

Jan. 16, 1934.

S. A. FORTER

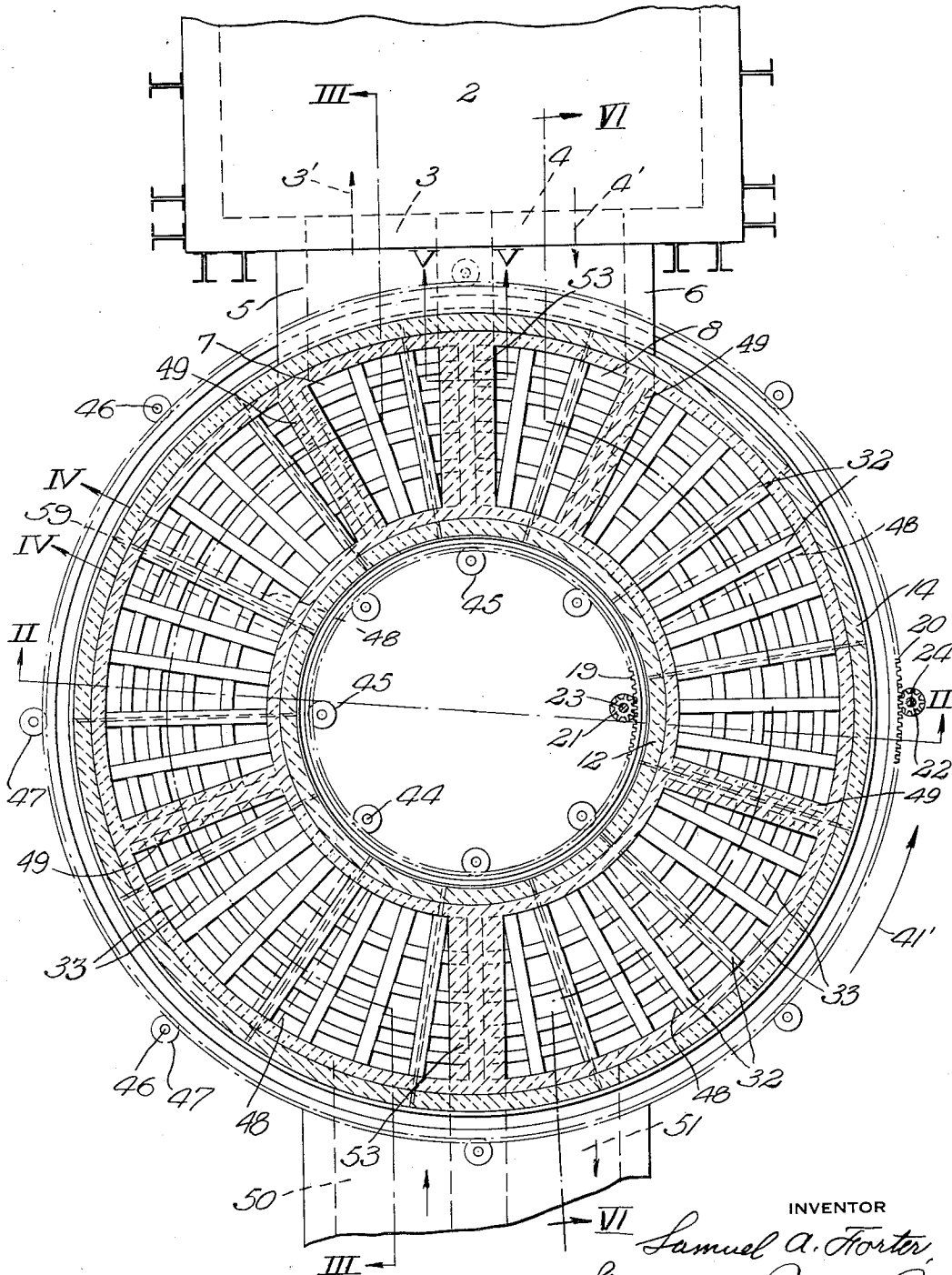
1,944,074

METHOD AND APPARATUS FOR OPERATING FURNACES

Filed Dec. 21, 1931

4 Sheets-Sheet 1

Fig. 1.



INVENTOR

Samuel A. Forter,
by *Byrnes, Lobbins, Carmichael & Plunkett*
his attys.

Jan. 16, 1934.

S. A. FORTER

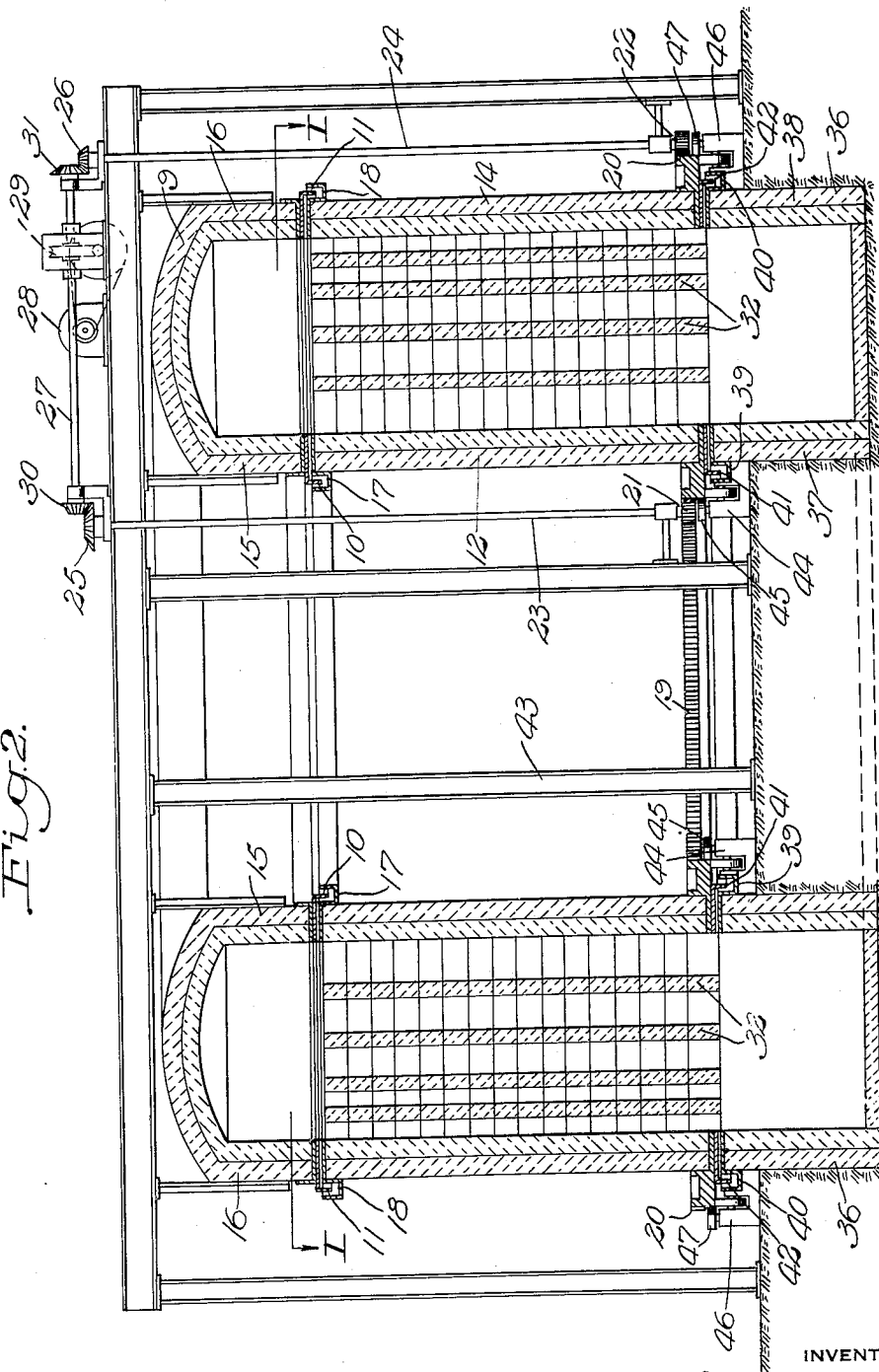
1,944,074

METHOD AND APPARATUS FOR OPERATING FURNACES

Filed Dec. 21, 1931

4 Sheets-Sheet 2

Fig. 2.



INVENTOR

Samuel A. Forter,
By *Arthur L. Smith, Bernard L. Smith,*
his attys.

Jan. 16, 1934.

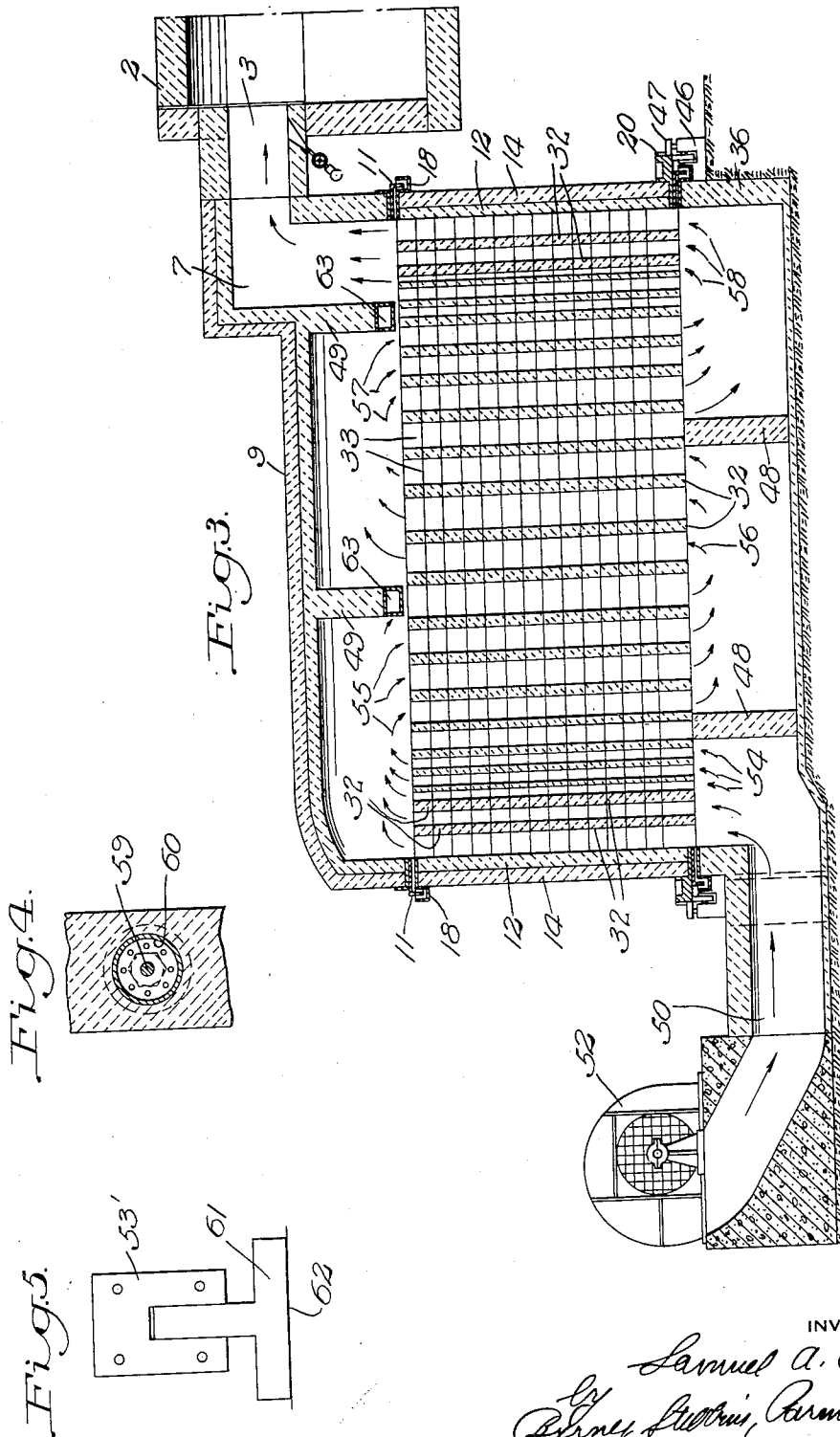
S. A. FORTER

1,944,074

METHOD AND APPARATUS FOR OPERATING FURNACES

Filed Dec. 21, 1931

4 Sheets-Sheet 3



INVENTOR

Samuel A. Forter,
 by *Byrnes, Lubin, Armella & Shuck,*
 his attys.

Jan. 16, 1934.

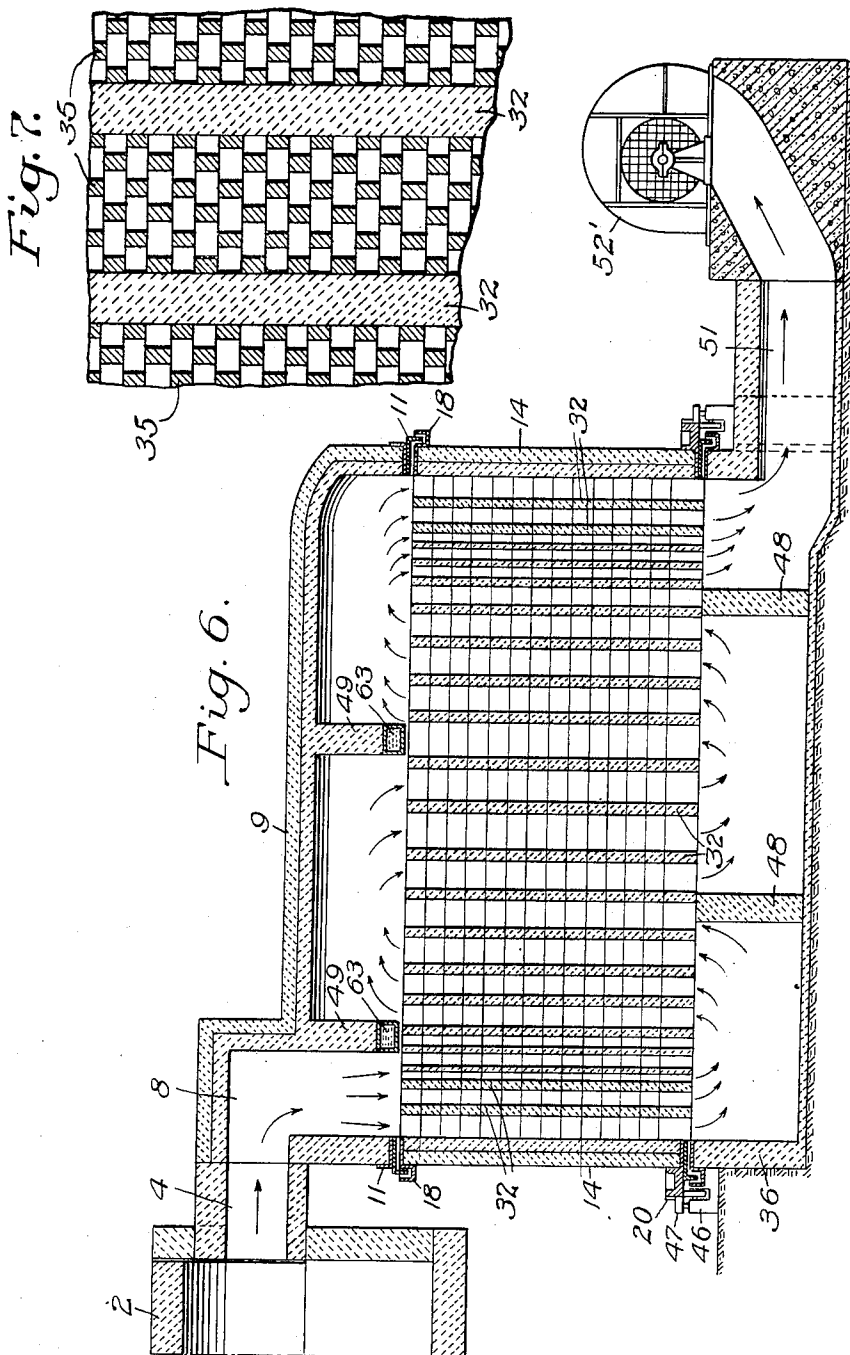
S. A. FORTER

1,944,074

METHOD AND APPARATUS FOR OPERATING FURNACES

Filed Dec. 21, 1931

4 Sheets-Sheet 4



INVENTOR

INVENTOR
Samuel A. Forter
By ^{by} Bynnes, Stebbins, Parmelee & Blenko
his attorneys.

UNITED STATES PATENT OFFICE

1,944,074

METHOD AND APPARATUS FOR OPERATING
FURNACESSamuel A. Forter, Pittsburgh, Pa., assignor to
H. L. Dixon Company, Pittsburgh, Pa., a cor-
poration of PennsylvaniaApplication December 21, 1931
Serial No. 582,353

13 Claims. (Cl. 263—19)

The present invention relates broadly to the art of heat exchanging, and more particularly to improvements in regenerator structures and methods of operating furnaces utilizing regener-
ators.

At the present time it is customary in the art to which the present invention relates to construct furnaces of two general types, these being known as recuperator furnaces and regenera-
tor furnaces respectively. Recuperator furnaces have a distinct advantage broadly, in that they may be operated at a substantially constant temperature. They are open to objection, however, in that this temperature, while constant, is ma-
terially lower than the temperatures which are obtainable in a regenerator furnace.

Regenerator furnaces on the contrary, while operative at higher temperatures, present a condition in which the temperature at any given time varies from the temperature at a preceding or succeeding time. At the instant of reversal, so that a hot regenerator is available for preheating one of the fluids supplied to the furnace, it is possible to obtain a condition of maximum temperature within the furnace. Just prior to reversal, however, inasmuch as the major portion of the heat has been abstracted from the regenerator, the furnace temperature is correspondingly lower.

Regenerator furnaces are open to the further criticism, that in order to obtain the reversal incident to their usual operation, it is usually necessary to provide the furnace itself with specially constructed ports either adapted to serve both as inlet and outlet ports at different times during the furnace operation, or with duplicate sets of ports properly controlled by valves, and in that it is further necessary to provide expensive reversing valve structures for the regenerators themselves.

It is one of the objects of the present invention to provide a regenerator furnace which may be continuously operated at a uniform maximum temperature in which the uniformity is that which characterizes a recuperator furnace but in which the temperature is in excess of that usually considered as obtainable in a recuperator furnace.

The invention has for another of its objects the provision of an improved method of, and apparatus for, effecting the interchange of heat within the regenerator structure whereby a greater heat transfer is obtainable both between the fluid being preheated and the regenerator, and the heating fluid and the regenerator.

A further characteristic of regenerator furnaces is found in the fact that the outgoing gases or products of combustion, at the commencement of a period of reversal, pass through a portion of the regenerator which is relatively cold, and therefore effective for abstracting a maximum amount of heat from such gases. As the heat abstraction continues, however, the portion of the regenerator subjected thereto gradually rises in temperature, with the result that the stack temperature of the outgoing gases gradually rises, thus representing an appreciable heat loss at such times.

The present invention has for another of its objects the provision of a furnace construction and operation such that the outgoing gases are continuously subjected, prior to their exit to the stack, to a heat absorbing surface which is characterized by a substantially constant temperature condition whereby the stack gases are maintained at a substantially constant temperature.

It is also characteristic of regenerator furnaces, that the fluid being preheated does not attain the full temperature in the regenerator which it should with the regenerator at any given temperature condition. This is due to the different paths of travel provided in the regenerator for the fluid medium being heated, which paths are of such nature that the temperature of the fluid leaving the regenerator is approximately equal to a mean temperature representing a compromise between the relatively cooler fluid portions and the relatively hotter fluid portions. It is a further characteristic of the present invention that the construction and operation shall be such that the fluid leaving the regenerator shall at all times leave the same through a portion of the regenerator heated to the maximum temperature, which maximum temperature is at all times substantially uniform.

In the accompanying drawings I have shown for purposes of illustration only, certain preferred embodiments of the present invention. In the drawings:

Figure 1 is a view partly in plan, and partly in horizontal section along the line I—I of Figure 2;

Figure 2 is a vertical sectional view along the line II—II of Figure 1;

Figure 3 is a vertical sectional view along the line III—III of Figure 1, looking in the direction of the arrows;

Figure 4 is a detail sectional view, on an enlarged scale, along the line IV—IV of Figure 1;

Figure 5 is a detail sectional view, illustrating

a slightly modified form of construction, the view being generally equivalent to a section taken along the line V—V of Figure 1, with a regenerator embodying the modification illustrated in Figure 5; and

Fig. 6 is a vertical sectional view similar to Fig. 3 and taken on the line VI—VI of Fig. 1, looking in the direction of the arrows.

Fig. 7 is a fragmentary detail view in elevation of one type of refractory filling which may be employed between the partitions of my regenerator body.

Referring more particularly to the drawings, there is illustrated in Figure 1 a furnace 2, which for purposes of a clearer understanding of the present invention, may be considered as comprising a continuous tank furnace such as used for the melting of glass, although it will be understood that the utility of the furnace is not thus limited. Formed in one end of the furnace is an inlet port 3 through which a preheated medium is adapted to be supplied thereto in the direction illustrated by the arrow 3'. Adjacent the port 3 is a second port 4 through which products of combustion or heated gases are adapted to pass in the direction indicated by the arrow 4'. The ports 3 and 4 respectively, communicate with inlet and outlet passages 5 and 6 leading from and to chambers 7 and 8 in a stationary cover 9. This cover is conveniently in the form of an annulus, as will be apparent more particularly from Figure 2, and has depending from the inner and outer walls thereof flanges 10 and 11.

Positioned below the cover 9 is a rotating regenerator body comprising an inner wall 12 and an outer wall 14, which walls are so spaced that they are adapted to aline with the side walls 15 and 16 respectively of the cover 9. Carried by the walls 12 and 14 respectively are channels 17 and 18, so positioned as to receive the flanges 10 and 11 and form therewith a water seal, it being understood that the channels are supplied with a sufficient water quantity for this purpose from any desired source.

Secured to the inner wall 12 of the rotating regenerator is a rack 19, a similar rack 20 being secured to the outer wall 14. Meshing with the teeth of these racks are driving pinions 21 and 22, respectively, which are illustrated herein as being carried by the lower ends of shafts 23 and 24 provided at their upper ends with bevel gears 25 and 26. Meshing with these gears, and tying the same together so as to insure simultaneous rotative movement thereof, is a cross shaft 27 adapted to be driven by a motor 28 through a suitable gearing 29. It will be noted from Figure 2 that the gears 25 and 26 are of different pitch diameters, and that the gears 30 and 31 which drive the same are of correspondingly different pitch diameters, the relationship of these gears being such that the racks 19 and 20, while being rotated in unison, will have a difference in peripheral speed corresponding exactly to their difference in diameters. In this manner, corresponding parts of the respective inner and outer walls are always maintained in the same relative relationship one to the other during rotation of the regenerator body.

Positioned within this rotating body, and extending from the top to the bottom thereof, are transversely disposed vertically extending partitions 32 dividing the interior of the body into a series of vertically extending parallelly disposed channels 33. The spacing of the walls 32 is preferably uniform whereby to provide channels 33

of a uniform cross sectional area. Intermediate these partitions there is arranged a refractory filling 35 of any desired construction, it being only necessary that the construction be such as to permit the flow of fluids vertically therethrough either upwardly or downwardly as illustrated by the arrows in Figure 3. As such filling, if illustrated in Figs. 1, 2, 3 and 6, might obscure the outlines of construction of the body, the filling is shown only in Fig. 7.

Positioned below the rotating regenerator body is a base 36 comprising side walls 37 and 38 of circular contour alining with the walls 12 and 14, and provided with channels 39 and 40 adapted to receive flanges 41 and 42 to form seals between the regenerator body and the bottom 36 similar to those provided between the regenerator body and the top 9, the bottom and top being adapted to be held stationary and the main body rotated between the two in the direction illustrated by the arrow 41' in Figure 1.

Suitably cooperating with the entire structure heretofore described is a framework 43 carrying an inner series of bearings 44 for rollers 45, and an outer series of bearings 46 for rollers 47, these rollers cooperating with trackways formed on the racks 19 and 20 whereby to definitely guide the regenerator body during its rotation. The framework 43 also provides bearings for the shafts 23, 24 and 27, and a support for the motor 28.

Formed at regularly spaced intervals in the bottom 36 are vertically extending partitions 48, similar downwardly projecting partitions 49 being carried by the cover 9. The relationship of these partitions is such that adjacent partitions 48 are disposed at a point half way between the partitions 49, as apparent more particularly from Figures 1 and 3 of the drawings.

Leading into the base 36 is a fluid inlet 50, substantially diametrically opposite the port 3, an outlet 51 being provided adjacent thereto and substantially diametrically opposite the port 4. The passages 50 and 51 communicate respectively with a pressure fan 52, as illustrated in Figure 3, and a suction fan 52', as illustrated in Fig. 6.

In addition to the partitions 49 in the cover 9, the cover is provided with diametrically oppositely arranged partitions 53, which partitions are of a width such that during the rotation of the regenerator body one of the vertically extending partitions 32 will come into sealing position thereunder before the adjacent partition 32 has passed out of sealing engagement therewith. The upper edges of the partitions 32, and the bottom faces of the partitions 53 are such that substantially tight joints will be continuously maintained therebetween during the operation of the apparatus. In such operation, a fluid to be preheated, which may be air, is delivered to the rotating regenerator body through the passage 50 into the base 36. From this base it is caused to travel upwardly through the passageways 33 by reason of the first partition 48, as illustrated by the arrows 54.

It will be understood that partitions similar to the partitions 53 are necessarily provided in the base so as to effect a similar division of the regenerator body into the desired parts with respect to the fluid flows therethrough.

Having traveled through certain of the passageways 33, it comes into the cover 9 and is deflected downwardly, as illustrated by the arrows 55 through adjacent passageways into a chamber in the bottom intermediate adjacent partitions 48. It then travels upwardly as indicated by the ar-

rows 56 into the roof 9, thence downwardly as indicated by arrows 57 into the base and is again deflected upwardly as indicated by the arrows 58, into the chamber 7 from which it passes through the port 3 into the furnace 2. During its travel, it moves in opposition to the direction of rotation of the regenerator body and in intimate contact with the refractory material therein, gradually absorbing more and more heat until it reaches a maximum temperature at which it is discharged into the chamber 7 before entering the furnace.

It will be apparent that during its upward travel into the chamber 7 as indicated by the arrows 58, it is passing through refractory material which has just rotated into a position in alinement with the chamber 7. This refractory material is at the highest temperature, it having been the last to receive heat from the outgoing gases. These outgoing gases travel in the reverse direction, passing from the port 4 into the chamber 8 from which they travel downwardly, and thereafter reverse their direction of flow through the passageways 33 until they reach the outlet chamber in the base communicating with the passage 51 leading to the suction fan. Just prior to leaving the regenerator body, they are subjected to contact with the refractory therein which is at the lowest temperature, this refractory having been freshly rotated into discharge position after it has just previously been subjected to the coolest ingoing air.

Inasmuch as the regenerator body is continuously rotating during the operation of the furnace, a fresh supply of uniformly heated refractory is continuously brought into alinement with the chamber 8, and a fresh supply of cool refractory continuously brought into discharge relationship with the passage 51. If the volume of gases being handled is increased, the speed of rotation of the regenerator body may likewise be increased, while if the gas quantity decreases, the speed may be decreased.

By properly correlating the speed of rotation to the gas volume, the desired temperature conditions may be maintained at all times within the body of the regenerator. At all times, also, the refractory adjacent the inlet port 3 will be at a constant maximum temperature, thus insuring uniformity of furnace temperature, while the refractory adjacent the passage 51 will be at a constant minimum temperature insuring maximum heat abstraction from the outgoing gases and constant stack temperature. These uniform temperature conditions constitute an advantageous feature of operation in accordance with the present invention.

If it is desired, the inner and outer walls 12 and 14 of the regenerator may be tied together by rods 59 extending through the partitions 32, as illustrated more particularly in Figure 4. Preferably these rods are disposed within tubes 60 which are spaced slightly therefrom to permit air circulation around the rods for cooling the same. Such rods constitute a mechanical tie between the walls of the regenerator and absorb inequalities in the driving mechanism such as would tend to rupture the refractory.

If desired, I may also construct the partitions 53 as illustrated more particularly in Figure 5, wherein one of the partitions 53' is illustrated as being slotted on its lower surface and fitted with a sealing slide 61, the lower face 62 of which will adapt itself automatically to the level of the partitions 32 so as to maintain the desired sealing engagement therewith.

It will be understood that the entire structure may be built up of suitable refractory material capable of withstanding the temperature conditions to which it is subjected, and that any desired heat insulating and water cooling means may be provided. In Figure 3, I have shown the partitions 49 as being formed on their lower ends with water cooling chambers 63. In operation, the cooling water supplied to these chambers will preferably discharge therefrom into the water seals provided for the regenerator.

From the foregoing description taken in connection with the accompanying drawings, it will be apparent that I have provided a furnace installation including a regenerator which, while of a given size, may have its speed of operation varied to accommodate it to the handling of different fluid characteristics while insuring the desired temperature conditions. Likewise, the rotation or continued movement of the regenerator obviates the necessity of any reversal in the direction of flow of the fluids passing therethrough, and enables such fluids to be continuously moved in the same direction through paths the entering and leaving temperatures of which are constant. This enables the attainment of uniform maximum temperature conditions within the furnace, and insures maximum heat abstraction from the outgoing gases.

By initially constructing the regenerator of a given size, and providing means for changing its speed of rotation, a given installation is made suitable for a wide variety of operating conditions, while insuring the maintenance of uniform temperature conditions at all times.

In the drawings I have illustrated the partitions 53 as being diametrically opposite, thereby dividing the regenerator into substantially equal capacities with respect to the ingoing and outgoing fluids. It will be apparent, however, that by shifting the relative location of these partitions, both in the cover and in the base, the portion of the regenerator body available for heating the ingoing fluids and abstracting heat from the outgoing gases may be changed as desired, thus affording capacities which are best adapted to insure the desired heat interchange between the refractory and the fluid medium in contact therewith.

In like manner the respective ports 3 and 4 may be constructed in the first instance to provide the desired area of flow therethrough, both with respect to the velocity desired and the volume to be handled.

Other changes in the construction with respect to the handling of the fluids will readily occur to those skilled in the art, it being apparent that while a circuitous or tortuous flow path of the character indicated is highly desirable from the standpoint of heat interchange, the flow may be a flow in parallel from either the base to the cover or from the cover to the base, and that the points of offtake and intake for the fluids may be reversed so that the passages 50 and 51 communicate initially with the cover and the passages 5 and 6 with the base. In all cases the manner of flow through the regenerator body, and the location of the fluid passages will be governed by the construction of the furnace and the necessary location of the regenerator with respect thereto. The drawings are thus to be considered as merely illustrative of one embodiment of the invention.

The term "rotation" as used in the claims, unless limited to continuous rotation, is to be construed as covering either a continuous or an

intermittent movement, it being understood that the continuous rotation is usually preferable due to the fact that by such a rotative movement the temperature conditions can be maintained more nearly constant at all times.

While I have herein illustrated and described certain preferred embodiments of the present invention, it will be understood that changes in the construction, arrangement and relationship of the parts may be made without departing either from the spirit of the invention or the scope of my broader claims.

I claim:

1. The combination with a furnace, of a rotatable regenerator, and means for continuously supplying fluid to be heated to said furnace through the regenerator and withdrawing heating fluid from the furnace through the regenerator in a constant direction and in opposition to the direction of regenerator rotation.

2. The combination with a furnace having an inlet and an outlet port, of a regenerator, means for supplying fluid to said regenerator, means for withdrawing fluid from said regenerator, and means for rotating said regenerator between said supply and exhaust means and said ports about an axis substantially normal to the direction of flow through said ports.

3. The combination with a furnace having inlet and outlet ports, of a regenerator adapted to supply heating fluid to said furnace and receive heating fluid from said furnace about an axis substantially normal to the direction of flow through said ports, and means for rotating said regenerator during its operation.

4. The combination with a furnace having inlet and outlet ports, of a rotatable regenerator providing a circuitous flow path in directions substantially parallel to the axis of rotation and circumferential, means for rotating said regenerator to continuously bring different flow paths therein into cooperative relation to said ports, and means for supplying fluid to and exhausting fluid from said regenerator.

5. The combination with a furnace, of a regenerator including a stationary cover and stationary base in spaced relation one to the other with a rotatable body therebetween and closing said space, of means for rotating said body, and means for sealing said body during rotation to both said cover and said base.

6. The combination with a regenerator furnace, of a regenerator adapted to have fluid flows therethrough in the same direction at all times and extending both transversely and circumferentially thereof, and means for continuously moving said regenerator to provide a refractory zone of constant temperature for the gases to the furnace and a refractory zone of constant temperature for the outlet gases from the regenerator.

7. In the method of operating furnaces, the steps comprising constantly passing a fluid medium to the furnace in one direction, constantly removing a heating medium from the furnace in a constant direction, and continuously moving

a heat exchanging surface with relation to said fluid medium and said heating medium and in a direction opposite to the flow thereof.

8. In the method of operating furnaces, the steps comprising constantly passing a fluid medium to the furnace in one direction, constantly removing a heating medium from the furnace in a constant direction, and moving a heat exchanging surface with relation to said fluid medium and said heating medium and in a direction opposite to the flow thereof.

9. The combination with a furnace having inlet and outlet ports, of a stationary cover, a stationary base, a regenerator rotatable between said cover and base, said base having supply and exhaust ports therein, and means in said cover and base insuring a flow through said regenerator in a plurality of passes from one side to the other thereof in a direction substantially parallel to the axis of rotation.

10. The combination with a furnace having inlet and outlet ports, of a stationary cover, a stationary base, a regenerator rotatable between said cover and base, said base having supply and exhaust ports therein, and means in said cover and base insuring a flow through said regenerator in a plurality of passes from one side to the other thereof in a direction substantially parallel to the axis of rotation, said means being in staggered relation in the cover and base respectively.

11. The combination with a furnace having inlet and outlet ports, of a stationary cover, a stationary base, a regenerator rotatable between said cover and base, said base having supply and exhaust ports therein, means in said cover and base insuring a flow through said regenerator in a plurality of passes from one side to the other thereof in a direction substantially parallel to the axis of rotation, and other means in said cover and said base respectively cooperating with said regenerator during rotation thereof for preventing short circuiting between the respective ports.

12. The combination with a furnace having inlet and outlet ports, of a stationary cover projecting outwardly from said ports and terminating in a sealing member, a regenerator rotatable about a vertical axis lying below said cover and in sealing engagement with said member, a base below said regenerator having sealing engagement therewith, and means for supplying a fluid medium to and exhausting a fluid medium from said regenerator to said ports through said base.

13. The combination with a furnace having inlet and outlet ports, of a stationary cover projecting outwardly from said ports, a regenerator rotatable about a vertical axis lying below said cover, a base below said regenerator and having supply and exhaust ports therein, and means in said cover and base in staggered relation to each other insuring a flow through said regenerator in a plurality of passes from the top to the bottom thereof.

SAMUEL A. FORTER.