The present invention relates to horizontal coke ovens and more especially to those of the combination type that are arranged for optionally underfiring with a rich gas or with a regeneratively-preheated lean fuel gas such as blast-furnace or producer gas.

Blast-furnace gas as a source of heat for coke-oven underfiring has the disadvantage of an inconstant calorific value and it is common practice to enrich such fuel gas by additions of minor amounts of a fuel gas of higher calorific value, for example coke-oven gas itself, in order to prevent any decrease in the coking capacity of a plant which would be occasioned by a reduction in the calorific value of an employed blast-furnace gas.

In prior practice, these additions of enriching gas have been made before the blast-furnace gas was introduced into the regenerators for purposes of preheating. In the present inventor's U. S. Patent No. 1,878,037 that issued September 6, 1932, there is described apparatus for automatically admixing with a stream of blast-furnace gas of fluctuating calorific value those amounts of rich gas required to correct the former to a predetermined heating value before it is introduced into the regenerators.

The practice, however, of enriching blast-furnace gas before a preheating step therefor is an inefficient method of attaining the desired objective because the rich gas contains hydrocarbonaceous constituents that are unstable at temperatures obtaining in the regenerators and are cracked during their traversing of the same, the cracking process not only causing a reduction in the temperature of the regenerators and the detrimental deposition of carbon therein but also a consequent loss of much of the potential effectiveness of such gases for enriching purposes.

A principal object of the present improvement is to provide in general such improved methods of and means for heating a horizontal coke-oven battery with gases of lower calorific values that a battery heated by the leaner fuel gases will have substantially the same capacity of coal throughput as it has when heated by rich gas exclusively.

A further object of the present improvement is to provide, for coke-ovens, means that are in general adapted for regulating within practical limits the calorific value of regeneratively-preheated fuel gases and are in particular adapted to fortify lean gases of low thermal content by enrichment with a gas of high calorific value in such manner that they are made suitable for use in the underfiring of horizontal coke-ovens without experiencing any of the above-mentioned disadvantages.

A further object of invention is to provide apparatus whereby, within a coke-oven structure itself, an enriching fuel gas can be admixed with a fuel gas of low thermal content that has been previously preheated in its regenerators but before it has been introduced into the heating flues, thereby to obviate decomposition of the enriching gas in the regenerators and to insure the delivery of substantially the total of it; available heat content into the heating flues, and to establish therein a higher thermal head than would otherwise obtain.

A further object of improvement is the provision, more especially for horizontal coke ovens, of means that are adapted to effect the above-stated objectives and are optionally operative independently of those fuel-gas distributive systems normally employed in combination coke ovens for exclusively rich-gas underfiring and for exclusively regeneratively-preheated lean-gas underfiring, so that more especially those calibrative regulatory features of the heating-gas distributive system that is employed in the former instance are entirely independent of the calibrative features employed for regulation of the enriching gas and an immediate change from the one to the other type of underfiring is possible without tedious recalibrating of any of those devices employed for apportioning heat units to the individual heating flues.

A further object of invention is to provide apparatus for the above-stated purposes that is in addition of utility during a period of exclusively rich-gas underfiring to effect a reduction in the oxygen concentration and a dilution of regeneratively-preheated air flowed from the regenerators into the heating flues of coke ovens, thereby to retard the combustion of rich gas in said flues.

The invention has for further objects such other improvements and such other operative advantages or results as may be found to obtain in the processes or apparatus hereinafter described or claimed.

According to the present invention, the heating flues of a coke-oven heating wall are each provided with an individual fuel-gas duct having its outlet port in that bridge brick which terminates below the regenerator-port of each heating flue and separates, for a considerable part of their lengths, those two conduits whereby each heating flue of a coke-oven battery is communicably connected with both a lean-gas and an air regenerator. In its preferred form, the novel fuel-
The improvement is embodied in a combination coke-oven of the underjet type wherein it is also formed as an underjet duct similar to and extending in parallelism with that well-known underjet duct whereby, during exclusively rich-gas underfiring, fuel gas is delivered into the bottom of a heating flue of the coking structure. In an underjet coke-oven battery equipped with the present invention, the heating flues are therefore individually supplied with a pair of underjet ducts, the one of said ducts extending from the battery-supporting mat upwardly through a regenerator wall to port into a heating flue optionally at or above the heating-flue sole, whereas the other is substantially co-extensive therewith but terminates in a port located below the heating-flue sole in those combustion-media conduits that connect the same heating flue with a pair of regenerators. The instant improvement provides, for all the underjet ducts of the invention, communicating connections between both a source of rich fuel-gas and of lean fuel-gas and also provides flow-reversing apparatus and calibrative flow-regulating means that are optionally operative independently of apparatus for controlling the flow of fuel gas into those underjet ducts employed during exclusively rich-gas underfiring of the battery-structure. The improvements in operating and heating methods and the results that are realizable in coke ovens provided with the instant improvement will be apparent to those skilled in the art by reference to the accompanying drawings and the following description of their construction and methods of use.

In the accompanying drawings forming a part of this specification and showing for purposes of exemplification a preferred apparatus and method in which the invention may be embodied and practiced but without limiting the claimed invention specifically to such illustrative instances or instances:

Fig. 1 shows a vertical section taken transversely of a battery of underjet coke ovens embodying the improvement of the present invention, said section being taken in part through a flue heating wall and in part through a coking chamber thereof;

Fig. 1a is a section taken along the line 1a—1a of Fig. 5;

Fig. 2 shows a composite vertical section taken longitudinally of the coke-oven battery of Fig. 1, the section A—A being taken along the line A—A of that figure and the section B—B along the line B—B thereof;

Fig. 3 is an enlarged partial horizontal section taken along the line III—III of Fig. 2 and showing the relative arrangement of the underjet ducts for exclusively rich-gas underfiring and the underjet ducts of the instant improvement along with the embedded header-pipes for independently distributing heating gases thereto along an entire heating wall;

Fig. 4a is a vertical section taken along the line IV—IV of Fig. 3;

Fig. 4b is an enlarged view of a portion of Fig. 4;

Fig. 5 is an enlarged horizontal section taken along the line V—V of Fig. 1 and showing the relative positions, in the lower parts of the heating flues, of the inlet ports for heating gases employed in exclusively rich-gas underfiring and the ports of the underjet ducts of the present improvement located beneath the heating-flue ports of those conduits that communically connect said flues with regenerators therebeneath;

Fig. 6 is an enlarged elevational view, parts broken away, of a fragment of Fig. 1 showing in detail the piping arrangement and the temperature-control devices for distributing fuel gases to the battery in accordance with the practice of the present invention; and

Fig. 7 shows an alternative form of apparatus that is adapted for practicing the improvements of the invention.

The same characters of reference designate the same parts in each of the views of the drawings.

Referring now to the drawings: the illustrated coke-oven battery comprises a plurality of coking chambers 10 and heating walls 11 arranged in alternating lengthwise thereof, the adjacent heating walls of the some of the coke ovens being communicably connected by means of crossover ducts 12 that are a characteristic feature of the well-known Becker oven in which the present improvement is shown embodied. Each heating flue 13 of a heating wall is communicably connected with two regenerative spaces 14, 15, thereby isolating the heating of the battery substantially its entire width and are separated by the heavy masonry of a division wall 16, the said regenerative spaces 14, 15, being respectively communicably connected with each said heating flue 13 of the heating wall thereof by means of conduits 18, 17, that are respectively adapted for flowing regeneratively-preheated lean gas and combustion-air therefor into the heating flues and, during the reverse period of flow in the regenerative heating cycle, are adapted to receive combustion-products from therewith associated heating flues at the opposite side of an adjacent coking chamber.

Beneath the regenerator sole-canals 19 whereby combustion-media are distributed through the various parts of the regenerative spaces by means of short ducts 20, the massive supporting-mat 21 for the entire battery structure is supported, by means of concrete and of metallic piers respectively, 22, 23, above the passageways 24 through which the operators can move from heating wall to heating wall to make various adjustments in the fuel-gas distribution system.

At such times as the illustrated battery is operated as a coke-oven, i.e., when it is heated exclusively with rich gas of high calorific value, the rich gas is introduced into the bottoms of the heating flues by means of underjet ducts 25 which extend from that level downwardly through those regenerator walls 16 that are directly beneath the heating flues and also through the material of supporting mat 21 where they communicate by means of pipe-connections with a wall-header 26 that is embedded in the material of the mat; said wall-headers 26 extend crosswise of the battery in parallelism with the heating wall above and from them rich fuel gas is distributed individually to all the heating flues of a single heating wall by means of calibrated flow-regulating means 27 that are removably supported in threaded surfaces on the inner walls of those short metal pipes 28 which are also embedded in the battery-mat and have their upper ends in register with a duct 29, and, at a point upstream of said flow-regulating means, communicate by means of a short nipple 30 with a wall-header 26. The lower ends of the short pipes 28 terminate substantially at the lower surface of the battery-mat where they are sealed with a removable pipe-plug 30 that permits ac-
cess to their interiors for exchanging flow-regulating means for one another or for its cleaning. Each wall-header 26 individually communicates at the one side of the battery with a principal rich fuel-gas distributing main 31 by means of valved pipe-connections 32 containing the two valve means 33, 34, the former being manually operative so that communication between the members 26, 31, is interruptive for any preferred interval whereas the latter of said valve means is connected by connecting-rod 35 and cable 36 with that usual fuel-gas flow-reversing mechanism (not shown) for horizontal coke-oven batteries whereby fuel gas is admitted into the heating flues at spaced intervals.

Regeneration sole-canales 19 are each provided at one of their outer ends, as shown at the left-hand side of Fig. 1, with combustion-media flow-boxes of which those, 37, that communicate with a regenerator 14, are provided with valve means whereby optionally either air from the alleles or a lean fuel gas that is delivered thereto from the larger lean fuel-gas main 33 by way of individual branch-pipes 53, can be introduced into the sole-canales, and those of the said flow-boxes that communicate at the same battery-side with regenerator 15 are provided with valve means whereby only air is admissible into their associated sole-channels. The battery illustrated in the drawings is arranged to have all its combustion-media flowed into the structure from the one battery-side and all the combustion-products are removed therefrom at the opposite side so that the flow-boxes 35 at the right-side of Fig. 1 have their valve means arranged alternately to interrupt or to establish communication between only combustion-products tunnel 40 and the regenerator sole-canales 19.

The basic idea of the present improvement, as hereinbefore mentioned, is to provide a coke-oven battery with an enriching-gas distribution system that is, firstly, optionally operative to introduce enriching quantities of a rich gas into a regeneratively-preheated lean fuel gas after the latter has traversed the regenerators and before it enters the heating flues, and is, secondly, so arranged for operation independently of systems for distributing other fuel gases to the heating flues that those characteristic features employed both for regulating the degree of enrichment and for gradually the added quantities of enriching gas in accordance with increasing heat requirements of the oven-charges from the pusher-to the coke-side of the battery, will not obstruct normal distribution either of rich gas or of unenriched, preheated lean gas when they are separately used as the exclusive source of underfire heat in their own distribution systems of the battery; when such an enriching-gas system has, therefore, been once adjusted for the delivery to the individual heating flues of a preferred amount of enriching gas, a coke-oven battery so provided stands always in readiness to employ exclusively rich gas, or regeneratively-preheated lean gas, or regeneratively-preheated enriched lean gas for its underfiring, and the change from the one to the other type of underfiring can be conveniently and quickly effected. In its present embodiment, the enriching-gas distribution system of invention comprises an arrangement of underjet ducts which is similar to that long known in the art for distributing only rich heating gas to the heating flues of under-jet coke ovens, but with this difference, however, that the ducts of the present invention in stead of porting directly into the lower parts of the heating flues have their outlets arranged to port, at a distance somewhat below the heating-flue soles, into those conduits whereby regeneratively-preheated fuel gases and air are delivered into the heating flues, and at the point of their bifurcation toward adjacent regenerators.

In such disposition, gases discharged therefrom enter the heating flues in admixture with the regeneratively-preheated gases. Individual heating flues of the improved coke-oven battery are thus associated with two underjet ducts of which the one is arranged for enrichment purposes and the other for the ordinary rich-gas underfiring.

In Figs. 1 and 2, the underjet ducts 41 of the distribution system for enriching gas are clearly discernible with their outlet ports at the upper end of the masonry that separates a pair of conduits 17, 18, and the underjet ducts 25 and 41 are both adjacent disposed in rows of staggered pairs in the regenerator division walls 16.

The enriching-gas ducts 41 of an entire heating wall all communicate with a wall-header 42 that is embedded in main 45 through which it extends crosswise of the battery in parallelism with a similar wall-header 26 for delivering rich fuel gas to the heating flues when heating exclusively with a gas of high calorific value, and each said duct 41 is individually connected to a header 42 by means of a short pipe and a short nipple that are also embedded in the mat similarly to those previously described in conjunction with ducts 25; and said short pipe contains an individual gas-flow regulating device 43 comprising an orifice plug that is removably mounted on the inner wall thereof and is calibrated to deliver the preferred quantity of enriching gas to the flue above. The level at which enriching gas is discharged from a duct 41 into the currents of preheated gases entering the heating flue from the regenerator-ports may be raised by a nozzle-brick that is support against the masonry adjacent the outlet of said duct and has its orifice in register with the port thereof.

The wall-Headers 42 each communicate at one end thereof, by means of a valved pipe-connection 44, with a primary enriching-rich-gas distributing main 45 this extends lengthwise of the battery closely above the similar main 31 with which it is communicably connected by the valve 46 whereby rich heating gas from the same source as that in the latter said main is admissible into the former. By means of hand valve 47, flow of gas into a header 42 from main 45 can be entirely interrupted, whereas valve 48, that is operative through link 49 by means of cable 36 and the gas-flow reversing mechanism (not shown) for the battery, serves to admit enriching gas into said wall-header 42 at spaced intervals.

Primary gas-distributing main 45, from which all the underjet ducts of the enriching-gas distributive system of the battery are directly supplied, will be hereinafter referred to as the "enriching-gas main," and it is not only communicably connected with the distributing main 31, as above stated, by means of valve 45 but it also communicates by means of pipe 50 and valve 51 with lean-gas distributing main 33 for an additional special method of operation to which the present improved battery-structure lends itself and which will be hereinafter described.

The calibrated devices 27, 43, for regulating the flow of heating gases respectively through the underjet ducts 25, 41, are, as clearly shown in
Fig. 4 and 4a, orificed plugs having threaded outer surfaces whereby they are supported in co-operating threads on the inner walls of the short pipe-connections whereby said ducts respectively communicate with wall-headers 26, 42. By means of the shaped recesses in their lower surfaces and a tool adapted to engage the same, the said calibrated ducDs can be removed and replaced through the openings provided by removed pipe-plugs 30. This device for regulating the flow of heating gas through underjet ducts is the invention of another and is described in detail in U. S. application S/N 250,427, filed February 15, 1939.

Assuming that the structure illustrated in the drawings is being heated exclusively with a rich fuel gas that requires no regenerative preheating for its effective use, all the flow-boxes 37 at the left hand of Fig. 1 then have their valve means arranged to deliver only combustion-air into the regenerators, and in those flow-boxes that also communicate with the principal lean-gas supplying main 39 for the battery, the mushroom valves 35 are closed as shown in Fig. 6. Preheated air from regenerators 14, 15, enters upflow heating flues 13 (as shown by the arrows in Fig. 5) by way of conduits 17, 18. In the heating flues the preheated air mixes with and burns rich fuel gas also delivered into the lower parts of the upflow heating flues in individually regulated amounts from the principal rich-gas supply main 31 for the battery after said gas has traversed in succession: apertures in the manually and the reversing-machine operated valves, respectively 33, 34; the branch riser-pipe 32 at the side of the battery; the main-enclosed header-pipe 26 for a fueled heating wall; the calibrated opening of an orificed plug 27; and thence upwardly through an underjet duct 25 into the bottom of an upflow heating flue 13.

After a preferred period of gaseous flow in the one direction through the regenerators and the heating flues, this flow-direction is reversed by a reversing machine that controls the movement of reversing valve 36 and by means of which the flow-boxes 37 leading to up-flow and down-flow regenerators are respectively closed and opened, and valves 33, 34 of a pair of adjacent riser-pipes 32 leading to adjacent up-flow heating walls are closed, whereas valves 34 of the thereto adjacent pairs of said riser-pipes are opened.

Similarly, those flow-boxes 39 at the right-side of Fig. 1 which communicate with down-flow and up-flow heating walls are respectively closed and opened by the said reversing machine.

During heating of the improved battery by exclusively rich fuel gas, the valves 46, 51, that interconnect the principal fuel-gas supplying mains, 31, 36, and 45, are closed as well as also the mushroom valves 32 in flow-boxes 37 and all those manually-operated valves 47 whereby the wall-headers 42 communicate with enriching gas-main 45; in this way valves 48 can continue to be operated by cable 49 of the reversing machine without gas passing through them.

In the conversion of the ovens of the battery from coke-ovens to gas-ovens by heating them only with extraneously-derived, regeneratively-heated gas of lower calorific value, communication between underjet ducts 28, 41, and the sources of gas supply to them are interrupted by closing all the hand-valves 33, 47, of the battery. Valves 51 and 48 also remain closed. A lean fuel gas such as blast furnace or producer gas is supplied to the entire battery by communicably con-
necting the principal supply main, 39, therewith a source of such gas. Lean gas is then supplied to all inflow regenerators 14 by opening mushroom valves 32 in the flow-boxes leading thereto from main 39 while at the same time air is introduced through those flow-boxes at the same battery-side which communicate with the inflowing regenerators 18. At any one instant, therefore, in a regeneratively-heating cycle, alternate regenerators 14 are receiving rich preheated lean gas from main 39 while intermediate regenerators 14 are receiving combustion-products from the heating flues of the heating-wall directly above, and those regenerators 15 directly contiguous to inflow regenerators 14 are operating to preheat air that is delivered to the same heating flues through conduits 17 whereby the other regenerators 15 that are directly adjacent combustion-products regenerators 14, also operate. Flow combustion-products to stack-flue 43 through the opened valves of flow-boxes 39.

When, in operating the illustrated coke ovens as "gas-ovens" the calorific value of an employed blast-furnace or producer gas falls below a value such that the temperature and thermal head in the heating flues can no longer be maintained at a preferred high level, the enriching gas-distributive system of the improvement makes it possible to continue the use of such lean gas and to exploit it for whatever of heating value it may contain by performing the following operations. Valve 48 that communicably connects rich-gas supply main 31 with enriching-gas main 39 is opened as well as as all the manually-operated valves 46, and rich gas enters the enriching-gas wall-headers 42 therefrom whence it is distributed to all the underjet ducts 41 of the up-flow flues in individually regulated amounts determined by the size of the openings in orificed plug 43 that are graduated, as hereinbefore mentioned, from the pusher-to the coke-side of the battery. Rising through the underjet ducts 41, the enriching gas that is apportioned individually thereto, is discharged from their outlets ports into the currents of preheated lean gas and preheated air respectively flowed upwardly through conduits 18, 17, and is carried along in admixture with these combustion-mass into the combustion zones of the heating flues, where available heat content supplementing that of the lean gas is supplied heat to the fueled heating walls. The process of enrichment can obviously be discontinued by closing the valve 48 whereby the principal enriching-gas main 45 is placed in communication with a source of such gas. As will be noted in Fig. 2, the heating wall at a battery-end is not supplied with means for enriching the lean gas because its flues, having a cooking chamber at only one side thereof, normally require less heat than all other flues of the battery.

As is now obvious from the above description thereof, the enriching-gas system of the present improvement is optionally operative as required to enhance the calorific value of a lean fuel gas to any practical extent and without sacrifice of any valuable constituents of the enriching gas. The introduction of the enriching gas into the regeneratively-preheated lean gas and air below the heating-flue soles is attended by other operating advantages for the cooking process. For example, a commonly observed condition in cooking chambers heated with a lean fuel gas is that the bottoms of the coal-charges may have a somewhat lower temperature than portions thereof higher in the oven charger; this
condition has its origin in the relatively sluggish combustion characteristics of lean gas. The present improvement, by introducing the enriching gas into the coking structure at a point adjacent the confluence of the streams of preheated lean gas and air, provides adjacent such cooler zones of the coking chambers a momentary contact between preheated fresh air and a fuel-gas mixture of relatively higher calorific value with the result that there develops a correspondingly more rapid elevation of heat at a point in the structure where such condition is especially desirable in lean-gas underfiring; this circumstance when together is fugitive and localized because the enriching gas is quickly diluted as it is swept along in admixture with the preheated lean gas, and throughout substantially the entire length of a flue, the admixture thereafter burns with the desirable characteristics of a lean gas. The momentary contact between a quantity of rich gas and unburned air is however sufficient significantly to improve coking conditions at the oven sole.

In the embodiment of the basic idea of the improvement shown in the drawings, the enriching gas after its appropriate portion flows through the individual heating flues is flowed through the regenerator walls by means of its own separate underjet ducts, but it will be also apparent to those skilled in the art that similar although not equivalent heating effects can also be obtained by communally connecting the enriching gas to the underjet ducts 42 with the underjet ducts 25 by suitable calibrative flow-regulating means, and the Fig. 7 shows a simple alternative form of apparatus for practicing features of the invention in coke ovens wherein the heating flues are each provided with only one underjet duct in the regenerator walls for distributing fuel gas thereto.

In this figure, the underjet duct 60 extends upwardly from the upper surface of the supporting-mat 61 of a coke-oven battery through a regenerator wall 62 and ports in the lower part of a heating flue, said supporting-mat being itself supported above the basement of the battery by a plurality of piers 63. The wall-headers 64, 65, for distributing rich gas to all the heating flues of a heating wall during its heating respectively with exclusively a rich fuel gas or with a regeneratively-preheated lean fuel gas that is fortified with a minor amount of rich fuel gas, have a side wall 66 in common. These wall-headers are, as shown, embedded in the material of the battery-mat and extend crosswise of the battery; they are both communicably connected with a duct 68 by a common port 67 but each communicates individually with the latter by means of an orificed plug replaceably mounted in the upper wall of said headers, the calibrated orifice in a plug 68 being of such size as to admit into the duct 68 sufficient rich gas to heat the heating flue therewithout without other source of fuel gas whereas the orifice in a plug 69 is calibrated to deliver into the same duct 60 in the form of rich gas that amount of heat which in addition to the preheated lean gas delivered from a regenerator is required to maintain a preferred temperature in the associated heating flue. From beneath the battery-mat, access to orificed plugs 68, 69, for their clearing or replacement, is individually provided by means of a short pipe 70 threaded into the lower walls of the distributor headers, the lower end of a said pipe being sealed to the atmosphere by means of a threaded pipe-plug 71. Removal of the latter from a pipe 70 enables the coke-oven operator to engage the special polygonally-shaped recess 72 in the lower side of an orificed plug with a long-handed wrench having a member that fits into said recess. By means of such wrench, an orificed plug is turned on its threads and thus removed from its seat; it is then replaceable by another having a differently calibrated orifice. At one side of the battery, the distributing wall-headers 64, 65, are each communicably connected individually by means of a vailed pipe with a source of rich heating gas.

During exclusively rich-gas underfiring, only wall-header 64 is in operation and by means of the said valve controlling its inlet, rich gas is delivered thereto at spaced intervals during which it is distributed into the bottoms of each of the heating flues therewith by means of an underjet duct 60 and the associated orifice in the member 68, said orifice being of adequate cross-section to supply a quantity of rich gas containing the total heat requirement of its associated heating flue.

During the period of heating the flues with a regeneratively-preheated lean fuel gas, the flow of rich gas into the wall-header 64 is shut off by closing its inlet valve at the battery-side. At such time, however, as the calorific value of the lean fuel gas entering the heating flues from the regenerator requires enrichment, the inlet valve to wall-header 65 is opened and rich gas is flowed thereinto at spaced intervals, the quantity of rich gas delivered to an underjet duct 60 being regulated by the calibration of the orifice in plug 69 which has a cross-section permitting admittance thereof of gas that is adequate in conjunction with the employed lean gas to deliver in a given period a preferred number of heat units to a heating flue. The Fig. 7 thus shows a simple alternative form of apparatus for communicably connecting an underjet coke-oven heating wall with a plurality of independently-operative distribution systems for rich fuel gas, the one such system being arranged to furnish in the form of rich gas the total coking-heat requirement of its associated heating flues wherein the other system is similarly regulable to restrict the delivery of rich gas to those minor amounts that in addition to a concurrently employed lean gas are required to maintain preferred temperatures and thermal heads in the heating flues and the coking chambers, and the both said systems employ the same duct in the regenerator walls for delivering the diverse quantities of rich gas to a single heating flue.

Those calibrated flow-regulating orifices that are required to provide a graduated delivery of rich fuel gas from the pusher-side to the coke-side of a battery during exclusively rich-gas heating are inappropriate to effect similar apportionment of the relatively minor flow of rich fuel gas required for enrichment purposes, and for this reason it is necessary for the operation of a coke-oven battery according to the present novel method to provide it with a rich-gas distributive system having two sets of flow-regulating means that are independently calibrative and operative, and a combination battery embodying them stands always ready at any time to be operated on either exclusively rich gas or enriched lean fuel gas as the source of heat.

Advantages that are additional to those above-recited accrue to a coke-oven battery equipped with the present improvements in fuel-gas dis-
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An example of such advantage will be now described by reference to Fig. 2 wherein it will be noted that the so-called "enriching-gas" main 45 is not only communicably connectable with a source of solely rich fuel gas by opening valve 46 and maintaining valve 51 simultaneously in closed position, but said main can also be placed in communication with a source of exclusively lean fuel gas by closing valve 46 and opening valve 51 of branch-pipe 49, thus furnishing fuel-gas supply mains 33 and 45 being thus supplied from the same source of lean fuel gas.

At such times therefore as the illustrated battery is being heated with exclusively lean fuel gas that is supplied to the heating flues from gas main 31 by flowing it in sequence through the valves 33, 34, the pipes 32, and the header-pipes 28, and into underjet ducts 25 whence it passes upwardly into the lower parts of said heating flues there to be burned by admixture with regeneratively-preheated air issuing from the both series of regenerators through conduits 17, 18, it now becomes advantageously possible to dilute the said preheated air with inert to reduce its concentration of oxygen before entering the heating flues in contact with the rich-fuel gas and to retard more especially that initially rapid evolution of heat which the use of such gas occasions adjacent the lower parts of the heating flues. This beneficial air-dilution effect is in the present instance achieved by introducing into the regeneratively-preheated air at the overjet ports of underjet ducts 41 a quantity of either blast-furnace gas or product gas from those features of apparatus that have been hereinabove described in their use for purposes of enrichment during lean-gas underfiring; that is, by flowing lean gas from supply-main 48 sequentially through valves 47, 48, pipes 44, and wall-headers 42 whence the lean gas is allocated to the individual underjet ducts 41.

Lean fuel gases in addition to their relatively low calorific values and sluggish combustion characteristics have a very high proportion of inert such as nitrogen, carbon dioxide and water vapor, and they are in consequence especially suitable for purposes of air dilution in the present use. It might however be anticipated that employing lean gas for the dilution of the combustion-air would cause the latter to enter the heating flues from the regenerators at a slightly higher temperature than would otherwise obtain because of the combustion of some of said diluting gas before the mixture enters the flues, and that, in consequence of the greater reactivity of such hotter air with rich gas, the temperatures at the bottoms of the heating flues would tend to be increased by this novel method of effecting preheated-air dilution. However, the practical results achievable by this expedient are quite contrary to such conception as should indeed be anticipated from consideration of the facts that the lean gas is of sluggish combustibility and the temperature of the lean gas issuing from the underjet ducts 41 is less than that of the air issuing from the regenerators. The net result of these two contra-acting influences is to effect the purpose without substantial change in temperature of the regeneratively-preheated inert-diluted combustion-air; and when the same comes into contact with rich gas issuing from the nozzles of ducts 98, the decreased opportunity for its oxygen content to encounter combustible molecules of the rich gas, provides a lengthening of the resultant flame and establishment of the desired lowering of temperatures at their points of initial contact.

It is of course obvious that with increasing calorific value of the lean gas employed in the practice of this novel method of diluting the combustion-air with inert, less of such gas is required for the purpose, and that eventually a point of calorific value is reached where the heat evolved by its combustion in the air-ports offsets any potential results from its use. Realization, therefore, of the potential improvements in heating effects made possible by the method necessarily requires that the quantities of lean gas used for air-dilution purposes be restricted to those which bring about the required reduction of temperatures at the bottom of the flues.

The coking chambers of horizontal coke ovens are tapered from the coke-side to the pusher-side of the battery, and in consequence there is a lesser amount of coal in the oven-charges at the latter than at the former side. In the interest of completing the coking process in all parts of a coal charge at the same time and preventing an over-coking of one part in order to complete the coking of another, the rate of heat penetration through the coal mass must be greater at the coke-side than at the pusher-side. A higher rate of heat between the heating-walls and the oven-charges is therefore required at the coke-side of the battery to effect this result.

In the heating of a coke-oven battery with blast-furnace gas, the situation therefore frequently arises in which the calorific value of a blast-furnace gas is inadequate to coke the coal at the pusher-side of the battery at a required rate, but it is impossible to maintain therewith that higher thermal head which is required at the coke-side to complete coking of the entire content of an oven-charge simultaneously; this circumstance is of course most pronounced when the calorific value of the lean fuel gas is at a relatively low level.

By means of the present improvement in fuel-gas distribution systems it becomes possible to overcome this difficulty by fortifying with additions of rich-gas from the blast-furnace gas that is delivered to the heating flues at the coke-side of the battery and also to taper off such additions towards the pusher-side so that the coking-reaction in all parts of a coking chamber is brought to completion at the same time. The illustrated enriching-gas distribution system is simply adapted to effect this purpose by removing from the underjet ducts 41 of those heating flues that require no additional heat, the calibrated plugs 43 and replacing them with blank plugs having no apertures. In this way the heating flues of a coke-oven battery can be supplied, for example, at the pusher-side with a lean heating gas having a calorific value of about 90 or 100 B. T. U. per cubic foot and those at the coke-side with a gas containing 120 B. T. U. per cubic foot. From the above-stated it is manifest that a coke-oven battery having access to blast-furnace gases of diverse calorific values for their heating should employ the gases of the higher and the lower calorific values in the heating flues respectively at the coke-side and the pusher-side of the battery.

The invention as hereinabove set forth is embodied in particular form and manner but may be variously embodied within the scope of the claims herinafter made.

I claim:
1. In a coke-oven battery having side-by-side
coking chambers and heating walls comprising vertical flame-flues, and air and gas regenerators thereunder, the combination of: means for supplying blast-furnace gas to said regenerators to be preheated therein; ducts connecting the regenerators with said vertical flame-flues individually; passages for individually supplying coke-oven gas directly to said flame-flues, without flowing into and being regeneratively preheated in said regenerators, and of capacity adequate to supply coke-oven gas to fire said flues in lieu of firing them with the aforesaid blast-furnace gas; supply means leading to said passages; other passages for supplying directly to said flues, without flowing into and being regeneratively preheated in said regenerators, and of capacity adequate to supply coke-oven gas to enrich said blast-furnace gas; separate supply means leading to said flues in lieu of firing them with the aforesaid blast-furnace gas; supply means leading to said other passages for supplying directly to said flues, without flowing into and being regeneratively preheated in said regenerators, separate individually restricted minor portions of said coke-oven gas for enriching said blast-furnace gas when said blast-furnace gas is the medium mainly employed for firing said flame-flues; and means adapted for alternatively controlling the several aforesaid supply means to fire the flame-flues alternatively with only said coke-oven gas or with only said blast-furnace gas or with said blast-furnace gas enriched by a restricted minor proportion of said coke-oven gas.

2. In a coke-oven battery having side-by-side coking chambers and heating walls comprising vertical flame-flues, and air and gas regenerators thereunder, the combination of: means for supplying blast-furnace gas to said regenerators to be preheated therein; ducts connecting the regenerators with said vertical flame-flues individually; passages for individually supplying coke-oven gas directly to said flame-flues, without flowing into and being regeneratively preheated in said regenerators, and of capacity adequate to supply coke-oven gas to fire said flues in lieu of firing them with the aforesaid blast-furnace gas; supply means leading to said passages; other passages for supplying directly to said flues, without flowing into and being regeneratively preheated in said regenerators, separate individually restricted minor portions of said coke-oven gas for enriching said blast-furnace gas; separate supply means leading to said other passages for the supply of the said restricted minor portions of coke-oven gas for enriching said blast-furnace gas when said blast-furnace gas is the medium mainly employed for firing said flame-flues; and means adapted for alternatively controlling the several aforesaid supply means to fire the flame-flues alternatively with only said coke-oven gas or with only said blast-furnace gas or with said blast-furnace gas enriched by a restricted minor proportion of said coke-oven gas.

3. In a coke-oven battery having side-by-side coking chambers and heating walls comprising vertical flame-flues, and air and gas regenerators thereunder, the combination of: means for supplying lean gas to said regenerators to be preheated therein; ducts connecting the regenerators with said vertical flame-flues individually; passages for individually supplying rich gas directly to said flame-flues, without flowing into and being regeneratively preheated in said regenerators, and of capacity adequate to supply rich gas to fire said flues in lieu of firing them with the aforesaid lean gas; supply means leading to said other passages for the supply of the said restricted minor portions of rich gas to enrich said lean gas; separate supply means leading to said other passages for the supply of the said restricted minor portions of rich gas for enriching said lean gas when lean gas is the medium mainly employed for firing said flame-flues; and means adapted for alternatively controlling the several aforesaid supply means to fire the flame-flues alternatively with only said rich gas or with only said lean gas or with said lean gas enriched by a restricted minor proportion of said rich gas.
gas or with said lean gas enriched by a restricted minor portion of said rich gas; the supply means for the first mentioned passages and those for the second mentioned passages comprising separate horizontal分支 conduits extending longitudinally of the heating walls underneath the regenerators, and the first and second mentioned passages comprising riser conduits extending upwardly through the regenerator division walls in communication with the flame-flues individually and each provided with separate regulating devices, accessible from the accessible passageway beneath the regenerators, for regulating the gas flow from the separate branch conduits into the riser conduits individual to the respective flame-flues.

6. In a coke-oven battery of the under-jet type having side-by-side coking chambers and heating walls comprising vertical flame-flues and air and gas regenerators disposed above an accessible passageway freely accessible to operators for manipulation of the under-jet regulating means, the combination of: means for supplying lean gas to said regenerators to be preheated therein; ducts connecting the regenerators with said vertical flame-flues individually; passages for individually supplying rich gas to said flame-flues and of capacity adequate to supply rich gas to fire said flames in lieu of firing them with the aforesaid lean gas; supply means leading to said passages; other passages for supplying to said flames separately individually restricted minor portions of said rich gas to enrich said lean gas; separate supply means leading to said other passages for the supply of the said restricted minor portions of rich gas for enriching said lean gas when said lean gas is the medium mainly employed for firing said flame-flues; and means adapted for alternatively controlling the several aforesaid supply means to fire the flame-flues alternatively with only said rich gas or with only said lean gas or with said lean gas enriched by a restricted minor portion of said rich gas; the supply means for the first mentioned passages, and the first mentioned passages, comprising horizontal branch conduits extending longitudinally of the heating walls underneath the regenerators and riser conduits individual to the respective flames and extending upwardly through regenerator division walls and porting directly into their flame-flues; and the supply means for the second mentioned passages, and the second mentioned passages, comprising separate horizontal branch conduits extending longitudinally underneath the regenerators and separate riser conduits individual to the respective flames and extending upwardly through regenerator division walls and porting beneath the soles of their flames into the gas regenerator ducts therefor.

7. In a coke-oven battery of the under-jet type having side-by-side coking chambers and heating walls comprising vertical flame-flues and air and gas regenerators disposed above an accessible passageway freely accessible to operators for manipulation of the under-jet regulating means, the combination of: means for supplying lean gas to said regenerators to be preheated therein; ducts connecting the regenerators with said vertical flame-flues individually; passages for individually supplying rich gas to said flame-flues and of capacity adequate to supply rich gas to fire said flames in lieu of firing them with the aforesaid lean gas; supply means leading to said passages; other passages for supplying to said flames separately individually restricted minor portions of said rich gas to enrich said lean gas; separate supply means leading to said other passages for the supply of the said restricted minor portions of rich gas for enriching said lean gas when said lean gas is the medium mainly employed for firing said flame-flues; the supply means for the first mentioned passages, and the first mentioned passages, comprising horizontal branch conduits extending longitudinally of the heating walls underneath the regenerators and riser conduits individual to the respective flames and extending upwardly through the regenerator division walls and porting directly into their flame-flues; and the supply means for the second mentioned passages, and the second mentioned passages, comprising separate horizontal branch conduits also extending longitudinally underneath the regenerators and separate riser conduits individual to the respective flames and extending upwardly through regenerator division walls and porting beneath the soles of their flames into the gas regenerator ducts therefor; means for optionally flowing lean gas into the supply means for the second mentioned passages from the means for supply of lean gas to the regenerators; and means adapted for alternatively controlling the several aforesaid supply means to fire the flame-flues alternatively with only said rich gas or with only said lean gas or with said lean gas enriched by a restricted minor portion of said rich gas, or with said rich gas blended by a minor portion of said lean gas.

8. In a coke-oven battery of the under-jet type having side-by-side coking chambers and heating walls comprising vertical flame-flues and air
and gas regenerators disposed above an accessible passageway freely accessible to operators for manipulation of the under-jet regulating means, the combination of: means for supplying lean gas to said regenerators to be preheated therein; ducts connecting the regenerators with said vertical flame-flues individually; passages for individually supplying rich gas to said flame-flues and of capacity adequate to supply rich gas to fire said flues in lieu of firing them with the aforesaid lean gas; supply means leading to said passages; other passages for supplying to said flues separate individually restricted minor portions of said rich gas to enrich said lean gas; separate supply means leading to said other passages for the supply of the said restricted minor portions of rich gas for enriching said lean gas when said lean gas is the medium mainly employed for firing said flame-flues; the supply means for the first mentioned passages, and the first mentioned passages, comprising horizontal branch conduits extending longitudinally of the heating walls underneath the regenerators and riser conduits individual to the respective flues extending upwardly through the regenerator division walls and porting directly into their flame-flues; and the supply means for the second mentioned passages, and the second mentioned passages, comprising separate horizontal branch conduits also extending longitudinally underneath the regenerators and separate riser conduits individual to the respective flues and extending upwardly through regenerator division walls to port into their flame-flues and communicating with the said means for supplying lean gas to the regenerators and also with the said means for supplying rich gas to the first mentioned passages; and means adapted for alternatively controlling the several aforesaid supply means to fire the flame-flues alternatively with only said rich gas or with only said lean gas or with said lean gas enriched by a restricted minor portion of said rich gas, or with said rich gas blended by a minor portion of said lean gas.

In a coke-oven battery of the under-jet type having side-by-side coking chambers and heating walls comprising vertical flame-flues and air and gas regenerators disposed above an accessible passageway freely accessible to operators for manipulation of the under-jet regulating means, the combination of: means for supplying lean gas to said regenerators to be preheated therein; ducts connecting the regenerators with said vertical flame-flues individually; passages for individually supplying rich gas to said flame-flues and of capacity adequate to supply rich gas to fire said flues in lieu of firing them with the aforesaid lean gas; supply means leading to said passages; other passages for supplying to said flues separate individually restricted minor portions of said rich gas to enrich said lean gas; separate supply means leading to said other passages for the supply of the said restricted minor portions of rich gas for enriching said lean gas when said lean gas is the medium mainly employed for firing said flame-flues; the supply means for the first mentioned passages, and the first mentioned passages, comprising horizontal branch conduits extending longitudinally of the heating walls underneath the regenerators and riser conduits individual to the respective flues extending upwardly through the regenerator division walls and porting directly into their flame-flues; and the supply means for the second mentioned passages, and the second mentioned passages, comprising separate horizontal branch conduits also extending longitudinally underneath the regenerators and separate riser conduits individual to the respective flues and extending upwardly through regenerator division walls to port into their flame-flues and communicating with the said means for supplying lean gas to the regenerators and also with the said means for supplying rich gas to the first mentioned passages; and means adapted for alternatively controlling the several aforesaid supply means to fire the flame-flues alternatively with only said rich gas or with only said lean gas or with said lean gas enriched by a restricted minor portion of said rich gas, or with said rich gas blended by a minor portion of said lean gas.

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