is then troweled on the back, sides and end of the block also at a minimum 1/16" thickness. The coated block is moved back and forth against the adhesive on the substrate as it is slid into place forming 1/8" side and back joints. This action removes voids that may form between the block and the substrate.

Inorganic Silica-Based Mortar: The completely compatible mortar is a two-component silica-based mortar used to bed and bond the block when the thermal and chemical environments exceed the capabilities of the adhesive/membrane and where vibration and thermal shock are not serious factors. Its thermal characteristics and chemical resistance are identical to that of the block. The cured joints are rigid, dense and abrasion resistant. (See Chapter 22.)

The mortar may be applied to properly prepared concrete or steel substrates by usual acid-resistant bricklaying methods. An epoxy, urethane asphalt, bitumastic, polyester or vinyl ester membrane is required behind the block to ensure corrosion protection of the substrate. Because the mortar joints are rigid, a system of expansion/contraction joints, usually filled with ceramic paper, must be designed to prevent cracks.

Combination Linings Incorporating Glass Block: A number of lining systems have been developed that combine the features of the glass block with those of other materials. These layered ceramic and refractory linings are less expensive than high-cost stainless steels and other alloys. They resist acids and abrasion better and reduce heat losses, saving energy. In all cases, the layer next to the substrate is the proper membrane selected for the operating conditions.

Figure 17-2 shows the block installed with its adhesive/membrane over FRP. The block extends the temperature limit of FRP and enhances its resistance to fire, chemicals and pickup of static electricity. The low density of the block allows for this type of design because, without heavy reinforcing, FRP cannot support the load of other, heavier linings. Depending on the thermal conditions, a layer of ceramic paper may have to be placed between the block and FRP to compensate for their large difference in coefficients of thermal expansion.

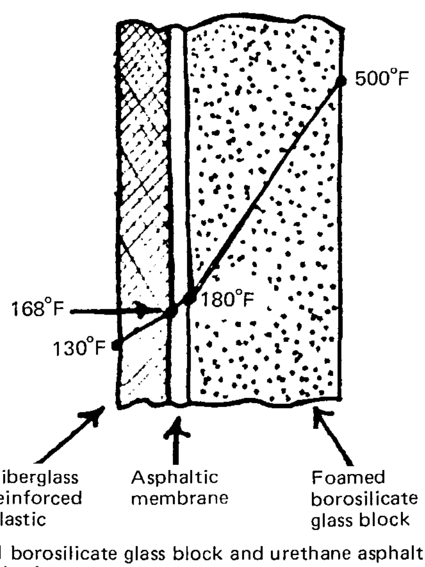

Figure 17-2: Foamed borosilicate glass block and urethane asphalt adhesive/membrane over fiberglass reinforced plastic.

Figure 17-3 shows a steel vessel lined with block under insulating firebrick and acid brick. At high operating temperatures, a proper brick thickness reduces the temperature on the block to 800°F or below. The maximum temperature limit for the block under brickwork or any other organic lining is 800°F. This limit, lower than the 960°F for the block alone, is necessary because the load placed on the block by another lining material may cause the block to creep and distort at temperatures above 800°F.

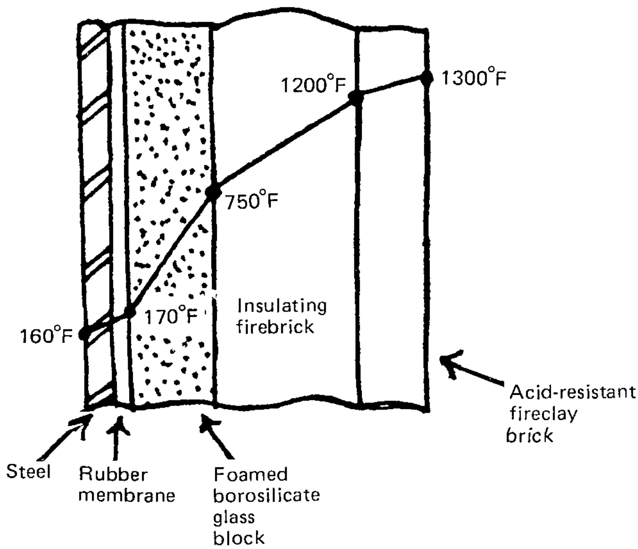

Figure 17-3: Combination lining incorporating foamed borosilicate glass block reduces courses of brick required to lower temperature to acceptable level at the membrane.

The block takes the place of additional courses of brick in further reducing the temperature at the hot face of the membrane to an acceptable level. The result is a thinner overall lining with added chemical resistance because of the closed-cell nature of the block.

Linings using high-temperature resistant monolithics over the block are based on the same principles as above.

In heaters and furnaces used for the combustion of wastes or other potential corrosives, highly insulating ceramic fiber blankets are used to reduce the temperature on the steel shell. The blanket itself is not chemical-resistant but because operating temperatures are in the 1800°-2000°F range, acid condensates are not thought to be a problem. However, the insulating blanket does its job too well! The temperature behind the blanket often drops below the acid dewpoint causing acids to condense on and attack the steel shell and saturate the ceramic fiber blanket. The steel becomes corroded and, because it is wet, the blanket loses its insulating ability.

A design which incorporates the foamed glass block behind the blanket eliminates this problem. The block prevents the acids from reaching and condensing on the steel and adds insulating power of its own to the lining.

The block lining, installed with either its urethane asphalt adhesive/membrane or inorganic mortar, affords a number of improvements over conventional acid brickwork or other organic linings in many applications. The following are brief expalantions of those environments where the foamed glass block lining system is particularly suitable.

Flue Gas Desulfurization Systems

Stack gases generated by the combustion of coal and petroleum coke are high in sulfur oxides that must be removed before venting the gases to the atmosphere. A lining in an FGD system may be subject to low temperature acid condensates and high temperature gases at alternating intervals. The borosilicate glass block is one of the few lining systems that combines the thermal resistance of semi-refractory materials, the acid resistance of chemical-resistant materials and the thermal shock resistance to fluctuate between the two conditions without harm.

Inorganic monolithics like calcium aluminate, calcium silicate, sodium silicate and potassium silicate gunites are able to withstand the dry flue gases at high temperatures. Because they are porous and tend to crack, however, they allow acid vapors to reach the substrate and condense.

Organic linings such as polyesters, vinyl esters or fluoroelastomers may resist wet acid condensates at low temperatures but will not accept higher temperatures where a semi-refractory is needed.

An independent testing laboratory gave the block its highest performance rating of 10 in FGD systems after an Atlas test cell program and test installations in online FGD systems. The block lining is expected to give much longer service than alternative linings many of which have failed in the same environment after only a year or less.

Waste Incineration

The incineration of liquid and solid wastes produces gases with a variety of potential corrosives present. Usually they are some combination of nitrogen, phosphorus and sulfur oxides and some hydrogen fluoride, but the primary contaminant is almost always hydrogen chloride. The exact composition oftentimes is variable and unpredictable in any one incinerator. Before incineration gases can be vented, they must be scrubbed of these noxious pollutants.

Depending on the particular operation, offgases from the incinerator may range from 1100° to 2100°F. Typically, the gases are sent to a conditioning chamber to lower the temperature to 500° to 600°F before they enter a scrubber. While the incinerator is in operation, the gases may remain above the acid dewpoint and corrosion problems will be minimal. But because most incinerators are cyclic operations with frequent periods of idleness, gas condensation in the inlet and outlet scrubber ductwork during shutdowns can cause serious deterioration.

Foamed glass block laid in its silica-based mortar over a suitable membrane is a good choice for lining these areas. During shutdowns, it is resistant to the wide range of acid that may condense on the surfaces of the ductwork. When the incinerator is operating, the block can withstand the high gas temperatures coming from the conditioning chamber and scrubber. Its thermal shock resistance allows the lining to alternate between the two environments without cracking.

Waste incineration systems may use electrostatic precipitators in conjunction with a scrubber. The precipitator may come before or after the scrubber. If it comes after the scrubber, usually no special lining is required for it. But if it precedes the scrubber, the gases from the conditioning chamber enter the precipitator hot and are saturated with vapor. This process inevitably produces some cooling and consequently acid condensates. The glass block lining provides a lightweight, acid-resistant barrier and eliminates the need for external insulation on the precipitator.

Smelting Operations

Smelter gases in the 600°-900°F range are carried through ducts to a scrubber to remove most of the contaminants, primarily sulfur oxides, before exiting through a stack. The efficiency of removal by a scrubber is not 100%; therefore, some corrosives are still present after scrubbing. Because the scrubbing operation normally lowers the temperature to the 125°-180°F range, acid condensates may form in the exit ducts leading from the scrubbers to the stack. This is an ideal area to install the borosilicate glass block.

In some smelters, a reheater is installed to raise the exit gas above the acid dewpoint (generally 350°-450°F) so the acid remains as a vapor and exits with the gas without adversely affecting the ductwork. Even with a reheater, however, during shutdowns the scrubber entry and exit ducts are subject to chemical attack from acid condensates.

The capabilities of the foamed glass block provide: (1) chemical protection against acid condensates, (2) lower outer shell temperature that eliminates the need for external insulation, (3) little added weight which saves on structural support, and (4) a quick and relatively inexpensive installation and easy repairs.

Baghouses

Baghouses are large rectangular steel structures containing an array of inverted cloth filter bags that collect particulates in flue gases flowing up through them. The flow is interrupted periodically to allow the filter bags to drop their contents into hoppers.

In certain applications, the exhaust stream may contain sulfuric acid and other acids that can be highly corrosive. At operating temperatures above 450°F, these corrosives are in the gas phase and not a problem. However, in intermittent processes, with frequent shutdowns and startups, these acids fall below their dewpoint and corrosive condensation eats away the steel baghouse walls.

Borosilicate glass block bonded with its adhesive/membrane can handle both the high operating temperatures and the acid condensates. Once again, the need for external insulation on the baghouse is eliminated.

Tall Stacks

Along with all its other features, the block's lightweight lends itself to lining tall stacks. Because it adds only 3 lb/ft^2, structural support can be minimized or eliminated on tall stacks.

Even though the gases entering a stack may be above the acid dewpoint and safe from a corrosion point of view, if the stack is tall ($>$200 ft), the temperature may drop below the dewpoint once it reaches the top. This presents a familiar problem to many lining materials. The wet condition at the top of the stack causes lining failure and forces frequent maintenance. With the borosilicate glass block from bottom to top, the stack designer need not try to determine the transition point and then specify different materials for each section of the stack.

Pickle Tanks

Pickle tanks can be continuous or batch processes that use sulfuric or other acids at elevated temperatures to condition and clean basic metals products. Conventionally pickle tanks are lined with two or more courses of acid-resistant brick set in a suitable acid-resistant mortar over a rubber membrane. More than one course of brickwork is usually needed to reduce the temperature to the desired level at the hot face of the membrane and to provide stability.

The insulating power and chemical resistance of the glass block allows for a thinner lining and better membrane protection for pickle tanks where stability is not a concern. The tank is first lined with the rubber membrane, the block is bonded over that with its urethane asphalt adhesive/membrane and finally a course of acid-resistant brick laid in acid-resistant mortar is placed over the block for mechanical protection.

The foamed glass block saves costs at the outset by requiring less brick and less installation time. It also yields long-term savings in: (1) energy costs by conserving heat, and (2) maintenance costs by giving better protection to the membrane against the deteriorating effects of strong acid and heat. The serviceable life of a block lining is expected to be as long as 30 years–10 years longer than the typical acid brick lining alone.

Vessel Covers

The glass block system, because of its resistance to acid liquids and vapors and its lightweight, is perfectly suited to lining vessel lids. Its insulative properties prevent the loss of process heat through the cover thereby saving as much as 17% of energy costs.

Since the mid-1970s, the foamed borosilicate glass block lining system has been used extensively in the applications mentioned. In most exposures, with proper installation, the linings are performing well. In some cases, they have solved a corrosion problem in which other lining systems failed. In other cases, the block lining handled an environment where previously only considerably more expensive metal alloys have worked.

As industrial processes change and new ones are developed, new solutions to corrosion must be found. As it continues to be adapted to new applications, the foamed borosilicate glass block lining system is providing one of those solutions.

BIBLIOGRAPHY

Pierce, Robert R. and Semler, Charles E., Ceramic and Refractory linings for acid condensation–Part I, *Chemical Engineering*, 81-84 (December 12, 1983).

Pierce, Robert R. and Semler, Charles E., Ceramic and refractory linings for acid condensation–Part II, *Chemical Engineering*, 102-104 (January 23, 1984).

Carpenter, W. Graham and Pierce, Robert R., Sulfuric and phosphoric acid plant lining systems, *Chemical Engineering Progress*, 57-61 (March 1982).

Rittenhouse, R.C., Protective coatings for power plants, *Power Engineering*, 30-38 (December 1982).

Berger, Dean M., Trewella, Robert J. and Wummer, Carl J., Evaluating linings for power plant SO_2 scrubbers, *Power Engineering*, 71-74 (November 1980).

Sheppard, Walter Lee, Using chemical-resistant masonry in air pollution control equipment, *Chemical Engineering*, 203-210 (November 20, 1978).