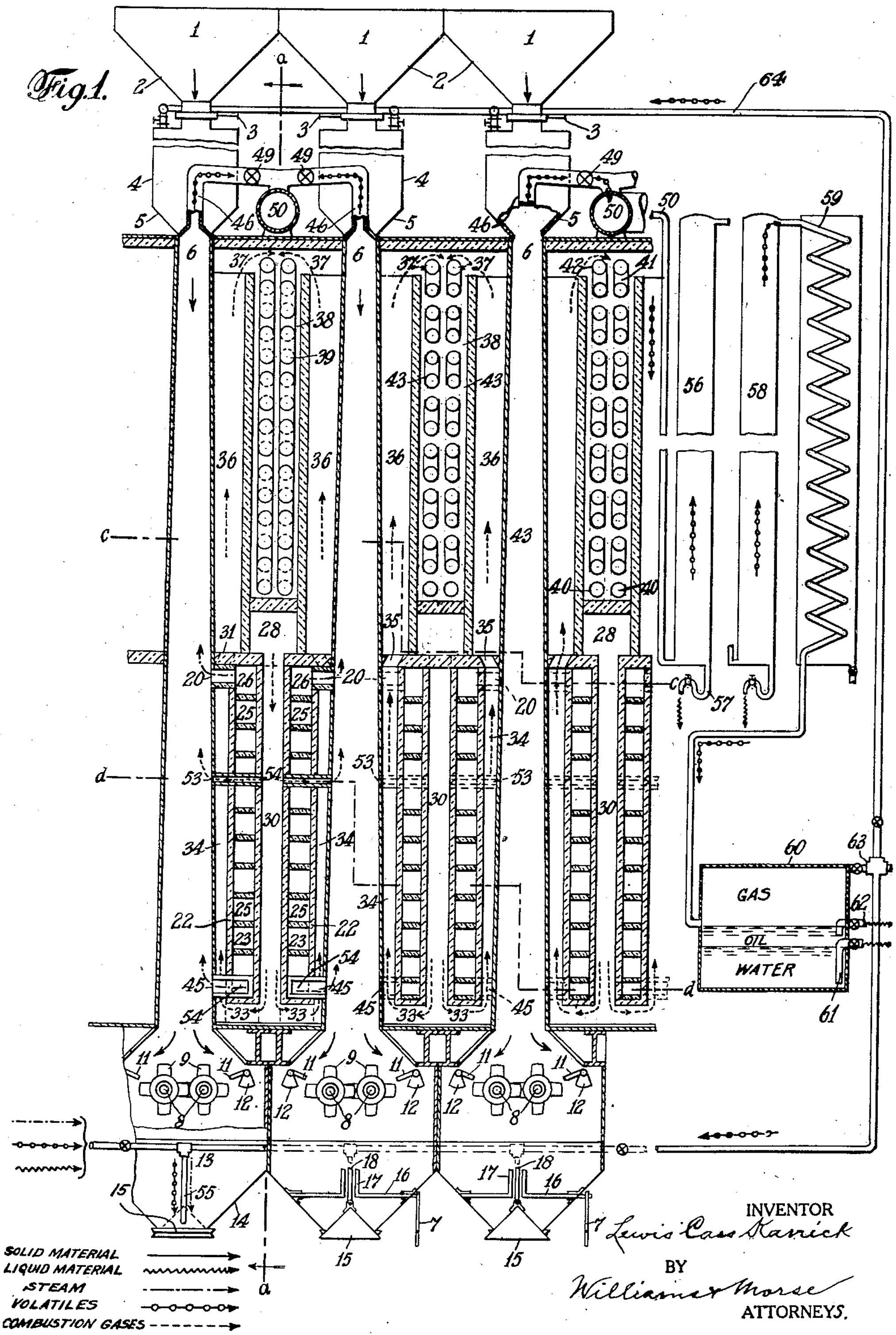
Jan. 17, 1933. L. C. KARRICK 1,894,691

DESTRUCTIVE DISTILLATION OF CARBONACEOUS MATERIAL

Filed Nov. 16, 1925 3 Sheets-Sheet 1



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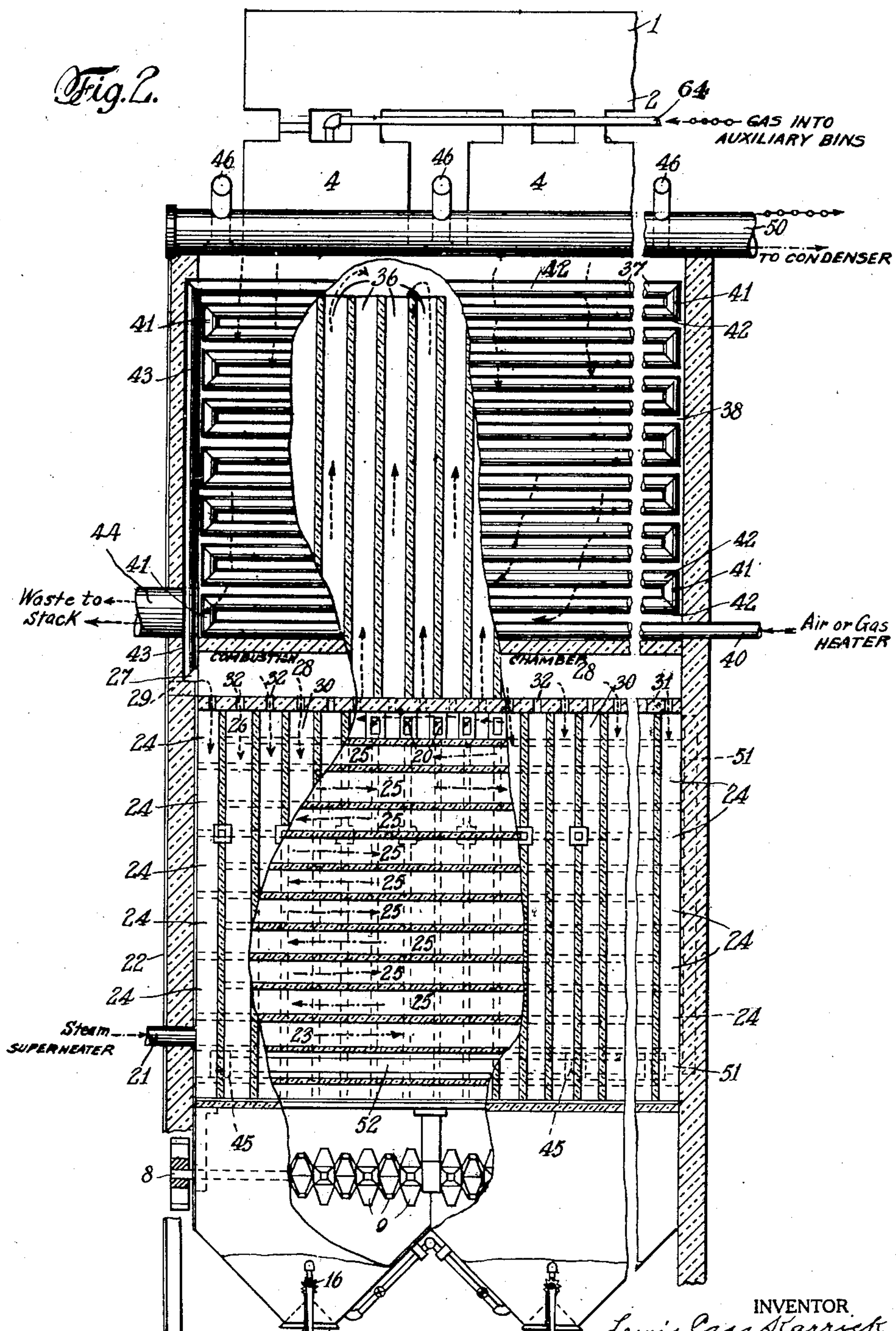
Filed Nov. 16, 1925 3 Sheets-Sheet 2

Fig. 2.



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Filed Nov. 16, 1925 3 Sheets-Sheet 3

Fig. 3.

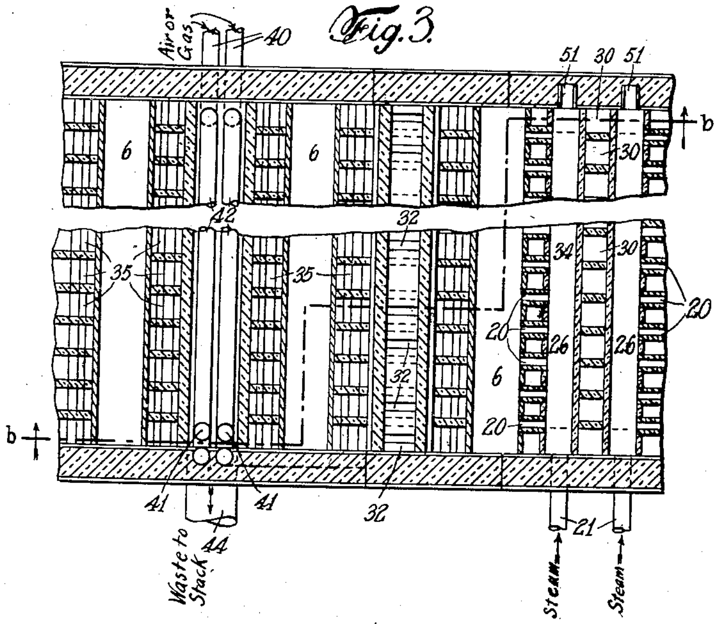
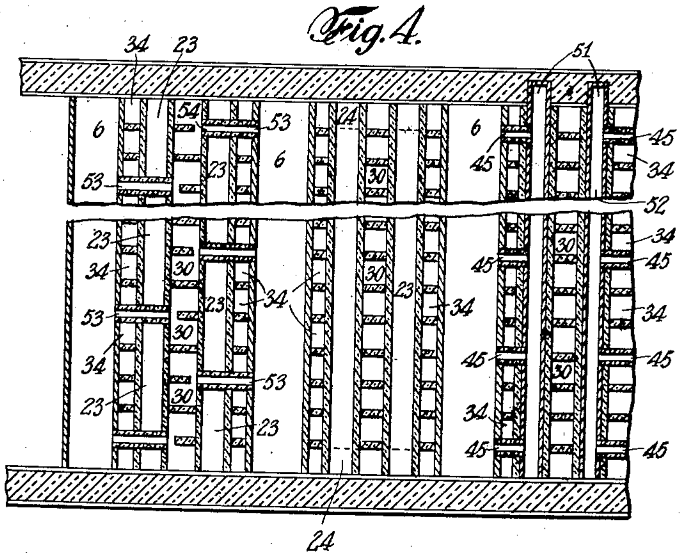


Fig. 4.



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DESTRUCTIVE DISTILLATION OF CARBONACEOUS MATERIAL

Application filed November 16, 1925. Serial No. 69,300.

This invention relates to distillation of carbonaceous material such as oil shales, coals, lignites, cannel coals, wood and oil sands, and partial gasification of fixed carbon. It is well known that variations in the time and the temperature of distillation will produce marked differences in the yield and quality of the products from such materials. According to the present invention distillation is effected at temperatures very low compared with those ordinarily employed in gas plants and coke oven practice. Not only does the temperature applied alter the yield and character of the volatile products but it also affects the character of the carbon residue so that, by the present invention, carbon which is easily kindled may be produced from coal and constitutes a product which is markedly different from the nearly graphitic product of coke ovens or gas plants which is difficult to burn. This carbon is in condition to yield readily to partial gasification in the process.

The invention will be particularly described in connection with the treatment of coal, but it is to be understood that it is applicable to the treatment of other carbonaceous materials such as those mentioned above.

Coal, preferably in the form of lumps, is heated in a retort and the source of heat is partly superheated steam flowing countercurrent to the coal but in addition a portion of the heat is transmitted through the walls of the retort from an external source. Provision is also made for increasing the gas yield at times by gasifying a portion or substantially all of the fixed carbon by the effects of a second supply of superheated steam and when occasion requires, also by a supply of hot products of combustion.

The invention herein disclosed as applied to bituminous coal yields a dense carbon residue which is very easily ignited and which burns readily without smoke. When the process is applied to anthracite coal the residual product has greatly improved kindling and burning properties, even though the volatiles distilled off are a relatively small portion of the coal. The residual carbonaceous products produced by the process from many kinds of coal may possess some of the physical and chemical properties of the generally used activated carbons of commerce.

Where coals like Utah coals are subjected to distillation the plastic or compressible nature of the heated coal may be utilized to press the mass into large, dense, solid masses or lumps of fuel suited to the commercial demand. This has been effected by making the column of distilling material in the retort of such a height that its weight accomplished the continuous compression of that portion of the mass which is in the hot plastic state. In this manner it has been found possible to supply pressure which has resulted in producing a product having an apparent specific gravity of 0.85, as contrasted with the usual apparent specific gravity of coke, to wit: 0.55.

The present invention is especially useful when the coal is uniformly sized, thus avoiding the obstruction to gas flow which would come from the distilling of material consisting of commingled large and small lumps or particles.

The residual coke may be quenched at the bottom of the retort by saturated steam so as to extract heat from it and cool it, thereby accomplishing continuous dry-quenching. This produces superheated steam which aids the distillation of the overlying material and reacts with the coke to produce water-gas and some ammonia.

The steam or gas used for quenching forms a barrier preventing the superheated steam entering high up in the retort from passing downward and condensing in the lower bin. Incondensable gas from the condensers is also preferably introduced continuously into the top charging bin so that its downward flow toward the vapor exit prevents steam or oil vapors from passing into the charging bin and condensing, with consequent loss of heat and wetting of the charge. The gas for the charging bin is preferably preheated so as to dry and preheat the raw material in the bin.

The easily kindled residual material is especially adapted to serve in the manufacture of water gas, as it reacts very rapidly and easily with steam. This material may also be used for other purposes since it is well adapted to adsorb salts from solution, hydrocarbon vapors, or odoriferous vapors, thus rendering easy the preparation of a fuel having any desired burning, light-giving and odor-producing qualities.

If desired, a part or all of the internal heating of the retort may be effected by using the sensible heat of products of combustion resulting from burning some of the incondensable gas from the retort. It has been found that where the products of combustion of gas, instead of the products of combustion of coal, were used for this purpose, the gases of distillation were less diluted by nitrogen and carbon dioxide and the effluent distilled gases were of greater calorific value than when the products of the combustion of coal were used for heating.

Under one condition of operation I found that the original lumps of coal passed through the retort substantially without disintegration. It was found possible to press the coal into large aggregates under conditions which permitted the lumps to agglomerate by their cohesive and plastic properties when hot. This was effected by using slower rates of feed and a higher distilling zone in the retort. The resulting smokeless fuel formed into lumps of the shape and diameter of the inside of the base of the retort, namely seven inches diameter and varying in length from six to eighteen inches.

Each large lump was almost homogeneous in texture and structure throughout its diameter although it was composed of an aggregate material passing a one-inch screen and retained on a three-fourths inch screen.

The process may be applied to coking coals which cake into large masses and thus, unless properly handled, tend to block the proper flow of steam and vapors. To treat such coals they are mixed with a suitable proportion of residual fuel from a previous run, with the result that no blocking takes place as they feed through the retort.

The superheated steam is supplied at a temperature high enough to distill the condensable volatiles and residual volatiles and gasify an appreciable amount of the fixed carbon. I have used temperatures varying from 950° F. to 1,725° F. depending on the product and conditions desired. At the lowest temperature named the distillate was almost exclusively coal resins. At the highest temperature named the thermal efficiency was greatly improved, a very large yield of oil and water-gas was obtained, and the smokeless fuel was superior in hardness, texture, and color.

In the accompanying drawings is shown, largely diagrammatically, a commercial plant for carrying out the process, wherein

Figure 1 is a vertical cross section through a series of retorts arranged along a bench, taken along the line *b—b* of Figure 3.

Figure 2 is a vertical cross section between two retorts, with parts broken away, along the line *a—a* of Figure 1.

Figure 3 is a horizontal section along the line *c—c* of Figure 1.

Figure 4 is a horizontal section along the line *d—d* of Figure 1.

The coal or oil shale is charged into the supply bins 1 which are closed at the center of their hopper-bottoms 2 by suitable valves 3 so that auxiliary feeding bins 4 may be conveniently charged. Each auxiliary bin 4 has a hopper bottom 5 which opens into a retort shaft 6 at its bottom. The retort shaft is herein shown as tall and narrow and is, therefore, adapted to contain a long column of carbonaceous material, which is supported at the bottom by a pair of rotatable shafts 8 having overlapping arms 9 which rotate outwardly to feed down the residual coal or oil shale after it has been distilled. The valves 3 are normally closed, with the result that the vapors rising from the charge in the shaft 6 pass through vapor off-takes which will be later described. The capacity of the auxiliary bins 4 is such that at no time does the top of the charge in the bin descend below the level of the vapor off-take and thus the shaft is completely filled with the charge at all times. The rate of downward movement of the charge is controlled entirely by the discharge mechanism or rotatable shafts 8. In addition to the rotatable shafts 8 and their arms 9 there are provided pivoted rock-arms 11 at each side of the retort under the upper walls of the residual receiving bin 13, each rock-arm being provided with a counterweight 12 so that the rock-arms may swing and allow the residual coal, etc. to feed downward by the rotation of the shafts 8. The receiving bins 13 are provided with hopper bottoms 14 and suitable closures 15 operated by rotating shafts 16 provided with cranks 17 connected by links 18 to the closure 15, and operated by external handles 7.

When the charge is feeding downwardly through the retort 6 superheated steam is admitted through ports 20 into the shaft to heat the charge to distill off the volatiles. These ports, in the form of retorts herein illustrated, are about half way up the height of the retort. The steam is derived from suitable sources, not shown, preferably engine exhaust steam somewhat above atmospheric pressure where such is available, or steam at lower pressure may be used so that the retort may be operated at a low pressure,—even below atmospheric. Where waste steam is available it furnishes a very inexpensive and otherwise desirable heat carrier to transfer heat into the retort.

Steam as above described feeds into a steam pipe 21 forming part of the superheater 22.

The steam passes from the pipe 21 through a horizontal passage 23 extending the entire length of a retort. This connects with a short vertical passage 24 and the steam passes through this and thence back through a horizontal passage 25 similar to the horizontal passage 23 and through another short vertical passage 24 and similarly through other horizontal passages 25 and vertical passages 24 until it reaches the top horizontal passage 26 of the superheater. The latter passage is provided with a number of ports 20 opening into the retort as described above. For heating the steam in its travel through the passages 23, 24, 25 and 26 there is provided a group of parallel vertical heating flues 30 situated outside the passages and between the superheater 22, above described, and an identical superheater for the adjacent retort. This superheater has similar ports 20 leading into a retort 6 which may be identical with the first retort.

The heated gases passing downward through the vertical flues 30 are produced by the burning of preheated fuel gas in a flue-like combustion chamber 28. The preheated fuel gas enters the chamber 28 by the port 27 at the end of the superheater structure, and the preheated air enters the chamber 28 by a duct 29 extending from the adjacent preheater, as hereinafter described. The preheated air and preheated gas burn in the combustion chamber 28 above the top of the vertical flues 30 so that the hot gases, which may be still burning, pass downwardly through the vertical flues 30. Immediately above the flues 30 is the floor 31 of the combustion chamber 28 which is perforated by ports 32 so as to communicate with the vertical flues 30.

When the hot gases pass to the bottom of the flues 30 they turn in short horizontal flues 33 outwardly in opposite directions toward the adjacent retorts and then pass upward on the opposite sides of the superheaters and through the flues 34 of which one wall forms part of the walls of the adjacent retorts. Then they pass through ports 35 in the floor 31 and enter the vertical parallel flues 36 of which one wall forms part of the upper walls of the retorts and rises substantially to the tops of the retorts. At the upper end of the flues 36 the gases turn horizontally through short flues 37 and are then directed downward through a chamber 38 which contains an air or gas preheater 39 (see Figure 1). The preheaters are alternately air and gas preheaters, i. e., each preheater consists of two parallel and independent piping systems one of which discharges its preheated product directly into the combustion chamber 28 beneath it and the other of which discharges its preheated product into the combustion chamber 28 to the right of that beneath it. Thus each combustion chamber 28 is supplied with preheated air from one preheater and preheated gas from another preheater. This arrangement is adopted to avoid having side by side in a preheater a pipe carrying air and a pipe carrying fuel gas, for obvious reasons. Air or gas enters its respective preheater by pipes 40, which extend the length of the retort horizontally through the chamber 38 of the preheater. Each pipe 40 delivers the air or gas through a short upward section 41, and then through a return section 42, back to above the point of entrance of the heater, and similarly the air or gas passes back and forth through pipes 41 and 42 until it reaches the top of the space 38.

The heated air or gas delivered by the last pipe 42 enters a vertical passage 43 which carries the air or gas down to the combustion chamber 28, delivering its preheated gaseous material either to the chamber 28 immediately beneath the preheater or to the chamber 28 beneath the adjacent preheater, as above described.

The products of combustion after passing downwardly over the preheater pipes 42 reach the bottom of the chamber 38 and are carried off horizontally through the duct 44 to a stack, not shown.

From the charge in the retort, heated by the superheated steam entering through the ports 20, most of the volatile ingredients distill. These volatile ingredients rise through the voids in the retort charges to the tops of the retorts and pass off through vapor off-takes 46 provided with valves 49 which lead to a vapor main 50. As shown in Figure 2 the auxiliary bins 4 are separated from each other, being set at intervals along the lengths of the retorts, thus providing clear spaces in which rise the vapor off-takes 46 from the tops of the retorts.

If not enough fuel gas is produced from coal by the procedure above described in which superheated steam is introduced at the ports 20, a modified procedure may be adopted in which superheated steam is introduced at lower ports 45 (of which only a few are illustrated) to evolve water-gas by reaction with the heated carbon residue. This additional supply of superheated steam enables the gas production to promptly meet peak loads. To supply superheated steam through the ports 45 there is provided a well-insulated steam duct 51 leading from the top steam passage 26 down to a bottom well-insulated steam passage 52 which extends directly under the lower passage 23 and opens into the retort through the ports 45. These ports 45 are located near the bottom of the retort but above the grate-shafts 8. The coal in the retort is in a highly activated condition and reacts rapidly with the introduced superheated steam to produce water-gas.

In order to introduce the hot products of combustion from the chamber 28 into the charge, there are provided ports 53, intermediate the ports 45 and the ports 20, opening into the retort and connected by short flues 54 with the vertical combustion flues 30. All the ports 20, 45, and 53 are under the control of the retort operator, who may control the flow through them by suitably placed bricks which serve as adjustable closures to alter the flow of gas or steam, and are not shown.

In order to control the character of the solid residue from the distillation of coal so that it may be suitable for use or for storage, as may be desired, there are provided valved pipes 55 which may be used to introduce steam or gas into the receiving bins 13 for the purpose of quenching the residual coal discharged from the retort.

In runs of some kinds of coal with a cylindrical retort such as described above I have successfully used both steam and gas for dry-quenching the residual coal to a temperature at which it would not take fire on exposure to air. It was found that this did not so lower the temperature within the retort by reason of the ascending steam or gas as to interfere with the proper functioning of the retort.

A form of condensing apparatus which has proved satisfactory is shown diagrammatically at the right of the retorts in Figure 1 on a greatly reduced scale in proportion to the other parts of the drawings. The vapors coming through the vapor mains 50 are carried to the bottom of a larger air-cooled tower 56 which may be of iron, provided with a valved bottom outlet 57. From the top of the tower 56 the uncondensed vapors and gases enter a second similar tower and so on for any desired number of towers. Finally from the last tower 58 the still uncondensed vapors and gases are carried to a water-cooled worm 59 which delivers them to a closed separating vessel 60. Here the water settles to the bottom and may be drawn off through a valved drain 61. On the water usually floats some light oil which may be drawn off by an upper valved drain 62. From the top of the separating vessel 60 leads a valved gas pipe 63, which may be connected to the gas pipe 55 for quenching the residues, and may also be connected to valved gas pipes 64, which enter the feeding bins 4 and serve to keep a steady flow down into the retorts, thus preheating the coal or other material fed to the retorts and maintaining a gas barrier which excludes from the feeding bins 4 the steam which is heating the contents of the retorts. This gas may be preheated by any suitable means, not shown.

It will be noted that the retort structure shown has straight walls and therefore there is no need to use special forms of brick in building it or to use any materials which are specially adapted for peculiar variations of form.

The retort itself should be constructed of material especially adapted to the work going on in the different parts, the upper part preferably being made of metal, such as good quality cast iron. The high temperature parts of the retort and auxiliaries may be found to give longer and more economical service if constructed of silica or carborundum brick. The lower part of the retort next the superheaters is preferably constructed of some material having better heat conducting properties than nonmetallic refractories, for example chrome iron or other suitable metallic material.

It will be noted that the coal or other material treated according to the present process is fed into a relatively cool section of the retort and gradually progresses downward through successively hotter zones until it reaches the level of an admission port where it is exposed to the greatest heat. The coal then feeds through a section of the retort of substantial length where it is maintained substantially at the temperature of greatest heat for a relatively long period of time. In this section considerable exothermic heat is evolved when Utah or other high-oxygen coals are treated, thus augmenting the supply of heat and meeting the requirements of heat for devolatilizing the coal. In cooling the residual material by steam a very large part of the residual heat is recovered. The rising steam may react to form water-gas and absorb a large amount of heat, but this heat is made up by heat transmitted from the walls. It is found that the water-gas reaction takes place efficiently under the conditions named even at the relatively low temperature of 1,275° F.

Having thus described certain embodiments of my invention, what I claim is:

1. The process of treating dust free lumps of coal to produce a useful solid fuel which comprises, heating the coal in the absence of an appreciable amount of air by a large supply of superheated steam at a temperature sufficient to cause heat decomposition of the coal, and providing additional internal heat by supplying and burning mixed fuel gas and air within the retort.

2. The process of treating coal to produce therefrom volatile and coke and gasify part of the coke which comprises, heating a body of coal in a chamber internally by superheated steam counter-current inside said chamber and also heating the coal externally through the walls of the chamber sufficiently to cause heat decomposition of the coal, said superheated steam being delivered to the coal body simultaneously at three different points spaced therealong, the steam at one stage being of lower temperature than the

steam in the other stages and being passed through the hot solid residue.

3. The process of treating coal to produce therefrom volatile and coke and gasify part of the coke which comprises, heating a body of coal in a chamber internally by superheated steam countercurrent inside said chamber and also heating the coal externally through the walls of the chamber sufficiently to cause heat decomposition of the coal, said superheated steam being derived from different sources and delivered to the coal body simultaneously at three different points spaced therealong, the steam at one stage being of lower temperature than the steam in the other stages and being passed through the hot solid residue, and gasifying more of the coke by admitting superheated steam in variable quantities at a point between the places where the other steam is admitted.

4. The process of treating coal to produce therefrom volatile and coke and gasify part of the coke which comprises, heating a body of coal in a chamber internally by superheated steam countercurrent inside said chamber and also heating the coal externally through the walls of the chamber sufficiently to cause heat decomposition of the coal, said superheated steam being delivered to the coal body simultaneously at three different points spaced therealong, the steam at one stage being of lower temperature than the steam in the other stages and being passed through the hot solid residue, and supplying steam to the coke residue to provide further heat while controlling the yield and quality of the fuel gas produced from the coal.

5. The process of treating coal to produce therefrom volatile and coke and gasify part of the coke which comprises, heating a body of coal in a chamber internally by superheated steam countercurrent inside said chamber and also heating the coal externally through the walls of the chamber sufficiently to cause heat decomposition of the coal, said superheated steam being delivered to the coal body simultaneously at three different points spaced therealong, the steam at one stage being of lower temperature than the steam in the other stages and being passed through the hot solid residue, gasifying more of the coke by admitting superheated steam in varied quantities at a point between the places where the other steam is admitted, and supplying hot products of combustion to the coke residue to provide further heat while controlling the yield and quality of the fuel gas produced from the coal.

6. The substantially continuous process of treating dust free lumps of coal to produce fuels including a useful solid fuel and gases which comprises continuously feeding the coal from a closed chamber into a retort, heating the coal in the retort in the absence of an appreciable amount of air by a large supply of superheated steam at a temperature sufficient to cause heat decomposition of the coal, providing additional internal heat by supplying and burning mixed fuel gas and air within the retort, collecting the solid products separately from the fluid products, partially condensing the fluid products so as to leave a residue of gases, and conducting a portion of said residue of gases into contact with the lumps of coal in said chamber before delivering the same into the retort.

In testimony whereof, I have affixed my signature to this specification.

LEWIS CASS KARRICK.