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F. H. NORTON

MASONRY ARCH FOR HIGH TEMPERATURE USE

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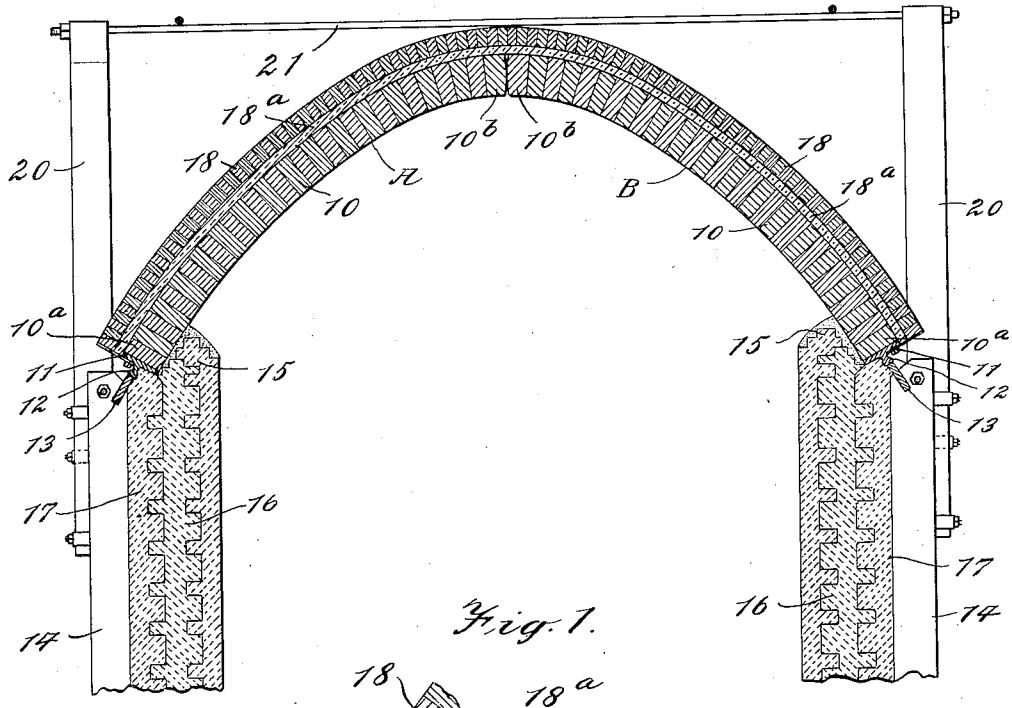


Fig. 1.

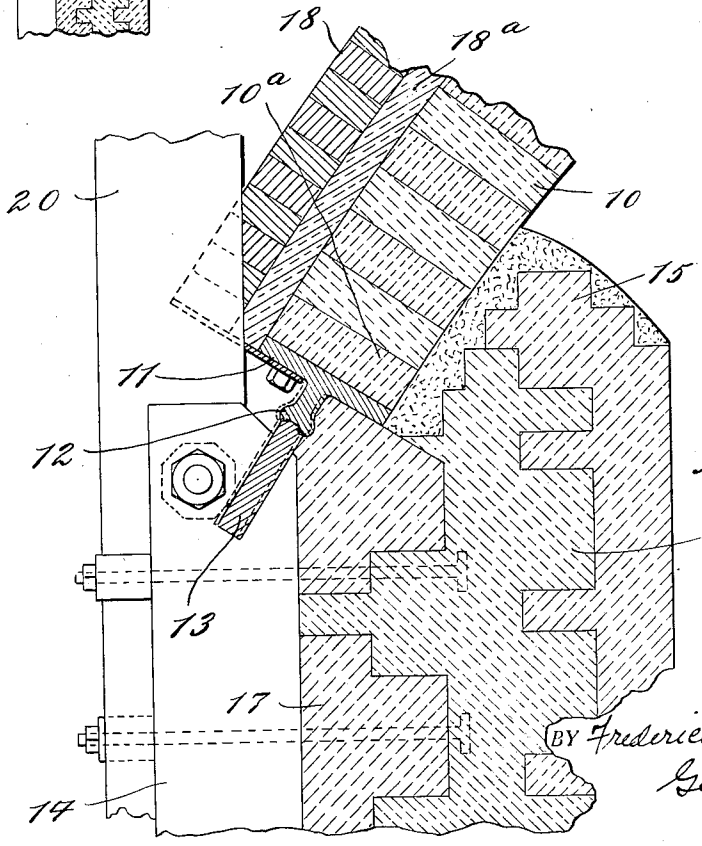


Fig. 2.

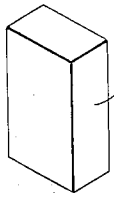


Fig. 3.

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MASONRY ARCH FOR HIGH-TEMPERATURE USE.

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In structures of various kinds which are subjected to high temperature conditions, considerable difficulty has been experienced with masonry arches forming a part of such structures. My invention is concerned with overcoming such difficulties and for convenience will be described in connection with kilns for burning high temperature refractories, but it is to be understood that it is applicable to industrial furnaces in general, including boiler furnaces, metallurgical furnaces, etc.

In kilns as heretofore designed for high temperature work, considerable difficulty has been experienced with the roofs. In the case of kilns having arched roofs which are uninsulated, no great difficulties are experienced, since, due to radiation, the temperature attained by such a roof is not high. When high temperatures are sought, e. g., in the neighborhoood of 3000° F. and above, the roof in common with the rest of the kiln must be well insulated, or else, due to loss of heat by radiation, it will be impracticable to attain such a temperature in the kiln. An arched roof thus highly heated will ordinarily undergo considerable expansion, and unless special precautions are taken, such expansion will often result in the roof failing after a single heat. An exception to this may occur when bricks are used which have been insufficiently burned, and which, when subjected to the kiln temperature, undergo such shrinkage, as a result of internal changes in the material composing the bricks, that the final effect is a contraction rather than an expansion. However, it will be understood that in the usual case, a considerable increase in length of the arch must be provided for, and that furthermore, unless proper provision is made, parts of the brick, as, for example, the lower ends, will be subject to excessive pinching, due to the relatively greater expansion of such lower ends over that of the upper.

After considerable study and experimentation, I have discovered that the failure of arches under high temperature conditions has been due principally to the following causes:

(1) Excessive stresses due to eccentric loading, i. e., such that the lines of thrust make considerable deviation from the center line of the arch.

(2) Excessive stresses due to change in length of arc on heating.

(3) Excessive stresses due to uneven expansion of the bricks occasioned by the fact that the lower ends of the bricks are heated to a higher temperature than the upper ends.

Accordingly, in constructing the arch of my invention, I so shape the arch as to enable the thrust through each brick or voussoir to coincide substantially with the geometric center thereof, or, what may be preferable, I may construct the arch so that the line of thrust will make a uniform, slight deviation from the center of each voussoir, so as to allow for the fact that when the under part of a voussoir is heated to higher temperature than the upper, the yield point of the material at the hotter surface is less than that of the cooler one. Such an arch in either of the two cases mentioned would, as is known, have the shape of an inverted catenary.

I have found that the excessive stresses, due to the second and third causes mentioned, may be eliminated by providing means allowing a free expansion of the arch. In the form at present preferred by me, and which I have illustrated in the accompanying drawing, I hinge the arch at each skew-back and provide for movement of the two halves of the arch with respect to one another at the longitudinal mid-section. This construction allows each section of the arch to expand as a unit, and substantially eliminates pinching of the ends of the bricks or voussoirs, due to unequal expansion of the lower and upper ends thereof.

It will be understood that particularly when an articulated construction is employed at the mid-section, it is desirable to make the stress at this section as small as practicable. It will be found in the case of a catenary arch that such stress will be diminished as the height of the arch is made greater. This is in contrast to an arch of circular shape for example, in which the stress per unit of cross section increases as the curvature (and consequently the height)

is increased, so that slightly beyond say a 50° slope at the skew-backs, such an arch has a marked tendency towards instability. By making the arch of inverted catenary shape, however, the height of the arch may be increased to any desired amount without affecting its stability. In practice, I have found an arch of catenary shape having a slope at the skew-backs of 55 to 70° to be desirable but prefer to use the higher values.

If desired, the use of cementing materials between the side faces of the voussoirs composing the arch may be dispensed with, as due to the improved construction, such cement is not necessary for the stability of the arch. This elimination of the cementing material is of advantage, in that it allows the ready removal of a single voussoir, and, furthermore, allows the voussoir to undergo some rearrangement during the heating and cooling process.

My invention will best be understood from the following detailed description taken with the accompanying drawing, in which Fig. 1 is a view more or less diagrammatic taken in vertical cross section of a kiln of rectangular shape embodying a preferred form of my invention; Fig. 2 is an enlarged view in vertical section through one skew-back and shows the manner of supporting the arch. Fig. 3 is a view in perspective of an individual voussoir.

Referring to Fig. 1, an arch is shown of inverted catenary shape composed of individual voussoirs 10, preferably of highly refractory material, the end voussoirs 10^a, resting upon a plate 11, having a socket member 12, engaging the curved surface of an inclined stay 13, suitably secured in vertical supports 14, which carry the weight of the arch. This hinged construction is protected from the heat of the furnace by means of an extension of the inner walls 15, 15. As shown the arch is divided at the longitudinal mid-section in sections, A and B and conveniently, the hinge between them may be formed simply by giving a slightly convex curve to the opposing voussoirs 10^b, 10^b. The amount of curvature required is very slight, the curvature shown being exaggerated for sake of clearness.

The side walls of the kiln are covered with insulating material, as, for example, by a layer of refractory bricks 16, outside of which is placed one or more layers 17 composed of a brick having high insulating qualities such as those made of diatomaceous earth. The roof is preferably covered with a layer of insulating brick 18, beneath which may, if desired, be placed a monolithic layer of suitably refractory material 18^a.

Vertical supports are fitted with extensions 20, opposite extensions 20 being joined by tie rods 21, by means of which the lateral thrust of the arch is opposed.

If desired, I may displace the locus of thrust throughout the arch upwardly from the center line by a slight amount. This may be done by shifting the socket member 12 slightly outwardly and also the line of contact of the two sections at the mid point the same amount. In this manner the load on the voussoirs is distributed more in accordance with their ability to withstand it, since the portion of the voussoirs having the greater temperature will not have the same resistance to stress as the cooler parts thereof. Preferably, this displacement is just enough so as to produce uniform distortion of the voussoirs and may be easily calculated, given the temperature gradient between the inner and outer surfaces of the arch when subjected to furnace temperatures and the yield points of the refractory material throughout the gradient. It is to be noted that only by the use of the inverted catenary shape for the arch, is such a result possible, as in any other form, the locus of thrust is not coincident with or parallel to the center line of the arch. The amount of displacement is small and as will be evident from the foregoing, is dependent upon the temperatures of the inner and outer surfaces and the particular kind of refractory used.

I have found a kiln roof embodying my improvements is exceedingly stable and that the temperature to which it may be repeatedly heated is limited only by the refractoriness of the material used. For example, a number of kilns embodying my improvements have been subjected to repeated heating at temperatures in excess of 3000° F., each of which heatings lasted for several days, without the roofs of any of them showing the slightest indications of failure.

Various changes within the spirit of my invention will occur to those skilled in the art, it being understood that the specific forms of my invention shown are by way of example only and that I do not intend to limit myself to such specific forms shown.

In the claims where the word "furnace" is used, it its to be understood that I intend to include not only furnaces but kilns where the roof or arch is subjected to high temperatures due to hot products of combustion.

I claim:

1. A furnace roof of refractory material for use under high temperature conditions, said roof being composed of two sections, each of which is free to move as a unit when heated, and said roof being of substantially an inverted catenary shape and supported only at its edges.

2. A furnace roof for use under high temperature conditions, said roof being composed of two sections, each of which has a hinged connection with the support on which it rests, and a movable connection with said other section, and said roof being of substantially catenary shape.

3. A furnace roof for use under high temperature conditions, said roof being composed of two sections, each of which has a hinged connection with the support on which it rests, and a movable connection with said other section, said roof being of substantially catenary shape and having a slope at the skew-backs in excess of 50°.

4. A hinged voussoir furnace roof of inverted catenary shape for use under high temperature conditions supported so as to displace the line of stress outwardly from the center line of the roof by an amount sufficient to give substantial uniform distortion of the voussoirs when the under side of the roof is heated to a given temperature.

FREDERICK HARWOOD NORTON.