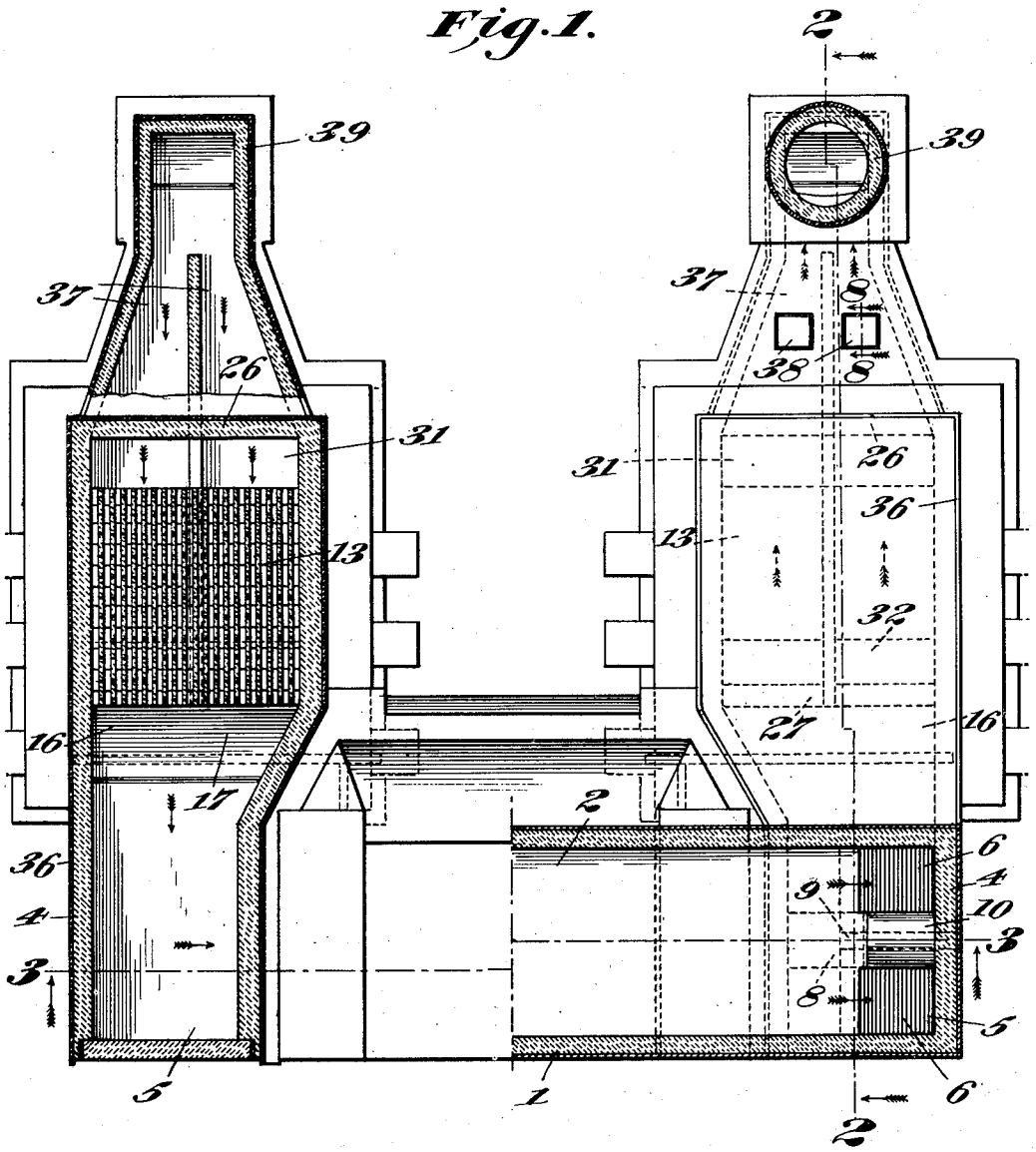
May 30, 1933. W. C. FRANK ET AL 1,911,495

OPEN HEARTH FURNACE

Filed April 8, 1931 5 Sheets-Sheet 1

Fig. 1.



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OPEN HEARTH FURNACE

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Fig. 2.

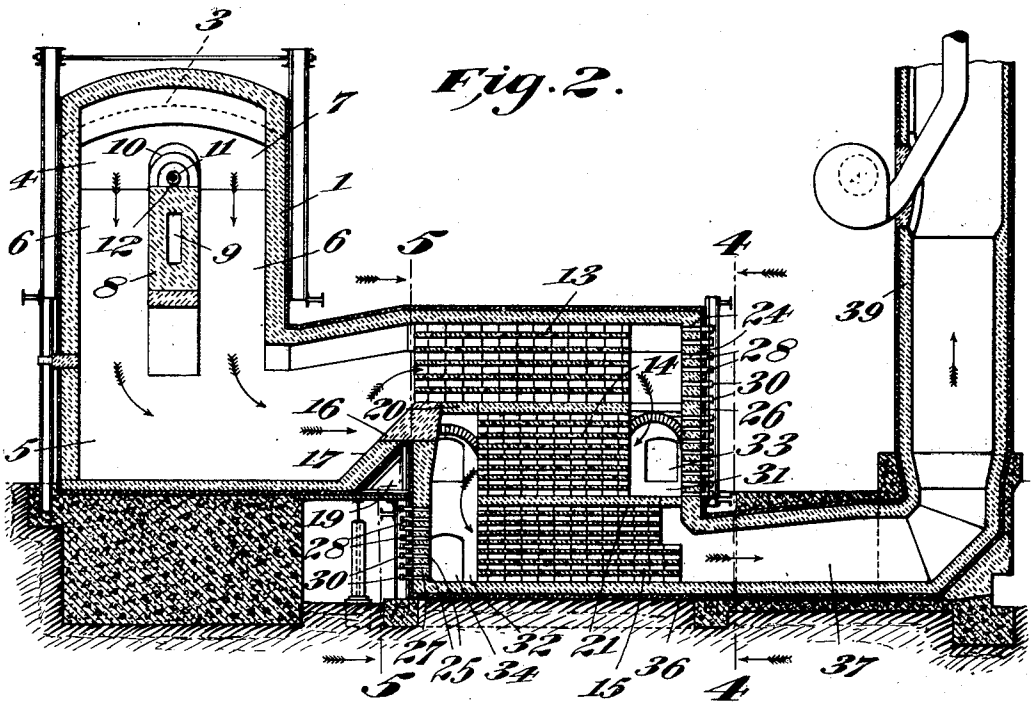
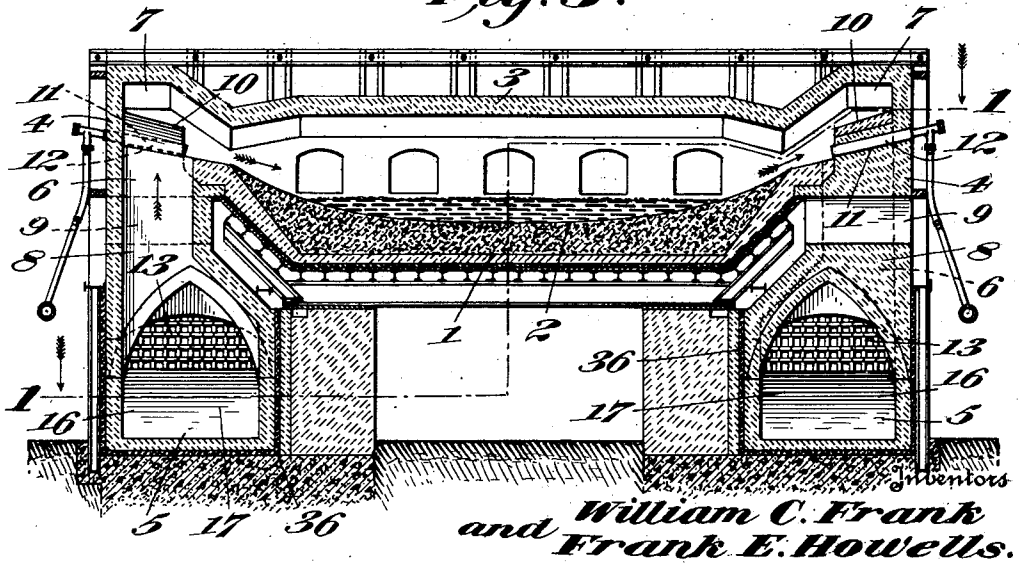


Fig. 3.



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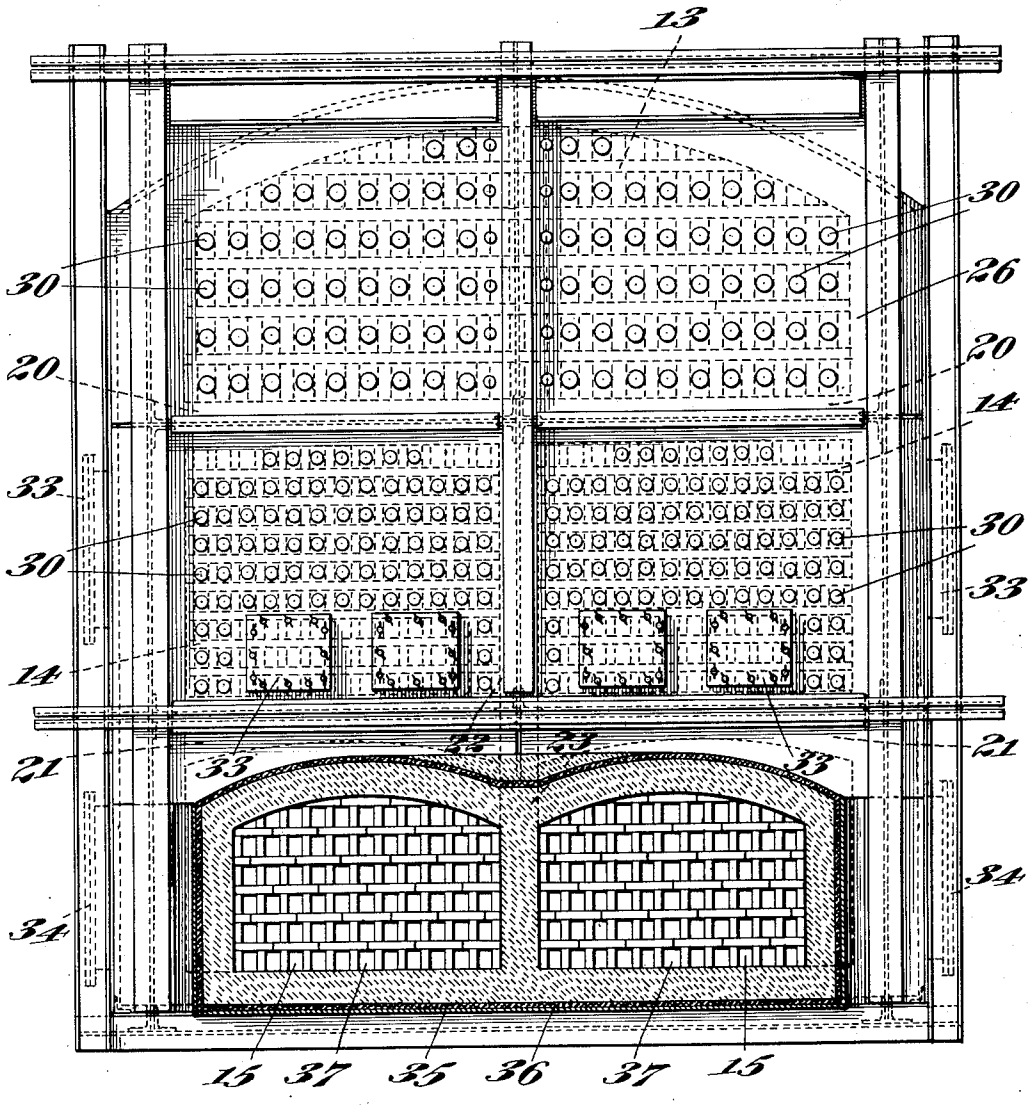
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OPEN HEARTH FURNACE

Filed April 8, 1931 5 Sheets-Sheet 3

Fig. 4.



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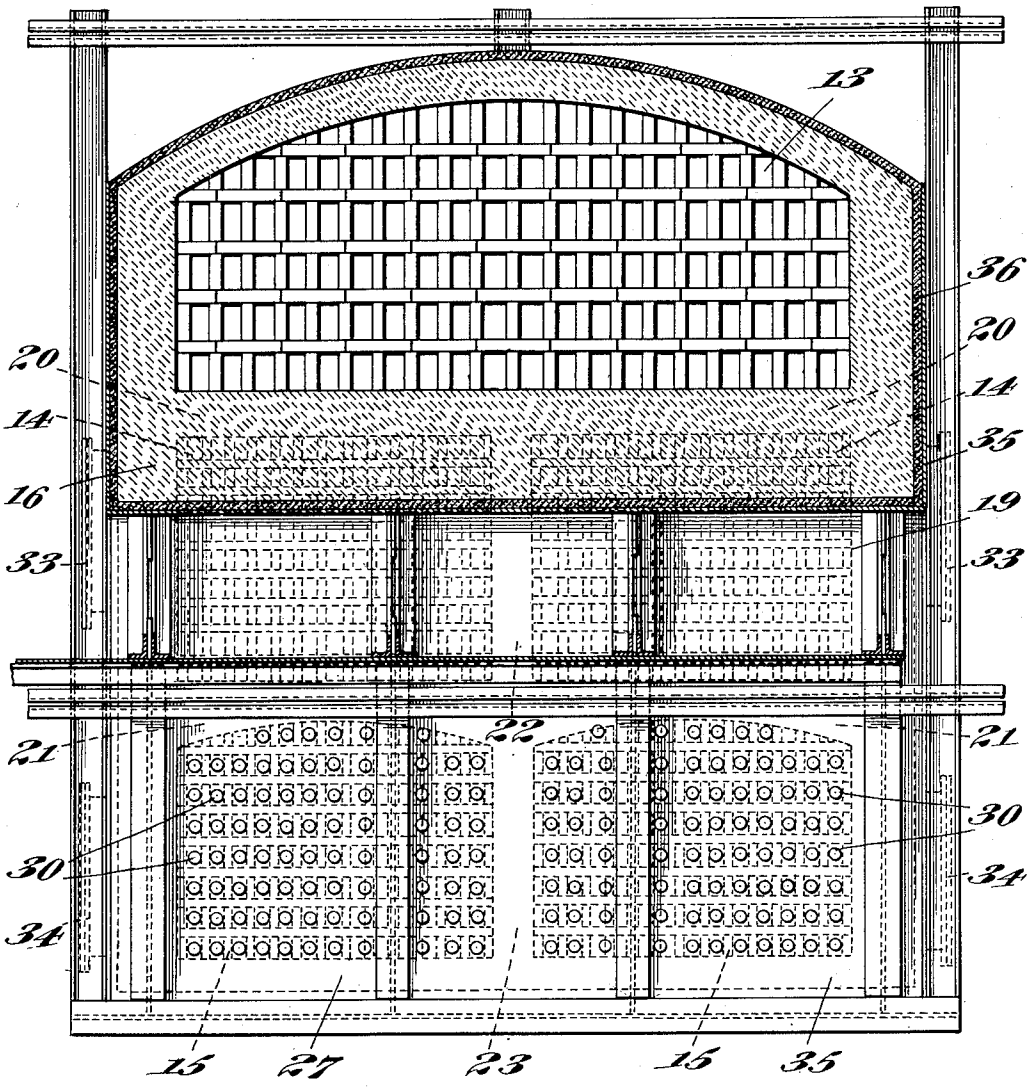
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OPEN HEARTH FURNACE

Filed April 8, 1931 5 Sheets-Sheet 4

Fig. 5.



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OPEN HEARTH FURNACE

Filed April 8, 1931 5 Sheets-Sheet 5

Fig. 6.

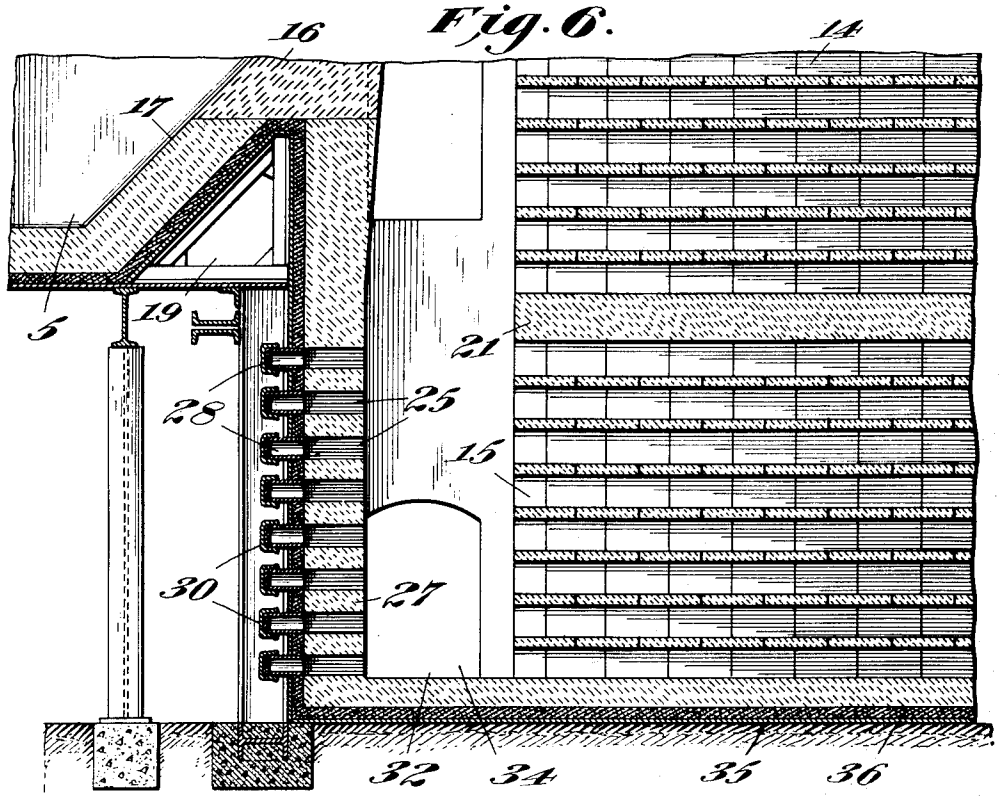


Fig. 7.

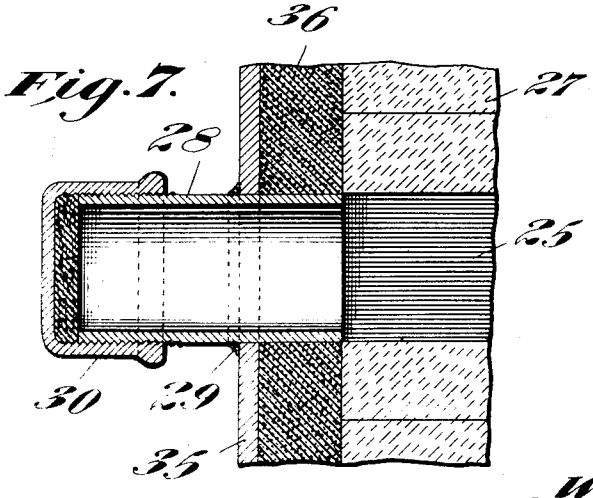
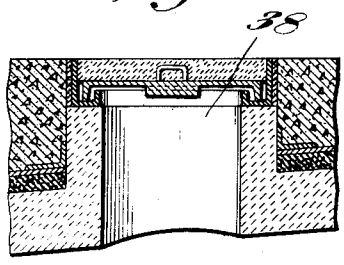


Fig. 8.



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UNITED STATES PATENT OFFICE

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OPEN HEARTH FURNACE

Application filed April 8, 1931. Serial No. 528,584.

Our invention relates to improvements in open hearth furnaces of the regenerative type having regenerators which are adapted to conserve the heat and add to the temperature of the furnaces for the treatment of iron and steel or the like, wherein air and gas or other gaseous or vaporizable combustibles are received at one end and directed over the "hearth" or "bath" and then the off gases discharged from the other end of the furnace.

Regenerators at the opposite ends of the furnace are adapted to heat the incoming air and gases before they enter the furnace, while the off gases from the furnace heat the regenerators at the opposite end of the furnace, the flow being reversed as the incoming air cools the regenerators to a certain temperature at that end of the furnace.

In the usual open hearth furnace practice in which producer gas or the like is used it has been the usual custom to have a pair of regenerators at each end of the furnace, one for heating the gas, and the other for heating the air.

With our invention however the air alone is heated.

One of the objects of our invention relates to forming the regenerators of checker brick work with a plurality of passes and sections, in such a way as to greatly increase the length of the heating ducts whereby a better and more economical manner of heating the air is obtained and a higher temperature for the air passing therethrough secured.

Another object of our invention relates to forming the first pass of the regenerator which is first subjected to the off gases of larger sized brick and flue ducts or passages and of firebrick capable of a higher resistance as to the melting point than those of which the remaining passes of the regenerator are formed, such bricks may be composed of chromite, magnesia, alumina, bauxite or silica or the like, although the first three kinds of brick are the most desirable on account of their higher temperature resistance as to the melting point.

Another object of our invention relates to the construction of the nozzles and caps for the cleanout holes in the front and back end walls of the regenerators.

Another object of our invention relates to forming a cooling passage or channel through the middle buttress between the uptake which provides a means for ventilating the space between the furnace bottom and the slag pocket roof, and also to act as a chill for the middle buttress which supports or stiffens the furnace end wall.

Another object of our invention relates to forming the slag pockets of ample capacity and so designed that the off gases have a comparatively long passage before entering the ducts of the first pass of the regenerator. This long passage in conjunction with the slow velocity, because of the large volume slag pocket, helps to separate much of the suspended slag particles before entrance to the checkers.

Another object of our invention relates to the manner of forming an air-cooled bridge wall beneath one end of the slag-pocket and under one end of the first pass of the regenerator which is open at each end to allow a cooling medium to circulate therein and the heated air to easily escape from each end of the bridge wall.

Another object of our invention relates to the manner of inclosing and insulating the walls of the regenerators.

Other objects will appear hereinafter.

Having thus given a general description of our invention we will now, in order to make the matter more clear, refer to the annexed five sheets of drawings in which like characters of reference indicate like parts.

Figure 1 is a sectional plan taken substantially on the line 1—1 of Fig. 3;

Fig. 2 is a transverse section taken on the line 2—2 of Fig. 1;

Fig. 3 is a longitudinal section through the furnace taken on the line 3—3 of Fig. 1;

Fig. 4 is a vertical section drawn on a larger scale taken at the front end of one of the regenerators, the section being taken on the line 4—4 of Fig. 2;

Fig. 5 is a vertical section drawn on the same scale as Fig. 4, taken at the back end of one of the regenerators, and taken on the line 5—5 of Fig. 2;

Fig. 6 is an enlarged detail section showing the back wall and adjacent portions of one of the regenerators and a portion of the slag pocket taken on the same line as Fig. 2;

Fig. 7 is a detail section drawn on an enlarged scale of one of the nozzle closures for one of the cleanout holes in the walls of the regenerator in alignment with the flue passages; and,

Fig. 8 is a detail section of one of the manhole constructions taken on the line 8—8 of Fig. 1.

It will be understood that the construction of both ends of the furnace and the regenerators therefor are similar and a description of one end will apply to both.

Referring now to the characters of reference on the drawings the furnace generally is indicated as 1, the hearth as 2, the roof as 3 and the end walls as 4. Beneath each end of the furnace proper is a slag-pocket 5, communicating with the ends of the furnace by means of a pair of uptakes 6 and port openings 7. The uptakes are separated by means of a buttress 8 having a cooling passageway or tunnel formed therein at an intermediate point as at 9, between the end of the furnace and the furnace bottom adapted to provide means for ventilating the space between the furnace bottom and the slag-pocket roof and also to act as a chill for the middle buttress.

Mounted upon or formed as a part thereof and extending above the buttress into the air port openings 7 is an arched portion 10 formed with a burner opening 11 for receiving a burner 12 by means of which the furnace is fired, which is supplied with suitable fuel such as gas, oil, tar or the like.

The slag-pockets 5 at each end of the furnace are of ample capacity and are so designed that the off gases from the furnace have a comparatively long passage before entering the first checker brick pass of the regenerators. This long passage in conjunction with the slow velocity, because of the large volume or area of the slag-pockets, helps to separate much of the suspended slag particles before entrance to the first pass of the regenerators.

The arrangement and construction of each of our regenerators is what is known as a single surface type, in which the heat of the outgoing or off gases is applied to and absorbed by the checkers, walls, etc. and given back to the incoming cold air from the same surfaces of the checkers, walls, etc. which received the heat.

These regenerators as above described differ from heat recuperators, which are of the double surface type, said recuperators depending upon the heat transferred or conducted through the materials of which they are composed, the heat being applied to one side of the materials and transmitted through them to the other side thereby the gases or air is heated.

The regenerators in our construction are each formed with three passes 13, 14 and 15 in such a manner as to greatly increase the length of the ducts over the single surface one pass regenerators now in use and thereby increasing the temperature of the air being heated. The upper pass indicated as 13 has its back end extending beyond the lower two passes 14 and 15. It will also be noted that the front end of the lower pass 15 extends beyond the passes 13 and 14 and in staggered relation with the top pass 13, thereby forming a chamber at each end of the regenerator above the front portion of the pass 15 and below the rear portion of the upper pass 13, as clearly indicated in Fig. 2 of the drawings.

Built directly under the back end of the first pass 13 and extending upwardly from the front end of the bottom of the slag-pocket is a bridge wall 16 having an inclined surface 17 which is adapted to deflect the flow of off gases and further assist in separating the suspended slag particles and to prevent a ledge being formed and accumulations to build up and choke the entrance of the gases to the checkers of the first pass 13. The bridge wall 16 is provided with a tubular air cooled passageway 19 which is open at each end to allow for the free circulation of cold air therein to protect the bridge wall and cool any slag deposited thereon.

As the upper pass 13 of the regenerator is subjected to intense heat by the off gases the bricks of which it is formed and the flue ducts therein are made of larger size than those of which the other two passes 14 and 15 are constructed, the fire brick being formed of material capable of a higher resistance as to the melting point than those of which the other two passes of the regenerator are formed.

The three passes of the regenerators are divided horizontally by means of baffle walls 20 and 21. The upper pass 13 extends entirely across the top of the regenerator and is of larger capacity than the lower two which are both divided centrally by means of walls 22 and 23.

Apertures 24 and 25 are formed in the front and rear walls 26 and 27 respectively in alignment with the ducts of the regenerators, to

allow for inspection and for the insertion of a tool for cleaning out the ducts from time to time as it becomes necessary. These apertures are closed by means of nozzles 28 welded to the wall casing as at 29 and having caps 30 screwed on the outer ends for closing the same. This manner of forming individual cleanout holes for the ducts of the regenerators has the advantage over large doors heretofore used, as the doors allow too much heat and air leakage when open, as the working conditions of the men engaged in cleaning the regenerators when doors are used is very severe.

When it is desired to clean the ducts of the regenerators, a cap 30 is removed and that particular duct is cleaned by means of a steam or air lance or the like, the cap is then replaced. This continues until all of the ducts have been cleaned, the dirt accumulating in the chambers 31 and 32 can easily be removed through doorways 33 and 34 provided in the walls of the regenerator chamber.

To prevent air infiltration and cut down the heat radiation, we have encased each of the regenerator chambers and slag-pockets with a steel casing 35 and an insulation 36. This steel casing is welded together at the joints to be waterproof below the ground level. In this manner the sides of the steel casing are exposed to the air for cooling and are accessible for repairs, etc., and any warping of the steelwork due to high temperature is eliminated.

The front end of the lower pass 15 of each of the regenerators are each connected by means of a divided conduit 37 having cleanout man-holes formed therein as at 38. This divided conduit 37 extends to an "Isley stack control" 39 which controls the admission and flow of cold air and the exhaust of the off gases to and from the furnace. This "Isley stack control" which is of standard construction forms no part of the present invention will be readily understood by referring to Patent No. 1,762,299, issued to G. H. Isley, June 10, 1930.

Having thus given a description of our invention we will now describe the operation:

Referring to Figs. 1, 2 and 3 of the drawings; assuming that the incoming air and off gases are flowing through the furnace from left to right as indicated by the arrows, the burner at the left hand side of the furnace being turned on and that at right hand side of the furnace cut off, cold air from the Isley control is forced through the divided conduit 37 at the left hand side of the furnace and enters the regenerator and flows in a zig-zag or sinuous manner from the lower pass 15 of the regenerator, which has been previously heated by the off gases of combustion, into the intermediate pass 14 and then into the upper pass 13, during which period the air becomes highly heated as it passes through the ducts of the regenerator. The highly heated air then flows through the slag-pocket 5 and then to the uptakes 6 and port opening 7 where it engages the flame of the burner 12 at the left hand end of the furnace and is deflected by the Venturi throat of the furnace in a downwardly direction onto and over the surface of the bath, thence it passes out of the right hand end of the furnace through the port opening 7, uptakes 6 into slag-pocket 5 where it impinges against the inclined surface 17 of the air cooled bridge wall 16 and is deflected upwardly into and through the first pass 13 of the regenerator thence into chamber 31, pass 14, chamber 32 and lower pass 15 thereby heating the checker brick work of the regenerator, from which point the off gases are conveyed through conduit 37 to the "Isley stack control" 39 and exhausted.

After the furnace has been operated in the manner described for the proper or desired length of time to cool the regenerator at the left hand end of the furnace to a certain temperature, the burner at the right hand end of the furnace will be opened and the burner at the opposite end of the furnace closed. The flow of air and off gases will then be reversed by means of the "Isley stack control" whereupon a reversal of currents takes place and the air and gases will flow through the furnace from right to left and in the direction opposite to the arrows on the drawings.

Although we have shown and described our invention in considerable detail, we do not wish to be limited to the exact and specific details shown and described, but may use such substitutions, modifications or equivalents thereof as are embraced within the scope of our invention, or as pointed out in the claims.

Having thus described our invention what we claim and desire to secure by Letters Patent is:

1. In a regenerative furnace, a three pass regenerator of the single surface type connected to each end of the furnace arranged with their passes superimposed in vertical alignment, one of the passes of the regenerator being of greater capacity and formed of a different kind of refractory material extending the full length of the pass and having a greater heat resistance than the other two passes, baffle walls extending longitudinally between each of the passes of the regenerators, a connection between the upper and central pass at one end of the regenerators, a connection between the lower and central pass at the opposite end of the regenerators and ducts extending longitudinally through each pass adapted to receive and provide a sinuous path for the flow of air to the furnace and to receive the flow of off gases of combustion when the flow of air to the furnace is reversed.

2. In a regenerative furnace, a three pass regenerator of the single surface type connected to each end of the furnace and arranged with their passes superimposed in vertical alignment, a chamber connecting the top pass with the central pass at one end of the regenerators, a chamber connecting the lower pass with the central pass at the opposite end of the regenerators, a baffle wall extending longitudinally between each of the passes of the regenerators, ducts extending longitudinally through each of the passes of the regenerators adapted to receive and provide a sinuous path for the flow of air to the furnace and to receive the flow of off gases of combustion when the flow of air to the furnace is reversed, the upper pass of the regenerators being of greater capacity and formed of a different kind of refractory material throughout the length of the pass and having a greater heat resistance than the lower two passes, said ducts in the upper pass being of larger size than the ducts in the lower two passes.

3. In a regenerative furnace, a three-pass regenerator of the single surface type connected to each end of the furnace arranged with their passes superimposed in vertical alignment, baffle walls extending longitudinally between adjacent passes, a connection between the ends of two of the passes at one end of each of the regenerators, a connection between one of the said two passes and an adjacent pass at the opposite end of each of the regenerators, the upper pass of the regenerator having ducts extending longitudinally across the entire width of regenerator, a central wall dividing each of the lower passes and ducts of smaller size than those through the upper pass extending longitudinally through the lower passes.

4. In a regenerative furnace, a reversing regenerator connected to each end of the furnace, a plurality of passes arranged in vertical alignment for each regenerator, a plurality of ducts in each of the passes of the regenerator, a wall surrounding the regenerators, a metal casing surrounding the regenerator walls an aperture in the wall and metal casing of the regenerators in alignment with each of the ducts, a nozzle for each aperture having its inner end welded to the casing, and a cap secured to the outer end of each nozzle for closing the apertures.

5. In a regenerative furnace, a reversing regenerator of the single surface type connected to each end of the furnace, a plurality of passes arranged with their passes superimposed in vertical alignment for each regenerator, ducts extending longitudinally in each of the passes of the regenerators, a connection between a pair of adjacent passes at each end of the regenerators, a wall surrounding the regenerators, insulation surrounding the walls of the regenerators, a metal casing surrounding the insulation, an aperture in the walls of the regenerators extending through the insulation and metal casing in alignment with each of the ducts, a nozzle for each aperture having its inner end welded to the casing, and a cap screwed on the outer end of each nozzle for closing the apertures.

6. In a regenerative furnace, a three-pass reversing regenerator at each end of the furnace, a chamber connecting the upper and central pass at one end of the regenerators, a chamber connecting the lower and central pass at the other end of the regenerators, a slag-pocket between each regenerator and the furnace, a bridge wall in each slag-pocket beneath the upper pass of the regenerator, and a tubular cooling passageway formed in the bridge wall.

7. In a regenerative furnace, a single surface three-pass regenerator connected to each end of the furnace, a plurality of longitudinal superimposed passes formed in the regenerator, the upper pass of each of the regenerators being of greater length and capacity than the other passes of the regenerator, a slag-pocket between each regenerator and the furnace, a bridge wall in each slag-pocket having an inclined face extending upwardly to the lower edges of the upper pass of the regenerator, and a tubular cooling passageway formed in the bridge wall.

8. In a regenerative furnace, a single surface three-pass reversing regenerator at each end of the furnace, said regenerators each formed with the plurality of passes superimposed in vertical alignment, the upper pass of each regenerator being longer and of greater capacity than the other passes of the regenerator, a connection between a pair of the passes at each end of the regenerators, a slag-pocket between each regenerator and the furnace, a bridge wall in each slag-pocket having an inclined side face extending upwardly to the upper pass of each regenerator, and a tubular cooling passageway formed in each bridge wall.

9. In a regenerative furnace provided with a hearth, a reversing regenerator connected to each end of the furnace, a slag-pocket between each regenerator and the furnace hearth, a pair of uptakes between each slag-pocket and the ends of the furnace hearth, a buttress between each pair of uptakes, and a tunnel formed in each buttress above the slag pocket between the end of the furnace and the bottom of the furnace hearth.

10. In a regenerator furnace provided with a hearth, a reversing single surface regenerator, connected to each end of the furnace, a slag-pocket between each regenerator and the ends of the furnace hearth, a bridge wall formed in each slag-pocket, a tubular cooling passageway formed in each bridge wall, a pair of uptakes between each slag-pocket and the ends of the furnace hearth, a buttress be-

tween each pair of uptakes, and an air cooling tunnel formed in each buttress between the ends of the furnace and bottom of the furnace hearth.

11. In a regenerative furnace provided with a hearth, an air reversing regenerator connected to each end of the furnace, a plurality of passes superimposed in vertical alignment for each regenerator, baffle walls between adjacent passes of the regenerators, a chamber connecting an upper and an intermediate pass at one end of each of the regenerators, a chamber for connecting a lower and said intermediate pass at the opposite end of each of the regenerators, longitudinal ducts formed in the passes of the regenerators, a wall surrounding each regenerator, apertures in the front and rear walls of the regenerators in alignment with the ducts of the regenerators, a nozzle having a cap screwed thereon for closing each aperture, a slag pocket between each regenerator and the furnace, a pair of uptakes between each of the slag-pockets and the end of the furnace, a buttress between each pair of uptakes, and an air cooling tunnel formed in each buttress between the ends of the furnace and the bottom of the furnace hearth.

12. In a regenerative furnace provided with a hearth, an air reversing regenerator connected to each end of the furnace, said regenerators each formed with three passes superimposed in vertical alignment, longitudinal baffle walls between adjacent passes of the regenerators, a chamber at one end of each of the regenerators for connecting the upper and central passes together, a chamber at the opposite end of each of the regenerators for connecting the central and lower passes together, longitudinal ducts formed in each of the passes of the regenerators, an insulated wall with a casing surrounding each of the regenerators, apertures in the front and rear walls of the regenerators in alignment with the ducts of the regenerators, a nozzle welded to the casing having a cap screwed thereon for closing each aperture, a slag-pocket between each regenerator and the furnace, a pair of uptakes between each of the slag-pockets and the end of the furnace, a buttress between each pair of uptakes, and an air cooling tunnel formed in each buttress between the ends of the furnace and the bottom of the furnace hearth.

13. In a regenerative furnace provided with a hearth, an air reversing regenerator connected to each end of the furnace, said regenerators each formed with three passes superimposed in vertical alignment, longitudinal baffle walls between adjacent passes of the regenerators, a chamber for connecting two of the passes at one end of each of the regenerators, a chamber for connecting one of the said two passes with another pass at the opposite end of each of the regenerators, longitudinal ducts formed in each of the passes of the regenerators, an insulated wall with a casing surrounding each of the regenerators, apertures in the front and rear walls of the regenerators in alignment with the ducts of the regenerators, a nozzle welded to the casing having a cap screwed thereon for closing each aperture, a slag-pocket between each regenerator and the furnace, a bridge wall in each slag-pocket having an inclined side face extending upwardly to the base of the first pass of the regenerator, a tubular cooling passageway formed in each bridge wall, a pair of uptakes between each of the slag-pockets and the end of the furnace, a buttress between each pair of uptakes, and an air cooling tunnel formed in each buttress between the ends of the furnace and the bottom of the furnace hearth.

14. In a regenerative furnace, a reversing regenerator connected to each end of the furnace, three passes superimposed in vertical alignment formed in each regenerator, a chamber at one end of each of the regenerators for connecting the upper and central passes together, a chamber at the opposite end of each of the regenerators for connecting the central and lower passes together, a baffle wall between the top and adjacent passes extending over and forming the top of one of the chambers at one end of each of the regenerators, a baffle wall between the lower and adjacent passes extending under and forming the bottom of the other chamber at the opposite end of each of the regenerators, and ducts extending longitudinally through each pass adapted to form a sinuous path to receive the flow of air to the furnace and the off gases of combustion from the furnace.

15. In a regenerative furnace, a single surface reversing regenerator connected to each end of the furnace, three passes superimposed in vertical alignment formed in each regenerator, a chamber for connecting two of the passes at one end of each of the regenerators, a chamber for connecting one of the said two passes with an additional pass at the opposite end of each of the regenerators, ducts extending longitudinally through each pass adapted to form a sinuous path to receive the flow of air to the furnace and the off gases of combustion from the furnace, a slag-pocket of large area between each of the regenerators and the furnace, a pair of uptakes between each of the slag-pockets and the end of the furnace, and an air cooled buttress between the uptakes and a burner mounted at the top of each buttress for heating the furnace.

16. A regenerative furnace provided with a hearth, a three pass single surface reversing regenerator connected to each end of the furnace having horizontal passes of substantially the same cross-sectional area superimposed in vertical alignment, the upper pass of

each of the regenerators extending beyond the back end of the other two passes, a slag-pocket between each regenerator and the end of the furnace hearth, a bridge wall in each slag-pocket having an inclined face extending upwardly to the lower edge of the upper pass of each regenerator, a direct connection between the slag-pocket and the extending back end of the upper pass of each of said regenerators, a chamber at the front end of each of the said regenerators for connecting the upper and intermediate passes together, and a chamber below each of the extending ends of the upper pass of the regenerators for connecting the ends of the lower and the said intermediate passes together.

17. In a regenerative furnace provided with a hearth, a three pass single surface reversing regenerator connected to each end of the furnace having horizontal passes superimposed in vertical alignment, the upper pass of each of the regenerators extending beyond the back end of the other two passes and the lower pass of each regenerator extending beyond the forward end of the upper two passes of each of the regenerators, a slag-pocket between each regenerator and the end of the furnace hearth, a bridge wall in each slag-pocket having an inclined face extending upwardly to the lower edge of the upper pass of each regenerator, a connection between the slag-pocket and the back end of the upper pass of each regenerator, a chamber above the forward extending end of the lower pass for connecting the upper and said intermediate passes of each of the regenerators together, and a chamber below the extending back end of the upper pass for connecting the lower and said intermediate passes of each of the regenerators together.

18. In a regenerative furnace provided with a hearth, a three-pass reversing regenerator connected to each end of the furnace having horizontal passes superimposed in vertical alignment, the upper pass of each of the regenerators extending beyond the back end of the other two passes and the lower pass of each regenerator extending beyond the forward end of each of the upper two passes of the regenerators, a baffle wall extending longitudinally between the upper and intermediate passes extending substantially the full length of the upper pass, a baffle wall between the lower and said intermediate passes extending longitudinally the full length of the lower pass in each regenerator, a bridge wall in each slag-pocket having an inclined face extending upwardly to the lower edge of the upper pass of each regenerator, a connection between the slag-pocket and the back end of the upper pass of each of the regenerators, a chamber above the forward extending end of the lower pass for connecting the upper and said intermediate passes of each of the regenerators together, and a chamber below the extending back end of the upper pass for connecting the lower and said intermediate passes of each of the regenerators together.

19. In a regenerative furnace, a three pass reversing regenerator connected to each end of the furnace having horizontal passes superimposed in vertical alignment, the upper pass of each of the regenerators extending beyond the back end of the other two passes and the lower pass extending beyond the forward end of each of the upper and said intermediate passes of the regenerators, a wall surrounding each regenerator, a metal casing surrounding each of the regenerator walls, a chamber above the forward extending end of the lower pass between the ends of the upper and intermediate passes and the front end wall for connecting the ends of the passes together, a chamber below the extending back end of the upper passes between the ends of the lower and said intermediate passes and the back wall of the regenerators for connecting the lower and said intermediate passes together, an aperture in the front end wall of each of the regenerators in alignment with each of the ducts of the upper and intermediate passes of the regenerators, an aperture in the back wall in alignment with each of the ducts in the lower pass, a nozzle for each aperture having its inner end welded to the casing, and a cap secured to the outer end of each nozzle for closing the apertures.

20. In a regenerative furnace provided with a hearth, a three pass reversing regenerator connected to each end of the furnace provided with ducts forming horizontal passes superimposed in vertical alignment, the upper pass of each of the regenerators extending beyond the back end of the other two passes and the lower pass extending beyond the forward end of each of the upper and said intermediate passes of the regenerators, a slag-pocket between each regenerator and the end of the furnace hearth, a bridge wall in each slag-pocket having an inclined face extending upwardly to the lower edge of the upper pass of each regenerator, a connection between the slag-pocket and the back end of the upper pass of each of the regenerators, a wall surrounding each regenerator, a metal casing surrounding the regenerator walls, a chamber above the forward extending end of the lower pass between the ends of the upper and intermediate passes and the front end wall for connecting the ends of the passes together, a chamber below the extending back end of the upper passes between the ends of the lower and said intermediate passes and the back wall of the regenerators for connecting the lower and said intermediate passes together, an aperture in the front end wall of each of the regenerators in alignment with each of

the ducts of the regenerators of the upper and intermediate passes, an aperture in the back wall in alignment with each of the ducts in the lower pass, a nozzle for each aperture having its inner end welded to the casing, and a cap secured to the outer end of each nozzle for closing the apertures.

In testimony whereof we hereunto affix our signatures.

WILLIAM C. FRANK.
FRANK E. HOWELLS.