

Dec. 5, 1939.

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2,182,674

OPEN-HEARTH FURNACE

Filed Jan. 10, 1939

2 Sheets-Sheet 1

Fig. I.

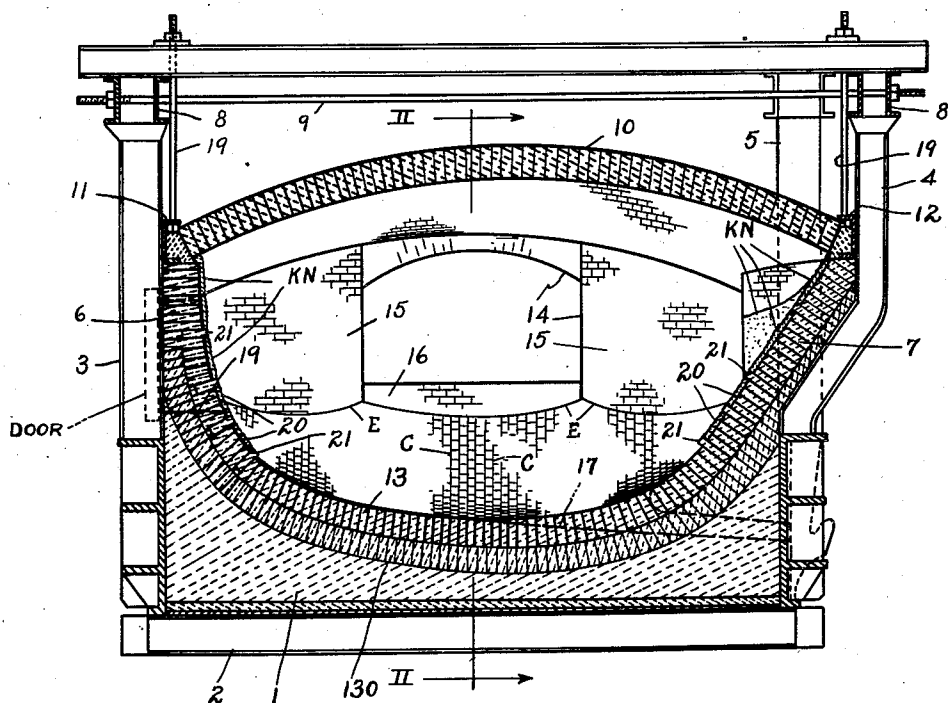
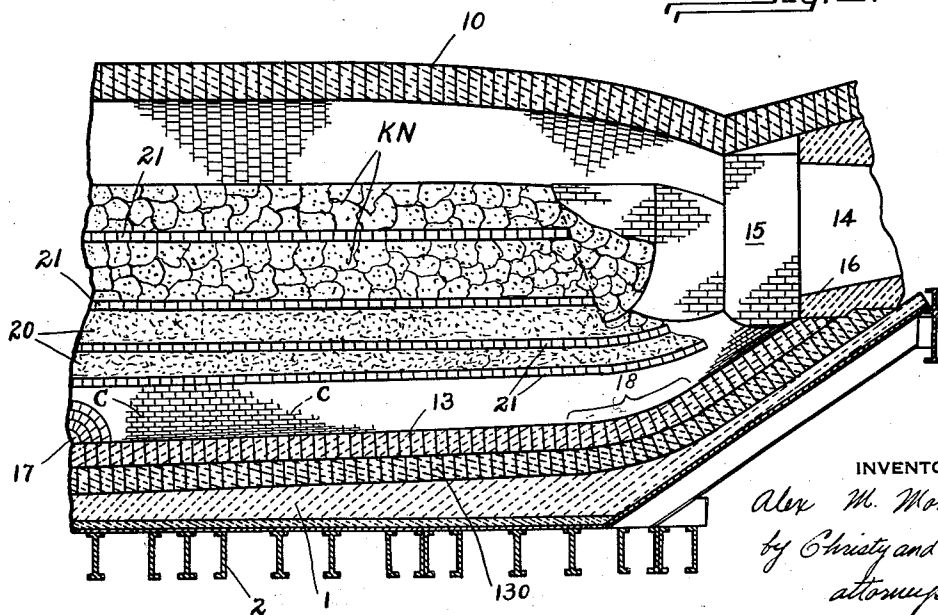


Fig. II.



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2 Sheets-Sheet 2

Fig. III.

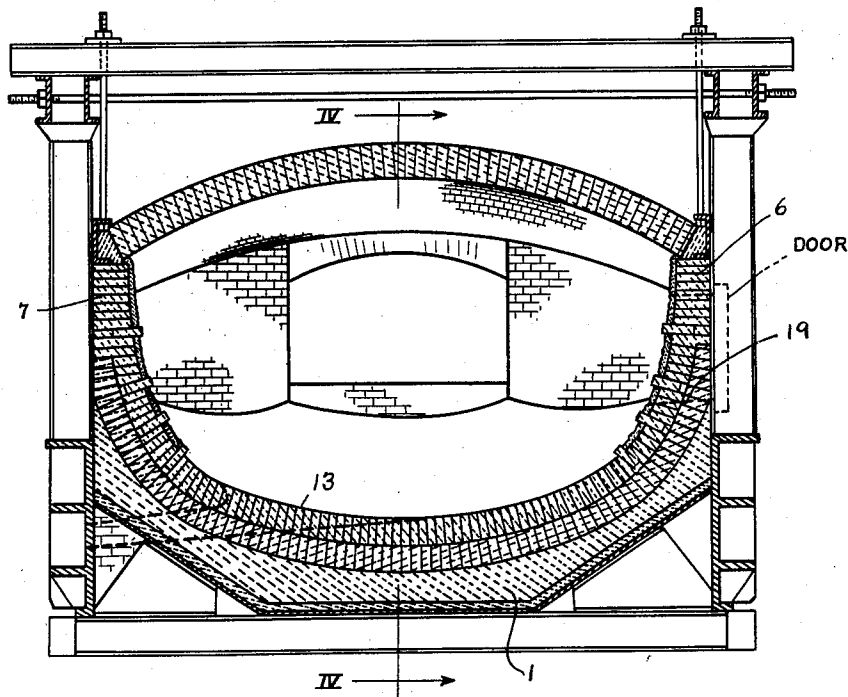
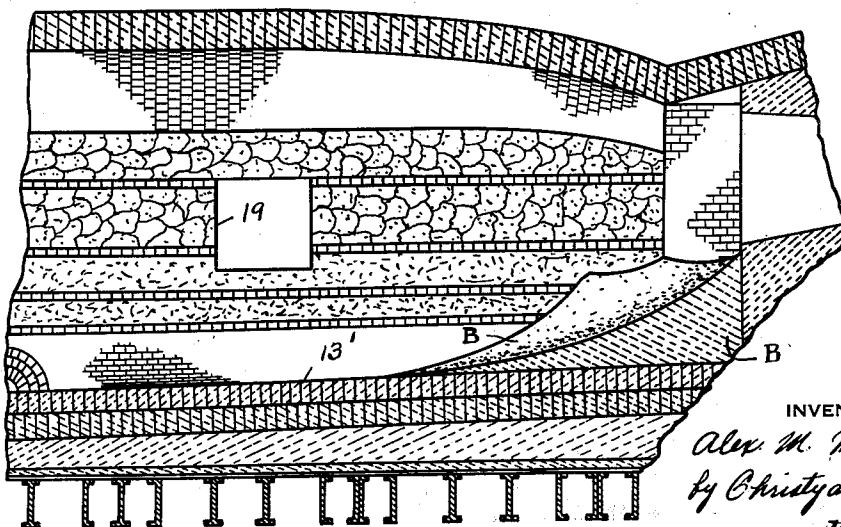


Fig. IV.



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UNITED STATES PATENT OFFICE

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OPEN-HEARTH FURNACE

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11 Claims. (Cl. 263—46)

My invention relates to open-hearth furnaces, particularly to basic open-hearth furnaces, and consists in improvements in furnace construction.

5 In basic open-hearth furnace practice, as commonly carried out, the furnace hearth is saucer shaped, and consists of a mass of broken mineral substance, such as granulated magnesite. The mass is properly supported, shaped, and bonded.
 10 (Open-hearth slag, fused in the body of the mass, is a widely used bonding material.) This saucer shaped hearth has two characteristics: First, it is the immediate support for the molten furnace charge; Second, it includes reagents that
 15 assist the limestone and other reagents, introduced with the furnace charge, in the refinement of the metal. As the furnace operation progresses, it is established practice to build up the hearth from time to time, as it is eroded
 20 by reaction with the molten metal.

Necessarily, where two factors so co-exist, there must be accommodation between them. The construction and material employed must be such in kind and quality as to serve the two
 25 ends.

If the furnace hearth, instead of being formed in situ of a mass of broken mineral, were formed of masonry, the bricks of the masonry might be made of a material that is inert to chemical reaction with the furnace charge, and then the reagent for the refinement of the molten metal might be chosen without regard to any other consideration, and might be introduced into the bath upon the hearth. Such a reconstruction of the open-hearth furnace has been proposed, and the advantages of such reorganization are manifold. The difficulties (and they are such as have hitherto prevented practical enjoyment) come to light only when attempt is made to operate a furnace so reconstructed. The arc of curvature of the bowl or saucer shaped hearth is of long radius; the inverted arch of the cross-section of the hearth is low and weak; the refractory bricks are less in specific gravity than is the molten charge; the structure under widely varying temperature conditions cannot be built and maintained with precision in detail; and the bricks spall and the mortar or cement of the masonry is subject to erosion. In consequence of these things, not only pieces of bricks, but whole bricks themselves are apt to loosen and escape from their positions in the hearth, and to float up in the molten metal, with impairment of the hearth. These are some of the conditions and circumstances that have prevented hitherto the prac-

tical realization of what might have been a desirable reorganization of the furnace structure.

This invention, broadly stated, consists in imposing upon the inverted dome or inverted vault of a brickwork hearth the weight, or a substantial portion of the weight, of the roof of the furnace. This weight, imposed upon the inverted dome or vault at the spring of the arch, has effect in maintaining the dome or vault under constant stress of compression. Such being
 5 the case, as the furnace continues in use, those changes of circumstance, notably changes in temperature, that otherwise have effect in spreading and buckling the arch and allowing component bricks to become loose and escape, are
 10 not so effective. Always in response to the superposed load the component units of the dome or arch are compressed together. The structure is effectively strengthened against disintegration.

The dome or arch in the roof of a building is
 15 strengthened against rupture or disintegration by the weight that rests upon it from above, and similarly the dome-shaped hearth of this invention is strengthened against disintegration by the weight that rests on it from above. The
 20 difference is that in the roof of a building the dome or vault is carried at the spring of the arch, with the weight borne upon the arch and concentrated at the keystone, while in the hearth it is the arc that is supported, with the weight
 25 imposed upon the spring of the arch.

The invention embraces particular refinements in the construction and organization of an inverted dome of brickwork in an open-hearth furnace, by virtue of which the brick-
 30 work, under compressive stress imposed upon the spring of the arch of the dome, provides an enduring hearth and wall structure for the furnace. The invention has become practical in consequence of recent developments in refrac-
 35 tories, particularly basic refractories having a low coefficient of thermal expansion and great mechanical strength under high temperatures.

In the accompanying drawings Figs. I and II illustrate an embodiment of the invention in an
 40 open-hearth furnace of known sloping back-wall construction, Fig. I being a view of the furnace in transverse section, and Fig. II a fragmentary view in longitudinal section, on the plane II—II of Fig. I. Fig. III is a view in trans-
 45 verse section of an open-hearth furnace of simpler design, illustrating a modified embodiment of the invention. And Fig. IV is a fragmentary view, showing the modified structure in longitudinal section, on the plane IV—IV of Fig. III.

The construction shown in Figs. I and II consists in a structural steel framework that supports and reinforces the refractory hearth, walls and roof of the furnace. The bottom of the furnace includes a base 1 of refractory masonry that is borne upon horizontal beams 2; the front and back walls 6 and 7 of the furnace are laterally supported by the usual buck-stays 3, 4 and 5; and on the upper ends of the buck-stays channel-beams 8 are secured, and tied with cross-rods 9. The roof 10 of the furnace consists of a dome, or vault, of refractory brickwork, arched between skewbacks 11 and 12 that extend longitudinally of the furnace immediately above the front and back walls 6 and 7.

In accordance with this invention, the hearth of the furnace consists in an inverted dome of brickwork, preferably an elliptical dome, a dome that is arched both transversely and longitudinally of the furnace chamber, as shown. In this case, and advantageously in any case, the inverted dome is constructed of two courses of brickwork 13 and 130, providing a double dome, or a dome within a dome. And as illustrated the masonry base 1 of the furnace is accurately fashioned into a basin that receives and externally sustains the brickwork that forms the inverted dome, or vault.

In further accordance with the invention, the front and back walls 6 and 7 of the furnace are embodied in one and the same dome of brickwork as forms the hearth. As viewed on the transverse plane of Fig. I, the front and back walls of the furnace form with the hearth an inverted arch that is continuous in its extent between the upper edges of such walls, and the upper edges of such walls constitute the spring of the arch.

The weight of the roof 10, or a substantial part of such weight, is imposed upon the spring of the inverted arch. Specifically, the roof-sustaining skew-backs 11 and 12, laterally supported by the buck-stays 3 and 4, instead of being immovably secured to the buck-stays are floating; they rest upon and are borne by the upper edges of the walls 6 and 7. Indeed, the oppositely arched dome structure (10 and 6, 13, 7), laterally confined by the external buckstay structure 3, 4, 5 is free for vertical flotation under the influence of the brickwork expanding and contracting in accordance with variations in furnace temperature.

While the roof of the furnace may be constructed in known way of silica brick having a relatively high coefficient of thermal expansion, the inverted dome or vault 6, 13, 7 that forms the hearth is preferably constructed of bricks of a basic refractory material that has a relatively low coefficient of thermal expansion. In practice I have used bricks formed of a mixture of chrome ore and magnesite, and while I can not give the expansion coefficient in usual terms, I can say that, in bringing a furnace from atmospheric temperature to normal operating temperature, the total linear expansion of the bricks was approximately 0.75%, which is much less than the expansion of the refractory bricks used hitherto. The bricks are oblong in form, and in building the inverted dome or vault the bricks are laid face to face, with rubbed joints. The major axes of the individual bricks are directed toward the center of curvature of the dome, with the structural advantage that the bricks in the hearth portion of the dome stand perpendicularly to the surface of the foundation 1, while the

bricks in the side wall portions 6 and 7 of the dome extend normally to buck-stays 3 and 4 that laterally support them. It is important to note that the courses C of bricks extend lengthwise of the hearth, parallel to the major axis of the inverted dome, with the bricks in adjacent courses arranged in overlapping relation, as may be perceived in Figs. I and II. Under the load of the superposed roof, the bricks in the inverted dome are frictionally interlocked, and in service it is impossible for them, when submerged beneath molten steel, to become dislodged.

On the longitudinal axis of the furnace the curvature of the inverted vault or dome is on a relatively great radius through the major portion of the hearth's extent between the opposite end walls of the furnace. Each end wall of the furnace includes two wall portions 15, 15 (known as monkey walls) that extend in convergent relation from the front and back walls of the furnace to a central end wall portion 16, through which the usual firing port 14 opens. Immediately inward from each end wall of the furnace the longitudinal curvature of the inverted dome or vault is accentuated, as at 18, to provide between the firing port and the center of the hearth, at the tap-hole 17, proper graduation in the depth of the molten bath upon the hearth.

The inverted dome or vault of brickwork meets the end walls of the furnace on lines E immediately below the ports 14. Advantageously, if not essentially, the end wall portions 15, 15, 16 are borne by the edge of the inverted dome, with the consequent effect that the inverted dome or vault is under compressive stress longitudinally of the furnace, as well as transversely thereof. The compression of the dome or vault on both major and minor axes—on both the transverse and longitudinal arches—provides a sound structure.

In service the compressive stresses effective on the inverted dome not only serve to secure the brickwork of the hearth and side walls of the furnace, but additionally serve to prevent cracks and fissures from developing in the brickwork, during the periods when the temperature of the furnace falls. I have found that, under the normal operating temperatures of the furnace, the bricks in the hearth and side walls become plastic to a substantial degree. Under the usual variations in furnace temperature, the expansion and contraction of the hearth and side walls is taken up within, or accommodated by, the plastic bodies of the bricks themselves. If the expansion and contraction of the structure exceeds the elasticity of the thermally plastic bricks, the dome-compressing roof 10 and end walls 15, 15, 16 of the furnace will shift vertically and provide compensation for the varying dimensions of the inverted dome or vault. Such self adjustment of the hearth to varying temperature is a valuable feature of my structure.

It is also important to note that under certain conditions the hearth may be relieved of the weight of the roof. That is to say, when the furnace is cooled down, or is temporarily taken out of service for repair, the dome-shaped hearth is relieved of the weight of the roof. To this end I mount the skew-backs 11, 12 upon suspension rods 19 that are so vertical adjusted as to sustain the roof when the furnace temperature falls and the cooling hearth shrinks and contracts on the arch lines of the inverted dome or vault.

In service the metal-bearing surface of the hearth is covered or screened with a thin protective blanket of magnesite or dolomite, a ma-

terial that promotes the refinement of the molten metal upon the hearth. This coating (not shown) is of substantially uniform thickness (one inch) over the entire area of the hearth, and it provides a working bottom that can be and is readily and economically maintained during furnace operation. Such slag as is produced in the furnace contains only a very small quantity of silicon—it is not a vitreous slag of the sort that is troublesome in usual furnace practice. And inasmuch as slag is not needed, as in the case of the usual furnace, to repair the hearth and walls, the total quantity of slag that must be removed from my furnace is relatively small.

At the front and the back of the furnace, I cover the internal surface of the metal-refining chamber, from a line below normal bath level to a line above, with a heavy protective coating 20, consisting of magnesite and a bonding material, and, above the coatings 20, I line the front and back walls 6 and 7 with KN—KN being the name of a material known in the art, consisting of coarsely ground chrome ore and a suitable bonding material. Means are provided for anchoring or securing the protective coatings 20 and KN in place upon the internal walls of the furnace, and such means consist in a plurality of ribs 21 that extend longitudinally of the furnace and in vertically spaced-apart relation. The ribs are formed, advantageously, by laying the bricks in certain of the courses C, with their inner ends extended out from the otherwise continuous inner surface of the brickwork that forms the hearth and side walls of the furnace. The provision of such means as the ribs 21 consists in an inventive refinement that will prove valuable in any metallurgical furnace, whatever its construction.

By virtue of the structural improvements herein described it becomes practical (when building new furnaces) to avoid the more costly sloping back-wall construction, with the specially shaped buckstays 4 illustrated in Figs. I and II. That is to say, in modification of the structure described, the front and back walls of the furnace may be built symmetrically with respect to the longitudinal mid-plane of the furnace, and, while the front and back wall-forming portions of the brickwork dome advantageously extend upwardly and outwardly from the hearth portion, as shown in Fig. III, it will be perceived that buckstays of the usual simple form may be used. It is to be understood, however, that in many cases the sloping back-wall will prove advantageous, and that in such cases it will be embodied in my hearth structure, as illustrated. And as already mentioned the front wall of the furnace may be built as a permanent, rather than a removable, wall.

Fig. III also illustrates that the masonry or concrete foundation of the furnace may be made of lighter and more economical construction.

Further modification is illustrated in Fig. IV, and, while it does not now appear that the modified furnace of Fig. IV is as desirable as those described above, I show it by way of example of the several modifications that are permissible within the terms of the appended claims. Specifically, Fig. IV illustrates that the inverted dome or vault of brickwork 13' may be barrel shaped or cylindrical. The desired saucer shape of the hearth is obtained, by means of bodies B of refractory material supported, at opposite ends of the furnace, upon the inner surface of the inverted barrel-shaped dome, or vault. The bodies B may each consist in a mass of broken refrac-

tory material shaped and integrated in situ, or it may consist of a plurality of preformed refractory units assembled upon the wall of the inverted dome.

It will be perceived of the furnace described that the front wall, hearth, back-wall and roof of the furnace chamber are entirely formed by two domes, or vaults, that are oppositely arched and borne one upon the other at the common spring of the arches. In the structure of Figs. I and II the elongate inverted dome is peripherally recessed at the opposite ends, to meet the end walls of the furnace in lines below the firing ports. In all of the structures illustrated, the front and back walls and the hearth, extending in a continuous inverted arch, include no angles or corners in which undue strains and overheating will occur. The furnace is less costly to construct; in service less repairing is required, and the maintenance costs are reduced. By virtue of the consolidated and inert hearth the furnace drains clean when tapped. The time required for tapping is shortened and may be accurately calculated for each heat. In consequence of my structure, irregularity in operation (due to irregularity in quality and composition of the hearth) is avoided; the refining of the charge may be more precisely circumstanced, and the time of treatment may be made regular, with reduction of the refining operation to precision, and a saving in the alloys used.

I claim as my invention:

1. A metallurgical furnace having an elongate metal-refining chamber formed by two oppositely arched domes of refractory brickwork, one dome providing the roof of said chamber and the other dome providing within the continuity of its arch the front wall, the hearth, and the back wall of such chamber, the bricks in said hearth dome being subject to compressive stress on arch lines of the dome, with the effect that in service the softening bricks in the heated hearth are consolidated and secured in position to sustain a bath of molten metal of superior specific gravity, a plurality of bricks in such hearth dome being extended inward from the arched expanse of the brickwork and providing anchorage for applied coatings of refractory material.

2. A metallurgical furnace having an elongate metal-refining chamber formed by two oppositely arched domes of refractory brickwork, one dome providing the roof of said chamber and the other dome providing within the continuity of its arch the front wall, the hearth, and the back wall of such chamber, the bricks in said hearth dome being subject to compressive stress on the arch lines of the dome, with the effect that in service the softening bricks in the heated hearth are consolidated and secured in position to sustain a bath of molten metal of superior specific gravity, the bricks in a plurality of the courses in said brick-work being extended inward from the arched expanse of the brickwork and forming ribs that, extending longitudinally of the furnace chamber, provide anchorage for applied coatings of refractory material.

3. A metallurgical furnace having a hearth and side walls formed of an inverted dome of refractory brickwork, the bricks in particular courses of said brickwork extending from the inner surface of such dome and providing anchorage for a refractory coating applied to the inner surface of the dome.

4. A metallurgical furnace including a hearth that consists in an inverted dome of refractory

brickwork of low thermal expansion, and a roof that consists in a dome of refractory brickwork of relatively high thermal expansion, the weight of such roof being imposed upon the spring of the arch of said inverted dome, with the effect that in service the softening brickwork of low thermal expansion in the heated hearth is, by compressive stress (effective upon the arch lines of the inverted dome), consolidated and the individual bricks in the hearth secured in position to sustain a bath of molten metal of superior specific gravity, the softened and consolidated brickwork being provided on its bath-sustaining surface with a protecting blanket of broken and fused refractory substance.

5. A metallurgical furnace including a roof and a hearth, said hearth consisting in an inverted elliptical dome of brickwork of low thermal expansion, the minor axis of the dome extending transversely of the furnace and the major axis extending longitudinally of the furnace, the individual bricks of said brickwork being laid in courses that extend longitudinally of the major axis of the dome, with the bricks in the successive courses arranged in staggered relation transversely of the dome, said roof consisting in a vault of brickwork of relatively high thermal expansion, the weight of said roof being imposed upon the spring of the transverse arch of said dome, with the effect that in service the softening bricks in such brickwork of the heated hearth are, by compressive stress (effective upon the transverse arch lines of the dome), consolidated and the individual bricks in the hearth secured in position to sustain a bath of molten metal of superior specific gravity.

6. A metallurgical furnace including a roof consisting in a vault of refractory brickwork extending between skewbacks arranged at the front and the back of the furnace, and a hearth consisting in an inverted dome of refractory brickwork, the weight of said roof dome being imposed upon the spring of the arch of said hearth dome, with the effect that in service the softening brickwork of the heated hearth is, by comparative stress (effective upon the arch lines of the inverted dome), consolidated and the individual bricks in the hearth secured in position to sustain a bath of molten metal of superior specific gravity, and adjustable supports organized with said skew-backs and adapted to sustain all or a part of the weight of said roof, with the consequence that the roof weight effective upon the hearth dome may be regulated as the furnace is heated and put into service.

7. A metallurgical furnace whose hearth consists in an inverted dome of refractory brickwork, with the individual bricks secured in position to sustain a bath of molten metal of superior specific gravity, and a protective blanket of broken and fused refractory substance spread upon the bath-sustaining surface of such brickwork dome.

8. A metallurgical furnace whose hearth consists in an inverted dome of refractory brickwork compressed on the arch lines of the dome, the softening brickwork of the heated hearth in service being, under compressive stress, consolidated and the individual bricks secured in position to sustain a bath of molten metal of superior specific gravity, and a blanket of broken and fused refractory substance spread upon and adapted to protect the softened bath-sustaining surface of such brickwork hearth.

9. An open-hearth furnace having opposite end walls, a front wall, a back wall, a roof, and a hearth adapted to carry a pool of molten metal, the hearth and the front and back walls of said furnace comprising a dome of refractory brickwork downwardly convex on every cross-section in vertical plane, said roof resting upon the portions of the periphery of said brickwork dome that extend along the front and the back of the furnace, the periphery of such dome being recessed at the opposite ends of the furnace, said end walls of the furnace bearing upon such recessed peripheral portions of the brickwork dome, the weight of the roof and the end walls of the furnace securing the component bricks of the pool-carrying portion of the hearth from displacement when a pool of molten metal of specific gravity greater than that of the bricks rests upon the hearth.

10. In a metallurgical furnace including a metal-refining chamber whose hearth, roof, and front and back walls comprise two domes of brickwork, one arched upwardly and the other arched downwardly, and arranged within an external supporting structure; the refinement herein described in which the weight of said upwardly arched dome is imposed upon the spring of the arch of the downwardly arched dome, with the effect that in service the brickwork of the downwardly arched dome is, by compressive stress (effective upon its arch lines) consolidated and the individual bricks secured in position to sustain a bath of molten metal of superior specific gravity, said oppositely arched domes being laterally confined within said external supporting structure and being free for vertical flotation under the influence of the brickwork expanding and contracting in accordance with variations in furnace temperature.

11. The structure of the next-preceding claim, in which the front and back walls of the furnace comprise portions of said downwardly arched dome that extend on the transverse arch lines of the dome upwardly and outwardly with respect to one another and with continuity of curvature.

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