Aug. 4, 1936. E. A. VIEROW 2,049,478

REGENERATIVE FURNACE

Filed May 12, 1934 4 Sheets-Sheet 1

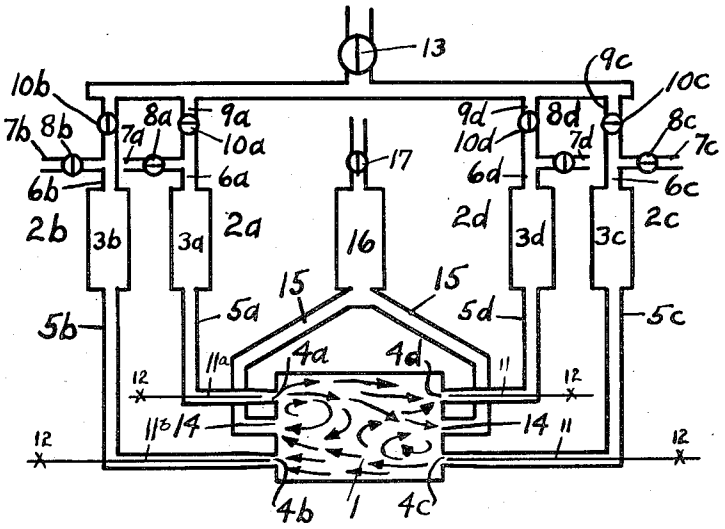


FIG. 1



FIG. 2

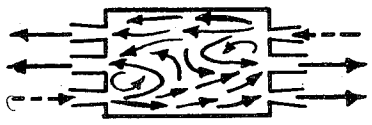


FIG. 3

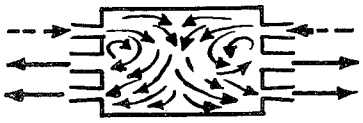


FIG. 4



FIG. 5

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REGENERATIVE FURNACE

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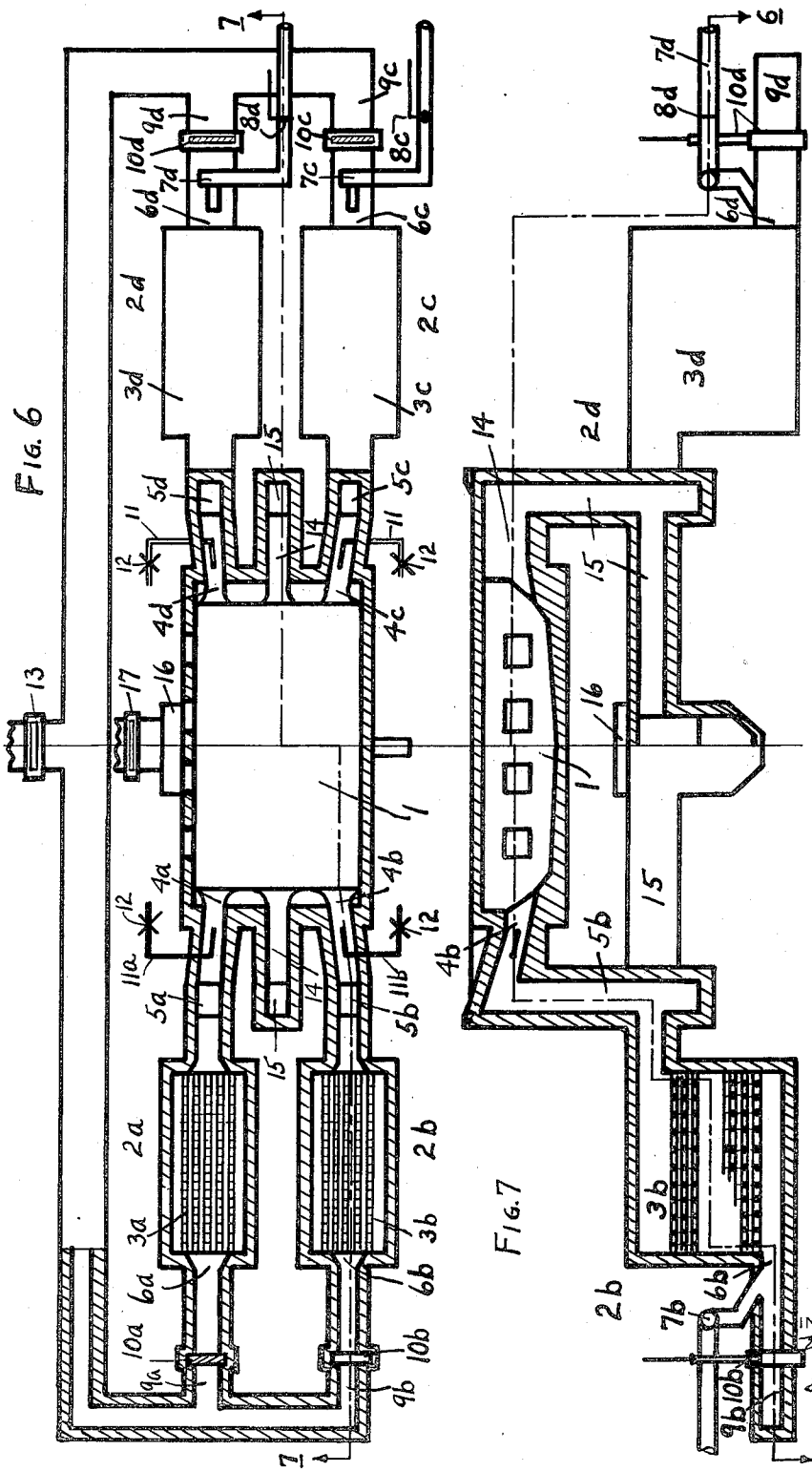


FIG. 6

FIG. 7

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REGENERATIVE FURNACE

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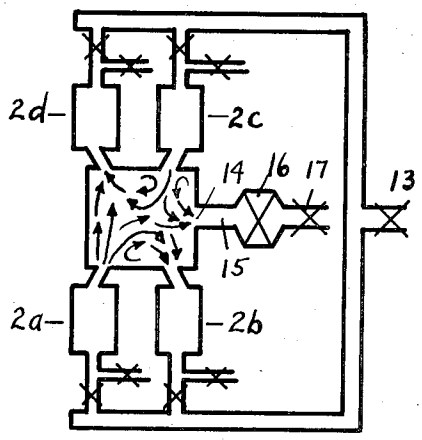


FIG. 8

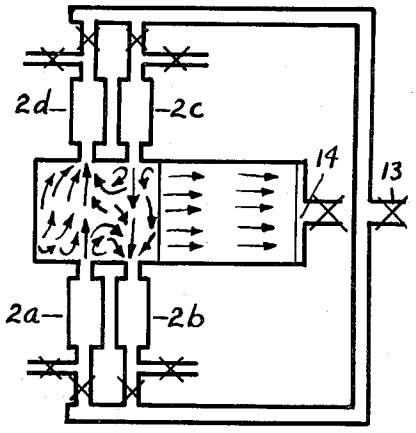


FIG. 9

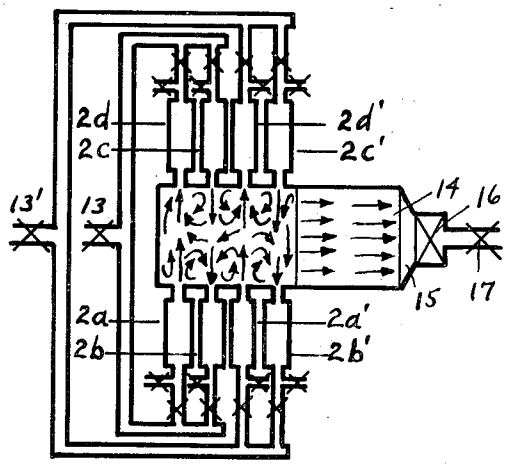


FIG. 10

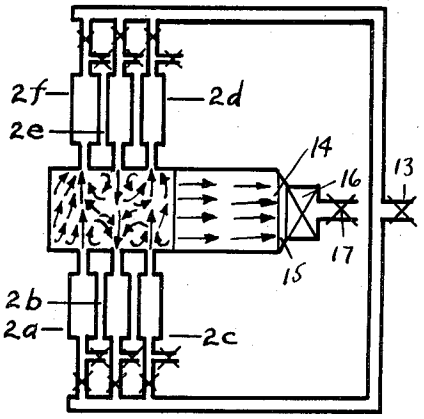


FIG. 11

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REGENERATIVE FURNACE

Filed May 12, 1934 4 Sheets-Sheet 4

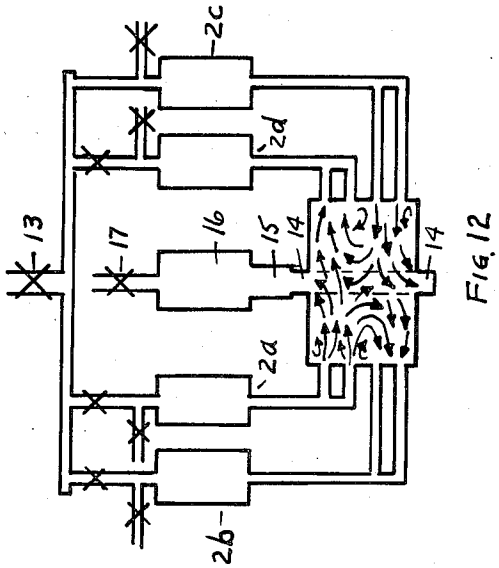


FIG. 12

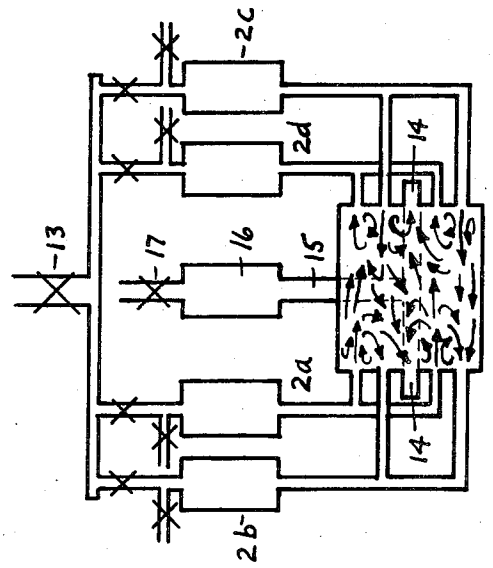


FIG. 14

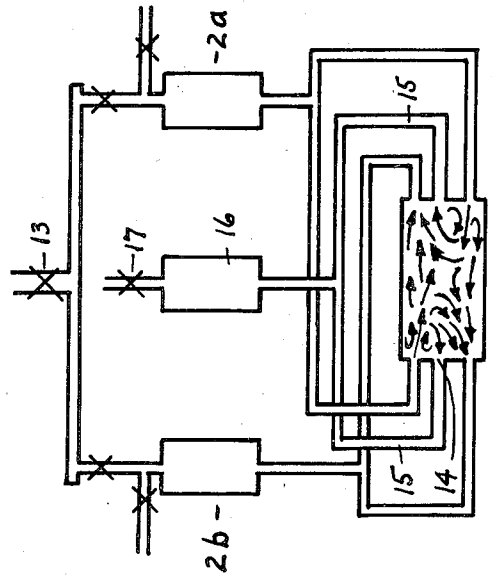


FIG. 13

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UNITED STATES PATENT OFFICE

2,049,478

REGENERATIVE FURNACE

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Application May 12, 1934, Serial No. 725,251

10 Claims. (Cl. 263—52)

This is a companion application of Serial No. 725,250 filed by applicant herein on May 12, 1934.

This invention relates to regenerative furnaces and more particularly to regenerative furnaces wherein only a part of the products of combustion produced in firing the furnace chamber are exhausted through ports and their corresponding regenerators, the remaining products of combustion serving either in preheating material, holding material at constant temperature, giving up heat to waste heat boilers, etc. or passing directly to the stack.

In ordinary practice regenerative furnaces are provided with two separate identical regenerative units having their respective ports in opposite parts of the furnace chamber.

A regenerative unit may comprise a port, a regenerating chamber, a flue and a source of air and/or fuel supply, all of which are connected by means of passages controlled by valves. Each unit may function alternately in preheating air or both fuel and air and introducing fuel and preheated air or both preheated fuel and preheated air into the furnace chamber and in conducting products of combustion away from the same and extracting heat therefrom.

When preheated air and non-preheated fuel are to be used the regenerative unit would comprise a regenerating chamber arranged to be connected alternately to an air supply and a source of draft, a port or ports arranged to function alternately to introduce fuel and preheated air for combustion into the furnace chamber and to conduct the products of combustion away from the same, and a passage or passages connecting the air regenerating chamber with the port or ports.

When preheated fuel and preheated air are employed the regenerative unit would comprise a set of regenerating chambers, one arranged to be connected alternately to a fuel supply or to a draft and the other arranged to be connected alternately to an air supply or to a draft, a port or ports arranged to function alternately to introduce preheated fuel and preheated air for combustion into the furnace chamber and to conduct the products of combustion away from the same, and a passage or passages connecting the air regenerating chamber and a passage or passages connecting the fuel regenerating chamber with a port or ports.

In accordance with present practice, the method of operation comprises employing the two separate identical regenerative units oppositely in their alternate duties of preheating air or both fuel and air and in introducing the same into the furnace chamber and of exhausting the total products of combustion from the furnace chamber and extracting heat therefrom.

It is a known fact however that the heat in the products of combustion leaving a furnace chamber at high temperatures is far in excess of the heat that can be economically recovered in preheating the required amount of air or both fuel and air for combustion.

This fact is evidenced by the relatively high temperatures at which the products of combustion leave regenerating chambers. The only real practical use to which the residual heat in the products of combustion leaving the regenerating chambers can be put to use is in steam raising and even for this purpose an equivalent heat content of products of combustion at furnace temperature might more economically be utilized. At the same time the maintenance of the regenerating chambers would obviously be less on account of the smaller quantity of products of combustion handled.

Accordingly, it has been proposed, for example, that the present regenerative open hearth furnaces for making steel be modified in construction and operation so that part of the products of combustion are exhausted directly to a boiler or other means of heat recovery.

In order to accomplish this it would be necessary to employ valves which alternately open and close flues from each end of the furnace chamber to the boiler, which valves would have to be water cooled and would extract much heat. Their operation would also be a nuisance. Under such conditions the proposed practice has not seemed profitable.

In addition, although the ports could be much smaller to adequately handle the lesser quantity of products of combustion, which would give a higher port velocity for the fuel and air entering the furnace, this would not be productive of any outstanding results.

Certain continuous furnaces such as steel heating where the material to be heated is advanced over the hearth from one end to the opposite end and discharged, are provided at the discharge end with two regenerative units having their respective ports or series of adjacent ports at opposite parts of the furnace chamber and at the charging end with a waste gas outlet. The firing is alternately from one regenerative unit to the other, a major part of the flame proceeding to the charging end of the furnace.

The only objective of this construction and

practice is to obtain the desired flame temperature when using lean fuels such as blast furnace gas. The firing is not complete at the firing end of the furnace chamber and the furnace gases are still burning as they travel through the ports and regenerators. This does not contribute to efficient recovery of heat. Furthermore a non-uniform temperature across the path of material is obtained.

It is an object of the present invention to provide a new and improved regenerative furnace whereby a part of the products of combustion are more advantageously and economically diverted from the furnace chamber with a resultant overall increase in furnace efficiency.

It is an additional object to provide the method and means for obtaining the desired uniformity of temperature and atmosphere within the one or more firing zones of the furnace chamber.

It is also an object to provide a regenerative furnace construction and operation capable of efficiently meeting widely flexible rates of production.

Other and further objects will appear as the description proceeds.

These objects I effect in a regenerative furnace of the character described by the method and use of a plurality of oppositely grouped ports in combination with the furnace chamber, said construction being particularly characterized by the fact that regenerative units can be operated so that simultaneously ports in each opposite group perform in their alternate functions. The method of operation is to simultaneously fire and exhaust part of the products with ports in each opposite group and to employ the same direct outlet means for conducting part of the products from the firing zone or zones of the furnace chamber.

In the drawings:

Fig. 1 is a diagrammatic view in plan illustrating one arrangement in accordance with my invention for in-and-out or batch type furnaces.

The arrows indicate the firing of the furnace chamber and the removal of products of combustion for one condition in a possible cycle of operation for this construction, in accordance with my invention.

Figs. 2–5 inclusive are diagrams showing the various conditions of firing and removal of products of combustion for the most extensive cycle of operation for the construction illustrated in Fig. 1. The dotted line arrows indicate ports engaged in firing and the solid line arrows show the travel of furnace gases to the ports and the additional direct outlet or outlets engaged in exhausting the same.

Fig. 6 is a plan view taken along the irregular line 6—6 in Fig. 7 showing an open hearth furnace embodying the arrangement diagrammatically illustrated in Fig. 1.

Fig. 7 is a vertical section of the same taken along the irregular line 7—7 in Fig. 6.

Figs. 8–11 are diagrammatic views in plan similar to Fig. 1 and illustrating some of the other possible modifications in accordance with my invention.

Figs. 12, 13 and 14 are diagrammatic views in plan showing possible modifications in regenerative units and their connections with the furnace chamber.

Referring now more particularly to the accompanying drawings, the numeral 1 represents a furnace chamber in combination with separate regenerative units generally designated by a reference numeral 2 and more specifically indicated as 2*a*, 2*b*, 2*c*, etc. Each regenerative unit is a separate and distinct combination of units and are generally designated as a regenerating chamber 3 and port 4, which are connected by passages 5 and more specifically as 3*a*, 4*a*, and 5*a*, etc. Each regenerating chamber 3 has a flue 6 which serves either as an entrance for air from the positive air supply pipe 7 through the air valve 8 or as an outlet for products of combustion to the source of draft by means of a waste gas flue 9 and a waste gas valve 10. By closing its air valve 8 and opening the corresponding waste gas valve 10 the products of combustion will pass through a selected regenerative unit; and on the contrary, by closing the waste gas valve and opening the air valve, the unit will deliver preheated air to its port.

For the sake of clearness throughout I have distinguished the above described elements of the various regenerative units shown in the drawings by the addition to the numerals generally designating the same of letters corresponding to those distinguishing the corresponding regenerative units.

The direct outlet means and related construction for handling part of the furnace gases produced in firing the furnace chamber are indicated by corresponding numerals in the various diagrams showing different furnace applications.

In the drawings, wherein I have illustrated certain embodiments of a preferred form of my invention it will be noted, that;

The drawings indicate the type of regenerative units for furnaces employing a high heat value fuel such as natural gas, coke oven gas, tar, pulverized fuel, etc. which do not require preheating, so that regenerating chambers for air alone are provided. This invention is also applicable, however, in furnaces using a preheated fuel, wherefor the regenerative units are provided with separate regenerating chambers and passages for air and fuel.

Referring now particularly to Fig. 1, the furnace chamber 1 is connected with four separate identical regenerative units, 2*a* and 2*b* having single ports 4*a* and 4*b* respectively at one side of the furnace chamber and 2*c* and 2*d* having single ports 4*c* and 4*d* respectively at an opposite side. The numeral 13 designates a valve or or means 17 for regulating the draft acting on the regenerative units as a whole.

Symmetrically located with respect to the ports at each side are direct outlet flues or continuously discharging ports 14 and passages 15 connecting with a waste heat boiler 16. At the outlet side of the waste heat boiler is provided a valve or means 17 for regulating the draft acting on the boiler system.

It will be observed in Fig. 1 that simultaneously in each of the two opposite groups of ports at opposite sides of the furnace chamber one port serves to fire the furnace chamber and the other port to exhaust a part of the products of combustion while a separate direct outlet means performs in conducting a part of the products of combustion away from the furnace chamber.

In particular this diagram shows regenerative units 2*a* and 2*c* having their respective ports 4*a* and 4*c* at diagonally opposite sides of the furnace chamber as employed in preheating air and introducing fuel and preheated air into the furnace chamber and regenerative units 2*b* and 2*d*

having their respective ports 4b and 4d at diagonally opposite sides of the furnace chamber as employed in exhausting a part of the products of combustion from the furnace chamber and extracting heat therefrom while the direct outlet means 14 and passages 15 continuously conduct a part of the products of combustion directly to a waste heat boiler. This operation of the regenerative units illustrates but one condition in a possible cycle of operations in accordance with my invention.

Thus a log for the most extensive cycle of operation of regenerative units for this structure, as illustrated in Figs. 2–5 might read:

(1) Reversal of units 2a and 2b. Units 2b and 2c firing and arrangements 2a and 2d exhausting a part of the products of combustion—Fig. 2.

(2) Reversal of units 2c and 2d. Units 2b and 2d firing and units 2a and 2c exhausting a part of the products of combustion—Fig. 3.

(3) Reversal of units 2b and 2a. Units 2a and 2d firing and units 2b and 2c exhausting a part of the products of combustion—Fig. 4.

(4) Reversal of units 2d and 2c. Units 2a and 2c firing and units 2b and 2d exhausting a part of the products of combustion—Fig. 5.

It is obvious that the cycle of operation might be modified so that only diagonally opposite ports would be engaged in both firing and exhausting a part of the products of combustion as illustrated in Figs. 3 and 5.

Assuming that only half the total products of combustion need be exhausted by regenerative units for economically obtaining the preheated air at the desired degree, the individual ports in arrangement shown in Fig. 1 need only be adequately large to handle but one-half the products of combustion produced by the firing of an identical port.

Consequently, when the ports are employed in their alternate function, i. e., in firing the furnace chamber, the preheated air is delivered at relatively high velocity and a relatively high flame velocity is obtainable.

The use of relatively high flame velocities in firing a furnace chamber does not in itself, as has been previously described, meet the requirements for satisfactory furnace operation.

However, with counter directional firing as practiced according to my invention, jets of fuel and air brought into the furnace in opposing directions at relatively high velocity expend their kinetic energy in acting upon the furnace gases and upon each other with the result that lively circulation and excellent turbulence in the furnace chamber is effected and maintained.

Such turbulence insures a thorough mixing of fuel and air and a homogeneous gaseous mixture within the furnace chamber.

It is possible therefore to control or maintain a given temperature by merely regulating the fuel and air supply.

A uniform heat distribution is likewise obtained because of the homogeneous gaseous mixture throughout the furnace chamber. This makes for a properly and uniformly heated, melted or refined product.

The nature of the atmosphere in the furnace chamber will not vary to any great extent at different parts of the heating, melting or refining surface because of the uniform mixture of gases throughout the furnace chamber.

The simultaneous firing and conducting of products of combustion away from each side of the furnace chamber also results in a more equalized furnace pressure.

Further, with complete mixing of fuel and air within the furnace chamber, combustion will not carry over and damage the ports, passages and regenerating chambers. The firing with complete combustion within the furnace chamber likewise makes for the efficient use of fuel as well as does the increased productivity obtained with such useage.

Furnace gases produced from the firing at each side will travel to and pass out at both the same and the opposite side. With the proper design and arrangement of ports there is no danger of furnace gases short-circuiting to and being exhausted by the adjacent port or ports before combustion is completed, because of the relatively high flame velocities obtainable.

Also, since only one-half of the products of combustion are exhausted through the regenerative units, the regenerating chamber may be designed with a long path of travel with a resultant high regenerating chamber efficiency and low maintenance. Of course no water cooled outlet valves are necessary, since the products of combustion leave the regenerating chambers at very low temperatures.

Finally, one-half of the products of combustion at the firing zone heat potential are available for heat recovery, which is accomplished by a waste heat boiler in this case. This makes for more economical recovery of the residual heat than in the usual case, where the total products of combustion leave the regenerators at a relatively lower temperature.

The preferred form of the method of operation according to my invention comprises the continuous use of a single system of operation for each set of regenerative units. A separate but like cycle of operation in each of the two opposite groups of ports is likewise preferable.

It is proposed that the furnace pressure be maintained constant for a given operating condition by varying the draft effect on the direct outlet means alone.

For example, in the case illustrated in Fig. 1, the valve 13 operating on the regenerative units would be set sufficiently open to exhaust the desired quantity of products through the regenerative units, and then the valve 17 would vary to maintain a constant furnace pressure. It is obvious that with automatic machine operation the furnace operation would be very simple.

If the preferred method for reversal according to my invention be embodied in the arrangement shown in Fig. 1, then:

Assuming that unit 2a which is supplying the furnace chamber with fuel and preheated air is to be oppositely reversed with unit 2b which is exhausting products of combustion and extracting heat therefrom. At the opposite side of the furnace chamber 2c is performing the first named function and 2d the second named function. Direct outlet means 14 and passages 15 are continuously employed in conducting part of the products of combustion from the furnace chamber through the waste heat boiler 16 and the valve 17.

If the waste gas valve 10 be closed and simultaneously the air and fuel valves 8a and 11a respectively be proportionately closed until one-half the original air and fuel rate of 2a is reached, the rate of flow of products of combustion through 14 will remain practically unchanged. Then if the air and fuel valves 8a and

11a respectively be further closed and simultaneously 8b and 11b respectively be proportionately opened until one-half the original air and fuel rate of 2a is reached there will be no change over the immediately previous condition. Finally if the waste gas valve 10a be opened and simultaneously air and fuel valves 8b and 11b be proportionally further opened until the original air and fuel rate of 2a is reached, the reversal is then complete.

This cycle of operation is readily adaptable to automatic machine operation.

With this method of reversal it is obvious that the firing is practically continuous and without variation of the pressure and atmosphere conditions in the furnace chamber so that the process within remains practically unaffected.

The same advantage may be obtained in lesser degree in certain furnaces such as shown in Fig. 1 in accordance with the modified system of furnace operation wherein at least one regenerative unit performs in preheating air or air and fuel and introducing fuel and preheated air or preheated fuel and preheated air into the furnace chamber and the direct outlet means in conducting products of combustion away from the furnace chamber and in extracting heat therefrom while reversing other regenerative units.

The embodiment of the invention diagrammatically shown in Fig. 1 is particularly illustrated in Figs. 6 and 7 as applied to open hearth steel furnaces utilizing a fuel such as natural gas, coke oven gas, or tar which does not require preheating in regenerators, the air only being preheated by the latter. Thus the fuel pipes 11 are shown projecting into the air passage to provide ports for firing, said pipes being provided with valves 12.

In Fig. 8 the diagram shows an arrangement similar to that shown in Fig. 1 in that of the four separate identical regenerative units, 2a and 2b having single ports at one side of the furnace chamber and 2c and 2d having single ports at an opposite side are provided.

Fig. 8 differs from Fig. 1 with respect to the location of the direct outlet means 14 and passage 15 which are provided at the center of the furnace at its side. This is merely to show that the location of the outlet means may be variously changed without departing from the spirit of the invention.

In Fig. 9 one set of four regenerative units is provided, one comprising units 2a and 2b having their respective ports at one side of the furnace chamber and units 2c and 2d having their respective ports at an opposite side. The direct outlet means 14 is located at an end of the furnace chamber somewhat removed from the firing zone.

This arrangement is such as may be desired in some processes involving both melting and refining such as for glass or metal where a high temperature is desired and a relatively lower temperature in refining the material flowing from the melting zone through the refining zone.

This furnace arrangement is also such as may be desired in continuous furnaces such as for heating steel wherein part of the products of combustion flow counter directional to the path of material flow and preheat the steel before it reaches the firing zone.

In Fig. 10 two sets of four regenerative units are provided one comprising units 2a and 2b at one side of the furnace chamber and 2c and 2d at the opposite side and the other set comprising 2a' and 2b' at one side of the furnace chamber and 2c' and 2d' at the opposite side.

This furnace arrangement has applications similar to that in Fig. 9 but has the further advantages that the temperature may be separately controlled in different parts of the furnace chamber.

In Fig. 11 a set of six regenerative units are provided 2a, 2b, 2c having their respective ports at one side of the furnace chamber and 2d, 2e, 2f having their respective ports at an opposite side of the furnace chamber. The direct outlet means is located in the same manner as in Figs. 9 and 10. This construction has applications similar to Figs. 9 and 10, the purpose of illustration being merely to show one possible modified form of construction and operation.

Figs. 12, 13, and 14 show some of the possible modifications in regenerative units and their connections with the furnace chamber.

In Fig. 12, four identical regenerative units are provided, 2a and 2b having double ports respectively adjacent at one side of the furnace chamber and 2c and 2d having double ports respectively adjacent at an opposite side. The direct outlet means is shown located at the center of the furnace at both sides.

In Fig. 13, two identical regenerative units are provided, 2a and 2b, each having a single port at each of two opposite sides of the furnace chamber. The direct outlet means is symmetrically located with respect to the ports at each side of the furnace chamber.

In Fig. 14, four identical regenerative units are provided, 2a and 2b having two ports each on one side of the furnace chamber wherein one of the ports of one regenerative unit is immediately adjacent one of the ports of the other regenerative unit, thereby providing alternate ports from the two regenerative units. The regenerative units 2c and 2d having two ports each are similarly arranged on the opposite side of the furnace chamber. The direct outlet means is shown symmetrically located with respect to two series of ports at each side of the furnace chamber.

Many other modifications in construction and operation embodying the same invention are readily apparent.

Any method of heat recovery or use of waste heat may be employed in practicing this invention. For example, the waste heat from the direct outlet means of several furnaces might in certain cases be economically conducted to a central waste heat boiler or other heat recovery apparatus. In certain cases where the furnace gases reach the direct outlet means at a relatively low temperature a recuperator might be employed to recover residual heat in the preheating of air or fuel for constant directional firing in parts of the same or in other furnace applications. Cold material in some cases could be charged to the furnace firing zone through a stack or kiln through which part of the products of combustion from the firing zone are exhausted and in this manner serves to preheat the material.

Therefore, while I have described my invention in numerous modifications it will be understood that other and further modifications in operation and construction might be made without departing from the principles of the invention. Therefore I do not wish to be under-

stood as limiting the invention to the particulars shown and described.

I claim:

1. A method of operating a regenerative furnace provided with a pair of regenerative units on each of its sides and a continuously discharging port on each side between the ports of the regenerative units, which comprises the simultaneous operation of the regenerative units in a cycle wherein one unit is firing on each side while the other ports are discharging therefrom.

2. A method of operating a regenerative furnace provided with a plurality of regenerative units on each of its sides and a continuously discharging port on each side and centrally positioned with respect to the ports of the regenerative units, which comprises the simultaneous operation of the regenerative units in a cycle wherein a lesser number of ports are employed for firing and a greater number for discharging therefrom and wherein on one side at least one regenerative unit which is functioning to discharge and the continuously discharging port are immediately adjacent the regenerative unit that is firing.

3. A method of operating a regenerative furnace provided with a pair of regenerative units on each of its sides and a continuously discharging port on each side between the ports of the regenerative units, which comprises the simultaneous operation of the regenerative units in a cycle wherein one unit is firing on each side while the other units and the continuously discharging ports are discharging therefrom, thus providing for furnace operation under constant pressure, and reversing the operation of the individual units without disturbing such constant pressure.

4. A method of operating a regenerative furnace provided with a pair of regenerative units on each of its sides and a continuously discharging port on each side between the ports of the regenerative units, which comprises the simultaneous operation of the regenerative units in a cycle wherein one unit is firing on each side while the other units and the continuously discharging ports are discharging therefrom, thus providing for furnace operation under constant pressure, and simultaneously reversing a pair of regenerative units which have been performing opposite functions in such manner that the discharging regenerative unit is being reversed at a faster rate than the firing regenerative units so that while both of these regenerative units are firing their combined capacity does not exceed one-half of the full capacity of a normal firing regenerative unit.

5. A method of operating a regenerative furnace provided with a plurality of regenerative units on each of its sides and a continuously discharging port, which comprises the simultaneous operation of said regenerative units in a cycle wherein on each side a lesser number of regenerative units are employed for firing and a greater number for discharging therefrom, thus providing for furnace operation under constant pressure, and reversing the operation of the individual regenerative units without disturbing such constant pressure.

6. A method of operating a regenerative furnace provided with a plurality of regenerative units on each of its sides and a continuously discharging port, which comprises the simultaneous operation under constant pressure, and simultaneously reversing a pair of regenerative units, which have been performing opposite functions, in such manner that the discharging regenerative unit is being reversed at a faster rate than the firing regenerative unit so that while both regenerative units are firing their combined capacity does not exceed one-half of the full capacity of a normally firing regenerative unit.

7. A method of operating a regenerative furnace provided with a plurality of regenerative units on each of its sides and a continuously discharging port substantially centrally positioned with respect to the ports of the regenerative units, which comprises the simultaneous operation of the regenerative units in a cycle wherein a lesser number of ports are employed for firing and a greater number for discharging therefrom.

8. A method of operating a regenerative furnace provided with a plurality of regenerative units on each of its sides and a continuously discharging port, which comprises the simultaneous operation of said regenerative units in a cycle wherein on each side a lesser number of regenerative units are employed for firing and a greater number for discharging therefrom, and reversing the operation of the individual regenerative units in such a manner as to maintain constant furnace pressure.

9. A method of operating a regenerative furnace provided with a plurality of regenerative units on each of its sides and a continuously discharging port, which comprises the simultaneous operation under constant pressure, and simultaneously reversing a pair of regenerative units which have been performing opposite functions on each side by regulating their respective capacities during the transition period in proper proportion to maintain constant furnace pressure.

10. A method of operating a regenerative furnace provided with a pair of regenerative units on each of its sides and a continuously discharging port centrally positioned with respect to the ports of the regenerative units, which comprises the simultaneous operation of said ports in a cycle wherein one port on each side of said furnace is firing while the other ports are discharging therefrom.

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