

Aug. 6, 1968

C. GLINKA
METHOD AND APPARATUS FOR TREATING SOLID
FUELS AND PETROLEUM OILS

3,396,099

Filed July 27, 1964

4 Sheets-Sheet 1

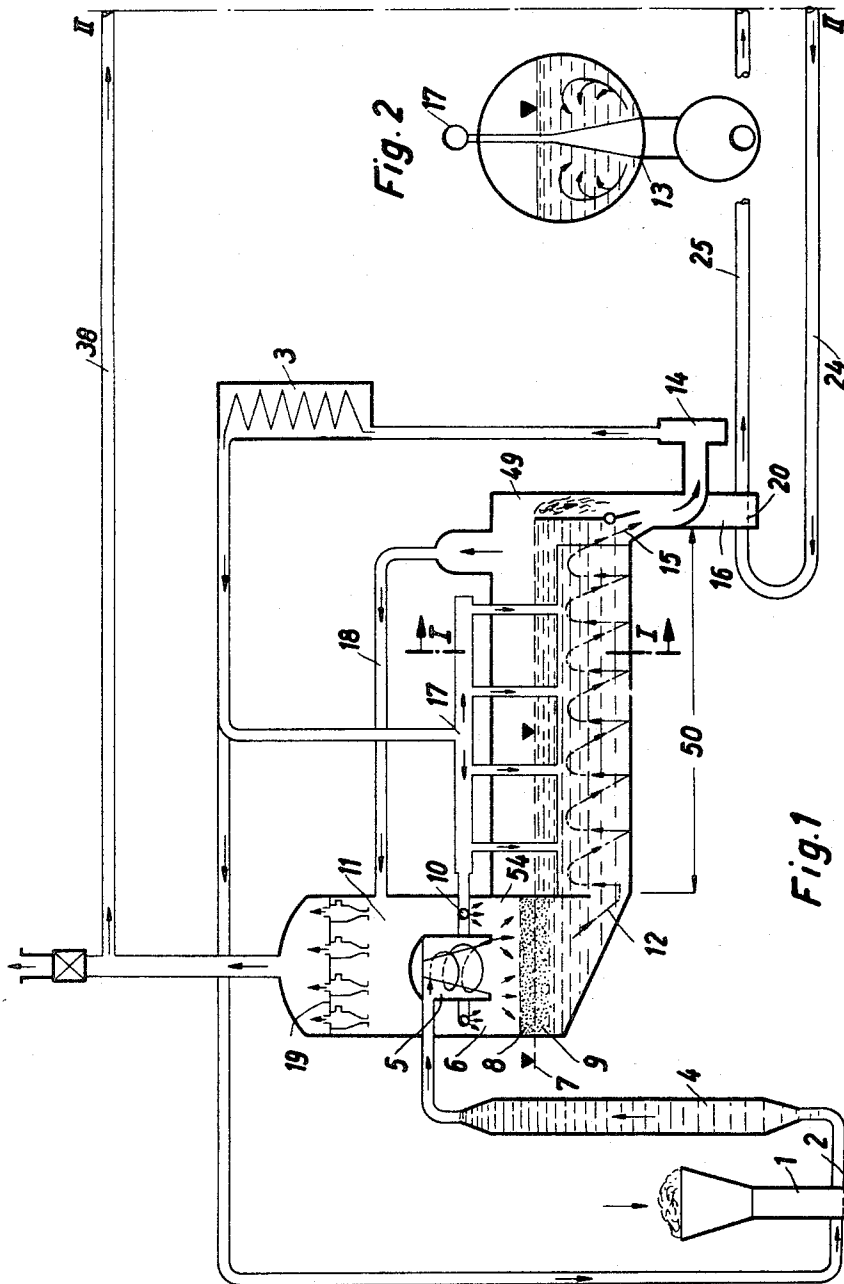


Fig. 1

Fig. 2

Inventor:

Care Glinka

Michael J. Striker

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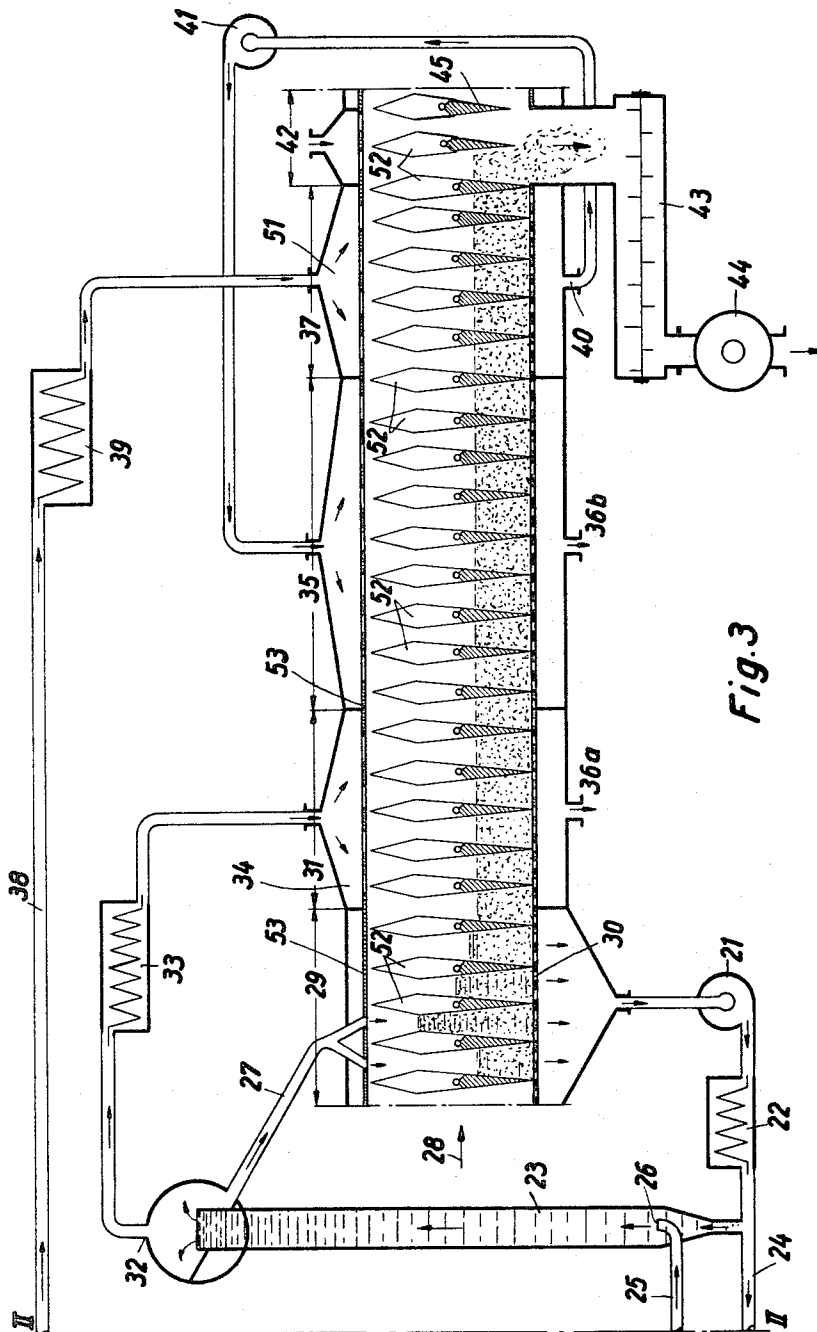


Fig. 3

Inventor:

Carl Glinka

Michael J. Striker

Attorney

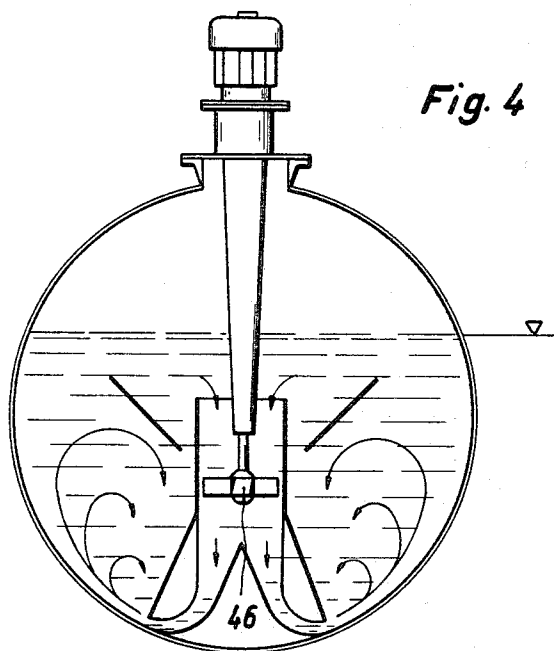
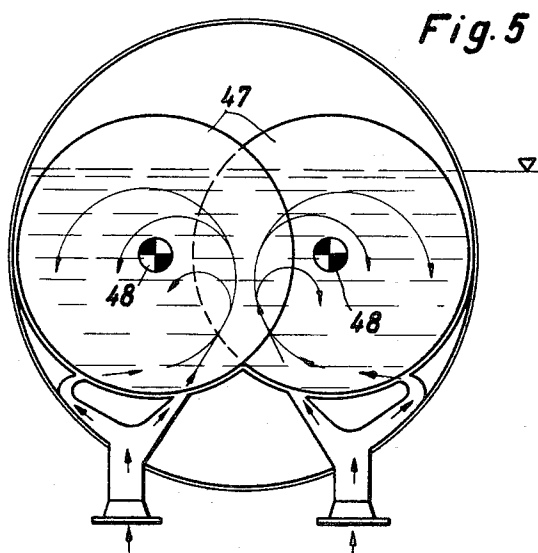
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Inventor:

Carl Glinka

Michael J. Striker

RMH

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FIG. 6

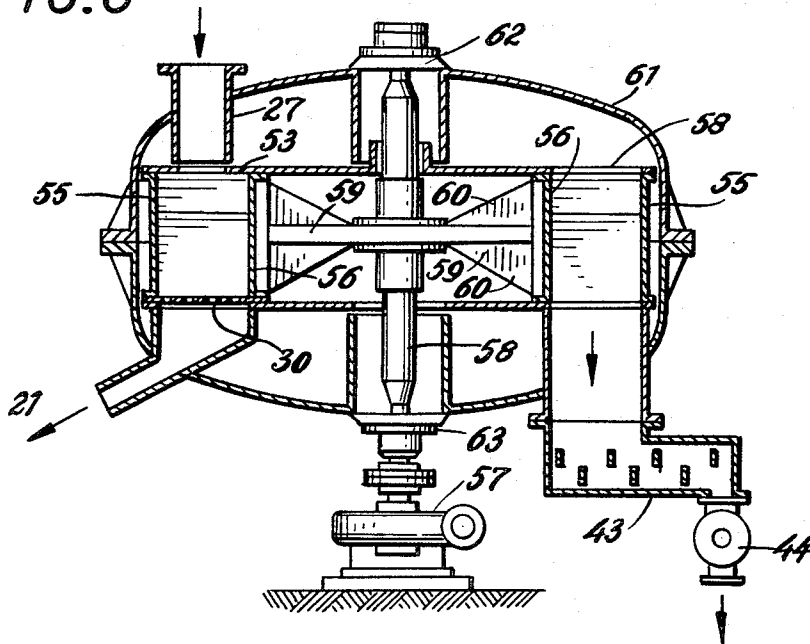
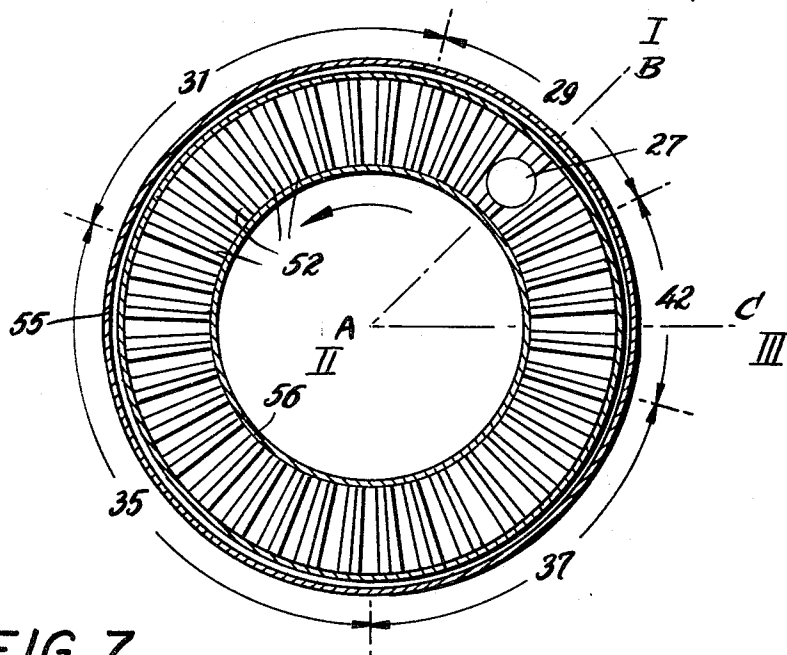


FIG. 7

INVENTOR
Carl Glinka
BY *Michael J. Striker*
ATTORNEY

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3,396,099

METHOD AND APPARATUS FOR TREATING SOLID FUELS AND PETROLEUM OILS

Carl Glinka, Stollwerckstrasse 2, Krefeld-
Urdingen, Germany

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G 38,355

8 Claims. (Cl. 208—107)

The present invention relates to a process and apparatus for treating solid fuels and petroleum oils.

More particularly, this invention relates to a process and apparatus for treating wet solid fuels so as to remove water and preferably bitumen or oily constituents therefrom. Thus, the present invention is concerned with the treatment of solid fuels which contain water and which also contain bituminous substances or oily constituents which may be subjected to cracking, and with the treatment of petroleum oils, particularly petroleum oils which have a low content of low-boiling components, such as petroleum oils which accrue as the residue from the distillation of petroleum crudes at temperatures of between 250 and 400° C.

Generally, the solid fuels and petroleum oils which are treated according to the present invention may be those described in my U.S. Patent No. 2,931,765.

It has been proposed to treat solid fuels which contain water and/or bitumen with hot petroleum oil under pressure so as to transform the water of the solid fuel into useful steam and/or to dissolve the oil-forming constituents of the solid fuel and separate such oil from the residue of the solid fuel. The oil which is dissolved in the solid fuel and a portion of the treating oil, i.e., a petroleum oil which contains only a relatively low proportion of low boiling constituents such as constituents boiling below 250° C. at normal pressure, may then be converted by cracking into more valuable hydrocarbon compounds.

According to these processes which may be carried out separately or combined with each other, the solid fuel is then eventually separated from the oil.

After the solid fuel has been separated from the oil by means of centrifuges or hydrocyclones, the solid fuel is further treated by evaporation or cracking of the oil adhering to the solid fuel or dissolved therein. This after treatment is carried out in a separate reaction vessel which is adjacent to the oil-solid fuel separating device.

It is an object of the present invention to carry out the dewatering and the removal of dissolved oil or oil-forming constituents from solid fuels containing water and such oil-forming constituents, combined with cracking of such oily constituents and/or a portion of heavy treating oil in a particularly simple and economical manner.

It is another object of the present invention to provide a simple and economical process and apparatus for the dewatering of water-containing solid fuels.

It is a further object of the present invention to provide a simple and economical process and apparatus for the removal of bituminous substances from solid fuels containing the same.

It is yet another object of the present invention to provide a simple and economical process and apparatus for refining, and for at least partially reducing the molecular weight of the constituents of petroleum oils containing

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only a relatively small fraction of low boiling constituents.

It is a further important object of the present invention to provide a simple and economical process and apparatus for considerably improving the burning value of inferior solid fuels, such as lignite and the like.

It is still a further object of the present invention to provide a simple and economical process and apparatus for jointly achieving in a unitary manner two or more of the objects described in the three immediately preceding paragraphs.

Other objects and advantages of the present invention will become apparent from a further reading of the description and of the appended claims.

With the above and other objects in view, the present invention contemplates in a method of treating a water-containing particulate solid carbonaceous fuel and a petroleum oil having a relatively low content of components boiling below 250° C. at normal pressure, the steps of introducing a mixture of the petroleum oil and of the carbonaceous fuel at an elevated temperature into a reaction chamber filled but partly with the petroleum oil and being maintained at an elevated pressure and at a temperature above the boiling point of water at the elevated pressure so that the carbonaceous fuel initially floats on the oil in the reaction chamber while water is evaporated therefrom and upon partial evaporation of water the carbonaceous fuel sinks downwardly in the petroleum oil into the lower portion of the reaction chamber, and moving the carbonaceous fuel from the reaction chamber along a substantially horizontal path through a layer of the hot oil communicating with the oil in the reaction chamber thereby withdrawing additional steam from the carbonaceous fuel.

The present invention also includes in a device for treating water-containing particulate solid carbonaceous fuel, in combination, an upright reaction chamber adapted to be filled to a predetermined level with a petroleum oil, the reaction chamber including a bottom and a wall portion extending downwardly from the predetermined level to a point spaced from the bottom so as to form an outlet opening near the bottom of the reaction chamber, first introduction means for introducing carbonaceous fuel into the reaction chamber, a horizontally extending reaction vessel communicating at one end with the outlet opening of the reaction chamber and having an outlet opening at its opposite end, oil heating means communicating with the reaction vessel and the reaction chamber for receiving oil from the outlet of the reaction vessel, heating the same and reintroducing the thus heated oil into the reaction chamber and the reaction vessel, and steam withdrawal means associated with the reaction chamber and the reaction vessel for withdrawing steam liberated from the carbonaceous fuel by the hot oil from the reaction chamber and vessel.

According to the present invention, the after treatment of the solid fuels and the cracking of the oils is combined with the process of separating the fuel from the oil and is carried out in one and the same apparatus. The stream of oil with the solid fuel therein is, in a preceding process, heated to between 300 and 400° C., preferably to about 370° C. and then introduced at a pressure of about 25 atmospheres above atmospheric pressure or at lower pressure into chambers which are arranged in series over

a perforated or grate-like screen. The oil flows through the screen, and on top of the screen a layer of solid fuel is formed, the height of which is limited by substantially unobstructed run-off of the oil. When the first chamber is filled, the solid fuel-containing oil stream is passed into the next chamber. In this manner, one chamber after the other is filled with solid fuel. Gas is then introduced into the solid fuel-containing chambers, which gas has been produced in the preceding process during heating of the fuel to about 400° C. The gas is under sufficient pressure so that it will be forced through the layer of solid fuel in the respective chamber and thereby will carry along and remove some oil which is still adhering to the layer of solid fuel.

In this manner, good conditions for the after treatment of the solid fuel and/or the cracking of the oils are provided. The layer of solid fuel which rests in the individual chambers consists of solid particles having a particle size of up to about 15 mm. and, consequently, many channels and interstices are formed in the solid fuel layer through which the gases may pass which are either formed in the solid fuel layer during the after treatment of the same or which are introduced into the layer from the outside.

The resting of the solid fuels during the after treatment is important, particularly when fuels having a relatively high content of oxygen are introduced into the process and the oxygen, i.e., the exothermic reaction between the same and carbon and hydrogen of the oil dissolved in the solid fuel are to be used for heating the solid particles and/or the oil to the cracking temperature of the latter. In the chosen temperature range of between about 400 and 500° C., these reactions proceed in a relatively short period of time, namely about 15 minutes, provided that the position of the individual fuel particles in the layer of solid fuel formed in the individual chambers remains unchanged during the reaction period. This has also a favorable effect with respect to the simultaneously carried out cracking reactions which take also about 15 minutes.

The chambers which are filled with the oil and solid fuel mixture are preferably arranged movable along a circular path and after each circular movement, the individual chambers are emptied and filled anew. Treating of the material is carried out along the portion of the path of movement of the individual chambers which is located between the filling and emptying positions. By subdividing the treating zone into several sections, in which gas as heat carrier may be introduced into the chambers, reactants may be introduced or gases may be formed, it is possible to control the cracking processes and the composition of the products formed by cracking.

Changes in the temperature and pressure will be only of slight influence on the reaction processes with respect to the type of cracking products formed. The type and composition of the cracking processes is mainly determined by the type of the heavy treating oil and of the oil or oil forming substances contained or dissolved in the solid fuel.

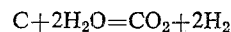
By heating the oils at a pressure of about 25 atmospheres above atmospheric pressure at a temperature of about 450° C., a smaller fraction of low boiling hydrocarbons will be formed and a heavy residue including free carbon molecules which are taken up by the solid fuel.

The desired larger quantities of lower boiling hydrocarbons and the C:H ratio can be obtained by introducing hydrogen in molecular form into the process. In this case, particularly favorable conditions are then obtained for converting the higher or high boiling oils into more valuable lower boiling hydrocarbons. Due to the removal of water in the pretreatment of the fuel and the dissolution of oil forming material, very fine pores are formed in the solid fuel which provide a relatively very large adsorption or reaction surface on which the oil will adhere in a very thin film. Upon heating the fuel and the oil adhering to the pore surface to about 450–500° C., due to the tensions and movements caused in the oil film in con-

tact with the solid fuel surface, a far reaching cracking of the larger hydrocarbon molecules into unsaturated hydrocarbons and free carbon molecules is achieved. These cracking products, will then form with the introduced hydrogen gas primarily saturated hydrocarbons. In this manner, a part of the heavy treating oil as well as a part of the heavy oil constituents of the solid fuels are converted into low boiling hydrocarbons.

The hydrogen gas which is required for forming the saturated low boiling hydrocarbons may be produced in the last section of the treating zone.

A portion of the steam which is formed in the preceding dewatering of the solid fuel may be passed after being heated to about 650° C. through the last section of the treating zone wherein the highly heated solid fuel is present in the form of a low-temperature coke. Thereby, carbon and water will react to form carbon dioxide and molecular hydrogen in accordance with the equation



By increasing the amount of hydrogen gas which is introduced into the reaction zone beyond the amount required for forming the saturated hydrocarbons and by maintaining the partial pressure of the hydrogen gas sufficiently high, it is possible to achieve simultaneously a hydrogenating refining of the cracking product. The sulfur which is carried along by the oil is then bound by the hydrogen gas and may be separated in the form of hydrogen sulfide from the gas and vapors withdrawn from the reaction zone. Such separation of hydrogen sulfide is carried out in conventional manner.

By combining the various processes and by the manner in which the same are carried out according to the present invention, the cracking of inferior oils in combination with the treatment of solid fuels becomes of considerable significance. The present invention results in a great simplification of the entire installation and consequently in a reduction of the investment and operating expenses and the manner in which the process is carried out according to the present invention will result in a trouble-free carrying out of the exothermic reactions which will require the same length of time as the endothermic cracking reactions which at the operating pressure of the device will primarily take place in the liquid phase.

The method of the present invention may also be used with similar advantages for the treatment of solid fuels which do not contain a significant amount of water. In such cases, the device may be operated at atmospheric pressure or at a slight over-pressure which will assure the outflow of the gases and vapors formed during the process.

It has been found that the upgrading process of the present invention is best carried out with solid fuels of relatively large particle size. Since furthermore, the fine comminution of wet solid fuels is connected with difficulties and, if necessary, can be carried out during the process in a simple manner, the pretreatment of the fuel for the purpose of removing water therefrom is carried out in such a manner that fuel having a particle size of up to 20 mm. or larger may be treated.

The larger particle size of the solid fuel increases the length of treatment and thus requires an increase in the length of the treating zone. The treating zone can only be lengthened within practical limits. The increase of the treating period will also prolong the floating period, i.e., the period of time for which the solid fuel which still contains moisture in its pores will float on the hot oil, as described in German Patent No. 1,048,378. This will result in an increase in the thickness of the floating fuel layer in the horizontally extending treating zone, which thickness may grow to such an extent that the floating fuel may be pressed against the roof or ceiling of the treating zone. This might lead to blocking or obstruction of the passage of the solid fuel and this blockage will be

further increased by the intensive steam formation in this treating zone.

A control of these processes and a trouble-free movement of the fuel within a relatively short treating zone is achieved according to the present invention by passing the solid fuel into a container or reaction chamber which is but partly filled with the treating oil and wherein the treating oil will have the largest possible free upper surface. Part of the reaction chamber is formed by walls which reach below the oil level for a sufficient depth so that the solid fuel which is introduced into the reaction zone will be maintained for the floating period within the thus limited space and the downwardly sinking fuel will then be directed towards an horizontally extending path. By heating the solid fuel which contains moisture in its pores prior to introduction of the same into the treating oil in the reaction chamber to the evaporation temperature of the water and thereafter introducing the thus heated moisture-containing fuel into the reaction chamber above the oil level maintained therein, then, the fuel will form a layer on the surface of the oil in the reaction chamber and the thickness of the layer will depend on the surface area of the treating oil, the amount of solid fuel which is introduced and the particle size of the latter. A portion of the solid fuel layer will sink downwardly below the surface of the treating oil and a portion of the fuel will extend upwardly above the upper level of the treating oil, carried by the uplift or buoyancy of the submerged portions of the fuel. This buoyancy is caused by the formation and flow of steam from the pores of the submerged solid fuel particles.

From the lower portion of the submerged fuel layer, individual particles of the solid fuel will sink downwardly after steam has been formed of a portion of the water contained in the pores of the solid fuel and the specific gravity of the fuel has thus been increased. The introduction of the particulate solid fuel above the level of the treating oil will be carried out at the same rate at which particles of the solid fuel sink downwardly from the submerged fuel layer so that at the beginning of the process a fuel layer of a predetermined thickness is formed and this thickness is then maintained throughout the entire length of the process.

During this floating of the fuel, about half of the moisture contained therein is vaporized. The heat required for vaporizing the moisture is withdrawn from the treating oil which through the fuel layer is introduced into the process, passes through the layer of solid fuel and thereby gives up part of the heat which has been previously given to the treating oil by passing the same through a heating device.

The steam which is formed in the fuel layer separates easily from the oil which in the portion of the solid fuel layer which extends upwardly from the oil level in the reaction chamber does not form a continuous mass. Thus, the steam easily reaches the surface of the oil and of the fuel layer.

In this manner, relatively large quantities of water can be vaporized on a relatively small surface or in a relatively small space while at the same time the desired movement of the solid fuel and the oil during the treating zone is assured. Thus, for instance by treating 75 tons per hour of brown coal containing 60% of water based on the total net weight, 22.5 tons of water can be evaporated while the brown coal or lignite is floating on the oil in the reaction chamber. The evaporation of the remaining half of the initial water content, i.e., the evaporation of a further 22.5 tons of water requires a longer treating period. This longer treating period for removal of the residual water may be reduced to just a few minutes provided that there is a quick change of contact between the individual portions of the heated oil and the solid fuel. It is also necessary that in this treating section the steam formed from the residual moisture is separated from the oil along a path which should be as short as possible, in

order to carry out this part of the process without difficulties.

This is accomplished according to the present invention by passing the solid fuel through a horizontally extending treating zone wherein the fuel is repeatedly raised upwardly in the oil layer or even out of the oil layer located in the horizontal treating zone and is then again permitted to drop downwardly through the oil layer. During the downward movement of the solid fuel particles, the same are also carried along by the flowing oil in the longitudinal direction of the treating zone so that, in fact, the solid fuel will carry out a spirally progressing movement through the horizontal treating zone. This spirally progressing movement of the solid fuel can also be achieved by passing a portion of the treating oil in a thin layer at high speed in a direction perpendicular to the direction of flow of the major portion of the oil layer horizontally along the bottom of the container, then diverting the thin layer in upward direction and allowing the thus diverted thin oil layer after the same has reached the upper portion of the main oil layer to flow back to its starting point at a reduced speed. This bottom flow extends over the entire length of the horizontal treating vessel so that wherever in the horizontal treating vessel solid fuel will drop towards the bottom of the vessel, it will contact this bottom flow and will be passed upwardly by the same. From the upper portion of the total oil layer in the horizontal treating vessel, the solid fuel will then sink downwardly towards the bottom flow and in this manner, the particulate solid fuel will pass through the entire length of the horizontal treating vessel. The cross sectional dimensions of the horizontal treating vessel will be such that the time required for the passage of oil through the same will correspond to the treating time required for the solid fuel. The treating time of the solid fuel can also be influenced by the above described bottom flow of oil. If this bottom current or flow is directed not perpendicular but under an acute angle with respect to the longitudinal axis of the horizontal treating vessel, then depending on whether the oil flow is in forward or rearward direction relative to the longitudinal flow of the major portion of the oil in the treating vessel, the time required for passage of the solid fuel through the horizontal treating vessel will be increased or decreased.

The above described measures have considerable advantages. Due to the spiral moving of the solid fuel in the oil, a quick change between contacting portions of the oil and the solid fuel and thus an extensive heat exchange is achieved. The steam formed thereby will be evenly distributed through the treating space, following the movement of the solid fuel and will quickly reach along a short path upwardly through the oil, the free space which is located above the relatively large surface of the flowing oil layer in the horizontal treating zone. The steam will be easily separated from the fuel and the oil and then withdrawn as will be described further below. The same advantages are achieved irrespective of whether this part of the process is carried out at elevated pressure or at atmospheric pressure.

The novel features which are considered as characteristic for the invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its method of operation, together with additional objects and advantages thereof, will be best understood from the following description of specific embodiments when read in connection with the accompanying drawings, in which:

FIG. 1 is a schematic elevational view of the portion of the device in which the moisture of the solid fuel is converted into utilizable industrial steam;

FIG. 2 is a cross sectional view taken along line I—I of FIG. 1;

FIG. 3 is the continuation of the device shown in FIG. 1 and illustrates the portion of the arrangement wherein separation of the solid fuel from the oil is carried out and the fuel is subjected to an after treatment;

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FIGS. 4 and 5 are cross sectional views of alternative arrangements taken along line I—I of FIG. 1;

FIG. 6 is an elevational cross sectional view through the treating zone illustrated in FIG. 3, taken along line I—II—III of FIG. 7; and

FIG. 7 is a plan view of the device illustrated in FIG. 6 with the cover portions removed therefrom.

All of the figures of the drawing are schematic illustrations of an arrangement according to the present invention.

The entire arrangement is shown in FIGS. 1 and 3, the device being cut along the line II—II which passes through conduits 24, 25 and 38.

The illustrated device may for instance be utilized for the treatment of raw brown coal or lignite containing about 60% moisture and 40% dry substance and the following description of the drawing will also serve as an example for the treating of such brown coal according to the present invention.

Referring first to the removal of water from the fuel (the term fuel is used herein to denote the solid fuel which is treated according to the present invention) in the portion of the device illustrated in FIGS. 1 and 2, the process is carried out as follows:

The fuel is introduced through conventional air lock 1 into the pressurized portion of the device which is maintained at a pressure of 25 atmospheres above atmospheric pressure. The solid fuel thus reaches inner air lock chamber 2 and is taken up by the oil stream which had been heated in heater 3 to about 300° C. The fuel is carried by the oil stream through riser vessel 4 and is heated therein to the evaporation temperature of the moisture contained in the fuel, namely to a temperature of about 200° C. The oil solid fuel mixture passes then through distributor 5 into the first treating zone 6. In the reaction chamber forming a treating zone 6, treating oil is maintained up to the level 7 and a floating solid fuel layer 8 will be formed above level 7, carried by the fuel layer 9 which is submerged below level 7. Treating zone 6 is located in the first portion 54 of a reaction device and the heat required in treating zone 6 for evaporation of water from the fuel is provided by a stream of oil flowing through ring conduit 10 from heater 3. The heat conveyed by the oil to the solid fuel will cause evaporation of part of the water content thereof and the steam formed thereby will be withdrawn from steam collecting space 11.

The solid fuel which separates from layer 9 below oil level 7 follows the flow of the oil which passes from the first treating zone 6 through outlet opening 12 into a second treating zone 50 which extends in horizontal direction and in which the same height of the oil level is maintained as in treating zone 6. In treating zone 50, the solid fuel is taken up by the oil stream flowing along the bottom of the treating zone as previously described and is passed in a spiral movement, as indicated by the arrows, through the horizontal treating zone. The bottom oil flow is created by nozzles 13, as shown in FIG. 2. Pump 14 passes oil through heater 3 and distributor 17 into the nozzle system from which the oil flows on both sides through nozzles 13 in a thin oil layer along the bottom wall of the treating zone and with a speed sufficient to prevent contact between the downwardly sinking solid fluid and the bottom wall of the treating zone. The solid fuel rises with this oil stream and, in view of the reduced speed of the oil once the same has risen in the peripheral portions of treating zone 50, the fuel will then again drop towards the bottom area to be again taken up by the oil stream. During the sinking of the fuel, the same follows the flow of the major portion of the oil in treating zone 50, namely in axial direction of treating zone 50 and will reach after a great number of upward and downward movements along a spiral path the outlet 15. In the rotating screen lock 16, the fuel is separated from the oil and the oil is passed by way of pump 14 and heater 3 to distributor 17 and again into nozzles 13 of treating zone 50. The heat which is given

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to the oil in heater 3 is given up in contact with the solid fuel and thereby steam is developed from the residual moisture of the same and the thus formed steam passes through steam conduit 18 into steam collecting space 11 from where the steam developed in treating zone 50, together with the steam developed in treating zone 6 may be conveyed to any desired steam consuming device.

Steam collecting space 11 is formed with an intermediate bottom 19 in which a number of small cyclones are arranged through which the steam passes at high speed and in which the steam is freed from any oil particles carried along up to now. Such oil particles may be carried along by the steam particularly when relatively large quantities of solid fuel with a relatively large amount of surface water are introduced into treating zone 6 causing a very quick evaporation of water.

The thus dewatered solid fuel is further treated in the device schematically illustrated in FIGS. 3, 6 and 8, whereby the circular device of FIGS. 6 and 7 is shown in FIG. 3 in developed form.

Treatment in the device of FIG. 3 is carried out in the following manner:

The pretreated, i.e., dewatered solid fuel coming from treating zone 50 is taken up at pressure lock 20 by a second circulating oil stream. Pump 21 passes the oil through heater 22 into riser pipe 23. A partial stream flows through conduit 24 and takes up the dewatered fuel at pressure lock 20 and passes the same through conduit 25 and elbow 26 into riser pipe 23. In riser pipe 23, the oil forming substance in the solid fuel is dissolved at a temperature of between 350 and 400° C. and the treating oil and the solid fuel are then passed jointly through conduit 27 into the individual chambers of the separating device. The chambers are separated from each other by separating walls 52 which slide tightly on perforated or screen bottom 30 and cover 53 which is provided with the required openings. Separating walls 52 and thus the chambers defined by the same move along a circular path in the direction of arrow 28 and during such movement the chambers are successively filled with the continuously flowing oil-fuel mixture. The oil flows into the filling zone 29 which is delimited by arrows 29 in FIG. 3 and then through the chambers and through the perforated bottom of the same and is then again circulated by means of pump 21 after being reheated in heater 22. In the then following first dry treating zone 31 which again is delimited in FIG. 3 by arrows, any oil which is still adhering to the solid fuel mass filling the chamber, is removed by means of gas which is formed by heating the fuel to about 400° C. and which from the withdrawal space 32 at the top of riser pipe 23 and from there to heater 33 is passed into distributing space 34. From there, the gas passes through the fuel mass located in the chambers of treating zone 31 and the oil-gas mixture is removed through outlet 36a. By contact with the heated gas, the heating of the fuel to cracking temperature is started.

In the next following dry treating zone 35 which again is delimited by arrows in FIG. 3, the fuel is heated by the reaction of the oxygen contained therein so as to reach a temperature of between 450 and 500° C. and thereby, the residual treating oil which is still adhering to the fuel and oil dissolved in the fuel will be cracked. Corresponding to the heavy oils which are initially used as treating oils, in addition to free carbon molecules, unsaturated hydrocarbon molecules are formed.

These cracking products may be converted by reaction with hydrogen gas into primarily saturated hydrocarbons so that only a small fraction of a heavy residue remains. The thus formed hydrocarbons are withdrawn through outlet 36b and further treated in conventional manner. The hydrogen gas which is required for forming the new saturated hydrocarbon compounds is produced in the next following dry treating zone 37 which again is delimited in FIG. 3 by arrows. A portion of the steam produced in treating zones 6 and 50 of FIG. 1 is passed through

through conduit 38 and heater 39 into distributing space 51 and from there at a temperature of about 650° C. through the fuel maintained at high temperature and forming at this point a low temperature coke. Thereby molecular hydrogen will be formed by the reaction of carbon with steam forming thus molecular hydrogen and carbon dioxide and the thus formed gas is withdrawn through outlet 40 and passed through blower 41 into treating zone 35.

Now follows a last dry treating zone 42 in which the solid fuel is removed through comminutor 43 and pressure lock 44.

In order to facilitate sliding out of the fuel from the chambers rotating along the circular path, the lower portion of separating walls 52 is formed by wedges 45 which may be raised when passing through the outlet area for the solid fuel.

Referring again at FIG. 1 and in this connection also to FIG. 4, it is noted that the bottom flow of oil in the horizontal treating zone 50 may also be produced by pumps such as the pump shown in schematic elevational cross section in FIG. 4. One or more of such screw type pumps may be distributed throughout treating zone 50 in order to impart to a portion of the oil the circulating movement indicated by the arrows in FIG. 4.

When solid fuels of differing specific gravity are to be treated, for instance lignite with wood constituents therein, then special measures have to be taken in order to assure an even passage of the fuel particles through treating zone 50. This can be accomplished by arranging in the area of the longitudinal axis of treating zone 50 one or two screw conveyors 47 as illustrated in schematic elevational cross section in FIG. 5. The fuel is then conveyed between the threads of the screw conveyor and the pitch of the screws 47 and the number of screw shafts 48 must be adjusted to the amount of oil which passes in longitudinal direction through treating zone 50.

In order to assure trouble-free withdrawal of floating fuel particles from treating zone 50, the treating zone at its outlet end is limited by overflow wall 49. The floating particles pass with the overflowing oil and these overflowing particles and oil combine with the main portion of fuel particles and the oil which pass through outlet 15. Upon separation, the oil then passes to heater 3 and the solid fuel particles are taken up by the oil stream of conduit 24-25.

Referring now to the portion of FIG. 3 which is also illustrated in FIGS. 6 and 7, according to one embodiment, as illustrated in FIGS. 6 and 7, the separating walls 52 move jointly with outer wall 55 and inner wall 56. The movement is achieved by means of gear or drive 57, a vertical shaft 58 and arms 59 which contact the circular inner wall 56 and which may be provided with braces 60. The perforated bottom 30 and cover 53 which also contains openings as required for the individual treating zones remain stationary. The entire device is covered by an outer cover 61 which carries bearings 62 and 63 for shaft 58.

It is the purpose of the arrangement shown by way of example only in FIGS. 6 and 7 to illustrate the actual circular arrangement which has been schematically shown in developed form in FIG. 3. It is of course possible to change in a manner known per se the specific arrangement of the cover, the vertical shaft and the drive mechanism.

Separating walls 52 slide relatively tight or nearly completely tight along cover 53 and perforated bottom 30. Since several chambers or separating walls 52 pass simultaneously through each treating zone, the thus obtained sealing has accumulative effect.

The following example is given as illustrative only, without, however, limiting the invention to the specific details of the example.

Example

In this example numerical data will be given pertaining

to the treatment of brown coal and heavy oil in accordance with the present invention.

A brown coal containing 60% water is treated. On a dry basis the coal contains 10% ash, 15% oil and 28% oxygen. The treating oil is a crude oil from which the light and medium oils, particularly those boiling up to 250° C. have been removed. The oil circulating in the process has a boiling range of about 380° C.

The apparatus (as illustrated) has an hourly capacity of 50,000 kg. brown coal, containing about 30,000 kg. water and about 20,000 kg. dry coal including about 3,000 kg. oil.

(1) *Dewatering.*—The apparatus (FIG. 1) is maintained at a pressure of 26 atmospheres absolute. The treating oil has a temperature of about 300° C. and the evaporation temperature of the moisture contained in the coal is about 200° C.

About 30,000 kg. of industrial steam are produced per hour and can be converted into about 6,500 kwh.

The length of the apparatus is about 8 meters and the diameter (in the treating zone 50) about 2 meters.

The treating period is about 5 minutes.

(2) *Treating of the dry coal.*—The dewatered coal is passed into a second oil stream (FIG. 3). Temperature of the oil, about 380° C.; temperature of the coal, about 380° C.; height of the riser pipe, about 6.0 meters; diameter of the riser pipe, about 0.4 meter; treating period, about 20 seconds.

During heating of the coal in contact with the oil in the riser pipe, the oil-forming constituents of the coal are dissolved.

Now follows separation of the coal from the circulating treating oil and introduction of the separated coal into the circular treating zones (FIGS. 3, 6 and 7).

Dry coal	-----kg./h---	About 20,000.
Dissolved oil	-----kg./h---	About 3,000.
Treating oil taken up by the dry coal	-----kg./h---	About 10,000.
Oil to be cracked	-----kg./h---	About 13,000.
Pressure in the circular reaction zones	-----atmospheres, absolute---	About 6.
Reaction temperature	-----° C---	About 480.
Developed length of the reaction zones	-----meters---	About 20.
Diameter of the circular reaction zone	-----do---	About 6.
Height of the solid fuel layer	-----do---	About 1

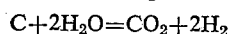
During the reaction between oxygen, carbon and hydrogen about 400 kcal. are developed per kg. of dry coal, or per hour about 8,000,000 kcal. This heat suffices for heating coal and oil to the cracking temperature as well as for supporting the endothermic cracking reactions.

The cracking of the 13,000 kg./h. of heavy oil produces, in addition to carbon dioxide and gaseous cracking products, 5,000 kg./h. of light and middle oils, 3,000 kg./h. of solid cracking residue which is taken up by the treated coal, and 5,000 kg./h. of heavy oil of which 3,600 kg./h. remain in the treated coal and 1,400 kg./h. are recycled into the process. Thus, from outside sources 10,000 kg./h. minus 1,400 kg./h. or a net total of 8,600 kg./h. of heavy oil are introduced into the process.

By removal of water and subsequent treatment, the calorific value of the coal is increased from 2,000 kcal. to 6,000 kcal.

(3) *Production of hydrogen.*—Part of the steam produced in the dewatering process (1) is superheated to about 650° C. and then passed through the low temperature coke formed of the coal in the circular treating zones and having a temperature of about 480° C.

Hydrogen is formed according to the formula:



The process is partially exothermic due to the combining of O and C to CO₂, and partially endothermic due to the formation of hydrogen.

The ratio between liberated heat and consumed heat equals 1:1.2, so that for the formation of hydrogen the heat is available which is liberated by reducing the temperature of the treated coal and of the steam to about 400° C. from 480° C. and 650° C., respectively.

The thus formed hydrogen gas and carbon dioxide may be passed into the reaction zone so that therein primarily saturated hydrocarbon compounds are formed in addition to a residual smaller proportion of heavy oil and without forming of a solid residue.

However, the valuable hydrogen gas may also be separated from the simultaneously formed carbon dioxide and used for any desired purpose.

It will be understood that each of the elements described above, or two or more together, may also find a useful application in other types of treating devices for carbonaceous fuel differing from the types described above.

While the invention has been illustrated and described as embodied in a device for dewatering solid carbonaceous fuel under simultaneous cracking of petroleum oils, it is not intended to be limited to the details shown, since various modifications and structural changes may be made without departing in any way from the spirit of the present invention.

Without further analysis, the foregoing will so fully reveal the gist of the present invention that others can by applying current knowledge readily adapt it for various applications without omitting features that, from the standpoint of prior art, fairly constitute essential characteristics of the generic or specific aspects of this invention and, therefore, such adaptations should and are intended to be comprehended within the meaning and range of equivalence of the following claims.

What is claimed as new and desired to be secured by Letters Patent is:

1. In a method of treating a water-containing particulate solid carbonaceous fuel and a petroleum oil having a relatively low content of components boiling below 250° C. at normal pressure, the steps of introducing a mixture of said petroleum oil and of said carbonaceous fuel at an elevated temperature into a reaction chamber filled but partly with said petroleum oil and being maintained at an elevated pressure and at a temperature above the boiling point of water at said elevated pressure so that said carbonaceous fuel initially floats on said oil in said reaction chamber while water is evaporated therefrom and upon partial evaporation of water said carbonaceous fuel sinks downwardly in said petroleum oil into the lower portion of said reaction chamber; moving said carbonaceous fuel from said reaction chamber along a substantially horizontal path through a layer of said hot oil communicating with the oil in said reaction chamber thereby withdrawing additional steam from said carbonaceous fuel; separating said carbonaceous fuel from said layer of oil; and heating the thus substantially water-free carbonaceous fuel to a temperature sufficiently high to crack the oil contained in and adhering to said carbonaceous fuel.

2. In a method of treating a water-containing particulate solid carbonaceous fuel and a petroleum oil having a relatively low content of components boiling below 250° C. at normal pressure, the steps of introducing a mixture of said petroleum oil and of said carbonaceous fuel at an elevated temperature into a reaction chamber filled but partly with said petroleum oil and being maintained at an elevated pressure and at a temperature above the boiling point of water at said elevated pressure so that said carbonaceous fuel initially floats on said oil in said reaction chamber while water is evaporated therefrom and upon partial evaporation of water said carbonaceous fuel sinks downwardly in said petroleum oil into the lower portion of said reaction chamber; moving said carbonaceous fuel from said reaction chamber along a substantially horizontal path through a layer of said hot oil communicating with the oil in said reaction chamber thereby withdrawing additional steam from said carbonaceous

fuel; separating said carbonaceous fuel from said layer of oil; and heating the thus substantially water-free carbonaceous fuel in the presence of hydrogen to a temperature sufficiently high to crack the oil contained in and adhering to said carbonaceous fuel.

3. A method according to claim 2 wherein said hydrogen is produced by passing steam over said heated carbonaceous fuel.

4. In a device for treating water-containing particulate solid carbonaceous fuel, in combination, an upright reaction chamber adapted to be filled to a predetermined level with a petroleum oil, said reaction chamber including a bottom and a wall portion extending downwardly from said predetermined level to a point spaced from said bottom so as to form an outlet opening near said bottom of said reaction chamber; first introduction means for introducing carbonaceous fuel into said reaction chamber; a horizontally extending reaction vessel communicating at one end with said outlet opening of said reaction chamber and having an outlet opening at its opposite end; oil heating means communicating with said reaction vessel and said reaction chamber for receiving oil from said outlet of said reaction vessel, heating the same and reintroducing the thus heated oil into said reaction chamber and said reaction vessel; steam withdrawal means associated with said reaction chamber and said reaction vessel for withdrawing steam liberated from said carbonaceous fuel by said hot oil from said reaction chamber and vessel; an annular treating chamber having perforated top and bottom walls and outer and inner walls; inlet means communicating with said outlet opening of said reaction vessel and said annular treating chamber for introducing substantially water-free solid particulate carbonaceous fuel from said reaction vessel into said treating chamber; means for circulating oil between said annular treating chamber and said inlet means; a plurality of substantially radial walls extending in said annular treating chamber from said bottom to said top wall thereof and subdividing said annular treating chamber into a plurality of compartments; moving means for moving said parallel walls and said outer and inner walls along a circular endless path; a plurality of fluid introduction and withdrawal means communicating with separate portions of said annular treating chamber for introducing fluid reactants into and withdrawing fluid reaction products from said separate portions of said annular treating chamber while said compartments pass through said separate portions; and withdrawal means for withdrawing solid reaction products from said annular treating chamber after the same have passed while being located in said compartments, respectively, through said separate portions of said treating chamber.

5. In a device for treating water-containing particulate solid carbonaceous fuel, in combination, an upright reaction chamber adapted to be filled to a predetermined level with a petroleum oil, said reaction chamber including a bottom and a wall portion extending downwardly from said predetermined level to a point spaced from said bottom so as to form an outlet opening near said bottom of said reaction chamber; first introduction means for introducing carbonaceous fuel into said reaction chamber; a horizontally extending reaction vessel communicating at one end with said outlet opening of said reaction chamber and having an outlet opening at its opposite end; oil heating means communicating with said reaction vessel and said reaction chamber for receiving oil from said outlet of said reaction vessel, heating the same and reintroducing the thus heated oil into said reaction chamber and said reaction vessel; steam withdrawal means associated with said reaction chamber and said reaction vessel for withdrawing steam liberated from said carbonaceous fuel by said hot oil from said reaction chamber and vessel; an annular treating chamber having perforated top and bottom walls and outer and inner walls; inlet means communicating with said outlet opening of said reaction vessel and said annular treating chamber for in-

roducing substantially water-free solid particulate carbonaceous fuel from said reaction vessel into said annular treating chamber; means for circulating oil between said annular treating chamber and said inlet means; a plurality of substantially radial walls extending in said annular treating chamber from said bottom to said top wall thereof and subdividing said annular treating chamber into a plurality of compartments; moving means for moving said parallel wall along a circular endless path within said annular treating chamber; a plurality of fluid introduction and withdrawal means communicating with separate portions of said annular treating chamber for introducing fluid reactants into and withdrawing fluid reaction products from said separate portions of said annular treating chamber while said compartments pass through said separate portions; and withdrawal means for withdrawing solid reaction products from said annular treating chamber after the same have passed while being located in said compartments, respectively, through said separate portions of said treating chamber.

6. In a device for treating water-containing particulate solid carbonaceous fuel, in combination, an upright reaction chamber adapted to be filled to a predetermined level with a petroleum oil, said reaction chamber including a bottom and a wall portion extending downwardly from said predetermined level to a point spaced from said bottom so as to form an outlet opening near said bottom of said reaction chamber; first introduction means for introducing carbonaceous fuel into said reaction chamber; a horizontally extending reaction vessel communicating at one end with said outlet opening of said reaction chamber and having an outlet opening at its opposite end; oil heating means communicating with said reaction vessel and said reaction chamber for receiving oil from said outlet of said reaction vessel, heating the same and reintroducing the thus heated oil into said reaction chamber and said reaction vessel; steam withdrawal means associated with said reaction chamber and said reaction vessel for withdrawing steam liberated from said carbonaceous fuel by said hot oil from said reaction chamber and vessel; an annular treating chamber having perforated top and bottom walls and outer and inner walls; inlet means communicating with said outlet opening of said reaction vessel and said annular treating chamber for introducing substantially water-free solid particulate carbonaceous fuel from said reaction vessel into said annular treating chamber; means for circulating oil between said annular treating chamber and said inlet means; a plurality of substantially radial walls extending in said annular treating chamber from said bottom to said top wall thereof and subdividing said annular treating chamber into a plurality of compartments; moving means for moving said parallel walls along a circular endless path within said annular treating chamber; a plurality of fluid introduction and withdrawal means communicating with separate portions of said annular treating chamber for introducing fluid reactants into and withdrawing fluid reaction products from said separate portions of said annular treating chamber while said compartments pass through said separate portions; withdrawal means for withdrawing solid reaction products from said annular treating chamber after the same have passed while being located in said compartments, respectively, through said separate portions of said treating chamber; and means for raising individually said radial walls while the same pass through the region of said withdrawal means for facilitating withdrawal of solid reaction product from said annular treating chamber.

7. In a device for treating water-containing particulate solid carbonaceous fuel, in combination, an upright reaction chamber adapted to be filled to a predetermined level with a petroleum oil, said reaction chamber including a bottom and a wall portion extending downwardly from said predetermined level to a point spaced from said bottom so as to form an outlet opening near said bottom of said reaction chamber; first introduction means for in-

roducing carbonaceous fuel into said reaction chamber; a horizontally extending reaction vessel communicating at one end with said outlet opening of said reaction chamber and having an outlet opening at its opposite end; oil heating means communicating with said reaction vessel and said reaction chamber for receiving oil from said outlet of said reaction vessel, heating the same and reintroducing the thus heated oil into said reaction chamber and said reaction vessel; steam withdrawal means associated with said reaction chamber and said reaction vessel for withdrawing steam liberated from said carbonaceous fuel by said hot oil from said reaction chamber and vessel; an annular treating chamber having perforated top and bottom walls and outer and inner walls; inlet means communicating with said outlet opening of said reaction vessel and said annular treating chamber for introducing substantially water-free solid particulate carbonaceous fuel from said reaction vessel into said annular treating chamber; means for circulating oil between said annular treating chamber and said inlet means; a plurality of substantially radial walls extending in said annular treating chamber from said bottom to said top wall thereof and subdividing said annular treating chamber into a plurality of compartments; moving means for moving said parallel walls along a circular endless path within said annular treating chamber; a plurality of fluid introduction and withdrawal means communicating with separate portions of said annular treating chamber for introducing fluid reactants into and withdrawing fluid reaction products from said separate portions of said annular treating chamber while said compartments pass through said separate portions; said plurality of fluid introduction and withdrawal means including means for introducing hot gas, means for introducing molecular hydrogen-containing gas and means for introducing steam; and withdrawal means for withdrawing solid reaction products from said annular treating chamber after the same have passed while being located in said compartments, respectively, through said separate portions of said treating chamber.

8. In a device for treating water-containing particulate solid carbonaceous fuel, in combination, an upright reaction chamber adapted to be filled to a predetermined level with a petroleum oil, said reaction chamber including a bottom and a wall portion extending downwardly from said predetermined level to a point spaced from said bottom so as to form an outlet opening near said bottom of said reaction chamber; first introduction means for introducing carbonaceous fuel into said reaction chamber; a horizontally extending reaction vessel communicating at one end with said outlet opening of said reaction chamber and having an outlet opening at its opposite end; oil heating means communicating with said reaction vessel and said reaction chamber for receiving oil from said outlet of said reaction vessel, heating the same and reintroducing the thus heated oil into said reaction chamber and said reaction vessel; steam withdrawal means associated with said reaction chamber and said reaction vessel for withdrawing steam liberated from said carbonaceous fuel by said hot oil from said reaction chamber and vessel; an annular treating chamber having perforated top and bottom walls and outer and inner walls; inlet means communicating with said outlet opening of said reaction vessel and said annular treating chamber for introducing substantially water-free solid particulate carbonaceous fuel from said reaction vessel into said annular treating chamber; means for circulating oil between said annular treating chamber and said inlet means; a plurality of substantially radial walls extending in said annular treating chamber from said bottom to said top wall thereof and subdividing said annular treating chamber into a plurality of compartments; moving means for moving said parallel walls along a circular endless path within said annular treating chamber; a plurality of fluid introduction and withdrawal means communicating with separate portions of said annular treating chamber for introducing fluid

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reactants into and withdrawing fluid reaction products from said separate portions of said annular treating chamber while said compartments pass through said separate portions; withdrawal means for withdrawing solid reaction products from said annular treating chamber after the same have passed while being located in said compartments, respectively, through said separate portions of said treating chamber; and comminuting means associated with said withdrawal means for comminuting the withdrawn solid reaction product.

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NORMAN YUDKOFF, *Primary Examiner.*

D. EDWARDS, *Assistant Examiner.*