Dec. 5, 1939. A. M. MORTON 2,182,675

METALLURGICAL FURNACE

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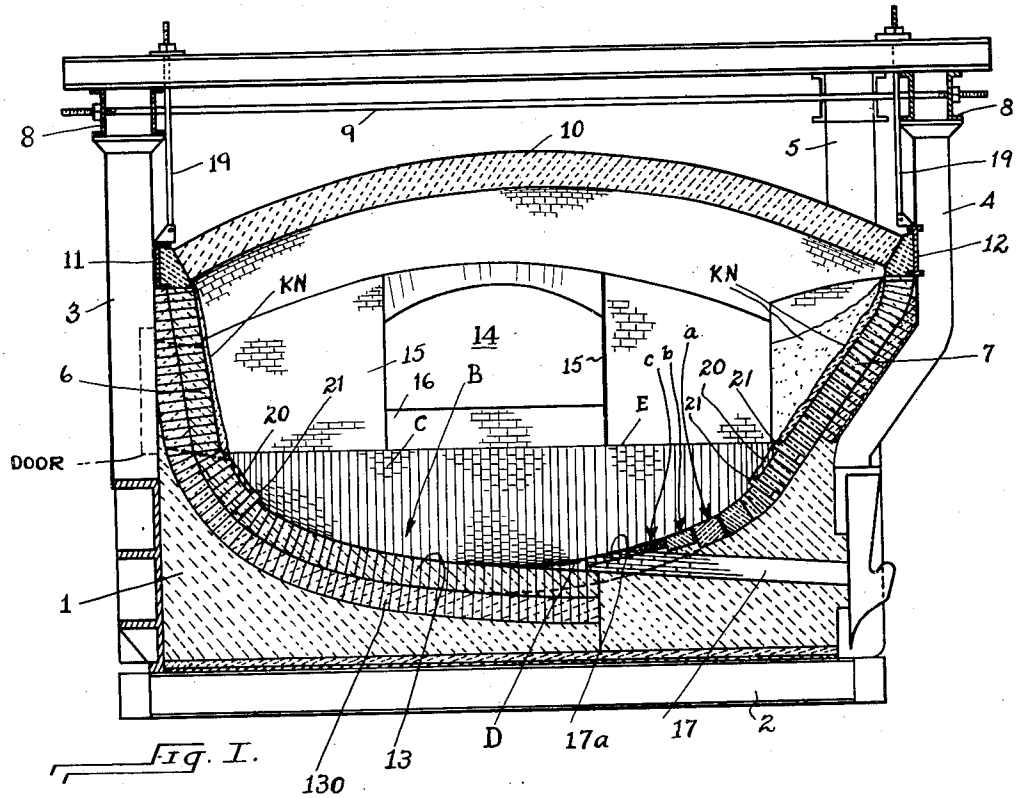


Fig. I.

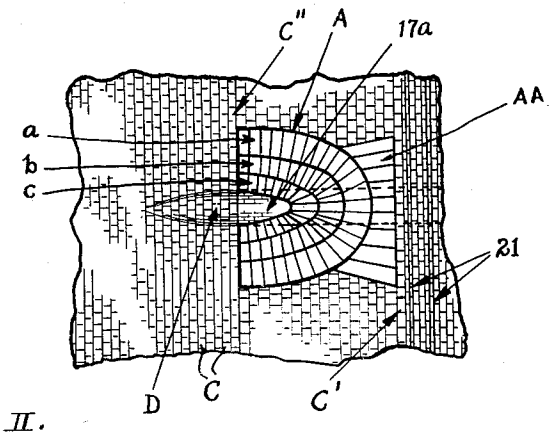


Fig. II.

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METALLURGICAL FURNACE

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8 Claims. (Cl. 263—46)

My invention relates to metallurgical furnaces, and consists in improvements in furnace construction, particularly to improvements in construction of basic open-hearth furnaces of the sort illustrated and described in application for United States Letters Patent Serial No. 250,132, filed by me January 10, 1939, and issuing as Letters Patent concurrently herewith.

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. (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 assist the limestone and other reagents, introduced with the furnace charge, in the refinement of the metal. As the furnace continues in service, it is established practice to build up the hearth from time to time, as it is eroded 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 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 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 practical realization of what might have been a desirable reorganization of the furnace structure.

The invention disclosed in my above-noted co-pending application, 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 or compression. Such being 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 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 strengthened against rupture or disintegration by the weight that rests upon it from above, and similarly the dome-shaped hearth of my construction is strengthened against disintegration by the weight that rests on it from above. The 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 imposed upon the spring of the arch.

The invention of my said co-pending application embraces certain refinements in the construction and organization of an inverted dome of brickwork in an open-hearth furnace, by virtue of which the brickwork, under compressive stress imposed upon the spring of the arch of the dome, provides an enduring hearth and wall structure for the furnace. The enjoyment of such improved furnace structure has become practical in consequence of recent developments in refractories, particularly basic refractories having a low coefficient of thermal expansion and great mechanical strength under high temperature.

My present invention consists in still other refinements in such a furnace structure. More specifically, I modify or elaborate the brickwork of the inverted dome in the region through which the usual tap-hole opens, with the consequence and effect that the brickwork in such region, otherwise weakened by the tap-hole, is strength-

ened and made secure and durable. Additionally, I not only embody the front and back walls of the furnace as constituent parts of the inverted brickwork dome, but on the transverse arch lines of the dome I slope both of such walls upwardly and outwardly from the metal-bearing portion or working bottom of the hearth formed by the dome. In consequence a more effective distribution of the weight of the furnace roof upon the hearth dome is obtained, and a more perfect structure is realized.

In the accompanying drawing Fig. I is a view in transverse section of a furnace embodying the invention; and Fig. II is a fragmentary view, illustrating in plan the brickwork of the hearth in the region of the tap-hole.

The furnace structure consists in a structural steel framework that supports and reinforces the refractory hearth, walls and roof of the furnace. As described in my co-pending application, 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 skew-backs 11 and 12 that extend longitudinally of the furnace immediately above the front and back walls 6 and 7.

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 my other application. 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.

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, and advantageously, if not essentially, both of the walls 6 and 7 slope upwardly and outwardly from the basin portion B that sustains the molten charge of metal (not shown). As viewed in Fig. I, on the transverse plane of the furnace, the front and back walls form in effect 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 in effect 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.

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 cannot 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, or substantially 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 or longitudinal axis of the inverted dome, with the bricks in adjacent courses arranged in overlapping relation, as may be perceived in the drawing. 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.

It will be understood that 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 in known way 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 shown in the drawing of my co-pending application, 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 in a plane E immediately below the port 14 at each end of the furnace. 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 held 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 vertically 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, dolomite, other suitable broken and fused refractory, or mineral substance. This coating (not shown) is of substantially uniform thickness (one inch, more or less) over the entire area of the hearth, and it provides a working bottom that, protecting the softened brickwork from the heat and erosion of the molten bath, may be 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 is a refinement that will prove valuable in any metallurgical furnace, whatever its construction.

Turning now to an important, if not the most important, feature of my present invention, it will be perceived that the brickwork dome of the hearth includes an arch A whose intrados forms the mouth 17*a* of the tap-hole that opens through the wall of the hearth dome 13. In this case the arch A is formed of three arched courses *a*, *b* and *c* of bricks or blocks of the same refractory material as that of which the hearth dome is formed, and at the crown of the arch an auxiliary stress-distributing arch—a key-arch AA—is provided. The arches A and AA are embodied in the brickwork structure of the inverted hearth dome, and are adapted, under the compressive stress applied to the dome, to provide at the mouth of the tap-hole 17 such security and durability of structure as is found elsewhere in the brickwork hearth. In earlier attempts to use brickwork hearths in open-hearth furnaces, it was found that the region of the brickwork through which the tap-hole opened was the region of greatest vulnerability. There it was that the distribution of stresses in the brickwork was disturbed; there it was that the deleterious action of the molten metal upon the brickwork was most acute; and in such region the tendency was greatest of the molten metal to lift and float the individual bricks away from their places in the hearth. My structure is sound and enduring under these peculiar circumstances of service.

The arches A and AA, built in the curved body of the hearth dome 13, are symmetrical with respect to a vertical plane extending through the axis of the tap-hole 17. The outer or upper edges of the blocks of the key-arch AA lie in common plane, and the course C′ of bricks in the hearth dome bear upon the aligned edges of such blocks, while the inner edges of such key-arch blocks extend on the curvature of and bear upon the extrados surface of arch A. The terminal blocks or springers of each arched course *a*, *b* and *c* lie in common plane at the spring of the arch A, and bear upon the longitudinally extending course C″ of bricks in the hearth dome. The hearth bricks, between the courses C′ and C″, laterally bear upon and secure the arches A and AA.

In a region extending from the plane of contact of the course C″ of hearth bricks with the spring of the arch A to the center of the hearth, a depression D is formed in the longitudinal courses of the hearth bricks, and this depression provides the desired gradient from the center of the hearth to the mouth of the tap-hole, insuring clean drainage of the furnace at the end of each heat. The compressive stress, effective (in consequence of the imposed weight of the roof in this case) upon the transverse arch lines of the hearth dome, is by the key-arch AA transmitted to and distributed upon the center or crown of the arch A, and such arch A, held secure against lateral spreading, transmits such compressive stress to the hearth brickwork to the left of the spring of the arch (i. e. to the brickwork to the left of the course C″, Fig II). Under such compressive stress and under the heat of the furnace, the brickwork in the arches A and AA is consolidated, and is integrated with the longitudinal courses of brickwork that form the body of the hearth. The individual bricks or blocks in the tap-hole arches A and AA are thus secured in position, and to all intents and purposes the structure is as strong and durable as it would be if the tap-hole opening 17*a* were not there.

The exposed surfaces of the arches A and AA, included in the expanse of the brickwork of the inverted dome, will be screened and protected by an applied coating of broken and fused refractory or mineral substance, or by a cement including such substance. And, as in the case of the protective blanket applied to the metal-sustaining surface of the hearth brickwork, this coating may be readily repaired and renewed as the furnace continues in service.

It will be perceived of the structure 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. The elongate inverted dome

is peripherally recessed at the opposite ends of the furnace, and meets the furnace end walls in lines or planes (E) below the firing ports. 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 of the form described, 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 the quality and composition of the hearth) is avoided; and refining 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 whose hearth, front wall and back wall consist in an inverted dome of refractory brickwork, in which the front wall and back wall portions extend upwardly and outwardly from the hearth portion, said brickwork being compressed on the arch lines of the dome, and softening under the heat of service, being consolidated under compressive stress, and the individual bricks in the hearth portion being secured in position to sustain a bath of molten metal of superior specific gravity, a tap-hole opening through the hearth, the brickwork of said dome including at the mouth of said tap-hole an arch arranged to sustain at its crown compressive stress effective upon the transverse arch lines of the dome.

2. A metallurgical furnace whose hearth, front wall and back wall consist in an inverted dome of refractory brickwork in which the front wall and back wall portions extend upwardly and outwardly from the hearth portion, said furnace including a roof whose weight is imposed upon the spring of the arch of said dome, a tap-hole opening through the hearth portion of said dome, the brickwork body of said dome including at the mouth of said tap-hole an arch whose crown is arranged to receive compressive stress on the transverse arch lines of said dome, the brickwork of said dome, with said included arch, softening under the heat of service, being consolidated under compressive stress, and the individual bricks in the hearth portion being secured in position to sustain a bath of molten metal of superior specific gravity.

3. A metallurgical furnace whose hearth consists in an inverted dome of refractory brickwork compressed on the arch lines of the dome, and including a tap-hole that opens through said dome, the brickwork body of said dome including at the mouth of said tap-hole an arch arranged to receive at its crown compressive stress effective on said arch lines of the dome.

4. A metallurgical furnace whose hearth consists in an inverted dome of refractory brickwork compressed on the arch lines of the dome, and including a tap-hole that opens through said dome, ths brickwork body of said dome including an arch whose intrados borders the mouth of said tap-hole, said arch being arranged in said body of brickwork to sustain, between its crown and its springers, compressive stress effective on the arch lines of said inverted dome.

5. The structure of claim 3, in which said arch includes a plurality of arched courses of bricks within the brickwork body of the dome.

6. The structure of claim 3, in which said arch includes a plurality of arched courses of bricks within the brickwork body of the dome, together with a key-arch bearing upon the crown of said arch.

7. The structure of claim 3, in which the brickwork body of said dome is formed with a depression extending from the mouth of said tap-hole towards the center of the hearth, to provide clean drainage in the tapping of the furnace.

8. A metallurgical furnace whose hearth consists in an inverted dome of refractory brickwork compressed on the arch lines of the dome, and including a tap-hole that opens through said dome, the brickwork body of said dome including at the mouth of said tap-hole an arch formed of a plurality of arched courses of bricks, said arch being arranged to sustain, between its crown and its springers, compressive stress effective on the arch lines of said dome, the brickwork body of said dome being formed with a depression extending from the mouth of said tap-hole towards the center of the hearth, to provide clean drainage in the tapping of the furnace.

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