Nov. 24, 1931. C. E. HAWKE 1,833,712

METHOD OF OPERATING FURNACES

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Fig. 1.

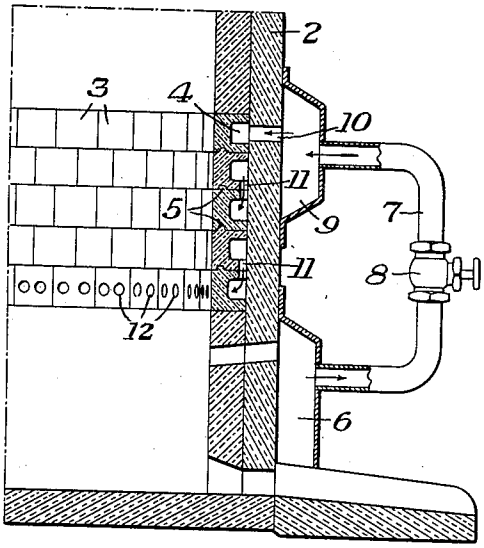



Fig. 2.

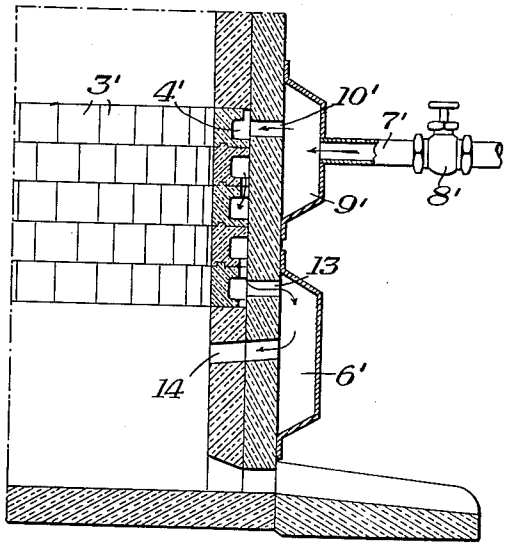



Fig. 4.

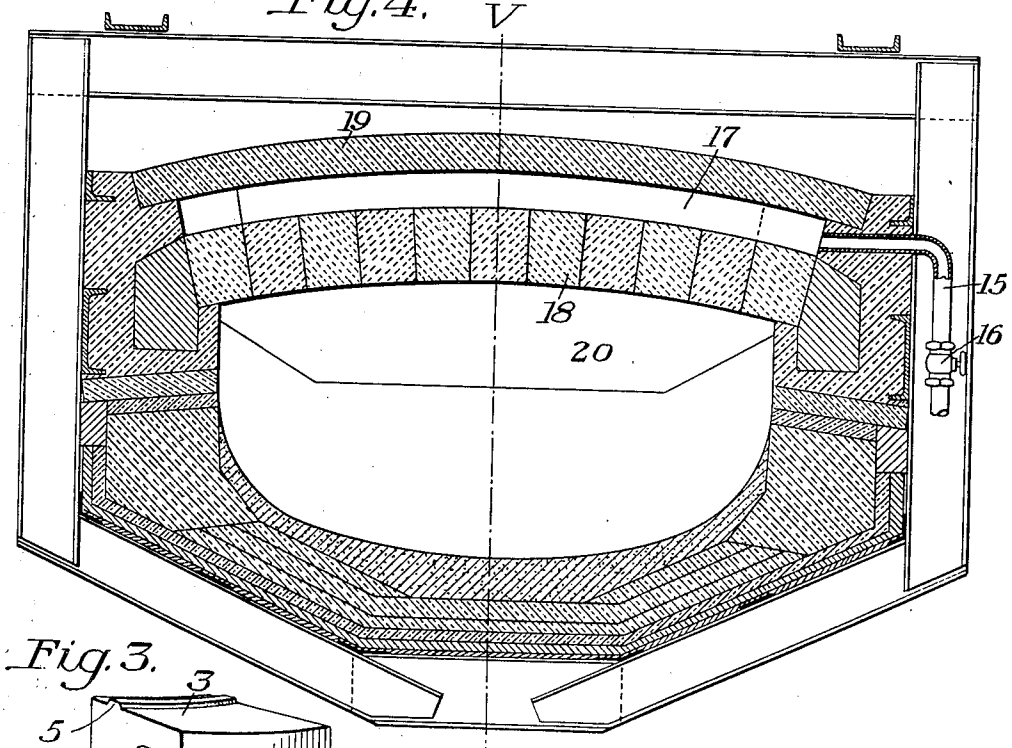
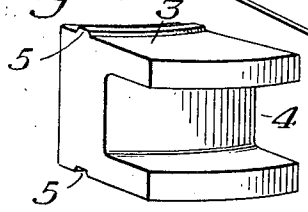



Fig. 3.




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Nov. 24, 1931. C. E. HAWKE 1,833,712

METHOD OF OPERATING FURNACES

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Fig. 5.

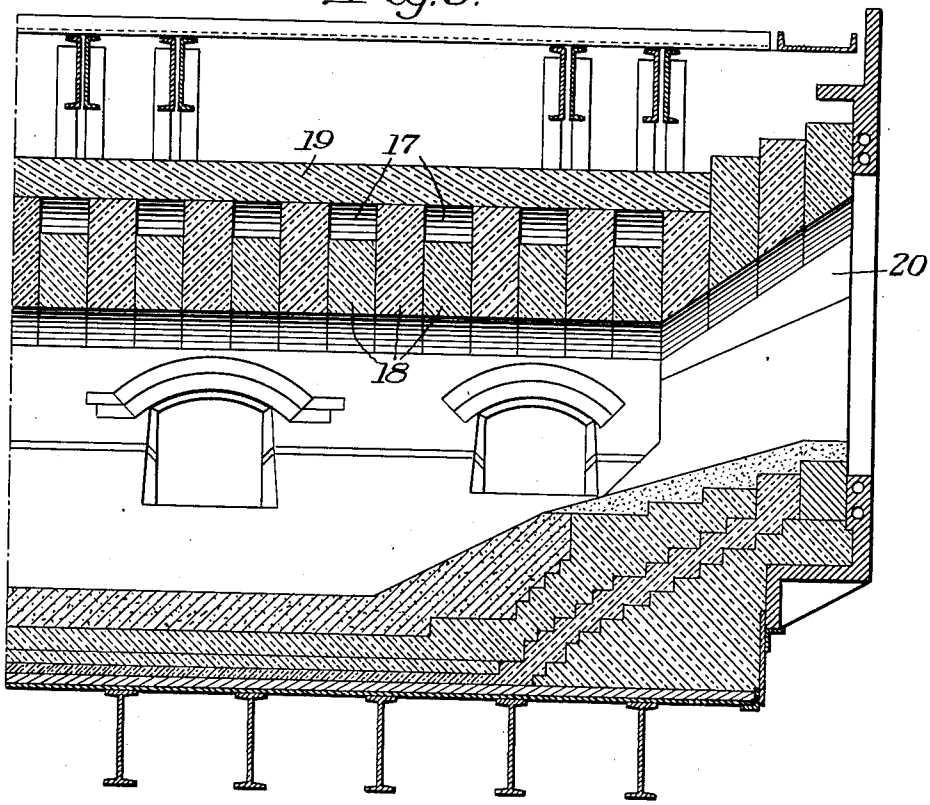
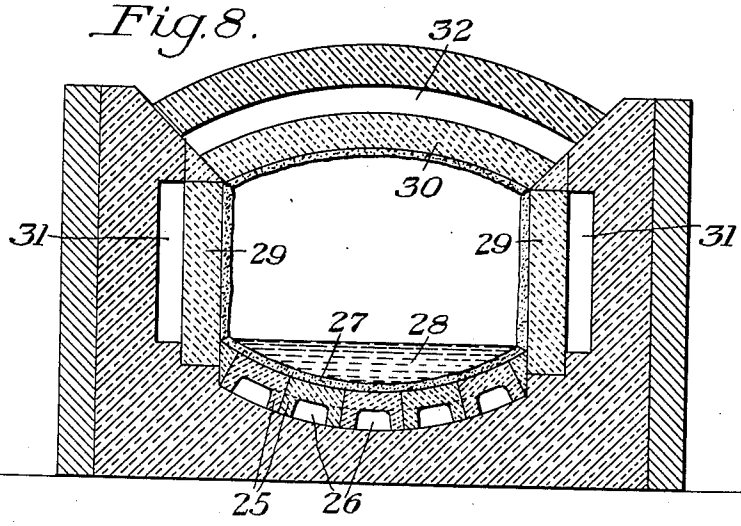



Fig. 8.




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Nov. 24, 1931. C. E. HAWKE 1,833,712

METHOD OF OPERATING FURNACES

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Fig. 6.

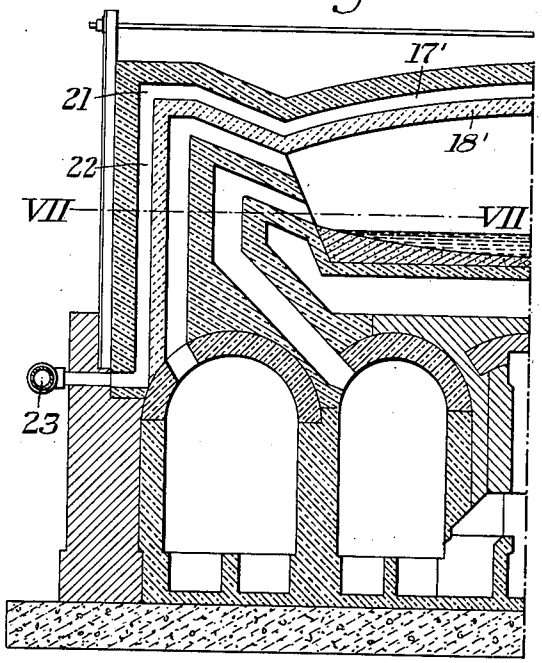



Fig. 7.

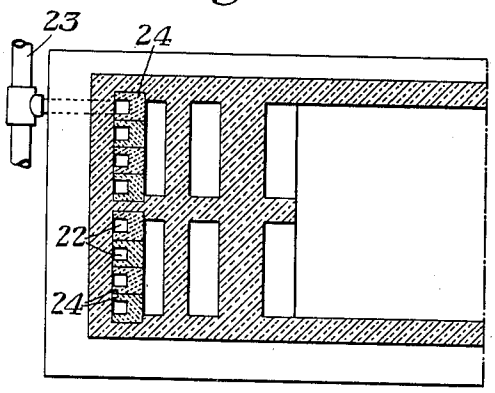
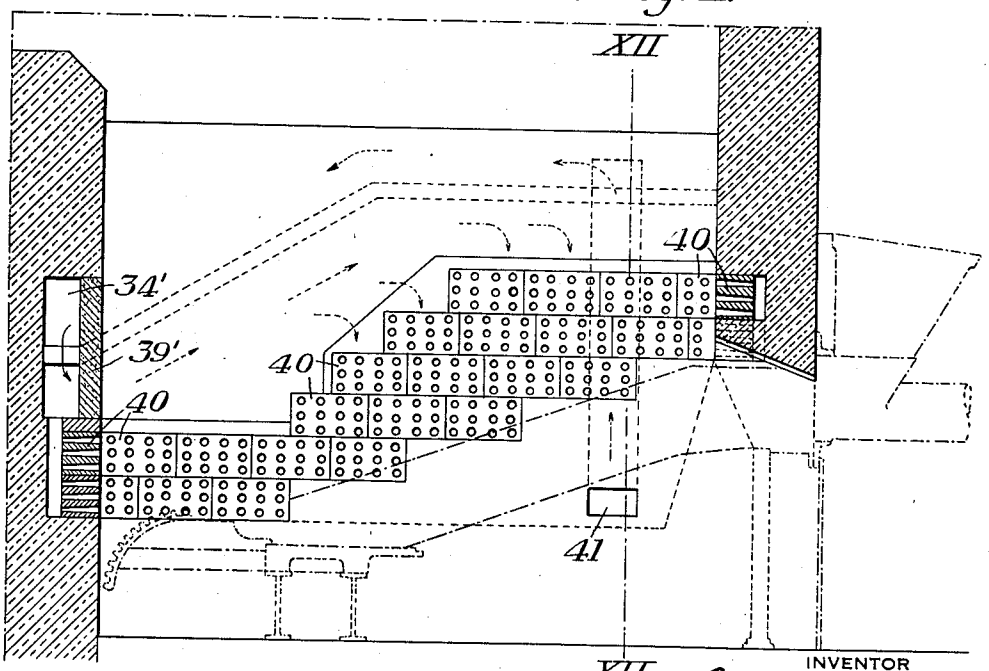



Fig. 11.




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METHOD OF OPERATING FURNACES

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Fig. 9.

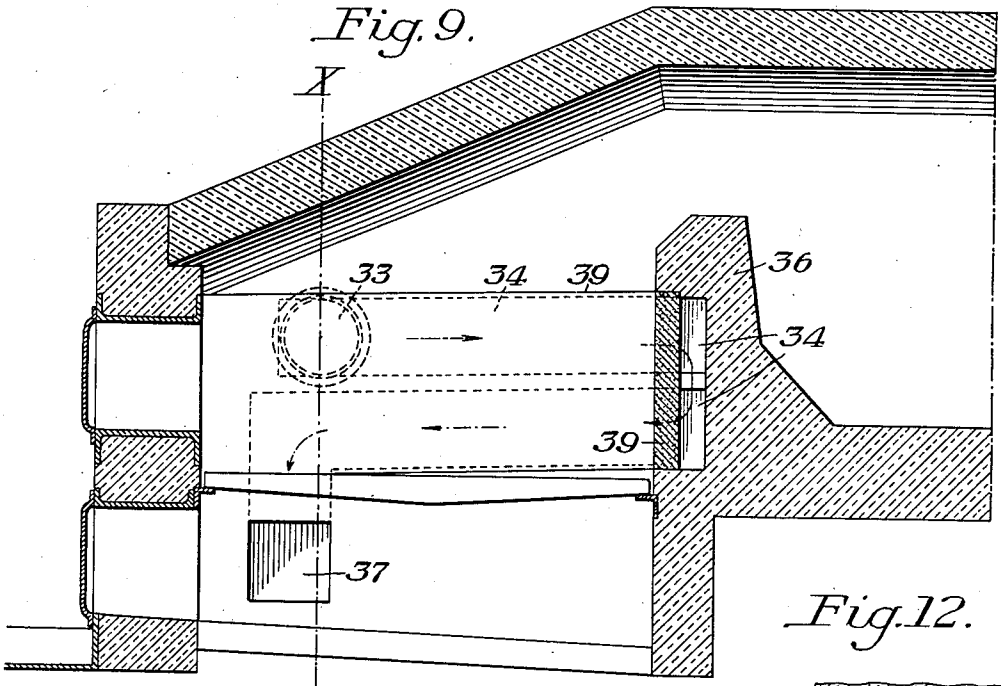



Fig. 10.

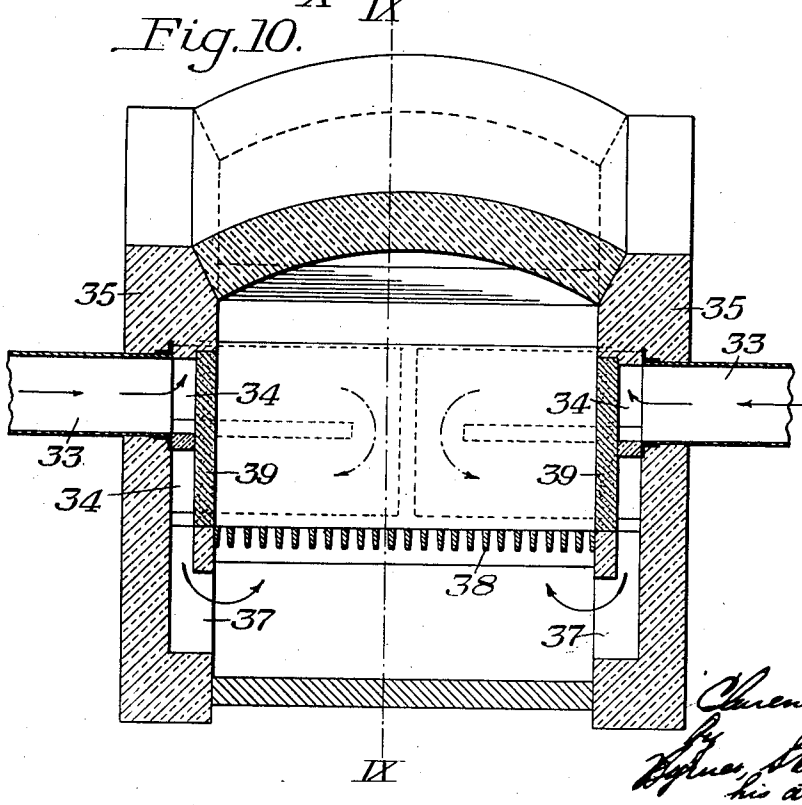
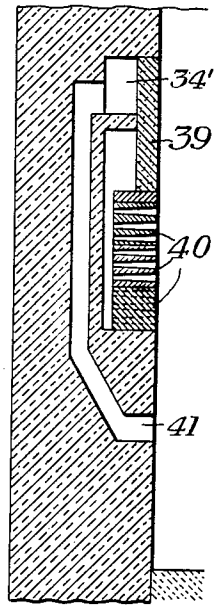



Fig. 12.




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Patented Nov. 24, 1931 1,833,712

# UNITED STATES PATENT OFFICE

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## METHOD OF OPERATING FURNACES

Application filed August 20, 1925, Serial No. 51,323. Renewed November 28, 1930.

This invention relates broadly to an improvement in the construction of furnaces and particularly metallurgical furnaces, with particular reference to a new means for preventing the erosion of the refractories by contact with slags, metals and other fused materials.

In all industrial furnaces in which fused materials come in contact with the refractory linings, there is continual dissolution or erosion of the refractory material composing the lining and eventual wearing down until replacement is necessary. In many instances this erosion is so rapid that furnaces must be rebuilt quite frequently, sometimes daily, with a consequent loss of use and expense of replacement.

In some furnaces this erosion of the refractory materials is detrimental because of the contamination to the material being melted. This case is illustrated by enamel smelting furnaces, glass tank furnaces, and the like.

The rate of wearing away, or dissolution or erosion of refractory materials in contact with fused materials, such as melted slag, metals, glass, enamels and the like depends not only upon the nature of the fused material and the refractory structure, but also to a large extent upon the penetration of the fused material into the pores of the refractory linings. Inasmuch as all commonly used refractory materials are made up of more or less inert particles held together by a fritted or slightly fused bonding material between the separate particles, it is obvious that the dissolution of a small amount of material, i. e., bond, will release or cause to be eroded a much larger amount of the composite refractory material. This results in the wall being quickly eroded until it becomes so thin as to be structurally unsound.

One method of decreasing this undesirable penetration of the fused slag or other liquid material is by the use of refractories of dense structure, that is, with a minimum amount of pore space into which the melted slag may penetrate.

I have discovered that this deleterious penetration into the pores of the refractory material (ultimately causing destruction of the refractory lining) may be almost entirely prevented by the use of highly refractory materials which have the property of conducting the heat away from the surface exposed to the fused material at such a rate that a solidified or viscous layer of the fused material forms at the boundary. The net result is that the slag, metal, glass, or other fused material is retained in a container lined with a solidified layer of the same material.

Not only must the furnace construction be such that for each particular case the rate of dissipation of heat through the linings will cause the fused material to chill at its contact with the lining, but the refractory material used must also have thermal and physical properties, which will permit the attainment of the desired temperature gradient through the lining, while at the same time giving a structurally sound furnace lining or wall.

In almost all cases there must be provision for the conservation of the heat which passes through the wall, as otherwise the operation of the furnace would be highly inefficient from the fuel consumption point of view.

I have found that of the commercially available refractory materials which suggest themselves for use in this connection, there is one which is particularly desirable and occupies a field practically by itself in having the requisite chemical, and physical properties requisite to accomplish the improvements in metallurgical furnaces in accordance with the present invention, and further description will refer to this particular material, namely, silicon carbide, although the utility of the invention is not in all respects limited thereto.

The two outstanding properties of silicon carbide refractories are its high thermal conductivity and its great mechanical strength, the combination of which properties are essential to the practical application of the present invention.

For example, in a refractory wall transferring heat from one side to the other, the temperature difference on the two sides is fifty (50%) per cent greater with fireclay than with silicon carbide refractories. Expressed differently, if the same amount of

heat energy flows through a fireclay wall as through a silicon carbide wall of the same dimension, the respective temperature gradients would be in the ratio of about 1:9. Still another way of expressing this marked difference between the thermal property of ordinary refractories (as represented by fireclay) and those of silicon carbide refractories is that with a fixed temperature drop through the two walls, the ratio of the quantity of heat passed by the fireclay to the silicon carbide wall is about 1:20. To get the same temperature gradient and at the same time transmit an equal amount of heat as a 4½ inch silicon carbide refractory wall, a fireclay wall must be reduced to about ½ inch in thickness. It is obvious that a commercial furnace structure of ½ inch thick walls would be unsound and unstable in comparison with a 4½ inch wall of silicon carbide refractories, not only on account of the decreased thickness, but also on account of the lower strength of fireclay.

The mechanical strength of silicon carbide refractories is well known. For example, at 1500° C., the very best fireclay or silica brick will break under a modulus of rupture of 200 pounds per square inch. A silicon carbide refractory composed of about 10% ceramic bonding material and 90% silicon carbide has about ten (10) times this strength. Likewise, under compressive loads, several thousands of pounds per square inch are required to crush the above silicon carbide brick, whereas 50 pounds per square inch is sufficient to crush the best fireclay, silica or other ordinary refractory material.

I have discovered that these peculiar properties of silicon carbide refractories make it particularly adaptable for improved furnace construction embodying the present invention. In order to decrease or prevent the erosion of refractories by the melted materials in contact with them, metallurgical furnaces are preferably constructed in such a way that the contact surface between melt and refractories is cooled by conducting away heat through the refractory. This causes the melted material to solidify or become very viscous at the surface contact, so that it does not enter the pores of the refractory material. The thickness of the heat conducting wall is made such that it is structurally sound, and at the same time gives the desired amount of cooling to solidify or thicken the molten furnace charge. The heat thus withdrawn from the melted material through its containing walls is recovered by utilizing the heated air used for cooling refractory wall surfaces external to the molten charge.

In the accompanying drawings there are shown for purposes of illustration only certain preferred embodiments of the present invention, it being understood that these drawings do not define the limits of my invention as changes in the construction and operation disclosed therein may be made without departing either from the spirit of the invention or the scope of my broader claims.

In the drawings:

Figure 1 is a vertical sectional view illustrating a portion of a cupola or shaft melting furnace;

Figure 2 is a view similar to Figure 1 illustrating a slightly modified embodiment of the invention;

Figure 3 is a detail perspective view illustrating one form of block suitable for a furnace structure of the kind shown in Figures 1 and 2;

Figure 4 is a transverse sectional view through an open hearth furnace illustrating the invention as applicable for the protection of the roof and bulkhead thereof;

Figure 5 is a longitudinal sectional view on the line V—V of Figure 4;

Figure 6 is a view similar to Figure 4 illustrating more particularly a bulkhead construction for an open hearth furnace;

Figure 7 is a horizontal sectional view on the line VII—VII of Figure 6;

Figure 8 is a vertical sectional view illustrating the invention applied to a reverberatory smelting furnace;

Figure 9 is a sectional elevation through a furnace taken on the line IX—IX of Figure 10;

Figure 10 is a sectional view on the line X—X of Figure 9;

Figure 11 is a section through a modified form of furnace in which the air is supplied to the furnace above the grate; and

Figure 12 is a section of the furnace wall on the line XII—XII of Figure 11.

In carrying out the present invention as applicable to shaft melting or cupola furnaces, there may be provided a furnace 2 of any desired construction adapted to be operated in accordance with generally known principles. In furnaces of this character molten metal and slag are continually flowing down the side walls and therefore present severe erosion conditions. In order to materially increase the length of life of such a furnace, as well as improve its operating characteristics, such furnace may have a predetermined zone thereof formed by highly conductive refractory blocks 3 arranged in any desired manner, as for example in superimposed circumferentially extending rows. The blocks 3 may be of the general configuration and construction illustrated in Figure 3 adapted to provide a circumferentially extending air passage 4 in each row of blocks. If desired, the blocks may be provided with suitable cooperating projections and grooves 5 whereby adjacent rows will be effectively

interlocked and secured in position. These blocks will preferably cover the zone of the furnace in which the greatest erosion of refractories has been found to take place and will preferably comprise material such as silicon carbide having a thermal conductivity many times greater than that of ordinary fireclay, as already pointed out in detail.

A portion of the air blast normally used for combustion purposes may be bypassed from the main air ports or tuyères 6 by pipes 7 through control valves 8 to a smaller air distributing ring 9 from which it passes through the outer refractory shell of the furnace through openings 10 to the air passages or ducts 4. Preferably the opening or openings 10 will directly communicate with the air duct formed by the upper row of blocks for initially cooling the blocks of that row. The air ducts in adjacent rows may be connected preferably at substantially diametrically opposite sides of the furnace for alternate rows by means of ports 11. With such a construction the air will pass successively through the rows of blocks until it reaches the bottom row which may comprise blocks having openings 12 immediately above the regular tuyères. This stream of air is so regulated, with a given furnace and given thickness of refractory lining that a layer of solidified slag forms on the blocks thereby protecting them from erosion.

As an alternative construction from that just described, I may use the construction shown in Figure 2 in which case all of the air admitted through the tuyères is utilized for cooling the zone of greatest erosion in the lining. The special blocks 3′ of recessed back design as illustrated in Figure 3 are preferably used for lining the cupola to a height above which there is little erosion. The air for combustion is introduced through a pipe 7′ having a control valve 8′ and delivered to the air ring 9′. This air ring delivers in turn through an opening or openings 10′ into the duct 4′ in the upper row of blocks and circulated by the blocks as before described. After cooling the blocks, however, the air is introduced into the usual tuyère ring 6′ through an opening or openings 13, and then admitted into the furnace through the tuyères 14. The blocks are of such thickness, as determined by the temperature of fusion of the slag within the furnace and the rate of cooling by the air, that the slag is just solidified at the surface and thereby protects the refractory blocks. No heat is lost from the furnace, as will be apparent, for the reason that all heat abstracted, as in the case of the form illustrated in Figure 1, is introduced again to the furnace.

As illustrating the applicability of the invention for the protection of the roof and bulkhead of an open hearth furnace, attention is directed to Figures 4 and 5 in which cooling air is admitted by the pipe 15 having a controlling valve 16 to the ducts or passages 17 extending between a heat conducting liner 18 of high refractory material such as silicon carbide and the thermal insulating lining 19 to the end of the furnace over the port or ports 20 where it is conducted to the preheated air supply used in the furnace combustion. By thus introducing preheated air into the furnace, none of the heat is lost by the use of the thermally conductive inner roof 18, and at the same time the roof is effectively protected.

Other parts of an open hearth furnace, or similar melting or heating furnaces may likewise be protected in a similar manner. Referring to Figures 6 and 7 there is shown a method of constructing the bulkheads of an open hearth furnace. Cooling air may be brought over a thermally conductive roof 18′ as described in connection with Figures 4 and 5 through ducts 17′ and delivered by the desired duct or ducts 17′ to a passage 21 located between the thermally conductive wall and the heat insulating wall. This passage may in turn deliver to a passage 22 effective for conducting the preheated air or gas behind a bulkhead lining from which it may be discharged to a pipe 23 or the like and carried if desired to the source of combustion air.

From an inspection of Figure 7 it will be understood that the passages 22 may be formed in blocks 24 similar to the blocks described in connection with Figures 1, 2 and 3, and that the respective passages may be connected in series or in parallel depending upon the character of the flow path which it is desired to produce therethrough.

The furnaces heretofore described are metallurgical furnaces, and the operation contemplated is such as to produce a congealed protective film within the furnace of the melt therein. The principle of the invention may be extended to reverberatory furnaces as illustrated in Figure 6 and may be effectively employed for the protection of the bottom or hearth, the side walls and roof, all of which may be so constructed as to give a chilled slag surface by air cooling passages positioned back of a special lining of highly conductive material, such as silicon carbide. As illustrated in Figure 8 there may be utilized hearth tile 25 recessed as illustrated in Figure 3 to allow passage of cooling air through the ducts 26. This cooling air will be effective for forming a thin layer of congealed melt 27 on the inner surface, thus preventing erosion of the bottom. Likewise, the slag or other molten material 28 which is contained in the furnace may, by volatilization, splashing or chemical reaction form a thin layer of material on the roof and sides which is solidified because of the high thermal conductivity of the walls 29

and roof 30, and the carrying away of heat in the ducts 31 and 32 respectively back of them. It will be understood that the walls and roof are so constructed as to thickness, that the required amount of air or gas fueling forms the desired protective solid layer of slag or metal on the interior surface.

In Figures 9 to 12 both inclusive the invention is illustrated as extending to a combustion furnace of a different type adapted for the burning of coal or similar fuel. At the present time there is a drawing tendency to work furnaces of this general nature at extremely high rates of combustion. Under the increased temperatures resulting from such practice, the setting frequently burns out, and when coal is used as a fuel, the fused ash reacts with the brick work and destroys the setting in a very short time. This is especially true with low grade coal, and when such fuel is used it is impossible to maintain heavy furnace loads regularly because of the rapid deterioration of the brick work. This may be effectively overcome by a construction such as disclosed in Figures 9 and 10 in which is illustrated a furnace adapted to receive cooling air by any suitable means, such as blowers not shown through air pipes or openings 33, or adapted to have a supply of air drawn thereinto by induced draft. Air from the pipes 33 passes through ducts 34 in the furnace walls. These ducts preferably extend not only through the side walls 35, but also through the bridge wall 36, and terminate in outlets 37 below the grate 38.

Plates or blocks 39 preferably of silicon carbide form the wall between the ducts 33 and the interior of the furnace, this material possessing the properties of low porosity, extreme refractoriness and high heat conductivity as pointed out.

In Figures 11 and 12 there is illustrated a slightly different form of furnace in which parts corresponding to parts referred to in Figures 9 and 10 are designated by the same reference characters having a prime affixed thereto. In this embodiment, a conventional hopper type stoker is illustrated in chain lines, and perforated blocks 40 are provided for introducing the air above the grate. The blocks 40 form a part of the combustion walls, and air is preferably supplied to them after it has passed through the air ducts 34′ behind the refractory plates 39′. Air may be supplied to the ducts 34′ from below the grate through an inlet 41, its direction of travel being clearly indicated by the arrows. I have found that the combination of refractory imperforate plates 39′ in combination with the perforated tuyère blocks 40 materially improves furnace conditions both from the standpoint of operating efficiency and long life. It will be understood that the perforated or tuyère blocks are so disposed as to lie adjacent the fuel zone whereby the preheated air may be directly introduced into the combustion chamber and the fuel zone.

With the forms of the invention illustrated in Figures 9 to 12, as with the other forms referred to, the air supply and thickness of the highly heat conductive lining would be determined in accordance with the operating conditions and will always be such as to insure the maintenance of a temperature condition adjacent the refractory lining such as to insure fusing of the ash or slag and the consequent formation of a protective layer between the refractory material and the interior of the combustion chamber. At the same time, it has been found that the admission of air through perforated or tuyère blocks will effectively prevent the adherence of clinkers, thereby improving the operating characteristics of the furnace.

At the present time it is not uncommon in the art to which the present invention relates to position a plurality of powdered fuel burners tangentially with respect to a combustion furnace or chamber so as to produce a swirling motion in the center thereof, to thereby mix the fuel and permit burning without the necessity of resorting to an extremely high setting in order to accomplish complete combustion. With such furnaces, it has been attempted to utilize water cooled refractories, but due to the insufficiency of the cooling, or difficulties encountered by reason of clogging of the water pipes, such installations have not been entirely satisfactory. It will be apparent to those skilled in the art that the present invention is applicable to installations of this character, or to other installations employing either powdered fuel, solid fuel, liquid fuel or gaseous fuel, the utility of the invention not being limited with respect either to the type of burner or the arrangement thereof, the character of the fuel, or the specific furnace construction.

While I have illustrated the invention as applied to certain forms of furnaces, it will be understood that it may be extended to other types, such as enameling smelters, rotary kilns, converters, air furnaces and the like, as will be readily apparent.

The advantages of the invention arise from an improved furnace structure and method of operating the same whereby a predetermined relationship is established between the circulation of cooling air and the heat conductivity such as to maintain at all times a protective lining within the furnace.

I claim:

1. The method of protecting walls of silicon carbide from oxidation and destruction in a metallurgical furnace wherein they are employed and at a temperature above which silicon carbide refractories ordinarily oxidize which comprises the step of conducting the heat away from the exposed face of the silicon carbide at a rate sufficient to insure the

maintenance thereover of a protective layer congealed thereon from basic slags and metal oxides coming into contact therewith and to protect the silicon carbide from destructive reaction therewith.

2. The method of protecting walls of silicon carbide from oxidation and destruction in a metallurgical furnace wherein they are employed and at a temperature above which silicon carbide refractories ordinarily oxidize which comprises the step of conducting the heat away from the exposed face of the silicon carbide at a rate sufficient to insure the maintenance thereover of a protective layer congealed thereon from basic slags and metal oxides coming into contact therewith and to protect the silicon carbide from destructive reaction therewith by the circulation of a current of air back of the exposed face thereof.

In testimony whereof I have hereunto set my hand.

CLARENCE E. HAWKE.