

Oct. 30, 1956

K. P. H. FREY
REGENERATIVE AIR HEATER

2,768,822

Filed Oct. 8, 1951

5 Sheets-Sheet 1

FIG. 1

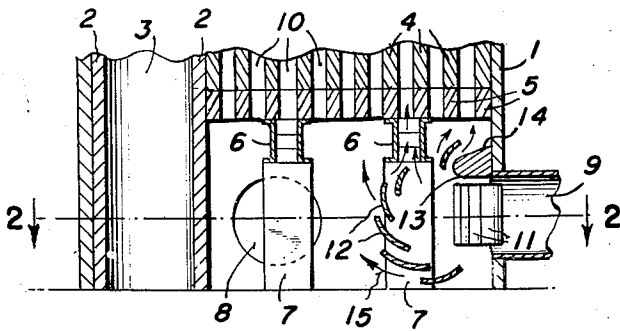


FIG. 3

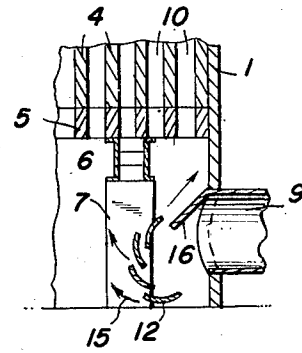


FIG. 2

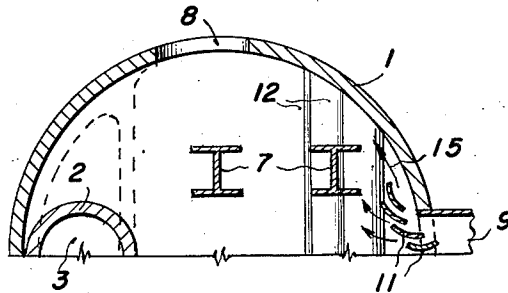


FIG. 5

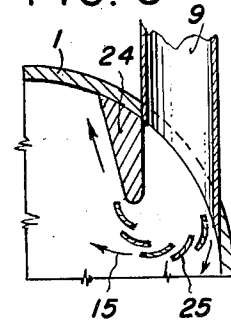


FIG. 4

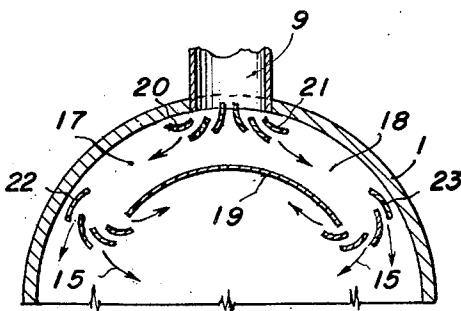
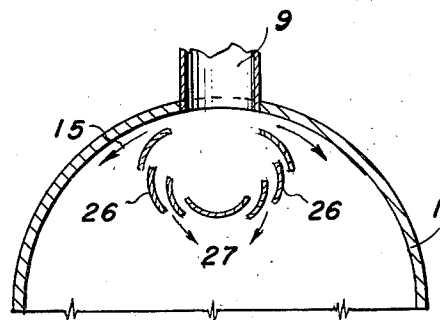


FIG. 6



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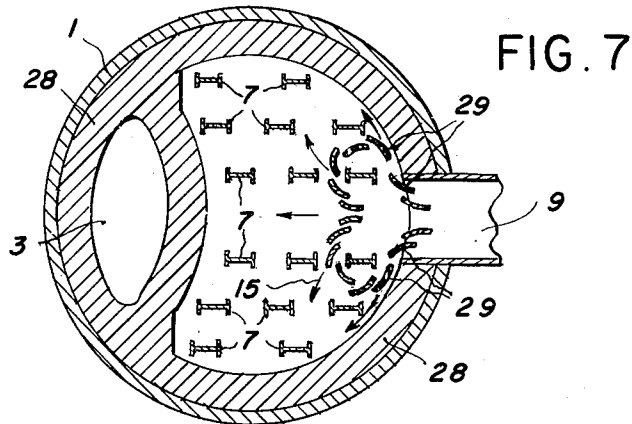
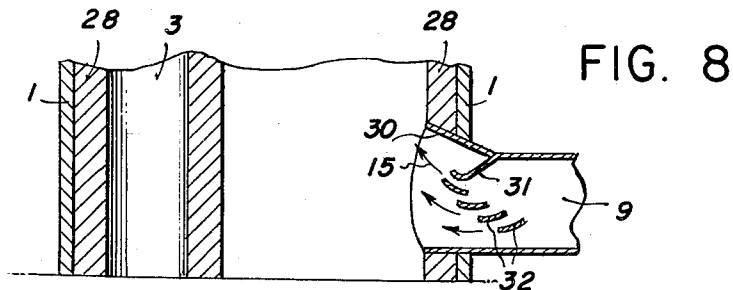
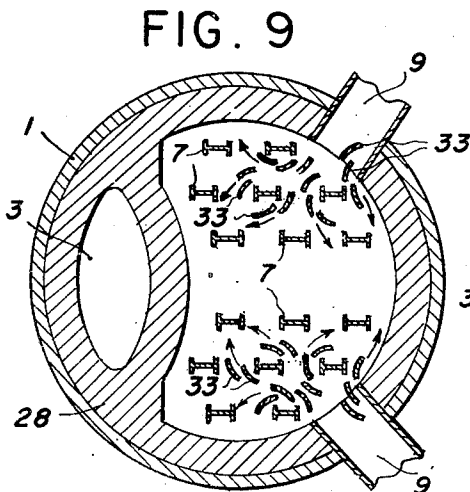
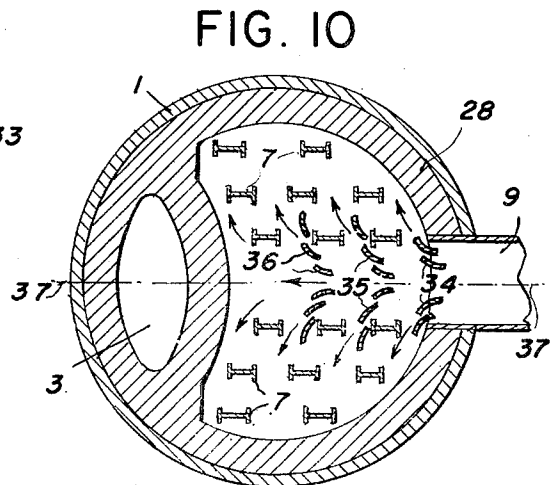
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FIG. 11

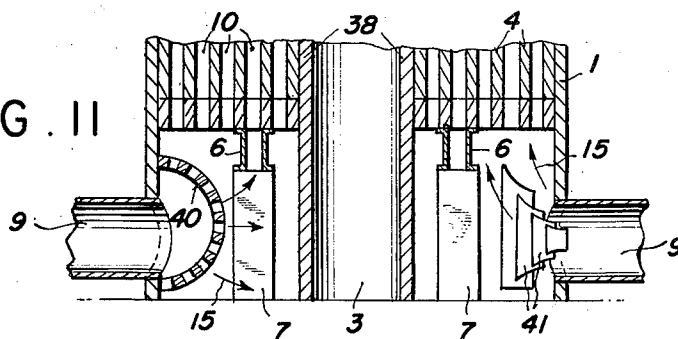


FIG. 12

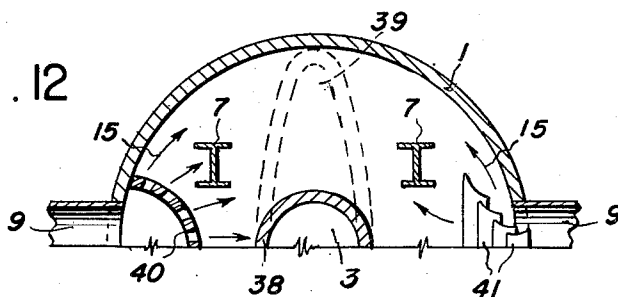


FIG. 13

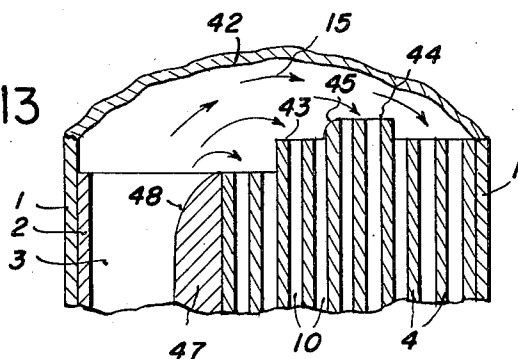


FIG. 14

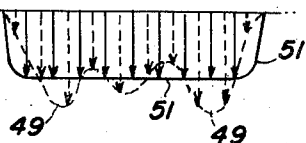


FIG. 15



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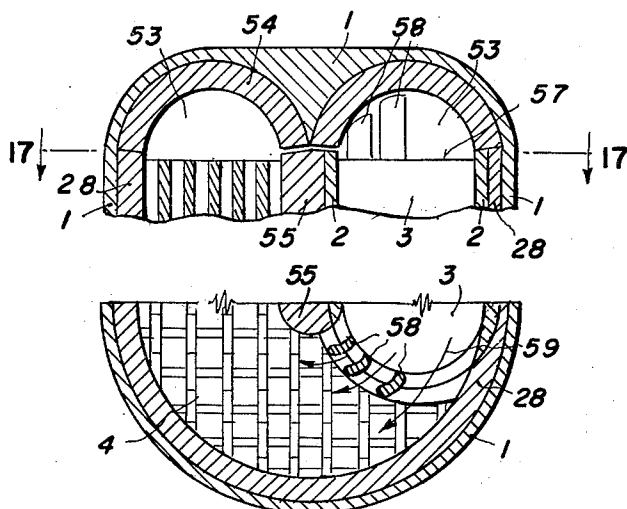


FIG. 16

FIG. 17

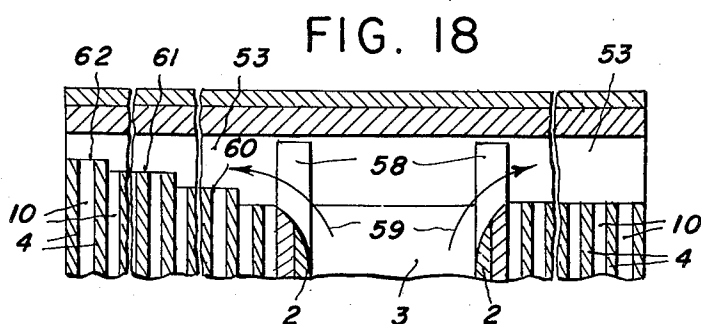


FIG. 18

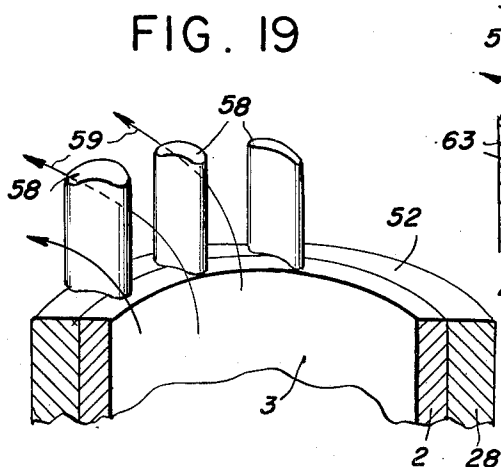


FIG. 19

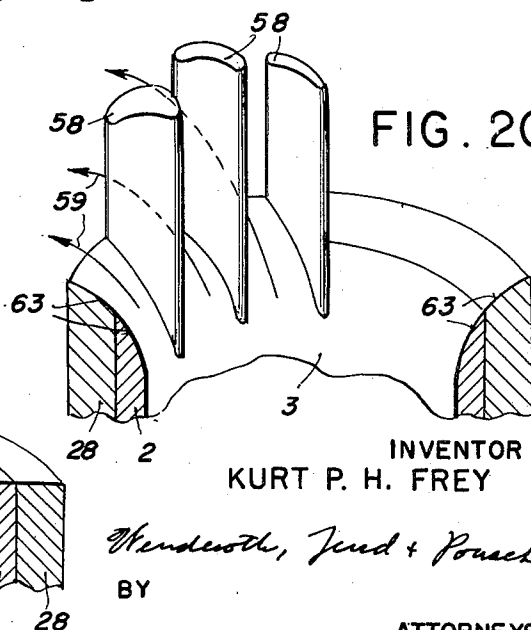


FIG. 20

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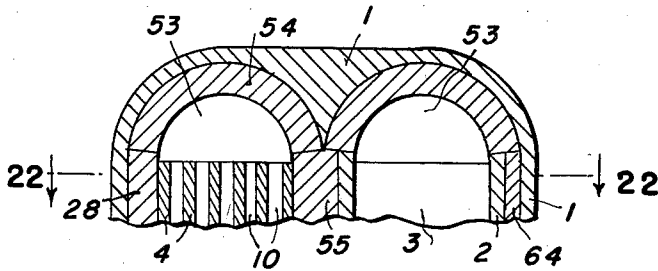


FIG. 21

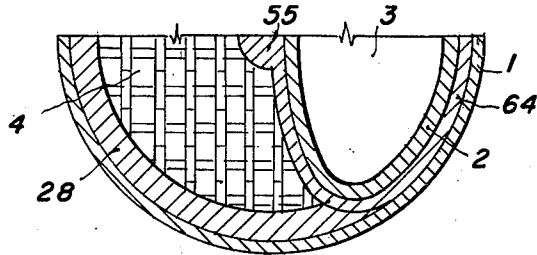


FIG. 22

FIG. 23

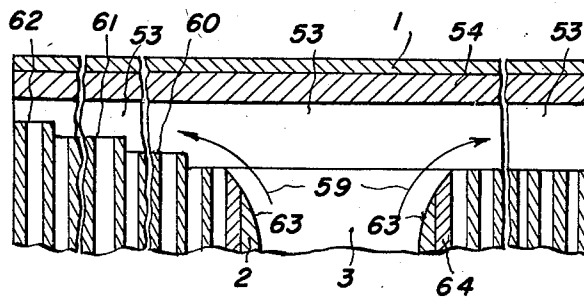


FIG. 24

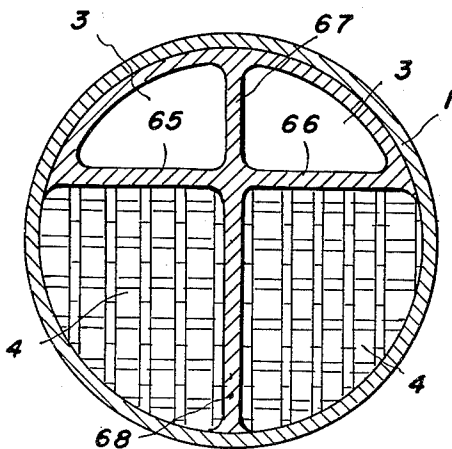
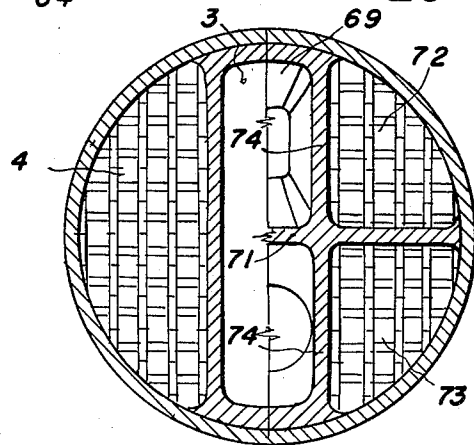


FIG. 25



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REGENERATIVE AIR HEATER

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Application October 8, 1951, Serial No. 250,361

4 Claims. (Cl. 263—19)

This invention relates to regenerative air heaters in general and more particularly to improvements in the flow characteristics, thermal load conditions and utilization thereof.

In heretofore known regenerative air heaters, particularly blast-furnace air heaters (Cowper), it has been found how to eliminate a series of defects in operation and to make operation more economical. It has already been found that for this purpose flow considerations play a part; but it has not heretofore been recognized that the large distribution spaces at both sides of the regenerator are critical for the quality of the flow through the regenerator. With the improved solution of these considerations further steps for obtaining economical air heaters can be attained, such as reduction of operating expenses and of repairs, as well as improved use of masonry, also a lower expenditure of bricks, etc. The favorable effects manifest themselves both for the regulator lining (refractory bricks) and for the hood. Beyond this there is also possible the advantages of increasing of hot-blast temperature in an economical manner and of lowering the exhaust-gas temperature in like manner.

The large distribution spaces at both ends, i. e. generally above and below the regenerator, are of such critical importance because at any particular time, for the inflow to the regenerator, i. e. for the blast period, the space below the grate of the regenerator and for the gas period, the hood space above the regenerator, provide abruptly widened diffusers of large dimensions with deflection of the flow to the extent of 90° or 180°, with reference to the air entry pipe and to the end of the combustion shaft respectively, and because the free cross-section in the regenerator, i. e. the sum of the cross-sections of the masonry channels, likewise with reference to the air entry pipe and to the end of the combustion shaft respectively, represents at any particular time a diffuser whose resistance to flow in the customary and preferred modes of construction does not suffice to attain even an approximation of a uniform distribution of flow in the regenerator. This is even applicable for the favorable case that the inflow into these distribution spaces takes place uniformly or somewhat uniformly, which is, however, frequently not the case of the cold-blast pipe. In the hood space this has special significance because uncontrolled distribution of speed in the hood space easily leads to excessive stresses on the hood, which becomes especially critical; furthermore for the reason that the distribution of speed at the hood wall is completely different during the gas period and the blast period—high speed in the gas period and low speed in the blast period—in which connection at the same time for reasons of temperature the blast has a higher specific gravity than the gas, i. e. cannot displace the gas in the upper part of the hood or can do so only with difficulty.

The mentioned irregular distribution of flow in the regenerator channels manifests itself in amplified form due to the fact that the places with high local speed and

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with low local speed respectively do not coincide. Thus it can occur that identical channels receive a high supply of heat in the gas period, but only little heat-accepting air in the blast period, and vice versa. Since the conduction of heat in the masonry is poor, such operative behavior of air heaters is to be rated as critical.

These new discoveries cause evaluations of air heaters to appear in an entirely new light, and therefore the means for overcoming the recognized defects are of special importance for successful further development of air heaters.

The present invention solves this problem in principle by providing, particularly in the spaces below and above the regenerator respectively, means for influencing the flow which are in part known from the physics of flow and which can, if desired, be built in.

An object of the invention is to modify the conventional refractory construction in a regenerative air heater, particularly a blast furnace such as a Cowper furnace, by providing a series of baffles constructed and arranged to deflect the fluid stream in the furnace into static and eddied zones and thereby make uniform and streamlined the resultant fluid flow, these baffles being provided in cooperation with curved vane deflecting means, the deflecting means comprising a staggered series of such vanes, each on the suction side of the subsequent vane, the resultant curvature of the series being greater than the curvature of any single vane, the overlap of the vanes to each other being sufficient to provide a jet directed velocity vector in a direction substantially tangential to the resultant curvature of the series and in the direction to convert the static and eddied condition into streamline flow, the resultant curvature being defined by the curve which joins the intersections of the chords of the vanes, and said deflecting means being oriented with respect to the direction of the velocity vector of the incident gas stream to provide an angle of attack of the first vanes of the series which is negative.

Other and further objects of the present invention will appear from the more detailed description set forth below, it being understood that such detailed description is given by way of illustration and explanation only and not by way of limitation, since various changes therein may be made by those skilled in the art without departing from the scope and spirit of the present invention.

In accordance with one form of the invention use is made of flow-engineering means which cause a uniform flow according to the resistance principle; such means are: choke grids, choke sieves, multiple arrangement of such grids or sieves, anemostats, and the like. In the case of use of such means, for example under the grate of the regenerator, a fairly constant pressure is attained under this grate, namely by a reduction of speed that is reached as far as possible immediately after the entrance of the cold air in the cold-blast period. In consequence of this purposely generated resistance, there will occur a decline in pressure, which can, however, be accepted for the sake of the other advantages attained.

In accordance with an additional form of the invention, use is made of flow-engineering means which cause a uniform flow according to the streamline principle, i. e. in the case of low, and under certain circumstances practically vanishing, resistances with avoidance of vortices; such means are: roundings, guide surfaces, guide bodies, guide surfaces arranged in steps in pyramidal fashion, means and arrangements for the control of and uniformity of the flow at places of abrupt widening of the cross-sections and under sudden deflections of the direction of flow, means for regulation and control of uniformity respectively of an inflow arriving in unregulated fashion, as, for example, guide bodies or guide plates arranged parallel to the principal direction or inclined obliquely to the

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principal direction, in connection with, for example, guide surfaces arranged in steps as mentioned hereinbefore. These means create, for example, in the blast period, in the case of arrangement below the grate of the regenerator, an immediate reduction of the speed of flow after the entrance of the cold blast, and with a rise in pressure, which gives therefore a loss-free or practically loss-free distribution of flow.

A further form of the invention promotes the desired effect by means of subdividing the combustion shaft and the regenerator respectively in such manner that two or more partial combustion shafts and partial regenerators are formed, in which connection the cross-section surfaces may be assimilated to one another.

In additional forms means are provided for the improved widening and deflection of the flow for the gas period in the form of roundings in the end of the combustion shaft at the transition to the hood and also for a substantial reduction in size of the diffuser between the combustion shaft and the regenerator in the form of novel hood vaultings, preferably an annular conformation of the hood space in the case of an otherwise substantially conventional construction of the air heater.

Further features and characteristics of the invention will be apparent from the following detailed description of preferred forms of the invention taken together with the accompanying drawings in which:

Fig. 1 is a partial vertical sectional view of a regenerator showing the space below the grate;

Fig. 2 is a horizontal sectional view of the space taken on the line 2—2 of Fig. 1;

Fig. 3 is a partial vertical section of the space below the grate of a regenerator;

Figs. 4, 5, and 6 are horizontal sectional views of several additional variant forms;

Figs. 7 and 8 are horizontal and partial vertical sectional views of an additional form of embodiment of the space below the grate;

Figs. 9 and 10 are additional horizontal sections of spaces below the grate;

Figs. 11 and 12 are partial vertical and horizontal sectional views of an additional form adapted for use in a centrally arranged combustion shaft;

Fig. 13 is a partial sectional view of a form of the invention in the hood zone of the regenerator;

Fig. 14 is a diagram of speed distribution in the gas period;

Fig. 15 is a diagram of speed distribution in the blast period;

Figs. 16, 17 and 18 are partial vertical and horizontal sectional views and in unrolled cylindrical section a hood with an annular space, Fig. 17 being taken on the line 17—17 of Fig. 16;

Figs. 19 and 20 are perspective views of superimposed structures on the combustion shaft;

Figs. 21, 22 and 23 are vertical and horizontal sectional views and in unrolled cylindrical section a hood zone of the regenerator; and

Figs. 24 and 25 are horizontal sections of a regenerator having special arrangements of the combustion shafts and of the grid equipment.

With regard to the space below the regenerator, shown in Figs. 1 through 12, the following numbers refer to standard parts of blast furnace air heaters shown in schematic drawings: 1 air heater jacket of steel and refractory in Figs. 1 through 12; 2 wall of refractory forming the combustion chamber, Figs. 1 and 2; 3 space of combustion chamber arranged beside the regenerator 4, Figs. 1, 2, and 7 through 11 where Fig. 2 shows in solid lines a circular cross section and in dotted lines a non-circular cross section; 4 regenerator consisting of checkerwork in Figs. 1, 3 and 11; 5 grate of cast iron supporting regenerator 4 in Figs. 1 and 3; 6 transverse beam supporting the grate 5 in Figs. 1, 3 and 11; 7 support of transverse beam, Figs. 1, 2, 3, 7, 9, 10 and 11; 8 gas outlet opening, Figs. 1

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and 2; 9 cold air entrance, Figs. 1 through 12; 10 channels in the checkerwork 4, Figs. 1, 3 and 11; 28 reinforced wall of refractory surrounding the combustion chamber 3 and the regenerator 4 including the space below the regenerator, Figs. 7, 9 and 10; 38 centrally located circular combustion chamber, solid lines in Figs. 11 and 12; 39 centrally located elliptical combustion chamber, dotted lines in Fig. 12.

Figs. 1 through 12 illustrate examples of structures used in the invention. The structures are arranged with respect to blast periods and are located in the space below the regenerator. The structures include deflecting means in step formation and baffle or sieve-like arrangements which cause a local flow distribution 15 either by themselves or in an arrangement as a combined unit. In particular the following examples are illustrated.

1. Guiding surfaces in step formation in a shape of an arc or a body of rotation shown by 41 in Figs. 11 and 12 on the right side; in vertical extension shown by 20, 21 in Fig. 4;

2. Guiding surfaces in step formation in combined units as

a. Vertical guiding surfaces 11 and behind them, when considered in direction of flow, horizontal guiding surfaces 12 in Figs. 1 and 2;

b. The same as in a, however, in addition a top plate in shape 13 or 14 or the like on top of 11 and alternately with a guiding surface or a set of guiding surfaces in step formation in front of 13, 14 as shown in Fig. 1;

c. Guiding surfaces in step formation combined with particular deflection wall at the entrance as 12 with 16 in Fig. 3; 25 with 24 in Fig. 5; 32 with 31 in Fig. 8;

d. Guiding surfaces in step formation combined with particular deflecting wall behind the entrance as 22, 23 with 19 in Fig. 4; 20, 21 and 22, 23 with 19 in Fig. 4; 26 with 27 in Fig. 6;

e. Guiding surfaces in step formation combined with supports as 15 with 7 in Fig. 7; 15, 29 with 7 in Fig. 7; 33 with 7 in Fig. 9; 36 with 7 in Fig. 10; 35, 36 with 7 and 34 in Fig. 10;

3. Baffle or sieve-like arrangements as 40 in Figs. 11 and 12 left side.

The particular kind of arrangement depends on the location, shape and size of entrance 9 and the number of entrances. Arrangements as shown in Fig. 5 may be used when two entrances are provided symmetrically opposite another, and when a deflection of more than 90° is to be accomplished. Arrangements as shown in Figs. 3 and 8 are preferable when heavy disturbances of flow in the incoming flow are to be expected. Fig. 8 may be used when the requirements are specifically that the means being used should not be extended into the space below the regenerator. Deflecting walls and top walls are installed when the means being used are extended into the said space. These walls prevent the stagnation in front from causing a three dimensional flow with a vertical component of a magnitude which is larger than desired. With regard to this effect these walls may be sieve-like. Oblique walls as 16 in Fig. 3 are particularly adapted with regard to handling dust. Such oblique walls may be used in combination with arrangements as shown in Figs. 4 and 6, in which the walls 19 and 17 may be sieve-like variations. The variety of sieve-like arrangements is applicable to example 40 in Figs. 11 and 12.

The openings may be holes or slots and may be distributed and determined in size according to the need. Both guiding surfaces in step formation and vertical walls or vertical sieve-like walls may be used as supports in connection with the regenerator replacing special supports which are otherwise necessary. When many supports 7 are used as shown in Figs. 7, 9 and 10 the invention suggests a moderate deflection of the flow at the entrance and a subsequent deflection of flow in the space in a combined arrangement with the supports. Combinations with guiding surfaces in step formation are shown in these

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Figs. 7, 9 and 10. Particularly preferable is a combination with supports in which the arrangement of supports is in accordance with the flow path as shown in Figs. 7 and 10; in contrary to this is the example shown in Fig. 9 in which the flow distribution is obtained more difficult due to the arrangement of supports in the flow.

The modifying structures of the invention do not disturb the flow in the opposite direction with regard to the gas periods when the gas leaves the apparatus through outlets 8. They facilitate an easy cleaning of the space below the regenerator. The local velocities are large enough to provide automatic cleaning of the devices which would not ordinarily stay clean due to dust settling by gravity when horizontal arrangements are used. Furthermore, space as 17, 18 in Fig. 4 can be readily cleaned manually because the full-scale arrangement of guiding surfaces 22, 23 leads to gaps large enough that a man may slip through.

Fig. 1 shows a vertical section through the lower part of the regenerator, and Fig. 2 a section on the line 2—2 of Fig. 1. The air-heater jacket 1 made of steel and refractory bricks contains, in lateral arrangement, the combustion shaft 3, which is formed by the wall 2 and whose cross-section is shown as round, but which may also be elliptical or similar, and also the regenerator 4 consisting of refractory bricks, below this the grate 5, transverse beams 6, and grate supports 7.

The gas outlet 8 leads away consumed gases during the gas period. In the blast period cold air enters through the cold-blast inlet 9. In the blast period the path of the flow has sudden abrupt widenings and sudden deflections, in which connection the sum of the cross-sections of the regenerator channels 10 is substantially greater than the cross-section of the cold-blast inlet 9. In accordance with the invention, for regulation of this flow and for the most uniform distribution possible and introduction of the flow into all channels 10, flow-regulating means are built in either at or in the cold-blast inlet 9. In the embodiment in accordance with Figs. 1 and 2 a distribution of the flow in the horizontal plane is attained by means of the guide surfaces 11 which are installed perpendicularly in the cold-blast inlet 9 and arranged stepwise as shown in Fig. 2 and the peripheral outline simulating the shape of a foresail, while the deflection upward and the further distribution of the flow for uniform charging of the channels 10 by the flow-regulating means that are situated in a horizontal principal extension is effected in this case by the guide surfaces 12 that are likewise arranged stepwise in the manner of surfaces 11. In connection with the guide surfaces 12 there is arranged a guide plate or cover plate 13 which may also, as shown in broken lines, be supplemented and completed to form a full body 14. The approximate course of the flow is represented by arrows 15.

In the form in accordance with Fig. 3 there is arranged at the cold-blast inlet 9, an obliquely downwardly inclined guide plate or cover plate 16, which in the illustrated spaced relationship and co-ordination with the guide surfaces 12, that are arranged stepwise in foresail fashion, provides an especially good distribution of the flow in accordance with the arrows 15.

In the embodiment of Fig. 4 the horizontal spread of flow can also be obtained by directing the cold-blast inlet 9 in forked fashion toward the left and toward the right into, for example, two branches 17, 18, and, more specifically, by means of the installation of a semicircular plate or of a similar perforated guide plate 19. In this connection for substantially uninterrupted deflection of the current of cold air entering from the cold-blast inlet 9, there are provided, in symmetrical arrangement, two sets 20, 21 of guide surfaces that are arranged stepwise in foresail fashion. Similar guide surfaces could be used, for instance deflection blades, in which connection at the end of the channels or branches 17, 18, in the shown spatial co-ordination to the ends of the guide plates 19,

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in each case there are provided an additional set 22, 23 of guide plates that are arranged stepwise in foresail fashion and built in. Such an arrangement yields a particularly favorable spread of the flow in accordance with the arrows 15 in the horizontal plane.

In the case of tangential introduction of the cold-blast inlet 9 in accordance with Fig. 5 there is provided a guide wall, cover plate, or a guide body 24, which again coacts with a set 25 of guide surfaces that are arranged stepwise in foresail fashion, which also yields an excellent, uniform, and but slightly interrupted spread of the flow in accordance with the arrows 15.

In Fig. 6 the cold-blast inlet extends radially to the jacket 1. Here guide surfaces 26, arranged stepwise in foresail fashion, are again installed in an archlike arrangement at the cold-blast inlet 9, and are preferably installed symmetrically with respect to the central guide plate 27 which can be flat or bent, or under certain circumstances perforated and which is situated opposite the cold-blast inlet 9.

In the embodiment in accordance with Fig. 7 there is provided within the jacket 1 a strong masonry lining 28, in which connection the combustion shaft 3 is arranged laterally and has a somewhat lenticular cross-section. In this embodiment a large number of grate supports 7 are provided, and in such an arrangement it is advisable to provide an arrangement of the guide surfaces 29 that are arranged stepwise in foresail fashion, in a similar manner as in Fig. 6. Under certain circumstances the guide surfaces 29 are passed around the grate supports 7 that are situated closest to the cold-blast inlet 9.

Fig. 8 represents a cross-section of the embodiment of Fig. 7, but for the sake of clearness the grate supports 7 and the guide surfaces co-ordinated with them have been omitted. The cold-blast inlet 9 has a diffuser-shaped widening 30 upward, at the beginning of which there is arranged obliquely downward a cover plate 31, which is in spatial co-ordination with the built-in guide surfaces 32 that are arranged stepwise in foresail fashion, and together with these brings about a favorable and but slightly interrupted distribution of flow in accordance with the arrows 15.

Another form is shown in Fig. 9, where in the cold-blast inlet 9, which is doubled in the figure, and, in the vicinity of the grate supports 7, there are provided surfaces or sets of guide surfaces 33, which secure a good distribution of the flow even in the case of such unfavorable conditions.

In Fig. 10, guide surfaces or sets of guide surfaces 34, 35, 36 are provided behind one another, in each case at the critical places, even in the case of symmetrical positioning of the cold-blast inlet 9, preferably in such a way that the distance from the guide surfaces 34, 35, 36 to the center line 37 decreases the farther distant the guide surfaces 34, 35, 36 are situated from the cold-blast inlet 9.

In Figs. 11 and 12 the combustion shaft 3 is arranged centrally; it may have a round wall 38 or an extended wall 39 as shown in dotted lines in Fig. 12 and in the latter case the wall 39 separates the air heater into two parts. At the cold-blast inlet 9, which in this case is doubled in diametrical arrangement, the distribution of flow can be secured by means of a sieve or the like 40 or by means of anemostat-like bodies 41 shown at the right of Fig. 12. These bodies 41 may also be fashioned and arranged in a substantially portal-arch shape or they may be constructed as oblique or horizontal or vertical choke sieves in a single or plural arrangement or in combined arrangement. Furthermore the cold-blast inlet 9 can be introduced farther into the space below the grate and be branched and can be provided with guide surfaces, particularly at places of widening and deflection, in which connection the outlet apertures are then likewise provided with flow-regulating means such as sieve bodies, anemostats, or guide surfaces that are arranged stepwise in foresail fashion, etc. Such built-in parts are also possible

for a lateral arrangement of the combustion shaft, and on the other hand the built-in parts described for a laterally arranged combustion shaft are also applicable in the case of a central combustion shaft.

Fig. 13 shows a vertical section through the hood zone. The jacket 1 is covered by the hood 42, and the regenerator 4 may have at its upper end steps 43, 44. These steps 43, 44 may be provided with bevels or roundings 45. In this connection it is important that the interior upper wall portion 47 of the combustion shaft 3 shall have a rounding 48 which is as large as possible and which, in co-operation with the steps 43, 44, makes possible a favorable distribution of the flow in the gas period, i. e. a uniform flow through all the channels 10 of the regenerator 4, to which uniform flow the flat construction of the vaulted hood 42 also contributes.

In Fig. 14 the speed-distribution diagram 49 in broken lines shows diagrammatically, for the gas period, the conditions prevailing in hitherto customary types of construction, i. e. a very irregular distribution of speed over the cross-section of the regenerator 4, while in Fig. 15 the speed-distribution diagram 50, likewise in broken lines, represents diagrammatically the distribution of speed over the regenerator cross-section in the blast period as it occurs in the case of the customary types of construction. It is clearly evident that these two diagrams, which are based on a customary air heater, do not correspond with one another in the absence of the means of the present invention. Where the speed in accordance with diagram 49 is great, according to diagram 50 it is at least in part small, and vice versa, so that zones of irregular heating and cooling are formed in the regenerator. In accordance with the present invention the actual distributions are substantially approximated to the ideal case, represented by diagrams 51 and 52 of Figs. 14 and 15, and accordingly the utilization of the regenerator 4 is improved and its thermal load is equalized; detrimental local overloads being eliminated.

The shown examples of devices make use of both principles, the resistance and the streamline principle. One of these modifications may be explained with regard to device 40 of Fig. 12. The extension of the flow path through such a device leads to arrangements at the entrance of flow which represents a multi-subdivided diffuser in which each small diffuser contributes to a distribution of flow fundamentally by an arrangement of non-staggered guiding surfaces. In such example, both principles are used in one device; however, the resistance principle is applicable more than the streamline principle when a greater efficiency is required because of the comparably small space available for the device to control the direction of flow. Guiding surfaces in step formation can be arranged and used in such manner that both principles, the resistance and the streamline principle, are employed.

Using these flow distributing devices one can easily change the distribution of flow in the said space and can adjust it as desired to obtain a uniform flow pattern throughout the checkerwork cross section as shown schematically in Fig. 15. The dotted line refers to a flow pattern obtained without any means of flow distribution in the flow path of the incoming flow. The velocity 50 increases with increasing distance from the entrance. The solid line shows the same flow pattern schematically when devices are provided in accordance with the invention. The velocity is distributed uniformly from the entrance to the opposite end 52. The average velocity is different in the two cases. If 52 presents the limit of velocity suitable for the checkerwork, then velocities greater than that shown by 52, such as 50, would cause damage. If the maximum of velocity in 50 is suitable, then, 52 may be increased to this value which would result in a smaller apparatus.

With regard to the space above the regenerator, shown in Figs. 13 and 16 through 25, the following numbers refer to standard parts of blast furnace air heaters shown in the drawings.

The numbers 1, 2, 3, 4, 10 and 28 refer to parts as explained with respect to the space below the regenerator. In Fig. 13 the number 42 refers to the hood of the apparatus. This hood is shaped like a hemisphere, sometimes elliptically, and presents the upper border of said space. The element 1 is extended to include the outer part of the hood as shown in Figs. 16, 17, 21, 22 and 23.

With regard to the figures concerning the space below the regenerator the numbers 1; 1 and 2; and 1 and 28 are used with reference to the vertical outside walls and the wall of the combustion chamber. In the upper space a few additional numbers are introduced with regard to the same function and for easier explanation. Fig. 13 shows in addition, number 47 referring to the wall which separates the combustion and regenerator chambers; Figs. 19 and 20 use the combination 2, 28; Figs. 21 and 22 use 1, 2, 55 and 64; and Fig. 23 uses 2 and 64. For the same reason, distinctions are maintained with regard to parts of the hood in a few figures. Figs. 16, 17, 21 and 23 use 1 and 54. The said space above the regenerator, which is the space below the hood and above both chambers, the combustion and the regenerator chambers, is numbered only in Figs. 16, 17, 18, 21, 22 and 23 and the number is 53.

In order to distinguish designs for a single unit with two combustion chambers and for regenerators operated in parallel, Fig. 24 uses the numbers 65, 66, 67 and 68 in addition to numbers 1, 3 and 4. For a similar design, Fig. 25 on the right side shows numbers 69 and 70 because of the different conic shape of the combustion chambers. Walls 71 and 74 refer to regenerators 72 and 73 shown on the right side of Fig. 25. Fig. 24 refers to combustion chambers located beside regenerators and Fig. 25 to centrally located combustion chambers.

Figs. 13 and 16 through 25 show arrangements with respect to the gas periods in the space connecting the combustion and checkerwork chambers. These include:

1. Rounding off of the upper end of the combustion chamber at the inner side of the bend at the transition from the combustion chamber to the said space as 48 in Fig. 13; Fig. 18; 63 in Fig. 20; 63 in Fig. 23;
2. Reducing the flow cross section of the said space by
 - a. Applying comparably flat hoods instead of using hoods shaped like a hemisphere covering the whole apparatus and used in connection with the rounding off design according to 1 as shown in 42 with 28 in Fig. 13;
 - b. Applying a T-shaped subdivision to the flow path following the upper end of the combustion chamber in addition to 1 and 2a as shown in Figs. 16, 17, 18, 21, 22 and 23 by 3 and 53;
 - c. Applying step formation of the upper end of the regenerator in addition to 1, 2a and 2b as shown by 43, 44 in Fig. 13; 60, 61, 62 to the left side in Fig. 18; and to the left in Fig. 23;
3. Guiding surfaces at the transition from the upper end of the combustion chamber into the said space as an additional feature like 58 in Figs. 16 through 20.

In accordance with Figs. 16 to 18 excellent guidance and distribution of the flow are attained by means of the hood space being constructed as an annular hood space 53. The actual hood 54 accordingly represents a ring which is approximately semicircular in profile section, in which case a central column 55 is provided. Between this column 55 and the hood 54 there can be arranged a space 56 which serves for compensation of heat expansions. The regenerator 4 is constructed around the central column 55 directly adjacent to the combustion shaft 3. On the outside, the hood 54 is supported by the lining 28, which together with the hood is enveloped by the jacket 1. On the upper edge 57 of the combustion shaft 3 there are installed or secured by masonry, guide bodies 58 which distribute the flow from the combustion shaft 3 toward both sides, as the arrows 59 show, so that a uniform or somewhat uniform charging or flow through the channels 10 of the regenerator 4 is attained. In this connection the upper edge of the regenerator 4 can be pro-

vided, in a manner previously shown and described, with steps 60, 61, 62, which may also be rounded-off or beveled.

In accordance with Fig. 19 the guide bodies 58 can be attached by masonry or a horizontal upper edge 57 of the combustion shaft 3. It is, however, also possible, as shown in Fig. 20, and also advantageous, to give the combustion shaft 3 at the upper end a rounding-off 63 upon which the guide bodies 58 are superimposed; the course of the flow is here also indicated by the arrows 59. Such arrangements are possible also if one chooses an arrangement in accordance with Fig. 13, i. e. in the case of a large hood and especially in the case of an upper rounding-off of the combustion shaft; they are also possible in the case of a central combustion shaft and in the case of subdivided combustion shafts and regenerators such as are shown in Figs. 24 and 25.

In the case of Figs. 16 to 20 the combustion shaft is shaped round, Figs. 21 to 23 show an oval-like cross-section of the combustion shaft 3, which here has a double wall 2, 54. This arrangement corresponds substantially with Figs. 16 to 18, but, especially in the case of a widened construction of the combustion shaft 3 in accordance with Fig. 22, the arrangement of guide bodies 58 can be dispensed with. The ratio between the cross-sectional surface of the combustion shaft 3 and the total cross-section of the channels 10 of the regenerator 4 is here more favorable.

An additional means for influencing the flow is shown in Figs. 24 and 25. Here several, for example two, combustion shafts 3 are provided, and one or more regenerators 4, in this example two. The separation is effected by means of walls 65, 66, 67, 68; the walls 65, 66 extending only as far as the upper edge of the regenerator 4, while the walls 67, 68 either extend likewise as far as the upper edge of the regenerator or else are preferably built up by masonry as far as the cover of the hood, under certain circumstances with the allowance of a slight space for the avoidance of detrimental heat tensions.

As shown in the left half of Fig. 25 a central, somewhat flat rectangular combustion shaft 3, with regenerators 4 situated on both sides of it are provided. In the right half of Fig. 25 this combustion shaft is shown as divided up into two partial combustion shafts 69, 70, and may be so divided by separation means such as wall 71, which also separates the regenerator 4 into two partial regenerators 72, 73. The separating wall 74 between the combustion shafts 69, 70 on the one hand and the regenerators 72, 73 on the other hand extend only as far as the upper edge of the partial regenerators 72, 73, while the wall 71 may be built up by masonry as far as the cover of the hood or the cover of the hood may there by drawn down as far as the height of the walls 67, 68, again under certain circumstances with the allowance of a slight expansion space. In Fig. 24 the ratio of the ratio of the interior cross-sections of the combustion shaft and of the regenerator has been chosen so as to depart substantially less from the value 1 than hitherto customary. Such favorable cross-section allotments are applicable successfully also for the previous examples. For further improvement of the distribution of flow the means shown in the previous figures and other means for influencing the flow that are in themselves known in part can also be employed additionally. Local zones of overheating are avoided or their formation is reduced. Additionally, for example, the combustion shafts 69, 70 may also receive a cross-section that increases from the bottom upwardly, under certain circumstances also with a transition from a round to an oval or rectangular or some other cross-section having a larger surface. Furthermore it is possible to make the cross-section of the entire air heater rectangular or square and to assemble several air heaters as a structural unit to form a battery whereby radiation losses are diminished. Finally, in the case of a suitable choice of materials (Fig. 24) it is pos-

sible to operate at the same time one-half of the air heater in the blast period and the other half in the gas period.

It is a very important aspect of the invention that the means employed for influencing the flow and particularly the employment of guide surfaces that are arranged stepwise in foresail fashion either with or without special cover plates, guide bodies, etc. admit of a very irregular inflow without failing in their activity. This means that even a very irregular inflow on the gas side or on the air side is regulated by such guide surfaces. That is also possible by flow-regulating means in accordance with the resistance principle, with the condition, of course, of contending with higher flow resistances.

In view of expense had with full-scale blast furnace air heaters, the flow pattern at the upper end of the combustion chamber is known to be sufficiently uniform, and the invention need not treat large disturbances of flow at the entrance into the said space. In this space instead of the problem of separation of dust and fragments which existed in the lower space this invention solves the problems due to high temperatures and unfavorable flow conduits. Thus there is need of avoiding large surfaces in contact with relatively high velocity fluids. Abrupt diffusers of large expansion which cause separation of the main stream with large secondary flow in the said space must be modified since they result in a non-uniform flow distribution throughout the free flow cross section of the checkerwork. These problems are solved by rounding off the entrance of flow into the said space, by modifying the specific design of the hood covering this space and by providing vane guiding surfaces at the space entrance. In rounding off the entrance into the said space particular consideration is given to the ratio of the radius to the width of the flow cross section. In the case of the T-shaped subdivided flow this is the ratio of the radius to half of the width of the flow cross-section. The optimum condition obtained when the value of this ratio is one. Then the deflection of flow occurs without separation of flow at the inner side and no contraction of flow occurs even when a sharp corner is provided at the outer side of the bend, the latter resulting in only a small separation of flow without further disturbances of the flow distribution throughout the free flow cross section of the checkerwork. When this ratio decreases separation of flow is produced at the inner side of the bend and the flow is deflected mainly by the hood. The wall 47 in Fig. 13 is therefore thickened and the curvature 48 corresponds to a large radius which is desirable. The effect of rounding off is particularly efficient when the free cross section at the end of the deflection is not substantially larger than that of the combustion chamber upstream of the rounding off. A diffuser shape should be avoided which is out of proportion to the free cross section or the total cross section of the checkerwork.

To ease the flow requirements, the step formation 43, 44 with sharp edges or with rounded or oblique edges is employed as shown by 45 in Fig. 13. Designs as shown in Figs. 16, 17, 18, 21, 22 and 23 provide even better conditions of flow than Fig. 13. The arc shape 54 is more suitable than 42 for structural reasons. As schematically shown the center of the arc may be supported by a reinforced wall section 55. Because of expansion of the refractory which becomes necessary due to temperature requirements, one may design 55 and 54 as having a gap at low temperatures as shown in Fig. 16. The invention provides guiding surfaces 58 shown in Figs. 16, 17, 18 and 20 to prevent undesirable flow patterns with respect to the flow through the regenerator. The local flow direction is illustrated by 59 in Figs. 17, 18, 20 and 23.

This invention endeavours to improve primarily the conditions of flow at the entrance of the space. The figures illustrate modifications without the step-formation deflection at the upper end of the regenerator, see Fig. 18 right side and Fig. 23 right side. To show the condi-

tion which is corrected, Fig. 19 shows a sharp edge instead of the rounding off (see 63 in Fig. 20). In Fig. 19 the support for the deflecting vanes 58 is easier to build and these deflecting vanes provide a favorable flow distribution at the entrance into the said space, namely, the deflection of flow with regard to the top view as shown in Fig. 17. On the other hand the significance of rounding off is somewhat diminished when a contour as 54 is provided because due to this contour the flow cannot rise straight into the space as is the case when a hood in the shape of a hemisphere is used. Fig. 19 is a typical example wherein the disadvantage of the sharp edge with regard to the flow can be eliminated when additional guiding surfaces are used in connection with this edge. The guiding surfaces are built of refractory bricks and may be applied with the step-formation vanes.

Other important modifications concern the design of the hood. The space 53 and the shape 54 in Figs. 16 and 21 may be provided on top of the combustion chamber, however, extended only throughout half the apparatus in combination with a shape of part 1 like a hemisphere. At the end of the contour 54 the shape is that of a sudden diffuser. In this case the mixing and turbulence caused by this sudden diffuser do not disturb the flow distribution to a harmful extend through the checkerwork cross section.

The same principle of modification may be used when the flow path is not subdivided as in Fig. 13 and Fig. 25 left side. For structural reasons this suggestion is preferable when used in connection with combustion and checkerwork chambers operated in parallel in a single unit as shown in Fig. 24 and Fig. 25 right side, because the walls 65, 66, 67, 68 in Fig. 24 and the walls 71 and 74 in Fig. 25 may be used as supports.

These examples and modifications result in improvements of flow distribution in the regenerator channels throughout its free flow cross section with regard to downwardly directed gas flow during gas periods. This is shown schematically in Fig. 14. Curve 49 refers to velocity distributions without the improvements made in this invention and are based on measurements in blast furnace air heaters. Curve 51 refers to designs improved in accordance with the invention. The two Figs. 14 and 15 present performance conditions of the apparatus during gas and blast periods with regard to the heating and cooling of the checkerwork and the cooling of the gas and heating of the air. Heating and cooling are unbalanced in curves 49 and 50, and heating and cooling are balanced in curves 51 and 52. This is also found when one compares the local ratio of velocity of gas to air flow. In the case of flow distributions, 51 and 52, one finds the average velocity in accordance with the equations for flowing fluids and the required heat exchange. Curves like 51 and 52 show greater economy and less damage due to changes in temperatures than those in 49 and 50. The best result is secured when improvements are provided in both of the lower and upper spaces. However, a considerable improvement is secured even when improvements are provided only with regard to the lower space beneath the regenerator.

Blast furnace air heaters are operated such that the average fluid velocity throughout the checkerwork lies within the turbulent range of flow, but close to the transition from laminar to turbulent flow. Therefore, a flow distribution such as shown by 50 easily results in turbulent and laminar flow in different channels at different parts of the cross section. This can be avoided by curves of flow distribution like 52. Laminar flow results in a lower heat exchange than turbulent flow. But, in addition to this general rise in heat transfer rate non-circular tubes cause secondary flow when the transition

to turbulent flow occurs in the boundary layer. This secondary flow exchanges fluid back and forth between the wall and the interior of the channel cross section. For this reason a further advantage with curve 52 is realized because improvement of heat transfer can be applied for cases in which the transition between laminar and turbulent flow occurs in the regenerator. With uniform velocity distribution obtained by this invention excessive heating of some sections of the checkerwork is entirely prevented and a greater economy in operation results.

I claim:

1. In a refractory lined regenerative air heater, that improvement for deflecting the fluid stream in said heater to prevent the formation of static, eddied and separation zones along the cross section of the streaming flow of the gases in said heater and thereby streamline the flow through the heater, comprising, the combination of baffles between the regenerator and the blast inlet of the heater to direct flow through the regenerator, and curved vane deflecting means to direct the fluid uniformly in streamline manner through the regenerator, said deflecting means comprising a staggered series of such vanes, each on the suction side of the subsequent vane, the resultant curvature of the series being greater than the curvature of any single vane, the overlap of the vanes to each other being sufficient to provide a jet directed velocity vector in a direction substantially tangential to the resultant curvature of the series and in the direction to convert the static and eddied condition into a streamline flow, the resultant curvature being defined by the curve which joins the intersections of the chords of the vanes, and said deflecting means being oriented with respect to the direction of the velocity vector of the incident gas stream to provide an angle of attack of the first vane of the series which is negative.

2. A Cowper furnace as in claim 1 wherein said baffles are vertically mounted refractory elements adjacent the blast inlet of said furnace and horizontally arranged with respect to the gases streaming from the blast inlet to direct the gases in a horizontal path towards the opposite end of the regenerator and to direct some of the gases in a vertical path for flow through said regenerator and wherein said deflecting means is arranged down-stream from the blast inlet to uniformly deflect the horizontally directed flow from the baffles into the vertical direction for flow through the regenerator.

3. A Cowper furnace as in claim 2 wherein the regenerator is a brick checkerwork and wherein the refractory inner walls of the blast inlet, furnace and hood of said Cowper furnace are gradually curved in streamline manner to prevent abrupt projections from the inner walls into the gas stream.

4. A furnace as in claim 3 wherein said baffles are formed in the shape of a sieve and wherein said curved vane deflecting means are provided at the entrance of the gases into the space below said checkerwork to improve the deflection of the gases to and from the baffles.

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