Nov. 2, 1937. W. H. PAVITT 2,098,013

COMBINATION REGENERATIVE COKE OVEN

Filed Aug. 8, 1933 3 Sheets-Sheet 1

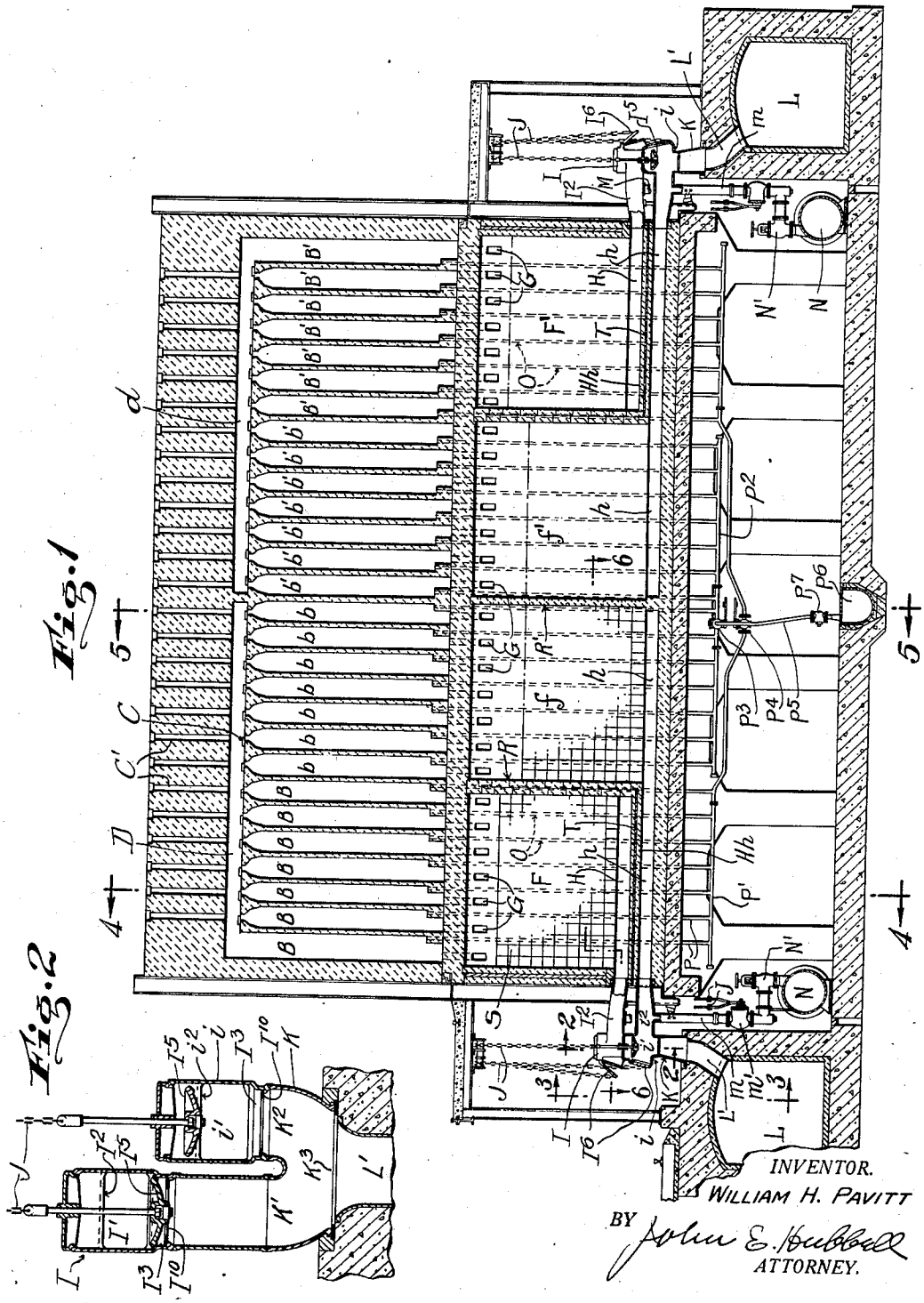


Fig. 1

Fig. 2

INVENTOR.
WILLIAM H. PAVITT
BY John E. Hubbell
ATTORNEY.

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Fig. 5

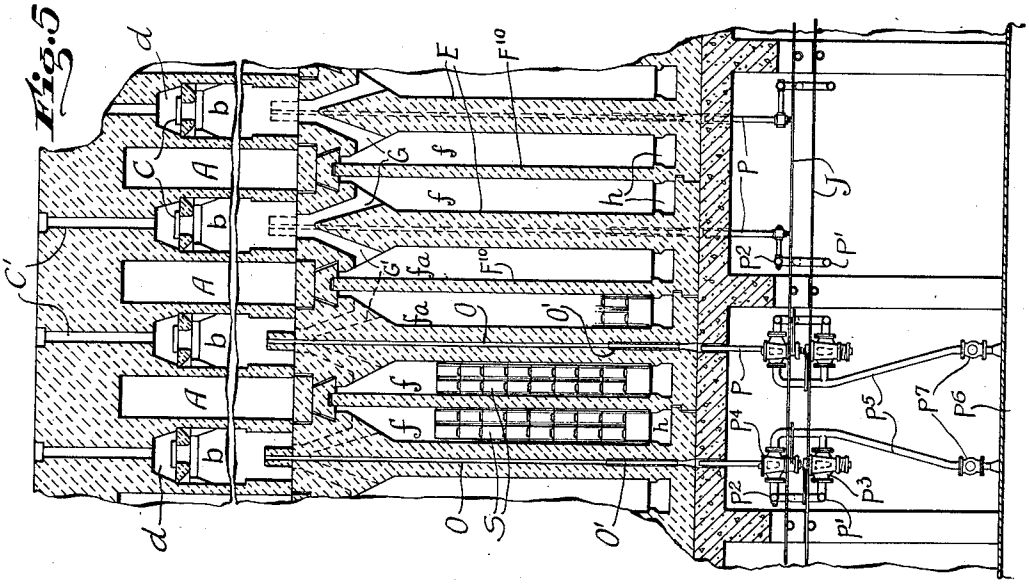


Fig. 4

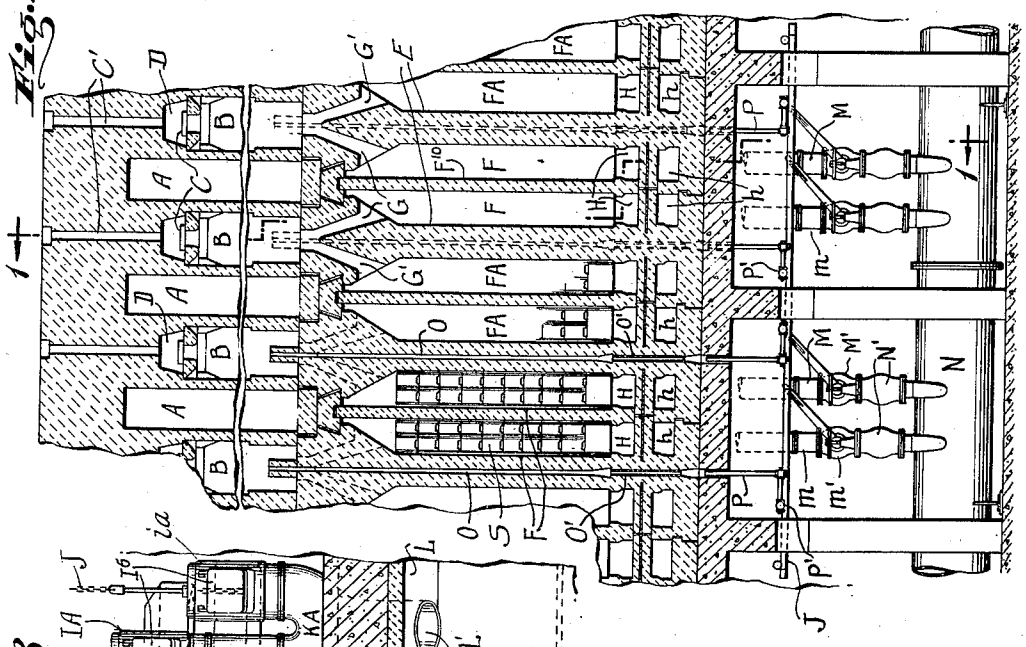
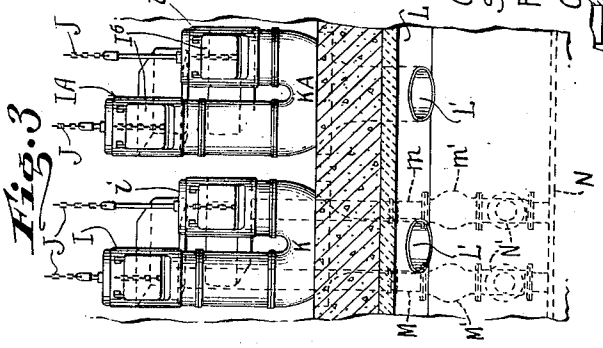


Fig. 3

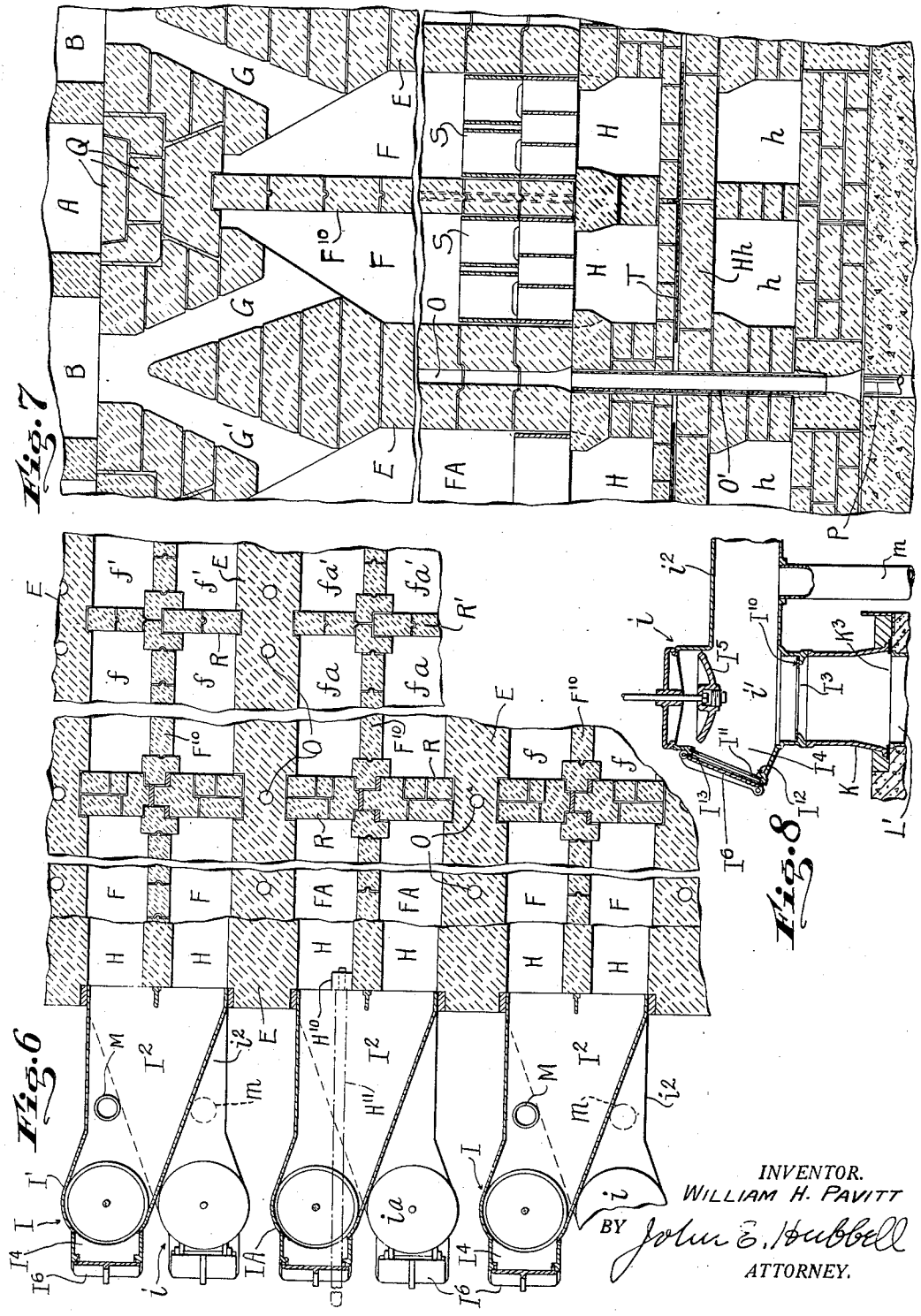


INVENTOR.
WILLIAM H. PAVITT
BY John E. Hubbell
ATTORNEY.

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INVENTOR.
WILLIAM H. PAVITT
BY John E. Hubbell
ATTORNEY.

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UNITED STATES PATENT OFFICE

2,098,013

COMBINATION REGENERATIVE COKE OVEN

William Hesser Pavitt, Bronxville, N. Y., assignor to Adele Johnson Wilputte, New Rochelle, N. Y.

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15 Claims. (Cl. 202—144)

My present invention relates to regenerative byproduct coke oven structures having horizontally elongated coking chambers separated by flued heating walls and particularly to such ovens of the type known as combination ovens which are adapted for operation optionally either with a rich fuel gas, as coke oven gas, which does not require regenerative preheating, or with a lean fuel gas, as blast furnace gas, which must be preheated in some of the regenerators of the oven structure, while the remaining regenerators are being used in preheating air for combustion, all of the regenerators being used in preheating air for combustion when the oven is heated by the combustion of rich fuel gas.

The general object of the present invention, broadly stated, is to provide an improved coke oven of the above mentioned general type, which is adapted for use in units of the large size and capable of operation with the short coking time required to meet the modern demand for high duty combination coke ovens, and which will permit of the close control and regulation of the heat distribution desirable in such high duty ovens, and which is characterized by features of oven construction and arrangement simpler and better from the construction and maintenance standpoint than are found in coke ovens which have been constructed heretofore and are now in use for high duty service, and which are capable of the heat distribution control and regulation required for high duty service.

In my improved oven, each heating wall is formed with a row of vertical flues extending from one end to the other of the heating wall, and with two end-to-end upper horizontal channels, each extending for approximately half the length of the wall and being connected to the upper ends of the subjacent vertical flues. Each such upper horizontal channel and the vertical flues beneath it form part of an individual heating unit which also includes two end-to-end regenerators at each side of the pillar wall beneath the corresponding heating wall, each such regenerator extending for approximately one-fourth of the length of the heating wall and being connected to each of the vertical flues in the corresponding quarter length of the heating wall. The two regenerators of each unit at one side of the corresponding pillar wall are used in preheating air for combustion, or optionally in preheating lean fuel gas accordingly as the fuel gas for the unit is a rich gas not requiring preheating or is a lean gas which needs to be preheated, and the other two regenerators of the unit are used at all times in preheating air for combustion.

In accordance with the present invention, the regenerators optionally usable in preheating air or lean fuel gas for combustion in any one heating wall are located alongside the regenerators similarly usable for preheating air or lean fuel gas for combustion in an adjacent heating wall, in the space between the pillar walls beneath the two heating walls. In consequence, the regenerators exclusively used in preheating air are arranged in spaces between adjacent pillar walls which alternate with the similar inter-pillar wall spaces containing the regenerators optionally usable in preheating air and lean fuel gas. With the heating wall and regenerator arrangement described, the regenerators are necessarily arranged for end-to-end reversal, so that the fluid flow (air or lean gas or products of combustion) is always in the same direction (up or down) in side-by-side regenerators.

In accordance with the present invention, the two side-by-side pairs of end-to-end regenerators between each two pillar walls and between one side of the coke oven structure and the longitudinal center plane of the latter are served each by an individual sole channel extending into the structure from the corresponding side of the latter, the two sole channels underlying and serving the two side-by-side regenerators adjacent the side of the structure being arranged side-by-side and directly above the two longer side-by-side sole channels which underlie and serve the two regenerators more remote from the side of the structure.

The improved coke oven structure is provided with means for supplying rich fuel gas to the vertical flues which may be of any usual form, and which preferably include an individual gas supply channel leading upward to each vertical flue through the corresponding pillar wall, and means for supplying a regulated amount of rich fuel gas to each such channel, such as are used in known regenerative coke ovens of the so-called under burner type. Reversing valves and conduit connections external to the coke oven structure are provided as hereinafter described to supply air and lean fuel gas to, and to withdraw waste heating gases from the regenerators in properly regulated amounts through their sole channels.

The features of construction and arrangement already referred to are well adapted for the attainment of the above stated general object of the invention and to avoid difficulties and to satisfactorily solve problems, the avoidance and so-

lution of which constitute specific objects of the present invention. For a proper understanding of the manner in which the objects of the invention are attained by the features of construction and arrangement referred to, account should be taken of various matters. In particular account should be taken of the great amount of heat which must be furnished by each heating wall which must have its heating effect properly distributed to properly coke the charge. In a modern high duty oven of the general type referred to, each individual coking chamber may well be forty to forty-five feet long and from twelve to fifteen feet high with an average width varying from fourteen to sixteen inches at one end to sixteen to eighteen inches at the other end. A single coal charge in such an oven chamber of average size is in the neighborhood of eighteen tons. Bearing in mind that the carbonization of each pound of coal ordinarily requires in excess of one thousand B. t. u.'s, and that high duty service may regularly require the complete coking of the charge in from twelve to fifteen hours, and that the heating wall between two coking chambers must furnish the equivalent of all the heat required for coking one oven charge, it becomes apparent that heat must be passed into the coal from each unit area of the sides of the heating wall at a relatively rapid rate, and that the quantities of air and gas flowing through the flues of the wall are very large. On the assumption that the air supplied for combustion is only ten per cent in excess of the amount theoretically required, the coking of an eighteen ton coal charge requires the supply to the heating wall of more than twenty tons of air. Furthermore, this air entering the vertical flues at a temperature in the neighborhood of two thousand degrees and with a corresponding increase in volume, creates a problem of distribution which is especially great because of the disturbing effect on distribution of the velocity head of the flowing fluid.

The creation of the necessarily high velocity of flow requires a pressure differential between the regenerator air inlets and waste gas outlets, and high local velocities in portions of the air and gas paths of restricted cross section augment the pressure differences created. Appreciable fluid pressure differences in a coke oven structure are prejudicial because they tend to gas leakage through the brick walls separating the flue passages in the heating walls from the coking chambers, with a resultant direct loss in the value of byproducts recovered, and because they tend to leakage through division walls separating portions of the heating system which interferes with proper distribution of flow, and still more importantly because they give rise to combustion in portions of the structure in which combustion is highly objectionable. In a combination oven, the flow velocities and pressure differentials are especially large in a heating unit in which lean gas is preheated and burned because of the great increase in the volume of flow through portions of the unit then over the volume of flow through the same unit portions when heated by the combustion of rich fuel gas.

With each heating wall having two separate flue units of the character described and with the vertical flues in each unit connected to regenerator chambers associated in pairs for end-to-end reversal, and with suitable regenerator supply and off-take connections and means supplying rich fuel gas to the vertical flues as above described, the flow paths through the regenerators and heating walls are short and direct and the maximum gas velocities therein may be relatively moderate, thereby making it easily possible to maintain good heat distribution and gas pressure conditions in the heating walls. With a coke oven having such features, it is possible to obtain as good, and as easily regulable, heat distribution as is required by present day practice in combination coke oven structures having as large coking chambers and operating with as short coking periods as are considered practically desirable, while keeping the oven structure simpler and better from the mechanical standpoint than is possible with the types of oven structure most favorably regarded and most largely built in recent years.

I am not the first to recognize the mechanical advantages of my improved oven in respect to the features mentioned in the previous paragraph, or to recognize that those features insure good heat distribution and gas pressure conditions therein, but I believe I am the first to combine those features with an arrangement of regenerator sole channels and external supply and off-take connections thereto suitable for use in a combination oven having separate regenerators for preheating air and lean gas for heating walls heated by the combustion of lean gas. I believe I am the first also to combine in a coke oven the desirable features of mechanical construction and ease of regulating the supply of air or gas to be preheated in the regenerators, and the withdrawal of heating gases therefrom, which are inherent in a coke oven in which the upper horizontal channel and vertical heating flues in one half of each heating wall and the regenerators connected to said flues form part of a heating unit which is separate from the analogous heating unit including the upper horizontal channel and vertical flues in the other half of the heating wall and the regenerators associated therewith, with the rich fuel gas supply provisions which are characteristic of the underburner type of coke oven. That combination makes possible a heat distribution substantially as good as is obtainable in any type of coke oven heretofore constructed and used, and which is better than is obtainable with any prior type of coke oven which is as simple and desirable from the standpoint of mechanical construction and operation as coke ovens having the flues in the two halves of each heating wall included in separate heating units as disclosed herein.

The provision of such a combination which is satisfactory from the practical standpoint, is made difficult primarily by the limited space available for the disposition of sole channels of adequate cross-section, and by the limited space available for the external reversing valves and their connections to the sole channels and to the supply and waste heat means, and by the difficulty in preventing leakage into waste heat sole channels from the adjacent sole channels through which fuel gas is supplied to regenerators. Such leakage is especially objectionable because it results in combustion in the waste gas sole channels, and is especially prone to occur because of the relatively large excess of pressure in the supply sole channels over that in the waste gas sole channels, and because of the tendency to the formation of cracks and open brickwork joints in the sole channel portion of the oven structure as a result of the practical necessity of making that portion of the oven structure of fire-clay bricks having a very small coefficient of thermal ex-

pansion and of making the portion of the brickwork above the sole channels of silica bricks which have a relatively high coefficient of thermal expansion and which can not be used in the sole channel walls because of the spalling of silica bricks when subjected to temperature conditions prevailing in the regenerator sole channels.

The described disposition of the sole channels of my improved oven coupled with the fact that each supplies air or gas to and receives products of combustion from a quarter only of the vertical heating flues in a heating wall, permits each sole channel to be made large enough in cross-section to desirably minimize the maximum pressure differential between adjacent supply and off-take channels. The described arrangement of the sole channels at different levels results in the separation of the channels serving as supply channels from the channels serving as off-take channels, by a horizontal wall which extends into the oven structure from the side of the latter only for approximately one-quarter of the width of the structure and because of its horizontal disposition lends itself to a type of construction and to the use therein of special expedients, if necessary, whereby the risk of leakage through that wall may be suitably minimized, and which is relatively accessible for repair operations when necessary.

The described disposition of the sole channels of my improved oven makes it possible to supply air or gas to and to withdraw products of combustion from two sole channels extending into the structure from one side between an adjacent pair of pillar walls by a single reversing valve which I have devised for the purpose, and which it is practically feasible to arrange in the limited space available to receive that valve and the similar valve required for the two sole channels in superposed relation with those served by the previously mentioned valve. The space available for and occupied by each pair of said reversing valves is too restricted to receive a separate reversing valve for each of the four sole channels served by the two valves used by me. My improved reversing valves are arranged to permit the insertion, adjustment and removal through them of throttle brick or obstructing devices desirably used under certain conditions to throttle the outer ends of sole channels and permit the passage of a spray pipe extending into the corresponding sole channels for spraying cement onto the sole channel walls, if and when necessary to close cracks and brick joints which may open therein.

In addition to the above mentioned advantages, my improved oven is characterized by its capacity for operation with the combustion in some of the heating walls of lean gas preheated in the regenerators while other heating walls of the structure are being heated by the combustion therein of rich gas, and is characterized further by the facility with which oven repairs may be made.

For a better understanding of the nature of the present invention, its advantages and the specific objects attained with its use, reference should be had to the accompanying drawings and descriptive matter in which I have illustrated and described a preferred embodiment of the present invention:

Of the drawings:

Fig. 1 is a transverse section of a coke oven battery, the section being taken along a broken line 1—1 of Fig. 4;

Fig. 2 is a partial sectional elevation taken on the line 2—2 of Fig. 1;

Fig. 3 is a partial section on the line 3—3 of Fig. 1;

Fig. 4 is a partial section on the line 4—4 of Fig. 1;

Fig. 5 is a partial section on the line 5—5 of Fig. 1;

Fig. 6 is a partial plan with portions broken away in section on the line 6—6 of Fig. 1;

Fig. 7 is a section taken similarly to Fig. 4 but on a larger scale and with parts broken away; and

Fig. 8 is a partial section taken similarly to Fig. 2 but on a larger scale and showing a portion only of what is shown in Fig. 2.

The coke oven battery structure illustrated in the drawings comprises open ended horizontally elongated retorts or coking chambers A, the ends of which are normally closed by removable doors (not shown in the drawings). At each side of each coking retort A there is a heating wall formed with a series of vertical heating flues extending from one end of the wall to the other, the flues in each heating wall between an adjacent pair of retorts A supplying heat to each of the latter.

While the vertical heating flues in each heating wall may all be similar to one another, the connections thereto divide the flues in each wall into four end-to-end groups B, *b*, *b'* and B', with the flow of the heating gases at any one time in one direction (up or down) through the flues B and B', and in the opposite direction (down or up) in the flues *b* and *b'*. The number of flues in each group is preferably the same, or at least approximately the same as the number of flues in each other group. Each heating wall is formed with two end-to-end upper horizontal channels D and *d*, the channel D being above and connected to the upper ends of the corresponding flues B and *b*, while the channel *d* is above and connected to the upper ends of the corresponding flues B' and *b'*. The usual slide bricks or dampers C may be provided at the upper ends of the various vertical flues, and may be adjusted in a known manner through normally closed vertical channels or inspection holes C' extending from the channels D and *d* to the top of the oven structure.

At one side of each pillar wall E beneath each heating wall are located four end-to-end regenerators F, *f*, *f'* and F'. Each regenerator F extends along the pillar wall for a distance approximately equal to one-quarter of the length of the wall and corresponding to the length of the portion of the heating wall above it containing the flues B and each of the latter is connected by a passage G to said regenerator F. The regenerators *f*, *f'* and F' similarly extend along the portions of the pillar wall beneath the portions of the heating wall containing the groups of flues *b*, *b'* and B respectively, each of the latter being connected to the corresponding regenerator by an individual channel G.

At the opposite side of the last mentioned pillar wall, there is another row of regenerators FA, *fa*, *fa'* and FA', respectively alongside, and shown as identical in construction and arrangement with, the regenerators F, *f*, *f'* and F'. Each of the flues B in the heating wall is connected by an individual connection G' to the regenerator FA alongside the pillar wall beneath the heating wall, and the flues *b*, *b'* and B' are similarly connected to the regenerators *fa*, *fa'* and FA' respectively alongside the pillar wall. In the ar-

rangement shown, as hereinafter explained, the regenerator connections are adapted to permit the use of the regenerators F, *f*, *f'* and F' optionally to preheat air when rich fuel gas is used, and to preheat lean gas when the latter is the fuel gas, while with either fuel gas, the regenerators FA, *fa*, *fa'* and FA' are used in preheating air for combustion. Two side-by-side rows of regenerators F, *f*, *f'* and F' alternate with two side-by-side rows of regenerators FA, *fa*, *fa'* and FA', so that only regenerators F, *f*, *f'* and F', or regenerators FA, *fa*, *fa'* and FA' are placed between any two adjacent pillar walls E.

Under each of the outside regenerators F and FA there is provided a corresponding short sole channel H opening at its upper side to the regenerator to which it pertains and connected to a corresponding reversing valve structure at the corresponding side of the battery as hereinafter described. Beneath each such sole channel H is located the outer closed half of a long sole channel *h* which extends beneath and has its inner portion opening at its upper side to the corresponding inner regenerator *f* or *fa*. Similarly, short and long sole channels H and *h* extend into the battery structure from its other side and are similarly associated with corresponding regenerators F' and FA' and *f'* and *fa'*, respectively.

The outer ends of the two short sole channels H underlying each pair of regenerators F or F' between two adjacent pillar walls have their outer ends connected to a conduit extension I^2 of the valve chamber I' of a reversing valve I serving both regenerators. Similarly, the two side-by-side sole channels *h* connected to the two regenerator chambers *f* or *f'* between an adjacent pair of pillar walls have their outer ends connected to a conduit extension i^2 from the valve chamber *i'* of a reversing valve *i* generally similar to and arranged alongside of, but at a lower level than the valve I which is connected to the superposed sole channels H. Alongside each side of the battery two valves I and *i* alternate with two generally similar valves IA and *ia*, each valve IA having the conduit extension I^2 from its valve chamber I' connected to the sole channels H of two regenerators FA or FA', and each valve *ia* being similarly connected to the sole channels *h* of two regenerators *fa* or *fa'* between two adjacent pillar walls E.

The various reversing valves I, *i*, IA and *ia* are shown as identical in construction and arrangement except that the valves I and *i* have, and the valves IA and *ia* do not have, lean gas supply connections thereto, and except for differences in the form or shape of the conduit extensions I^2 from the valves made to accommodate the difference in the position of the two valves at each end of the regenerative space between two adjacent pillar walls, relative to the sole channels to which they are connected. Thus, as clearly shown in Figs. 1 and 6, the conduit extensions I^2 and i^2 of the valves I and *i* are horizontally extended in opposite directions longitudinally of the battery so that while the bodies of each pair of valves I and *i* are at opposite sides of the plane midway between the transverse center planes of the two adjacent pillar walls E, the end of the extension I^2 of the valve I is directly above the end of the extension i^2 of the adjacent valve *i*. The extensions I^2 and i^2 of the valves IA and *ia* similarly overlap. Furthermore, as shown, the vertical displacement of the valves I and IA relative to the valves *i* and *ia* is greater than the vertical displacement of the sole channels H relative to the sole channels *h*, and this difference in vertical displacement is accommodated by the vertical deflection toward one another of the ends of the extensions I^2 and i^2 of the adjacent valves I and *i* and IA and *ia*.

Each of the reversing valves I, *i*, IA and *ia* is provided with a waste gas outlet port I^3 in the lower end of its chamber I' and *i'* and with an air inlet port I^4 in its side remote from the oven structure. Flow through each outlet port I^3 is controlled by the corresponding valve disk or poppet valve member I^5, the stem of which is slidingly mounted in the cap member closing the upper end of the corresponding chamber I' and *i'* and is connected to a chain or operating member part of the oven reversing mechanism J, which may be of the usual type. Flow through each air inlet port I^4 is normally controlled by a corresponding pivoted valve member I^6 connected to a corresponding portion of the oven reversing mechanism J. When blast furnace gas is being supplied through the conduit extensions I^2 and i^2 of valves I and *i*, the valve members I^6 of those valves are disconnected from the oven reversing mechanism J, and those valve members are then kept in their closed positions.

The outlet ports I^3 of each adjacent pair of valves I and *i* open into a common waste gas connection member K through upper inlet ports K' and K^2 at the top of the latter. Each member has a single bottom outlet port K^3 in communication with the waste heat tunnel L at the corresponding side of the battery through a corresponding passage L' in the top wall of said tunnel. As shown, each pair of valves I and *i* are mounted on and are directly supported by the corresponding connection member K. The valves IA and *ia* are similarly connected to and mounted on waste gas connection members KA alternating with the connection members K along the lengths of the waste heat tunnels.

Such of the regenerators F, *f*, *f'* and F' as may be used at any time in preheating lean fuel gas, are supplied with the latter through connections which, in the preferred construction illustrated includes vertically disposed lean gas supply pipes M and *m*, each pipe M being connected at its upper end to the bottom of the conduit extension I^2 of a corresponding valve I, and each pipe *m* being connected to the underside of the extension i^2 of a corresponding valve *i*. The lean gas supply pipes M and *m* at each side of the battery are connected to a corresponding lean gas supply main N. Each pipe M includes a reversing valve M' and each pipe *m* includes a reversing valve *m'*, these reversing valves being connected to portions of the oven reversing mechanism J, so that when the valves M' are open, the valves *m'* are closed, and vice versa. Advantageously each of the pipes M and *m* is connected to the corresponding main N through an individual cut off valve N'.

Rich fuel gas may be supplied to the lower portions of the different vertical flues B, *b*, etc. through individual supply channels O formed in the subjacent pillar walls from supply piping in the chamber space beneath the bottom of the oven structure proper. As shown, said supply piping includes two horizontally disposed supply pipes P' and P^2 for each heating wall. Each pipe P' has a separate branch P for and opening into the lower end of each of the flues B and B' of the corresponding heating wall, and

each pipe P^3 has separate branches P for and opening into the lower ends of the different flues *b* and *b'* in the same heating wall. Each of the pipes P' and P^2 for a single heating wall is connected through a corresponding reversing valve P^3 or P^4, respectively, to a corresponding branch P^5 from a rich gas supply main P^6. In respect to the manner in which rich gas is supplied to the lower ends of the channels O, my improved oven does not differ from other modern underfired coke ovens and comprises provisions which need not be illustrated as they may be of any usual and well known form, for separately regulating the gas flow through the different pipes P. The reversing valves P^3 and P^4 may be connected to the oven reversing mechanism J in the usual manner.

In the intended operation of the oven structure illustrated, when all of the heating walls are to be heated by the combustion of rich gas, the various valves are connected to the oven reversing mechanism J, so that during one period of operation, i. e., between reversals, the various pipes P' supply rich fuel gas to all of the heating wall flues B and to all of the heating wall flues B', the regenerators F, FA, F' and FA' then receive air through the corresponding valves I and IA which then have their inlet ports I^4 open, the ports I^3 in the valves I and IA being then closed, and the regenerators *f*, *fa*, *f'* and *fa'* then discharge waste heating gases in the waste heat tunnels L through the corresponding valves *i* and *ia*, which have their ports I^3 open and their ports I^4 closed. The fuel and air unite in combustion and ascend in the flues B and B' and pass from the latter into the flues *b* and *b'* which then serve as downflow flues. When the oven reversing mechanism J is operated to reverse the flow through the flues and regenerators, the pipes P^2 supply rich fuel gas to the flues *b* and *b'*, the valves *i* and *ia* supply air to the regenerators *f* and *f'*, and the valves I and IA pass waste heating gases to the waste heat tunnels L which are continuously connected to a chimney stack or other gas exhausting apparatus.

When it is desired to operate with lean gas as the fuel gas employed in some or all of the heating walls of the battery, the supply of rich gas for the heating walls so operated is interrupted, as by closing the cut-off valves P^7 in the corresponding branch pipes P^5, and the valves IA and *ia* associated with the regenerators for the last mentioned walls have their air inlet ports I^4 closed as by disconnecting the corresponding valve members I^6 from the reversing mechanism, and lean fuel gas is supplied to the conduit extensions I^2 of those valves through the corresponding pipes M and *m* which then have their stop valves M' opened and have their reversing valves M' and *m'* operatively connected to the oven reversing mechanism J.

The division of the battery heating means into units as described makes it readily possible to operate with rich fuel gas supplied to some, and with lean fuel gas supplied to other of the heating walls, and the described construction makes it readily possible to vary the combustible agents supplied to different portions of the battery heating system, not only for heat distribution adjustment purposes, but also to effect the large changes in flow volume which occur when the fuel gas in one or more heating units is changed.

In the practical use of the apparatus shown, each of the side-by-side heating units in two heating walls at the opposite sides of the fuel gas regenerators of those units must always be operated alike with lean gas or with rich gas. To change the operation of those units from rich gas to lean gas, the only changes in the flow controlling valves required are the closure, during lean gas operation, of the air inlet ports I^4 of the corresponding valves I and *i*, the valve adjustment required to insure the alternate supply of lean gas through the pipes M and *m*, connected to said valves I and *i*, and the interruption of the previous supply of rich fuel gas to the vertical flues of the units.

Changes in the flow capacity of ports and passages are required, however, as a result of the required changes in volumes of flow. For example, in operation with coke oven gas having a B. t. u. value of 550, the volume of combustion air required by a heating unit, including regenerators F, *f*, FA, and *fa*, is only about three per cent greater than that required with blast furnace gas having a B. t. u value of 99, but in preheating the air for rich gas operation, one-half of the air for the unit is preheated in the two air regenerators (FA and *fa*) and one-half in the two regenerators (F and *f*), whereas with lean gas operation almost the same total amount of air must be preheated in the two air regenerators FA and *fa*. Moreover, with the gas B. t. u. values assumed above, the volume of lean gas to be then preheated in the regenerators F and *f*, will be about 20% greater than the total amount of air preheated in the four regenerators F and *f*, and FA and *fa*, with rich gas operation. The amount of waste gases to be withdrawn from each of the end-to-end pairs of regenerators F and *f*, and FA and *fa*, will be nearly twice as great with lean gas operation as with rich gas operation.

The resultant increase in the rate of waste gas withdrawal requires an increased suction effect on the outlet port I^3 of each of the valves I, *i*, IA and *ia* connected to the regenerators of the unit. The suction effect on the port I^3 of any of those valves may be varied by replacement of the apertured throttling disc I^{10} shown in Figs. 2 and 8, by a similar disc having an orifice of suitably different size. Since the regenerators F and FA supplying air for combustion to the units changed over to lean gas operation must receive more air through their inlet ports I^4 in the corresponding valves IA and *ia*, the flow area of those ports should also be increased. This may be effected, with the construction illustrated, by replacement of the throttling discs I^{10} previously in place with throttling discs having larger orifices. As shown each throttling disc I^{10} when in place at the inner side of a port I^4 rests against an inclined flange I^{12} and is held against accidental displacement by a lip I^{13} in front of the top edge of the disc.

As will be apparent, while the port I^4 of each valve IA and *ia* must pass approximately twice as much air when both sets of regenerators to which it is connected supply air to heating units in which lean gas is burned as when those units are both heated by the combustion of rich gas, only three-quarters of as much air must be passed by those parts when one unit is burning lean gas and the other unit is burning rich gas as when both units are burning lean gas. When one of the two units is burning lean gas and the other rich gas, the increase in the flow capacity of the corresponding ports I^4 required to increase the air supplied to the unit burning lean gas tends to objectionably increase the air supply to the regenerators of the unit burning rich gas. This may be readily compensated for with the com-

bustion illustrated by inserting one or more throttling bricks H^{10} or other obstructions in the outer ends of the sole channels H and *h* of the air regenerators in which the previous volume of air flow is to be maintained. Such a throttling brick H^{10} is shown in one of the sole channels H of Fig. 6. Such throttling bricks may readily be inserted, adjusted in, or removed from the sole channels through the air inlet ports I^4 of the corresponding reversing valves, as by means of an implement in the form of tongs or of a rod H^{11} adapted to enter a hole in the throttling brick H^{10}. Such an implement may be extended and manipulated through the port I^4, chamber I' or *i'* and extension I^2 or i^2 of the corresponding valve, as shown in Fig. 6.

When as a result of the change in volume of heating gas flow, or as a result of other changes in operating conditions, some change in the relative flows through the different vertical heating flues of a unit become necessary, that change may be effected by suitable adjustment of the corresponding slide bricks C at the tops of the vertical flues. In general, a change in the heating requirements such as a change in the coking time, requires adjustments, readily made, in the pressure at which fuel gas, whether it be rich gas or lean gas, is supplied by the corresponding mains P^6 or N, or at least by the rich gas branch supply pipes P^5 or the lean gas branch supply pipes M and *m*. The flow capacities of the pipes P^5, M and *m* may be varied by inserting therein apertured throttling discs analogous to the discs I^{10} and I^{11}. The corresponding adjustment in the suction effects of reversing valve exhaust ports I^3 then required may be effected by increasing the exhaust suction in the waste heat tunnels L, or by replacing the corresponding orifice members I^{10} with other orifice members having larger openings, or in both ways. The corresponding changes in the amounts of air supplied require analogous adjustments in the throttling effects of the orifice members I^{11}.

The flexibility of the heating system and the ease with which it can be adjusted, makes it possible to operate some of the coking ovens of the battery with one coking time, while operating other ovens with a different coking time. While it is possible to operate with lean gas in one heating unit and with rich gas in another heating unit for the same heating wall, in practice I consider it ordinarily preferable to regularly operate with the same fuel gas supplied to the two heating units for each heating wall. The capacity for operation with different fuel gases in the two units of the same heating wall, however, facilitates the operation of changing over from one fuel gas to another.

The independence of the different heating units facilitates oven and regenerator repairs when necessary. In particular, it is to be noted that when it becomes desirable to open up the regenerator space between any adjacent pair of pillar walls at either side of the battery, the cutting off of the supply of air and gas to the corresponding heating units is all that is required to prevent gas flow into the regenerator space then opened up. In general, however, in opening up any one such regenerative space, it is desirable to interrupt regular operations in heating units alongside those including regenerators in the space actually opened up, to simplify the control of the heating gases and to avoid excessive temperatures.

The making of regenerator repairs is facilitated, with the construction shown, by the fact that the brick work Q forming the floor of each oven chamber A is wholly carried by the adjacent pillar walls E, so that no portion of its weight need be supported by the longitudinal regenerator division wall F^{10} between and parallel to the corresponding pillar walls, or by the regenerator division walls R and R' extending longitudinally of the battery. The removal of those division walls and the regenerator checker brick S from the regenerative space between an adjacent pair of pillar walls, permits access to the regenerator and pillar wall portions requiring repairs, and provides sufficient space for the workmen effecting the repairs without weakening the oven structure.

The division wall R' at the center of the battery does not need to be made with especial care to avoid leakage through it, since the flow is always in the same direction (either up or down) in the two regenerators *f* and *f'*, or *fa* and *fa'* separated by that wall and in normal operation, therefore, the gas pressures at opposite sides of that wall are normally equal or practically so. The regenerator division walls R which separate the regenerators F and *f*, FA and *fa*, F' and *f'*, and FA' and *fa'*, need to be constructed with some care to avoid leakage because of the considerable excess of pressure in the "on" regenerator at one side of each such wall over the pressure in the "off" regenerator at the other side of the wall. However, the positions and dispositions of the walls R are such as to facilitate their construction and the use of known expedients for preventing leakage through, and in repairing those walls.

As previously explained, the practical necessity for making the oven brickwork below the level of the tops of the sole channels of clay bricks, while using silica bricks in the brickwork above, subjects the lower portion of the structure to heavy thermal expansion stresses which tends to crack and open joints in the lower portion of the structure. This is particularly important in the case of the division wall H*h* between the upper sole channels H and the lower sole channels *h* because of the relatively large difference between the pressures in the channels H and *h*. However, as is clearly shown in the drawings and particularly in Fig. 7, the wall H*h* may readily be made thick and of bricks or blocks, some of which extend into recesses in the adjacent pillar walls E, so that the inherent capacity of the wall H*h* to prevent leakage therethrough is relatively large. Furthermore, the horizontal disposition of each such wall coupled with the fact that it extends into the oven structure only for ten or eleven feet or so makes it readily possible to employ special expedients in its construction to prevent leakage and to repair it when necessary. For example, as shown in the drawings, an impervious plate or layer of material T may be incorporated in the wall between upper and lower courses of brickwork and mortar bedding the plate. Such a plate may be formed of various materials, for example, aluminum or various alloy steels which are unaffected by the temperatures to which the plate is subjected, and which are suitably immune to the destructive effects of furnace gases. When leakage develops in a wall H*h* or other sole channel wall portions, the leaking cracks or joints may be filled with a suitable cementitious material sprayed against the walls by a spray pipe introduced, as is the implement H^{11}, shown in Fig. 6, into the sole channels

through the air inlet port I^4 of the corresponding reversing valve.

Leakage of rich fuel gas through the lower clay brick portions of the pillar walls surrounding the channels O may be guarded against by lining the corresponding portions of the passages O by a tube O' formed of a material such as those mentioned above for use in the plates T.

While in accordance with the provisions of the statutes, I have illustrated and described the best form of embodiment of my invention now known to me, it will be apparent to those skilled in the art that changes may be made in the form of the apparatus disclosed without departing from the spirit of my invention as set forth in the appended claims and that in some cases certain features of my invention may be used to advantage without a corresponding use of other features.

Having now described my invention, what I claim as new and desire to secure by Letters Patent, is:

1. A coke oven structure, comprising in combination a series of alternate coking chambers and heating walls therefor arranged side by side in a row, each heating wall being formed with two end to end upper horizontal channels extending along respective halves of the wall and with an interior group and an exterior group of vertical flues beneath each horizontal channel and connected at their upper ends to the latter, spaced apart pillar walls one beneath and parallel to each heating wall, regenerators in the space between each two adjacent pillar walls arranged in two side by side rows extending longitudinally of said pillar walls and each of said rows of regenerators including two interior and two exterior regenerators connected, respectively, to the lower ends of the flues of the two interior and two exterior groups of flues of the heating wall above the pillar wall adjacent the row of regenerators, whereby the said flues in each half of a heating wall and one interior and one exterior regenerator at each side of the subjacent pillar wall constitute the regenerators and flues of a heating unit individual to said half of the heating wall, separate sole channels for the regenerator chambers of each heating unit extending into the structure from the adjacent side of the latter, the sole channels for the two regenerator chambers between two adjacent pillar walls and immediately adjacent the same side of the structure being arranged side by side and directly above the two sole channels for the regenerator chambers in end to end relation respectively with said two regenerator chambers, connections external to said structure for supplying air and fuel gas to, and withdrawing products of combustion from the regenerator chambers through said sole channels for the use of the regenerator chambers between alternate pairs of adjacent pillar walls in optionally preheating lean fuel gas and air or for preheating air only in the remaining regenerator chambers, and means for supplying rich fuel gas to the different vertical flues.

2. A coke oven structure as specified in claim 1 having a horizontal brick wall interposed between the upper pair and the lower pair of sole channels at each side of the structure between two adjacent pillar walls with its side edges recessed into said pillar walls.

3. A coke oven structure as specified in claim 1 having a horizontal masonry will interposed between the upper pair and lower pair of sole channels at each side of the structure between each two adjacent pillar walls and having a layer of material less apt than masonry to permit gas leakage incorporated in said wall and extending between the sole channels respectively above and below said wall.

4. A coke oven structure as specified in claim 1 having a horizontal masonry wall interposed between the upper pair and lower pair of sole channels at each side of the structure between each two adjacent pillar walls and a nonpervious layer of metal incorporated in said wall and extending between the sole channels respectively above and below said wall.

5. A coke oven structure as specified in claim 1 in which the means for supplying rich fuel gas to the vertical flues comprise channels extending upward through the pillar walls and having the lower portions of each of said channels lined by a metal tube.

6. A coke oven structure as specified in claim 1 in which the connections external to said structure for supplying air to, and withdrawing products of combustion from the regenerator chambers of the structure include a pair of reversing valves at each end of the space between two adjacent pillar walls, one valve for the corresponding pair of sole channels at one level and the other for the corresponding adjacent pair of sole channels at the other level, each of said valves comprising separate valve controlled ports one for air admission and the other for the discharge of products of combustion and comprising a conduit extension through which each of said ports communicates with both sole channels of the corresponding pair.

7. A coke oven structure as specified in claim 1 in which the connections external to said structure for supplying air to, and withdrawing products of combustion from the regenerator chambers of the structure include a pair of reversing valves at each end of the space between two adjacent pillar walls, one valve of each pair for the corresponding pair of sole channels at one level and the other for the corresponding pair of sole channels at the other level, each of said valves comprising separate valve controlled ports one for air admission and the other for the discharge of products of combustion and comprising a conduit extension though which each of said ports communicates with the both sole channels of the corresponding pair, said conduit extension and air admission port of each valve being disposed to permit the projection therethrough of a rod like implement extending into either of the communicating sole channels.

8. A coke oven structure as specified in claim 1 in which the connections external to said structure for supplying air to, and withdrawing products of combustion from the regenerator chambers of the structure include two reversing valves at each end of the space between two adjacent pillar walls, one valve for the corresponding pair of sole channels at one level and the other for the corresponding pair of sole channels at the other level, each of said valves comprising separate valve controlled ports one for air admission and the other for the discharge of products of combustion and comprising a conduit extension through which each of said ports communicates with the two adjacent sole channels at the corresponding level, each valve having means for removably supporting an apertured disc throttling device for each of its said ports, with the aperture in said device in register with and

restricting the flow through the corresponding port.

9. A coke oven structure as specified in claim 1 in which the connections external to said structure for supplying air or gas to, and withdrawing products of combustion from the regenerator chambers of the structure include two reversing valves at each end of the space between two adjacent pillar walls, one valve for the corresponding pair of sole channels at one level and the other for the corresponding pair of sole channels at the other level, each of said valves comprising separate valve controlled ports one for air admission and the other for the discharge of products of combustion and comprising a conduit extension through which each of said ports communicates with the two adjacent sole channels at the corresponding level, and means associated with each valve of alternate pairs at each side of the structure and independent of the air admission port thereof, for supplying lean fuel gas to the conduit extension of the valve.

10. A regenerative coke oven structure of the type comprising a series of alternate pillar walls and intervening spaces arranged side by side in a row, each of said walls and spaces extending between opposite sides of said structure and transversely to the length of the structure and a group of regenerator chambers comprising two side by side pairs of end to end regenerators in the space between each two adjacent pillar walls with a separate sole channel for each of said regenerators extending into the structure from one side of the latter, two of the four sole channels for each such group of regenerator chambers being located side by side at one level and respectively above the other two sole channels for the group and a pair of reversing valves for each group of regenerators, the bodies of the two valves of each pair being displaced from one another transversely of the length of the pillar walls, and each having a valve controlled port for the discharge of products of combustion and means for the supply thereto of fluid to be preheated in the regenerators and each having a conduit extension, the conduit extensions of the two valves of each pair having superposed portions adjacent the structure with the end of one in communication with the sole channels of the group at the upper level and the other in communication with the sole channels of the group at the lower level.

11. A regenerative coke oven structure of the type comprising a series of alternate pillar walls and intervening spaces arranged side by side in a row, each of said walls and spaces extending between opposite sides of said structure and transversely to the length of the structure and a group of regenerator chambers comprising two side by side pairs of end to end regenerators in the space between each two adjacent pillar walls with a separate sole channel for each of said regenerators extending into the structure from one side of the latter, two of the four sole channels for each such group of regenerator chambers being located side by side at one level and respectively above the other two sole channels for the group and a pair of reversing valves for each group of regenerators the bodies of the two valves of each pair being displaced from one another transversely of the length of the pillar walls and each having a valve controlled outlet port for the discharge of products of combustion and means for the supply thereto of fluid to be preheated in the regenerators and each having a conduit extension, said conduit extensions of the two valves of each pair having superposed portions adjacent the structure with the end of one in communication with the sole channels of the group at the upper level and the other in communication with the sole channels of the group at the lower level, and a common discharge conduit connection for, and on which valve bodies of both valves of each pair are mounted and with which the outlet ports thereof communicate.

12. A coke oven structure comprising in combination a series of alternate coking chambers and heating walls therefor arranged side by side in a row, each heating wall being formed with two end to end upper horizontal channels extending along respective halves of the wall and with an interior group and an exterior group of vertical flues beneath each horizontal channel and connected at their upper ends to the latter, spaced apart pillar walls one beneath and parallel to each heating wall, regenerators in the space between each two adjacent pillar walls including two interior and two exterior regenerators connected respectively to the lower ends of the flues of the two interior and two exterior groups of flues, respectively, of a heating wall adjacent said regenerators, whereby the said flues in each half of a heating wall and the interior and exterior regenerators connected thereto constitute parts of a heating unit separate from the analogous heating unit for the other half of the heating wall, supply and off-take connections including reversing valves for the said regenerators of one of said units at one side of the structure and separate supply and off-take connections including reversing valves for the regenerators of the other of said units at the other side of the structure, and means for supplying fuel gas to the lower ends of said vertical flues separate from said connections and comprising a separate gas supply channel for each vertical flue leading upward to the latter through the subjacent pillar wall and separate flow regulating means beneath the pillar walls for each of said supply channels, and reversing valves associated with said supply channels and operable to supply gas alternately to the interior and exterior groups of vertical flues in each heating wall half.

13. A coke oven structure as specified in claim 1 comprising regulable means for varying the relative amounts of flow through the two sole channels for each group of regenerators, which are located at the same level and connected to the same reversing valve.

14. A coke oven structure as specified in claim 12, in which the regenerator supply and off-take connections for the regenerators of each unit comprise two sole channels extending into said structure from the same side of the latter, one of said channels communicating with the exterior regenerator of said unit, and the other of said channels communicating with the interior regenerator of the unit and located beneath the said channel communicating with said exterior regenerator, and a horizontal wall between said channels comprising masonry and an imperforate metallic plate imbedded therein and forming an impervious barrier to vertical leakage flow through said wall between said channels.

15. A coke oven structure as specified in claim 12, in which the regenerator supply and off-take connections for the regenerators of each unit comprise two sole channels extending into said structure from the same side of the latter, one

of said channels communicating with the exterior regenerator of said unit, and the other of said channels communicating with the exterior regenerator of the unit and located beneath the said channel communicating with said exterior regenerator, two reversing valves arranged side by side exterior to said structure, one of said valves having a flattened conduit extension communicating with the first mentioned one of said channels and the other valve having a flattened conduit extension extending beneath the first mentioned extension and communicating with the second mentioned channel.

WILLIAM HESSER PAVITT.