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REFRACTORY WITH EXPANSION MEANS ATTACHED

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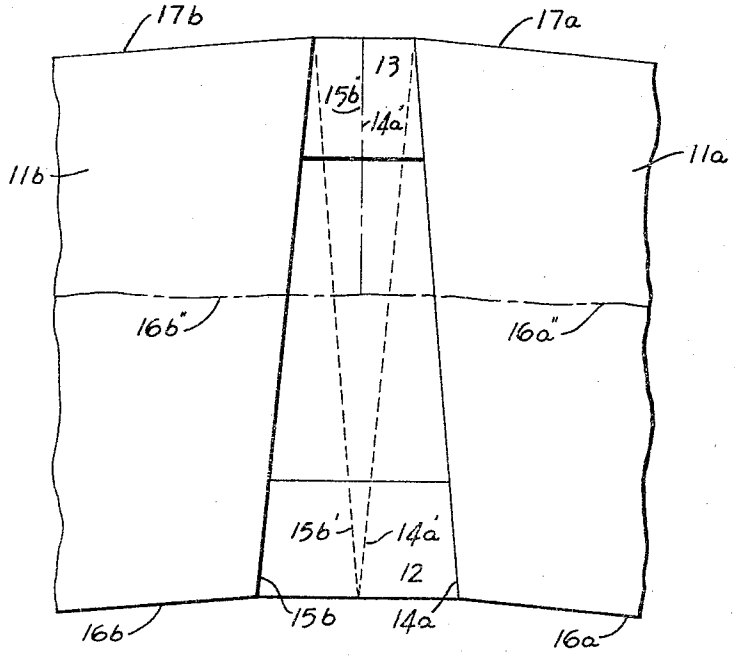


FIG_1

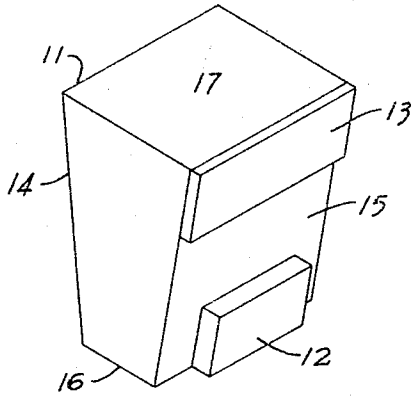


FIG_2

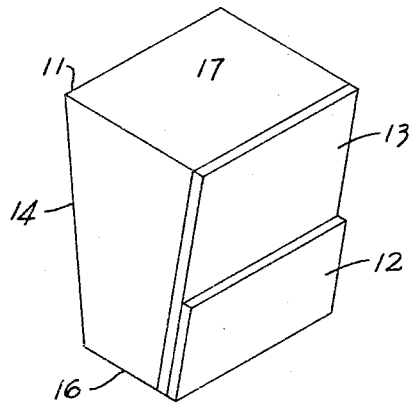


FIG_3

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REFRACTORY WITH EXPANSION MEANS ATTACHED

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This application is a continuation-in-part of application S.N. 348,386 filed Mar. 2, 1964, now abandoned.

This invention concerns refractories and especially means to compensate for their thermal expansion.

There are at least two problems connected with the thermal expansion of refractories under operating conditions, as in a high temperature metallurgical furnace, which have not as yet been satisfactorily solved. In the first place, refractories in a furnace or other structure do not expand the same amount throughout. The inner or hot ends of the refractories expand more, due to their higher temperature, than do the outer or cold ends of the refractories. In the second place, as the refractories are subjected to use, for example in a steel making furnace, their hot faces wear away and the refractory wall or roof structure becomes thinner. One result of this is that the outer or cold end of the refractories becomes hotter than it was when the furnace was first heated up. Thus the cold end of the refractories shows an increasing thermal expansion as the wall or roof becomes thinner. Furthermore, the portion of the refractory which was originally midway between the hot and cold faces when the structure was new has, after the wearing away of approximately half the thickness of refractory, become the hot face and has, accordingly, expanded more than when the furnace was new, when such intermediate portion of the refractory was heated only to an intermediate temperature.

When the refractories are in a structure, for example a furnace arch, particularly a self-sustaining arch, where relatively high stresses are generated, these stresses must be supported by the refractories and the thermal expansion of the refractories becomes of vital significance, since such expansion, if not allowed for, can easily cause disruptive stresses in the structure.

In a furnace arch built of tapered refractory shapes with no allowance for expansion, the inner faces of the refractories will expand upon heating of the furnace and the arch will tend to rise due to the thermal expansion. Additionally, all the load of the arch, if it is a self-sustaining one, will be carried on the inner, hot, expanded faces of the refractories, tending to cause them to break under the stress.

In an arch built with uniform expansion joints, for example strips of cardboard of uniform thickness between the refractory shapes, and covering substantially the entire side face of a shape, the burning out of the combustible expansion joints at a temperature well below the full operating temperature of the furnace sometimes results in subsidence of the roof. Furthermore, even when a furnace roof, for example in an open hearth steel-making furnace, is brought up to operating temperature without excessive rising or falling, the gradual increase in the temperature of the outer or cold face of the refractories due to the wearing away of the hot face causes a gradual thermal expansion and consequent rising of the arch.

Ideally, a furnace roof, for example, would be built with such expansion allowance that it would neither rise nor fall during the initial heating up period nor during prolonged use and wearing away of the refractory hot face.

It has now been found that a furnace structure, especially a furnace roof arch, and more particularly a self-supporting arch, is produced by forming such arch of suitable refractory shapes and incorporating between such shapes an inner or hot end expansion element to provide greater expansion space and an outer or cold end expansion element to provide lesser expansion space. An expansion allowance means or element which is effective only at temperatures above about 500° C. is preferably used for the outer expansion means.

In a particularly advantageous structure, particularly a furnace arch, and most particularly a self-supporting arch, the desired expansion characteristics are obtained by placing an inner expansion strip between adjacent refractory shapes adjacent their inner or hot face, such inner expansion strip being of a material, for example a combustible organic material such as paper or cardboard, which will be removed, preferably by combustion, at a relatively low temperature, for example at about one-third the operating temperature of the furnace or at not over about 500° C., and an outer expansion strip between adjacent refractory shapes adjacent their cold or outer ends, the outer expansion strip being of a material, for example asbestos, which will be removed, for example by disintegration or decomposition, at an intermediate temperature, for example at about half the operating temperature of the furnace or from about 500° C to about 1000° C.

The expansion joint of this invention is most useful with fired refractories, most particularly with refractories composed of magnesia and chromite grains which have been fired at such a temperature that there is direct crystal-to-crystal bonding between the magnesia and the chromite grains. Such refractories have sufficient strength and resistance to deformation at high temperatures so as to be able to form a self-supporting arch. Also, because of their resistance to deformation at high temperatures, these high fired or direct bonded refractories have less ability than other refractories to deform under the thermal expansion stresses and thus are more susceptible to cracking and spalling under such stresses. Accordingly, correct expansion allowance is more important with such directly bonded refractories. However, it will be understood that the refractory shapes can be made of any type of refractory, either fired or unfired.

The inner expansion strip is made of a material which is removed, for example by combustion at a low temperature, preferably not over about 500° C. Such combustion will form gaseous products of combustion, such as CO_2 and water, which go off with the furnace gases. Such a combustible material will leave no deleterious residue to adversely affect the refractory. Preferably the inner expansion strip is made of an organic material, cardboard being a material found particularly suitable. The thickness of the inner expansion strip is preferably substantially equal to the thermal expansion of the refractory material upon heating from room temperature to the operating temperature of the furnace.

The outer expansion strip will be made of a material which disintegrates, for example by decomposition or by melting or by reacting with the refractory shape, at an intermediate temperature, for example from about 500° C. to about 1000° C. In other words, the outer expansion means is effective only at a temperature above about 500° C. Generally, it is desirable that the outer expansion strip be slightly compressible. Asbestos has been found to be a particularly suitable material for the outer expansion strip. Asbestos is particularly suitable because of its somewhat compressible structure and because it is chemically compatible with basic refractories. The thickness of the outer expansion strip is preferably about 75%, most preferably from about 50% to about 90%, of the thermal

expansion of the refractory material upon heating from room temperature to the operating temperature of the furnace.

The invention will be more fully understood by reference to the following description of a specific embodiment thereof, taken in conjunction with the drawings, in which:

FIGURE 1 is a partial side elevational view of two refractory shapes in a furnace or other high temperature structure showing an expansion joint between them according to this invention, the scale of the drawing being distorted by greatly enlarging horizontal distances in order to more clearly show the structure involved;

FIGURE 2 is a perspective view of a refractory unit according to this invention; and

FIGURE 3 is a perspective view of an alternative embodiment.

The operation of an expansion joint according to this invention can be described with regard to FIGURE 1 wherein are shown two refractory shapes **11***a* and **11***b* placed in a furnace structure, for example a roof arch, to be subjected to high temperatures. Each refractory shape has an outer or cold end **17** and an inner or hot end **16**. Between the ends **16** and **17** are disposed opposed side faces **14** and **15**, sides **14***a* and **15***b* being shown in FIGURE 1. In the case of refractory shapes for use in a furnace arch, for example, the side faces **14** and **15** of a single shape will preferably converge toward the hot or inner end **16** of the shape to provide a wedge or tapered configuration.

Between shapes **11***a* and **11***b* are placed an inner expansion strip **12** and outer expansion strip **13**. Preferably the inner strip **12** extends along the side face **14** or **15** not more than half and most preferably not over one-quarter the distance from the inner face **16** toward the outer face **17**. Likewise, it is preferred that the outer strip **13** extend not more than half and preferably not more than about one-quarter the distance from the outer face **17** toward the inner face **16**. The inner strip can be narrower than the full width of the refractory shape **11**, as shown in FIGURE 2, but it is preferred that the outer strip be the full width of the refractory **11** to close the joint between the shapes against the entrance of dirt and the escape of hot furnace gases. It will be understood that the area of the outer strip will be at least large enough to carry the weight of the arch or other structure. Since the load on the inner strip is much less than that on the outer strip, the former can be smaller than the latter. In a suspended open hearth roof it is preferred that the outer strip extend inwardly at least 15% of the length of the side face and that the inner strip extend outwardly sufficient to provide proper bearing surface to space adjacent bricks, preferably at least one-half inch. However, the outer strip can extend inwardly as far as the nearest edge of the inner strip.

In an alternative embodiment, shown in FIGURE 3, the outer expansion strip **13** extends the full length of the side face **14** or **15**. In this case, the thickness of the inner strip **12** will be decreased so that the total thickness of the inner strip **12** plus that of the underlying portion of outer strip **13** will substantially equal the total thermal expansion of the refractory shape when it is heated from room temperature to the operating temperature of the furnace. When the outer strip **13** extends to the inner end **16** of the refractory shape and underlies the inner expansion strip **12**, the thickness of the inner expansion strip **12** should be about half the total thermal expansion of the refractory upon being heated from room temperature to the operating temperature of the furnace.

When the furnace arch, a segment of which is shown in FIGURE 1, is heated up the inner expansion strip **12** will burn or be otherwise removed and, upon heating of the furnace to operating temperature, the side faces **14***a* and **15***b* will have come together at the inner end of the refractory shapes as shown by dashed lines **14***a'* and **15***b'*.

On the other hand, the other cold ends **17***a* and **17***b* of the refractory shapes **11***a* and **11***b* will have been increased little, if any, in temperature and therefore will have undergone little expansion, When the furnace is at operating temperature, the outer or cold ends **17** of the refractory shapes **11** are held in their original or cold position by the outer expansion strip **13** which remains in place.

However, as the furnace is used, the inner ends **16** of the refractory shapes **11** will become worn away until the thickness has substantially decreased as indicated by dot-dash lines **16***a''* and **16***b''*. In the case of an open hearth roof, this decreased thickness may be as little as about four inches. When this stage is reached, the outer ends **17***a* and **17***b* of the refractory shapes **11***a* and **11***b* will have increased considerably in temperature for example to about 800° C., and the material of outer expansion strip **13** will have been removed, as by disintegration or decomposition, providing space into which the outer ends **17** of the refractory shapes **11** can expand, as indicated by the dot-dash lines **14***a''* and **15***b''*. It can be seen that at this stage of operation both expansion strips **12** and **13** have been consumed and the side faces **14** and **15** of the refractory shapes **11** have expanded so that they are touching.

While it is possible to place the inner and outer expansion strips **12** and **13** between each pair of refractory shapes **11** as they are laid, for example in a furnace arch, it will generally be found more convenient to attach the strips **12** and **13**, for example by means of glue or other adhesive, directly to one or both side faces **14** and **15** of the refractory shapes **11** before they are installed, most conveniently at the time of manufacture and before shipment to the user.

It will be understood that, while it is preferable to have expansion joints according to this invention between each refractory unit, it is possible to space the expansion joints at greater intervals, for example in every second or third joint, or even more infrequently. Where the expansion joints do not occur between each refractory unit, the thickness of the expansion strips will be related to the total thermal expansion of the number of refractory units between each expansion joint. Thus, for example, if the expansion joints are placed in every other joint rather than every joint, the expansion strips will be twice as thick as if they were placed in every joint. The principles of this invention are applicable to providing expansion joints in vertical furnace wall structures and in other types of high temperature structures besides arches. Likewise, although the expansion strips **12** and **13** are shown, in FIGURE 2, as being placed in the same side face **14** of the shape **11**, it will be understood that they can be placed on opposite side faces or that strips of about half the thickness can be placed on both opposed side faces.

The refractory shapes **11** may have steel plates affixed thereto, either to their outer surfaces or internally embedded within, or in both positions.

When refractory shapes with expansion joints according to this invention are used to construct a self-sustaining arch, that is to say one in which the individual refractory shapes are not supported by hangers or the like, it is preferred that the roof be constructed with thick and less thick portions, the thick portions forming ribs or bands extending across the arch from one skewback or support to the opposite skewback or support. These ribs or rings have the effect of strengthening the roof.

In the refractory article of this invention each expansion strip is disposed on one side face of a shape, respectively at or near the cold end and the hot end of the shape or brick. The abutting side face of the next adjacent brick is preferably free of such expansion strips when both the inner and outer strips are affixed to one shape. Alternatively, the inner expansion strip can be affixed to one shape and the outer expansion strip to the abutting face of the next adjacent shape. In still another embodiment, both expansion strips, each of one-half the desired expansion

allowance, can be affixed to opposed side faces of each shape and so disposed that upon assembly into a structure such as a roof, the respective expansion strips abut each other and provide the total desired inner and outer expansion allowances, respectively.

In this application, the term "cold" face or end is intended to mean that face or end of the shape which is disposed at the exterior of the arch and farthest from the furnace heat, whereas "hot" end or face is intended to mean that face or end exposed to the furnace heat.

By the term "room temperature" is meant the atmospheric or ambient temperature at the time of constructing the furnace or other structure.

While cardboard and asbestos have been shown as the preferred materials for the inner and outer strips respectively, in the embodiments shown in FIGURES 1, 2 and 3, it will be understood that other, equivalent materials with the desired property of being removed, as by combustion, disintegration, decomposition, melting, and the like, in the specified temperature ranges, can be used. Thus, for example, tar, pitch, sulfur, burlap, wood, fiber board, and the like can be used instead of cardboard, and materials such as matted mineral fibers used in place of asbestos.

Having now described the invention,

What is claimed is:

1. A refractory unit comprising: a refractory shape having an outer end, an inner end, and opposed side faces disposed between the said ends; an inner strip of a combustible material attached to at least one of said side faces adjacent said inner end; and an outer strip of asbestos attached to at least one of said side faces adjacent said outer end.

2. A refractory unit according to claim **1** wherein said inner strip is cardboard.

3. A refractory unit comprising: a refractory shape having an outer end, an inner end, and two opposed side faces disposed between the said ends; an inner strip of a combustible material attached to at least one of said side faces adjacent said inner end and extending less than half the distance along the side face from the inner end toward the outer end; and an outer strip of asbestos attached to at least one of said side faces adjacent said outer end.

4. A refractory unit according to claim **3** wherein said inner strip is cardboard.

5. A refractory unit comprising: a fired refractory shape having an outer end, an inner end, and two opposed side faces disposed between the said ends, said side faces converging toward said inner end, said refractory shape comprising grains of magnesia and grains of chromite, said magnesia grains and said chromite grains being directly bonded to each other; an inner strip of a combustible material attached to at least one of said side faces adjacent said inner end and extending less than one-quarter the distance along the side face from the inner end toward the outer end; and an outer strip of asbestos attached to at least one of said side faces adjacent said other end, said outer strip extending less than one-quarter the distance along the side face from the outer end toward the inner end; the total thickness of outer strips attached to said side faces being from about 50% to about 75% of the amount of the thermal expansion of the refractory material between the side faces at the outer end of the shape upon being heated from room temperature to the intended operating temperature of said unit; and the total thickness of inner strips attached to said side faces being substantially equal to the thermal expansion of the refractory between the side faces at the inner end upon heating said refractory from room temperature to the intended operating temperature of the unit.

6. A refractory unit according to claim **5** wherein said inner strip is cardboard.

7. A refractory unit comprising: a fired refractory shape having an outer end, an inner end, and two opposed side faces disposed between the said ends, said side faces converging toward said inner end, said refractory shape comprising grains of magnesia and grains of chromite, said magnesia (periclase) grains and said chromite grains being directly bonded to each other; an inner strip of a combustible material attached to at least one of said side faces adjacent said inner end and extending less than one-quarter the distance along the side face from the inner end toward the outer end; and an outer strip of asbestos attached to at least one of side faces adjacent said other end; the total thickness of outer strips attached to said side faces being from about 50% to about 75% of the amount of the thermal expansion of the refractory material between the side faces at the outer end of the shape upon being heated from room temperature to the intended operating temperature of said unit; and the total thickness of inner strips attached to said side faces plus the thickness of any portion of any outer strips attached to said side faces extending to adjacent the inner end being substantially equal to the thermal expansion of the refractory between the side faces at the inner end upon heating said refractory from room temperature to the intended operating temperature of the unit, the total thickness of said inner strips being at least equal to the thermal expansion of the refractory between the side faces at the inner end upon heating from room temperature to about half the intended operating temperature of the unit.

8. A refractory unit according to claim **7** wherein said inner strip is cardboard.

9. A furnace structure comprising: a plurality of adjacent refractory shapes, disposed side by side, each of said shapes having an inner end disposed toward the inside of the furnace and an outer end disposed toward the outside of the furnace; inner strips of combustible material disposed between at least some of said adjacent shapes adjacent the inner ends thereof; and outer strip of asbestos disposed between at least some of said adjacent shapes adjacent the outer ends thereof.

10. A furnace structure comprising: a plurality of adjacent refractory shapes, disposed side by side, each of said shapes having an inner end disposed toward the inside of the furnace and an outer end disposed toward the outside of the furnace; inner strips of combustible material disposed between at least some of said adjacent shapes adjacent the inner ends thereof, said strips extending less than half the distance from the inner toward the outer ends of said shapes; and outer strips of asbestos disposed between at least some of said adjacent shapes adjacent the outer ends thereof, said outer strips extending less than half the distance from the outer end toward the inner end of said shapes.

11. A furnace structure comprising: a plurality of adjacent refractory shapes disposed side by side, each of said shapes having an inner end disposed toward the inside of the furnace and an outer end disposed toward the outside of the furnace; inner strips of cardboard disposed between at least some of said adjacent shapes adjacent the inner ends thereof, said strips extending less than one-quarter the distance from the inner toward the outer ends of said shapes; and outer strips of asbestos disposed between at least some of said adjacent shapes adjacent the outer ends thereof, said outer strips extending less than one-quarter the distance from the outer end toward the inner end of said shapes; the thickness of said outer strips between two refractory shapes being from about 50% to about 75% of the thermal expansion of the refractory shapes between said outer strips when heated from room temperature to the operating temperature of said furnace; the thickness of said inner strips being substantially equal to the thermal expansion of the inner ends of said refractory shapes between said inner strips when heated from room temperature to the operating temperature of the furnace.

12. A furnace roof structure comprising: an arch of refractory shapes disposed side by side, said shapes each having an inner end disposed toward the inside of the roof and an outer end disposed toward the outside of the roof; inner strips of combustible material disposed be-

tween at least some of said shapes adjacent the inner ends thereof; and outer strips of asbestos disposed between at least some of said shapes adjacent the outer ends thereof.

13. A furnace roof structure comprising: an arch of tapered refractory shapes disposed side by side, said shapes each having an inner end disposed toward the inside of the roof and an outer end disposed toward the outside of the roof; inner strips of cardboard disposed between at least some of said shapes adjacent the inner ends thereof, said strips extending less than half the distance from the inner toward the outer ends of said shapes; and outer strips of asbestos disposed between said shapes adjacent the outer ends thereof; said outer strips extending less than half the distance from the outer end toward the inner end of said shapes.

14. A furnace roof structure comprising: a self-sustaining arch of tapered refractory shapes disposed side by side, said shapes each having an inner end disposed toward the inside of the roof and an outer end disposed toward the outside of the roof; inner strips of a combustible material disposed between at least some of said shapes adjacent the inner ends thereof, said strips extending less than one-quarter the distance from the inner toward the outer said shapes; and outer strips of asbestos disposed between at least some of said shapes adjacent the outer ends thereof; the thickness of said outer strips between two refractory shapes being about half of the thermal expansion of the refractory shapes between said outer strips when heated from room temperature to the operating temperature of said furnace; and the thickness of said

inner strips plus the thickness of any portion of said outer strips extending to the inner ends of said shapes being substantially equal to the thermal expansion of the inner ends of said refractory shapes between said inner strips when heated from room temperature to the operating temperature of the furnace, the thickness of said inner strips being at least equal to the thermal expansion of the inner ends of the refractory shapes between said inner strips when heated from room temperature to about half the operating temperature of said furnace.

15. A structure according to claim 14 wherein said inner strip is cardboard.

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