April 5, 1960

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PROCESS AND APPARATUS FOR TREATING PETROLEUM OILS AND SOLID FUELS

2,931,765

Filed Oct. 17, 1958

4 Sheets-Sheet 1

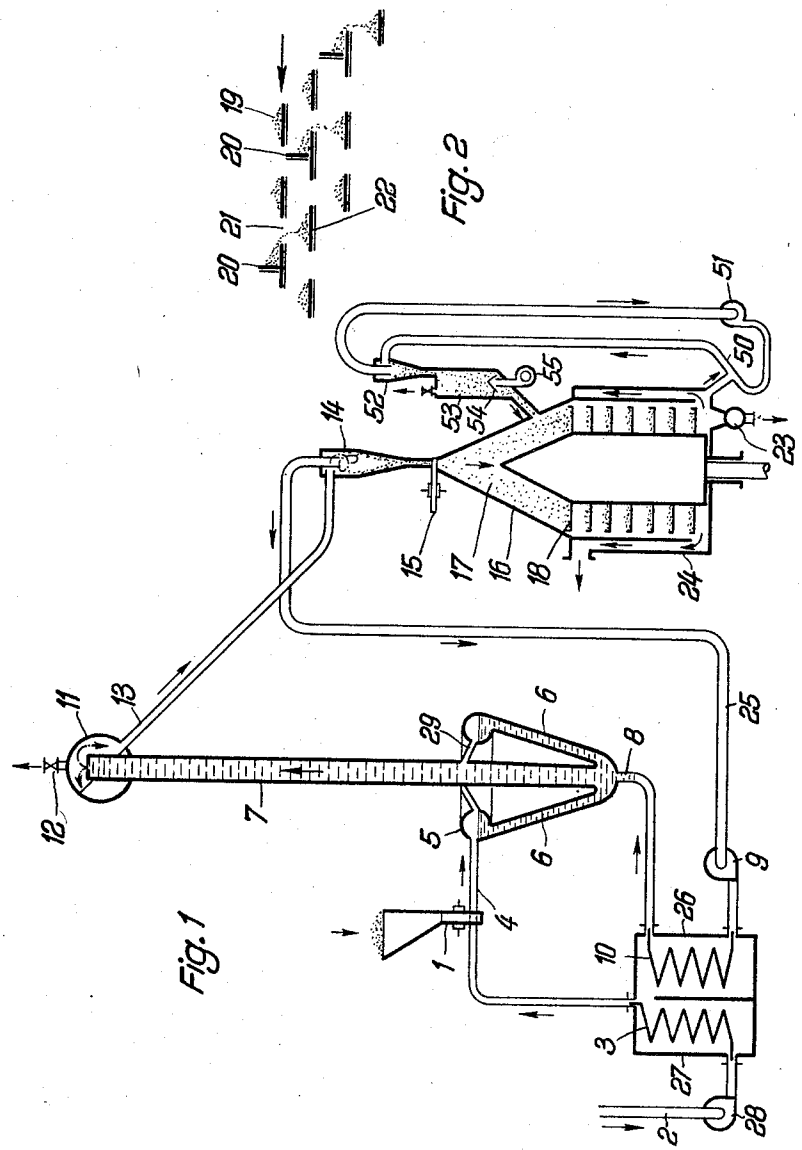

Fig. 1

Fig. 2

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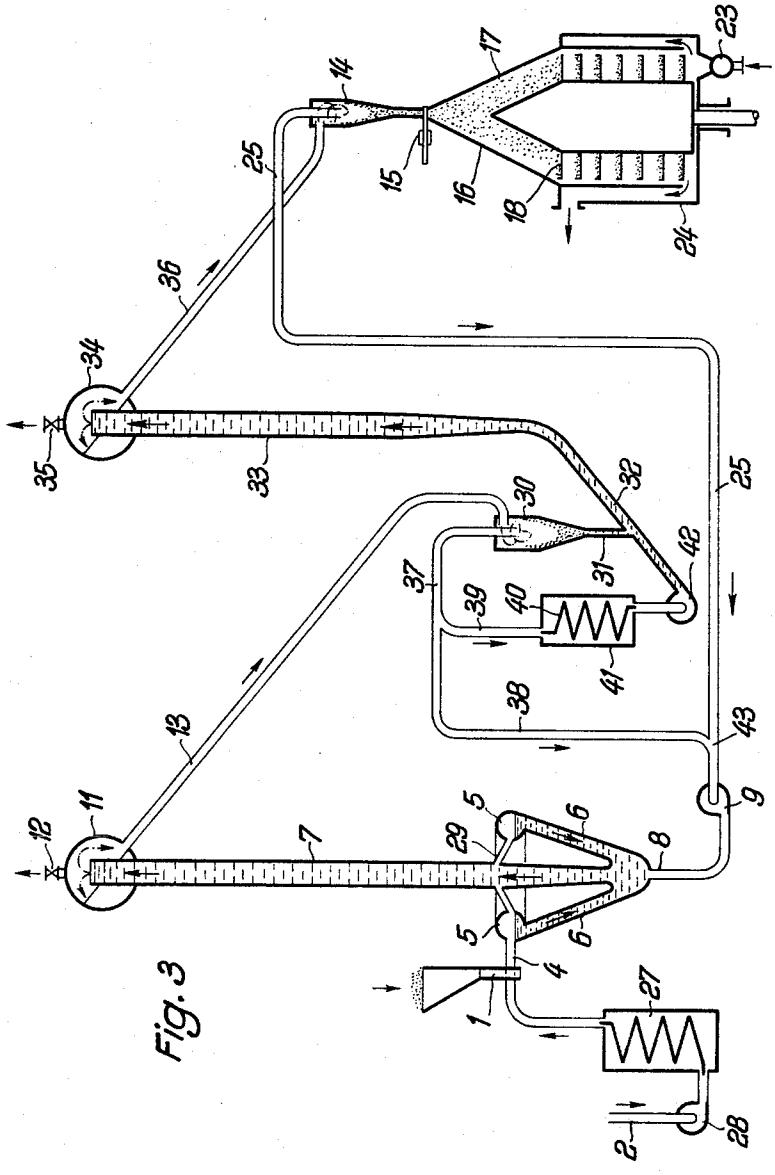

Fig. 3

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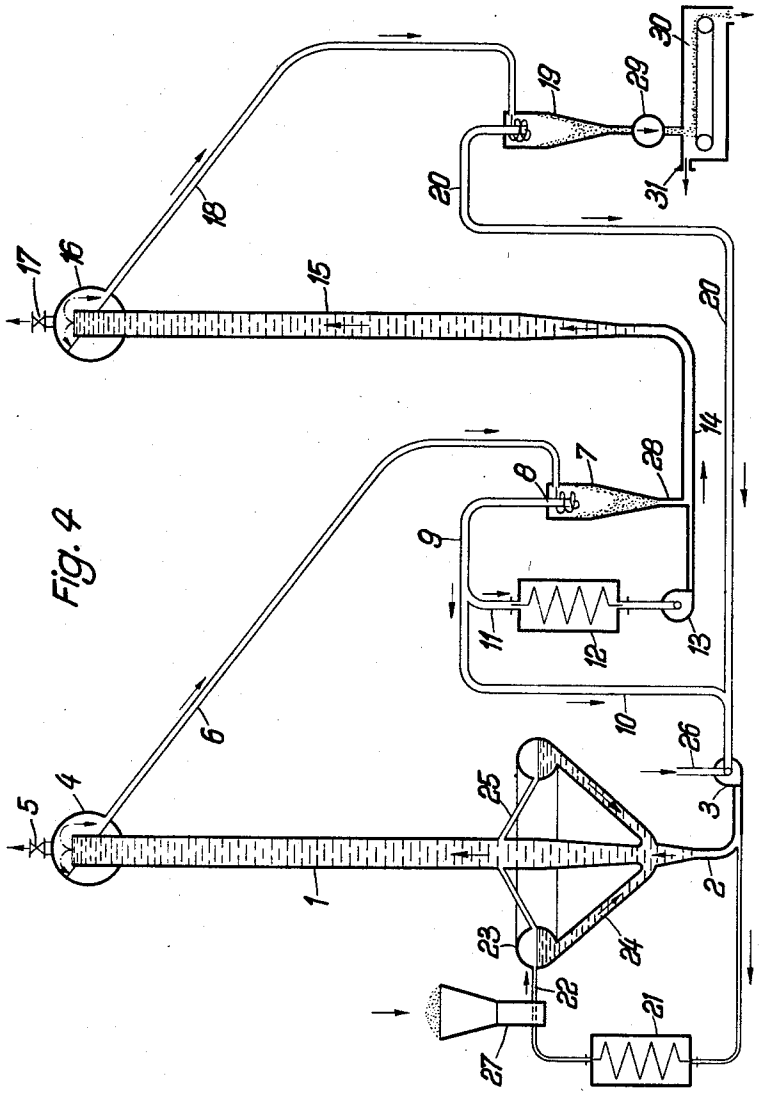

Fig. 4

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4 Sheets-Sheet 4

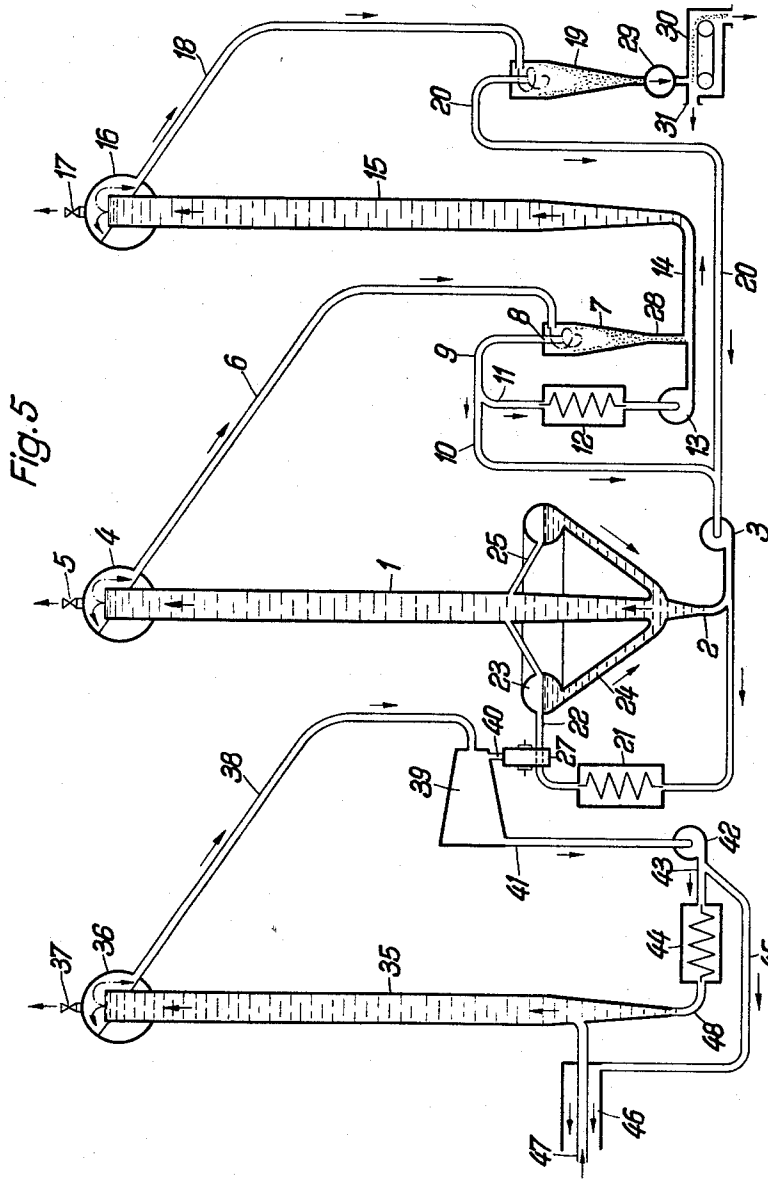

Fig. 5

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2,931,765

PROCESS AND APPARATUS FOR TREATING PETROLEUM OILS AND SOLID FUELS

Carl Glinka, Krefeld-Uerdingen, Germany

Application October 17, 1958, Serial No. 767,850

Claims priority, application Germany October 19, 1957

20 Claims. (Cl. 208—8)

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

More particularly, this invention relates to a process for the treatment of 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. The invention also relates to a process for the removal of water and preferably of bitumen from wet solid fuels, i.e. from solid fuels which contain water and which also contain substances convertible into bitumen by the application of heat, such as oil shales or peat. As will be seen further below, the treatment of such petroleum oils and of such solid fuels can be advantageously carried out in a single process and in a unitary apparatus.

It is frequently of great economic importance to reduce the molecular weight of the hydrocarbons forming high boiling petroleum oils, so as to obtain high-grade lower molecular weight hydrocarbons. It is also of great economic importance to reduce or eliminate the water content of water containing solid fuels prior to combustion of the fuel, and also to remove from the fuel bituminous substances which can be more economically utilized than would be the case by combustion as part of the solid fuel.

Various processes are known for the removal of water from, or the drying of, solid water-containing fuels, and for the cracking, i.e. the reduction of the molecular weight of the constituents of high boiling petroleum oils, as well as for the extraction of bituminous substances from solid fuel prior to utilization of the solid fuel as a source of heat.

However, all of these prior art methods for achieving one or the other of the above discussed results are relatively expensive, require a very high fixed investment, and are not capable of achieving all of the above results in a unitary process and apparatus.

In the context of the present application low boiling oils are understood to mean oils boiling at temperatures in the region below 250° C. The upper limit for oils regarded as low boiling within the meaning of the invention may depend upon various factors, such as the type of the crude, and especially the proportion of oils contained therein which boil above the specified limit, the processing method, and the final product required.

Processes for refining such oils are already known which consist in converting the preheated oils into low boiling hydrocarbons whilst in contact with hot substances, especially substances known as catalysts. In these processes contacts which have no catalytic effect merely serve as carrier means for the transfer of heat. Contacts which have a catalytic effect—frequently employed in these processes in mixture with contacts that have no catalytic effect—favorably influence the process itself—for instance in that they permit the reaction temperature which in purely thermal processes may be about 600° C. to be

reduced to say 500° C.—as well as upon the yield, and the quality of the products obtained.

The efficiency of a catalyst depends to a considerable extent upon the size of its contacting surface. Lumpy catalysts of a porous nature have a very large surface. However, the surface formed by the pores is very inefficiently utilized because the oil vapors evolved by the oil in contact with the hot catalyst cannot penetrate from the outside to the interior and into the core of the catalyst since, when entering the pores of the very hot catalyst their temperature considerably rises, and they expand, the pressure set up expelling them again from the pores before they have penetrated into the catalyst very far. In practice use is therefore made of fine-grained or even dust-like catalysts. In any event, solid residues from the cracking reaction are soon deposited on the catalyst and reduce its catalytic efficiency. These deposits may be removed by a process of regeneration and the catalyst reheated again to its previous temperature. Nevertheless, repeated reheating causes catalytic efficiency to deteriorate so that at certain intervals of time the catalyst must be renewed.

It is, therefore, an object of the present invention to provide a simple and economical process and apparatus for the de-watering of water-containing solid fuels.

It is another 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 a further 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 only a relatively small fraction of low boiling constituents.

It is still another object of the present invention to provide a simple and economical process and apparatus for jointly achieving in a unitary manner two or all three 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 the appended claims.

With the above and other objects in view, the present invention includes a process 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, comprising the steps of contacting the petroleum oil with the water-containing, particulate, solid carbonaceous fuel the same being capable to be partially converted into bitumen by application of heat, so as to form a mixture of the petroleum oil and the solid fuel, subjecting the mixture to a temperature of about 350° C. at an elevated pressure so chosen as to substantially prevent evaporation of oil from the mixture while allowing evaporation of water therefrom, thereby forming steam and filling pores of the solid fuel with petroleum oil, withdrawing the thus formed steam, raising the temperature of the thus formed substantially water-free mixture to about 400° C. so as to convert a portion of the solid fuel into liquid bitumen, while maintaining a pressure sufficiently high to substantially prevent vaporization of the thus formed liquid bitumen, separating the oil-containing solid fuel from the remainder of the reaction mixture, subjecting the separated, oil-containing solid fuel to a temperature of at least about 500° C. while maintaining a pressure of about between 0.5 and 5 atmospheres, so as to crack the oil within the pores of the solid fuel thereby transforming the oil at least partially into lower molecular hydrocarbons, and separating the thus formed lower molecular hydrocarbons from the solid fuel, whereby steam at relatively high pressure

and temperature, a dry solid carbonaceous fuel, bitumen and lower molecular hydrocarbons are formed from the petroleum oil and the water-containing carbonaceous solid fuel.

The present invention also contemplates in an apparatus for simultaneously dewatering water-containing, solid, carbonaceous fuel, and at least partially reducing the molecular weight of higher-boiling petroleum oil and the like, in combination, first reaction means for subjecting a mixture of water-containing, carbonaceous, solid fuel and petroleum oil to superatmospheric pressure and to an elevated temperature sufficiently high to cause evaporation and steam formation of the water contained in the solid fuel while retaining the petroleum oil in unvolatilized condition, whereby petroleum oil will enter into the pores of the thus dewatered solid fuel, means for removing the formed steam from the first reaction means, hydrocyclone means operatively connected to and communicating with the first reaction means for separating free petroleum oil from the thus dewatered petroleum oil-containing solid fuel, conveying means communicating with the hydrocyclone means and with the first reaction means for conveying the free petroleum oil from the hydrocyclone means to the first reaction means, second reaction means operatively connected to the hydrocyclone means for receiving the dewatered petroleum oil-containing solid fuel and subjecting the same to a temperature sufficiently high to cause at least partial transformation of the petroleum oil contained in the solid carbonaceous fuel into lower molecular hydrocarbons, and at a pressure sufficiently low to volatilize the thus-formed lower molecular weight hydrocarbons, and means operatively connected to the second reaction means for separating the thus-formed volatilized hydrocarbons and water-free, solid, carbonaceous fuel.

According to the invention it is proposed in the processing of the specified oils to replace such catalytically effective contact substances with solid fuels containing water and substances which are convertible at elevated temperature into bitumen. Such fuels are for example oil shales, brown coal, and peat. The treating oil is brought into contact with these fuels at a temperature at which the bitumen produced by the solid fuel is liquid, but at pressures which are sufficiently high to prevent the bitumen from evaporating. However, the water contained in the solid fuels does evaporate and turn into steam which is removed. The treating oil now enters the pores in the solid fuel which had been previously filled with the water. The solid fuels are then separated from the remainder of the oil by mechanical means, for instance in a hydrocyclone, and at atmospheric pressure or a pressure which differs only slightly therefrom, for instance at a pressure between 0.5 and 5 atmospheres, they are heated to a temperature, say 500° C. or more, at which the oil that has penetrated into the pores will be transformed into higher grade hydrocarbons by cracking. If desired, the water may be driven out of the pores of the solid fuels before these are introduced into the oil, for example by previous desiccation until all their water has been expelled.

Fresh brown coal, peat, and oil shale all contain more or less appreciable quantities of water and bitumen-forming substances. By evaporating the water inside the pores a finely porous solid material results which has a very large surface of the kind synthetic catalysts are desired to have.

Analytical tests have disclosed that this finely solid material consists of silicic acid or of alumina, with oxides of iron, aluminum and magnesium embedded therein, in addition to traces of other elements, i.e. of substances which are known to have a catalytic effect.

It follows that when their water content has been evaporated and their bitumen-forming substances liquefied these solid fuels can serve as catalysts for processing oils. Their efficiency depends upon their content of catalytically active elements which may vary in quantity according to the natural deposits from which the fuels originate. On the average such solid fuels contain 10% oil and about 50 to 150% water related to dry weight. The bitumen-forming substances contained in the fuels generally liquefy at temperatures of about 400° C. However, this liquid bitumen which has an oily consistency fills only a small proportion of the cavities in the fuels. Some of the treated oil enters the pores that had been filled with the water. After having been heated the pores of the fuels therefore contain an oily mixture consisting of the liquid bitumen which is rich in hydrogen and the treated oil which contains little hydrogen. If now the solid fuels containing this oily mixture are separated from the remaining volume of oil and heated to about 500° C. under a pressure which permits the oils at this temperature to volatilize, then the oil that has penetrated into the pores will react with the liquid bitumen and form fresh compounds consisting of high-grade hydrocarbons.

The changes in the structure of the hydrocarbons that occur inside the pores of the solid fuels proceed in conditions which in every respect favor the process of cracking. It may be assumed that the vaporized oil in the pores of the solid fuels is forced to travel through comparatively long channels, frequently changing its direction of flow, and that the buffeting it receives promotes the complete decomposition of the compounds which have already been loosened up by the high tempeartures that prevail.

Other conditions favoring the progress of the reaction are that the vapor that has been formed in the pores is in constant intimate contact with the embedded catalytically effective elements which present a large surface and that escape of the vapor from the system of pores is retarded by the frequent changes in its direction of flow.

In these excellent reaction conditions the high hydrogen content of the bitumens and of the oils and vapors which have already been formed and which evolve when the fuels are heated gives rise to the formation of high grade hydrocarbons without the production of major quantities of solid carbon. In any event, any elementary carbon that does form will be deposited on the fuel. In the circumstances this has no disadvantageous effect, because the treated solid fuels pass only once through the process and the solid deposits are removed with the fuels.

Furthermore, it is important to note that the solid fuels have a comparatively high content of oxygen which in the temperature range of the process reacts with the carbon and to some extent with the hydrogen. This is an exothermic reaction which at high temperatures proceeds at great speed so that the heat of reaction becomes fully available for promoting the process at the points where the solid fuels and the oil are required to have a temperature of about 500° C. and even higher. The heat liberated in these reactions is sufficient not only to replace the consumption of heat by the endothermic cracking reaction but also to heat the fuels to the temperature level required for cracking.

The velocity of the reaction can be greatly accelerated by mixing the fuel at a temperature of about 400° C., before admitting it to the reactor, with a proportion of the fuel which leaves the reactor and which has already achieved a temperature of about 600° C. or even more. The oil-charged fuel will then rapidly attain a temperature of 500° C. or more, at which the exothermic and endothermic reactions proceed very quickly.

The reaction process may be performed in this way with especial advantage in cases in which the fuel employed has a low content of oxygen or of catalytically effective components.

The oil vapor evolved in the process can be desulfurized with the aid of the treated fuels by cooling them after

leaving the process, submitting them to an ageing process by oxygenation to prevent self-ignition, and by then contacting them with gases containing hydrogen sulfide. The hydrogen sulfide will then be adsorbed by the fuel and oxidized into sulfur which is then taken up by the fuel.

The gases thus purified can be used for refining the products of cracking.

In the described processing of residual oils functions are thus allocated to the solid fuels and to the liquid and gaseous components liberated therefrom which in existing plant are performed by products of which at least some must be produced in auxiliary plant.

In performing the method according to the invention the possible advantage of controlling the course taken by the cracking reaction by the selection of the synthetic catalyst may be lost, but this advantage decreases materially in importance if local conditions are suitable for using the process, such as for instance the location of the solid fuels in relation to the oil, and the general nature of the solid fuels that are available.

The method of the present invention permits exploitation of oil shale deposits which had hitherto been considered uneconomical to work, especially if the moisture content of the shale is fairly high and would consume a large proportion of the energy derived from the oil in evaporating the water.

Brown coal which, owing to its high content of water, has a low calorific value of only 2500 cal. is transformed into a high-grade fuel with a calorific value of about 7000 cal. by the ageing effect due to the withdrawal of oxygen and the removal of water during the process.

Peat can similarly be transformed into a high-grade low temperature carbonization coke.

Thus, besides high-grade hydrocarbons, the process yields valuable by-products.

The fact that two processes are combined into a unitary process leads to a simplification of the entire plant and a consequent reduction in capital and maintenance cost.

Other advantages arise in connection with the thermal economy of the process. In this connection an important factor is the conversion of the moisture contained in the fuel into steam which is free from dust and leaves the process, free from oil vapor, at a pressure of about 30 atmospheres. In this condition it can be used in a power station of a capacity limited only by the volume of available steam, i.e. by the amount of water contained in the fuels. The high-pressure steam obtained without the use of a boiler should at least be sufficient to generate all the power needed for operating the whole of the processing plant.

From the point of view of removing water and possibly bitumen from wet solid fuels, the present invention achieves the separation of the oil vapor of the steam evolved in the process in such a way that the steam will contain no oil and especially no oil vapors. Thus, a simple method of obtaining from the solid fuels an oil which contains absolutely no water is provided.

The heat contained in the vapors evolved in the process can be utilized for the generation of mechanical energy in an energy transforming plant, and more particularly, the steam which contains no oil and particularly no oil vapors can be used for the generation of mechanical energy in a conventional prime mover.

To this end the invention proposes to perform the process by treating the solid fuel in two consecutive temperature stages, namely in a first treatment stage at a pressure above 12 atmospheres, for instance 30 atmospheres, performed at a temperature above the boiling point of water at the said pressure, and in a second stage at approximately the same pressure performed at a temperature above about 400° C. at which the bitumen-forming substances will be released and the oils formed by the bitumen vaporize, the oil employed for this process

being of a kind that will not begin to vaporize at the temperature or at the pressure used in the first stage.

In the temperature range of the second stage exothermic reactions occur in the oxygen-carbon-hydrogen system of the solid fuels, which, as has been established by empirical tests, rapidly raise the temperature of the treating oil. This internal heating of the oil is an advantage for reasons of thermal economy. However, since it results in oil vapor formation the process proposed by the invention suppresses it in the stage in which the expulsion of the water takes place.

To permit the process to take full advantage of this internal heating effect of the treating oil whilst at the same time in the stage in which the water contained in the solids evaporates definitely maintaining the temperature at a level at which the treating oil will not vaporize, the invention divides the treatment of the solid fuels into two separate temperature stages. In the first stage the moisture contained in the solids is evaporated at a pressure such as 30 atmospheres and a temperature between say 250 and 350° C. conditions under which the treating oil will not form oil vapors. However, the steam released from the solids will escape from the treating oil and can be withdrawn at the operational pressure of the plant. In the second stage the solid immersed in the oil is heated to about 400° C., a temperature at which the oil-forming substances in the solid will be released. These substances will change from the solid into the liquid state from which the light and middle oils can then escape in vapor form. The heavy oil fraction which has a boiling point equal to that of the treating oil remains in the solid fuel in liquid form and, after separation of the solids from the treating oil, this fraction will also be vaporized when the solids leave the operational pressure in the treating chamber of 30 atmospheres and enter the lower pressure obtaining in a decompression chamber.

In this second stage the exothermic reaction of the oxygen-carbon-hydrogen system of the solids can take full effect. The heat absorbed by the oil may be usefully employed by returning the oil to the first stage.

Tests have shown that fuels with a higher content of moisture initially sink in the hot oil for a short period of time but then rise and float on the oil. This is due to the fact that the rapid increase in temperature causes intense evaporation of water in the pores of the particles of the fuel, giving rise to the formation of small bubbles. During their formation these bubbles adhere to the surface of the fuel and support it. As the generation of steam becomes less and fewer bubbles are formed the fuel sinks again in the treating oil.

Allowance is made in the process of the present invention for the occurrence of this phenomenon in that the comminuted fuel is introduced into a current of oil which circulates in a horizontal plane in this part of the plant. The smaller particles of fuel will then sink in the current of oil after having travelled a short distance along the circular path, whereas the larger ones travel a greater distance, and the largest ones circulate several times. They therefore enter the next treating zone by the same route but at the end of different periods of dwell which depend upon the size of the particles. The treatment time may thus be adapted to grain size. In the following treating zone the oil travels from below in an upward direction at a velocity which transcends the sinking speed of the largest particles of the fuel so that the entrainment of the whole of the fuel will be assured. The particles of fuel are therefore conveyed upwards freely suspended in the current of oil, the period of dwell of the particles in the current of oil depending upon the size of the particles.

If it is desired to treat fresh peat by the process that has been described it must be remembered that the moisture content of wet peat amounts to something like 90% of its weight. It will therefore usually be necessary to

remove the greater part of the water prior to the processing of the peat. This may be effected by heating the peat under pressure to a temperature of about 180° C. At this temperature the major proportion of the colloidally bound water is released and can then be separated from the peat by mechanical means. The preliminary dewatering of the peat can be combined advantageously with the main features of the present process. The crude peat is pumped in a macerated condition from the bog to the plant and there passed through a treatment in a zone in which water is circulated instead of oil at the operational pressure of the plant. At a pressure of f.i. 30 atmospheres, the water-peat mixture can be heated to 180° C. without the evolution of any substantial volume of steam since the boiling point of water at this pressure is at about 232° C. The small volume of steam and gas that is formed in the course of this heating can be utilized in the process. At the operational pressure of the plant the peat is separated from the surplus water and, together with the heat absorbed during this treatment, it is directly transferred to the process according to the invention. The surplus water which is still at the operational pressure of the plant gives off its heat to the water-peat mixture that is pumped into the plant and may then be used for the wet excavation of the peat and for washing it into the excavated bog in a manner that is well understood.

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 representation of plant for processing a residual oil with the aid of a previously dewatered brown coal;

Fig. 2 diagrammatically illustrates the course of the brown coal through the reactor;

Fig. 3 is a schematic representation of plant for the treatment of a residual oil with the aid of a brown coal which still contains water;

Fig. 4 shows a plant for dewatering said fuel, operating in two temperature stages; in the first stage the water and in the second stage those substances are removed which can be transformed by heating into oil or oily bitumen; and

Fig. 5 shows a plant for treating fresh peat.

The apparatus illustrated in Fig. 1 comprises a riser pipe **7** of sufficient diameter to permit major quantities of lumpy solid material to be entrained by an ascending column of oil. The diameter of the pipe may be say 30 cms. and its height 600 cms. to deal with a throughput of 2000 kg./h. At the foot of the riser **7** is a pipe **8** through which the oil enters the riser after having been pumped through the coil **10** of a heater **26** by pump means **9**. The head of the riser **7** is connected with a container **11** fitted at the top with a steam outlet **12** and connected at the bottom with a pipe **13** which may have a diameter of perhaps 10 cms., and which leads to a hydroclone **14**. The liquid is discharged from the hydroclone **14** through a pipe **25** and returned to the suction side of pump **9**. The oil is thus circulated by pump **9** through the riser pipe **7** and the pipe lines **13**, **25**, **10** and **8**. The lower end of riser pipe **7** is also connected with several pipes **6** which are all jointed at the top into a common pipe ring **5**. Another pipe **4** connects this ring with the coil **3** of a heater **27** which receives oil through a pipe **2** incorporating a pump **28**. Pipe **4** contains a gate **1** through which comminuted solid fuel such as peat, oil shale, or brown coal, can enter pipe **4** in which the flowing oil is under a pressure of several atmospheres—for instance 30 atmospheres.

The discharge of the solids from hydroclone **14** is through a trap **15** through which the solid substances separated in the hydroclone which operates at the above mentioned pressure of 30 atmospheres can be gated into a chamber **16**, the reactor proper, in which a much lower pressure, for instance 0.5 atmosphere, is maintained. Rotatably arranged inside the rigid shell of the reactor **16** is a system comprising a plurality of annular plates **18** arranged one above the other and provided with peripheral gaps **21** (Fig. 2) which are relatively angularly displaced from one plate to the next. The plates **18** therefore actually consist of annular segments. The annular segments **19** (Fig. 2) which constitute the top plate are therefore angularly displaced in relation to the annular segments **22** of the next plate below in such manner that the major proportion of solid material **17** dropping into the reactor through trap **15** will be intercepted by the segments **19** and the smaller remainder by segments **22**. A stationary scraper **20** is arranged above each of the plates **18** so that when the plates **18** are rotated the solid fuel deposited on one of the segments will be dislodged and finally reach an outlet **23** at the foot of the reactor **16**. This arrangement prolongs the dwell of the fuel inside the reactor. The lower portion of the reactor **16** is provided with a second shell **24**. The gases can rise in the gap between the two shells to be withdrawn.

In this apparatus the process is performed as follows:

Through pipe **2** as much oil (oil residue) is pumped into the apparatus as is required to fill the tubes and pipes **6**, **7**, **8**, **13**, **25**, and **10** completely. As it passes through the heater **27** the oil asumes a temperature of about 400° C., the pump generating a pressure in the tubes and pipes of about 30 atmospheres.

The oil is now circulated through the system by pump **9** and the temperature of the heater **26** is maintained at slightly over 400° C. At the same time pump **28** introduces as much residue oil through pipe **2** as is required to replace the amount discharged from the hydroclone **14** into the reactor **16**. About 800 kg./h. of oil are thus introduced at a throughput of 2000 kg./h. of dry brown coal. The proportions of the processed quantity of oil to the quantity of fuel introduced varies since this will depend upon the pore volume of the fuel.

The brown coal which has been crushed to a grain size of 6 mm. and dried until free from water is continuously introduced through gate **1** into pipe **4** and thence reaches the pipe ring **5**. The upper portion of the ring fills with gas evolved by the fuel as its temperature rises. The gas is discharged into the riser **7** through the pipes **29**. The coal sinks in the stream of oil in pipe ring **5** and through pipes **6** reaches the foot of the riser **7** where it is entrained by the ascending column of oil delivered to the riser **7** by pump **9** to be carried upwards freely suspended in the current of oil. The velocity of the oil slightly exceeds the sinking speed of the coal. Assuming the velocity of descent of the coal to be 10 cms./sec., then the velocity of ascent of the oil would be 12 cms./sec. As it travels up the riser **7** the temperature of the brown coal increases to 400° C. and at this level the bitumen-forming substances in the coal liquefy. Oils may be formed which vaporize at this temperature. Any such light oil vapors are discharged through a valve **12**. The pores of the brown coal which are emptied by this process of vaporization, and more particularly those pores in the brown coal which were formerly filled with water, now fill up with the circulated oil, i.e. the residue oil, as the coal gradually ascends up riser **7**. At the head of the riser **7** the oil and the brown coal flow into container **11** whence they reach the hydroclone **14** via pipe **13**. In the hydroclone the oil is separated from the oil-enriched brown coal. The oil flows back to pump **9** through pipe **25** and, after having been reheated in heater **26**, it is returned to the riser **7**. The brown coal is gated through trap **15** into the reactor **16**, where at low pressure it is exposed to a temperature sufficiently elevated to ensure that during its

period of dwell, which is prolonged by the particular construction of the reactor, the required reactions of the oils contained in the pores of the coal will take place. The resultant desired hydrocarbon compounds are gaseous and can be withdrawn through the space between the two shells of the reactor. Part of the coal treated in the reactor is withdrawn through outlet 23. Another part enters pipe 50 where it is entrained by a current of inert gas which is circulated through pipe 50 by a blower 51 and which delivers the coal into a cyclone 52. From there this part of the coal reaches a container 53 provided at its bottom end with a nozzle 54 through which air is blown by a second blower 55. The volume of air blown into container 53 is so controlled that it will burn as much coal as is needed to raise the temperature of the coal to 600° C. or to any desired higher level. The combustion gases can escape from the top of container 53 through an exhaust 56, whereas the coal thus heated in the container is reintroduced into the reactor and mixed with the coal arriving from hydroclone 14 at about 400° C. and further raises the temperature of the latter to 500° C. or more.

Owing to the exothermic nature of the reactions which take place in the riser 7 and in pipe 13 at a temperature of 400° C. the oil returning through pipe 25 may have a temperature that greatly exceeds the temperature the oil in riser 7 need possess, so that this oil need not be reheated in heater 26.

The plant illustrated in Fig. 3 differs from that shown in Fig. 1 principally in that two riser pipes are provided each constructed substantially like riser 7 shown in Fig. 1 and that the temperature in the riser first entered by the solid lumpy fuel which in this instance still contains its natural water, is not raised beyond the level at which the water will evaporate without the simultaneous liquefaction of the bitumen-forming substances, whereas in the second riser, through which the mixture of oil and lumpy fuel then passes, the temperature level is such as to cause the bitumen-forming substances to be transformed into an oily bitumen or into oils, the evolving oil vapors being withdrawn. This plant therefore separately delivers water vapors containing no oil, and oil vapors containing no water.

In the plant illustrated in Fig. 3 the construction of the riser 7 as well as the arrangement of the associated pipe system is similar to that shown in Fig. 1. The reactor 16 and the trap 15 as well as the hydroclone correspond to the equivalent apparatus in Fig. 1.

The top of the riser 7 is connected by pipe 13 with a hydroclone 30. The outlet for solids 31 discharges into the bottom end 22 of the second riser 33. The head of the latter communicates with a container 34 with a gas outlet 35. Pipe 36 connects container 34 with hydroclone 14. The liquid discharged from hydroclone 30 enters a pipe 37 which divides into two branches 38 and 39. Branch 38 leads to the suction side of pump 9, whereas branch 39 is connected through the heating coil 40 of a heater 41 with a pump 42.

Two streams of oil circulate in the plant, the first incorporating pump 9. This pump forces the oil through riser 7 into container 11. From here the oil reaches hydroclone 30 through pipe 13 and, after elimination of the solids by the hydroclone, the oil returns through pipe 37 and branch 38, part being diverted into branch 39, to the suction side of pump 9.

The second circulatory oil system incorporates pump 42 which receives part of the oil from the first stream through branch 39. Pump 42 forces the oil which is heated in heater 41 to a temperature slightly over 400° C. through riser 33 into container 34. This oil then flows through pipe 36 into hydroclone 14 and, after elimination of the solids contained therein, returns through pipe 25 to the suction side of pump 9, to be thus recombined with the first circulatory oil system.

Before entering pump 9 the oil from the first circulatory system returning at a lower temperature of about 250° C. through branch 38 is recombined at 43 with the oil returning at a temperature of about 400° C. through pipe 25, the combined stream of oil being pumped by pump 9 back into riser 7 at a temperature of about 300° C.

At the operational pressure of the plant, i.e. approximately 30 atmospheres, pump 2 delivers the volume of oil that is to be treated, after having been preheated to about 350° C. in heater 27, to the circulating system from which a like volume including the fuel is withdrawn and transferred to reactor 16.

The crushed brown coal in this plant is likewise introduced through a gate 1 into pipe 4. As soon as the brown coal in the pipe ring comes into contact with the hot oil, the greater part of the water contained in the coal will be rapidly converted to steam. So long as the brown coal still occludes an adequate volume of steam it will float in pipe ring 5. The upper part of pipe ring 5 fills with steam at a pressure sufficient to force it through pipes 29 and upwards through riser pipe 7. When the greater proportion of the water has been driven out of the brown coal the latter will sink down pipe 6 to the foot of riser 7, where it will be entrained by the rising column of oil and conveyed upwards suspended in the ascending oil. In this stage the remaining steam is expelled. The steam is withdrawn through a steam outlet pipe 12. The oil pumped through the riser 7 heats up to a temperature which is sufficiently high to ensure that the water will vaporize at the pressure at which the plant operates, but not high enough to cause the liquefaction of the bitumen-forming substances in the coal. This temperature may be, for instance, in the range between 300 and 350° C., whereas the pressure may be between 20 and 30 atmospheres. The steam delivered through outlet 12 will then contain no oil whatsoever.

The pores of the brown coal which are thus emptied of water will therefore fill with the residual oil.

The mixture of oil and brown coal enriched with residual oil will now flow through pipe 13 to the hydroclone 30 which separates the coal from the oil. The oil returns through pipe 37, thence partly through branch 38 to riser pipe 7, the remainder returning through branch 39 to pump 42. During its course through this latter branch it is reheated in heater 41 to a temperature at which the bitumen-forming substances liquefy. The brown coal leaves the hydroclone 30 through the outlet 31 for the delivery of solids and enters the bottom 32 of riser 33 whence it is carried upwards by the oil that is forced by pump 42 into the riser 33. As it ascends the riser the fuel is heated to about 400° C. so that the bitumen in the fuel is liquefied. The gases evolved by the coal during this process escape through the gas outlet 35. From container 34 the oil-coal mixture is taken through pipe 36 to hydroclone 14. From the hydroclone the oil returns to riser 7 through pipe 25 whereas the brown coal, enriched with the oil that is to be treated, is conducted through gate 15 into the reactor 16. The process performed in the reactor 16 corresponds with that already described by reference to the plant shown in Fig. 1.

The apparatus illustrated in Fig. 4 comprises a riser pipe 1 of sufficient diameter to permit larger quantities of lumpy fuel to be carried upwards therein by an ascending column of oil. The velocity of the ascending oil slightly exceeds the sinking velocity of the fuel. For instance, if the fuel should sink in the oil at the rate of 10 cms./sec., then the velocity of ascent of the oil is arranged to be about 12 cms./sec. The diameter of the riser pipe may be for instance 30 cms. and its height 600 cms. to deal with a throughput of about 2000 kg. of fuel per hour. The foot of the riser communicates with a pipe 2 through which the admitted oil is pumped by a pump 3. The upper extremity of the riser 1 is fitted with a header 4 with a steam outlet 5 at the top and connected at the bottom with a pipe 6 which in the illustrated embodiment may have a diameter of 10 cms., and

which descends to a hydroclone 7. The outlet 8 for the liquid discharged from the hydroclone is connected by a pipe 9 and a further pipe 10 with pump 3. In this part of the plant the oil is therefore circulated by pump 3 through the riser pipe 1 and the pipes 6 and 10.

A proportion of the circulated oil reaches a pump 13 through pipe 11 and a heater 12. This latter pump forces the oil through pipe 14 into a second riser pipe 15 which at its upper end likewise carries a header 16 with an oil vapor outlet 17. Through a pipe 18 the oil flows into a hydroclone 19 whence it is returned through pipe 20 to pump 3. Before reaching pump 3 the oil which has been heated to a temperature above 400° C. by the exothermic reaction occurring in the oxygen-carbon-hydrogen system in this part of the plant, is recombined with the oil returning through pipe 10 which has a lower temperature, in the region of 250° C., so that pump 3 will force the recombined oil back into riser 1 at a temperature of about 300° C.

A small proportion of the oil delivered by pump 3 is heated to about 300° C. in a heater 21 and through pipe 22 enters a pipe ring 23 which communicates with riser 1 through pipes 24 and 25.

This plant operates as follows:

The pipe system of the plant is first filled through pipe 26 with a heavy oil fraction boiling between about 300 and 400° C., pumps 3 and 13 circulating this oil through the pipe system at a pressure of about 30 atmospheres in the manner that has been described.

The fuel which has been disintegrated to a grain size of about 6 mm. is continuously introduced into pipe 22 through a gate 27 and the oil in the pipe conveys it into the pipe ring 23. Contact between the fuel and the hot oil in the pipe ring quickly turns the water contained in the fuel into steam. The upper portion of the pipe ring 23 will therefore fill with steam under sufficient pressure to force it through pipes 25 into the interior of the riser pipe 1 in which it ascends to the header 4. So long as a sufficient volume of steam is evolved by the fuel it will swim in the oil which flows through pipe ring 23 in a circular path as a result of its tangential introduction from pipe 22. When the major proportion of the water has been expelled from the fuel the latter will sink in the oil in pipe ring 23 and descend through pipes 24 to the foot of the riser pipe 1. Particles of fuel of different sizes will sink at the end of different periods of time and therefore descend from the pipe ring through different pipes 24 to reach the foot of the riser 1. Consequently, larger lumps of fuel will undergo a longer period of treatment than small ones. At the foot of the riser the fuel is entrained by the current of oil entering the riser from pipe 2 and it is carried upwards freely suspended in the rising column of oil. During its ascent any residual moisture still contained in the fuel will be transformed into steam. The steam collects in the header tank 4 and is discharged through valve 5 at the operational pressure of the plant. The oil pumped through the riser 1 is heated to a temperature which is sufficiently high to ensure that at the prevailing pressure the water will evaporate but the bitumen-forming substances in the fuel will not yet be liquefied. At a pressure of between say 20 and 30 atmospheres this temperature may be for instance 250 to 350° C. The steam evolved by the moist fuel in these operational conditions will therefore be free of oil.

The fuel from which the water has thus been removed is then taken, together with the oil, from the header tank 4 through pipe 6 into the hydryclone 7 where it is separated from the oil and discharged through the outlet 28 for solids into pipe 14. In heater 12 the temperature of the fuel is now raised to about 400° C. and the fuel is then entrained by the current of oil forced up the riser pipe 15 by pump 13. In the course of its ascent up the riser the temperature of the fuel is established at about 400° C. and the bitumen-forming substances liquefy.

The lighter fractions evaporate from the liquid bitumen, whereas the heavier ones remain in the liquid state. The light oil vapors collect in the header tank 16 together with the gases evolved by the fuels in the course of their heating and are discharged through valve 17. Through pipe 18 the fuel and the oil reach the hydroclone 19 where fuel and oil are separated and the fuel enters a decompression chamber 30 through a trap 29. The liquefied heavy oil remaining in the fuel is vaporized in this chamber, discharged at 31, and further processed in the conventional manner.

The plant shown in Fig. 5 differs from the plant illustrated in Fig. 4 by the provision of an additional unit comprising a riser pipe 35 in which the colloidally bound water contained in the treated fresh peat, i.e. about 90% water related to the wet weight of the peat, is released by heating the peat in hot water, and removed, leaving about 60% residual water.

This additional unit comprises a riser pipe 35 with a header tank 36 and a steam exhaust 37. A pipe 38 connects the bottom of the header tank 36 with a centrifuge 39. The outlet 40 for solids from the centrifuge discharges into a trap 27 connected with the main part of the plant which is constructed as already described by reference to Fig. 4. The outlet 41 for liquids from the centrifuge is connected with a pump 42 which forces part of the water removed from the crude peat in the centrifuge through pipe 43 and a heater 44 back into the riser pipe 35, and the remainder of the still hot water through a pipe 45 into a heat exchanger 46 where the heat contained in the water is transferred to the fresh incoming peat.

This plant operates as follows:

A pump not shown in the drawing pumps the fresh peat from the bog at the operational pressure of the plant, for instance at about 30 atmospheres, through pipe 47 and heat exchanger 46 into the riser pipe 35. In this riser pipe the peat is entrained by the hot current of water which has been heated in heater 44 to a temperature of about 250° C. and conveyed in the upward direction. During its ascent the peat heats up to about 180° C. at which temperature the colloidally bound water in the peat is released. The water-peat mixture then descends through pipe 38 into the centrifuge 39 where water and peat are separated. With the water content reduced to 60% the peat is now gated through trap 27 into pipe 22 and thus enters the pipe ring 23 from where it travels through the plant in the manner already described in greater detail in connection with Fig. 4.

The following examples of the process according to the present invention are given as illustrative only, the present invention, however, not being limited to the specific details of the examples.

Example I

A solid fuel, such as oil shale or brown coal, is crushed to an average grain size of about 6 mm. A fairly fine comminution is to be preferred to open up as much pore space as possible for the reception of oil, and hence to permit the temperature of the fuels to be raised to the desired level sufficiently quickly. The treated oil flows through the process in continuous cycle at a pressure of something like 30 atmospheres. At the beginning of the process the oil is heated to a temperature of about 300° C. The solid fuel is then introduced into the oil. First, the water contained therein is very rapidly turned into steam which is withdrawn and may be utilized for the generation of power. Despite the elevated temperature no oil vapors are as yet formed because of the high pressure prevailing. In the further course of the process the oil is heated to over 400° C. so that the fuel assumes a temperature of about 400° C. At this temperature the bitumen-forming substances in the solid fuels change into a liquid oily state. The solid fuels from the pores of which the water has been expelled and which have in-

stead been filled with the oil that is to be treated are then separated from the remainder of the oil and conducted into a chamber where a pressure of between 0.5 and 5 atmospheres is maintained. In this chamber, the reaction chamber, the solid fuels containing the oil in their pores are heated to about 500° C. or even higher and the oil is cracked into high-grade hydrocarbons. The temperature to which the fuels are heated determines the rate at which the reaction proceeds, but it is also controlled by the nature of the final product required and the catalytic effect of the fuels that are being used. The steam and vapors emerging from the reaction chamber are submitted to further processing in the manner known to the art.

Example II

In this example, numerical data will be given pertaining to a specific manner of carrying out the dewatering of soft coal according to the present invention.

The apparatus used has an hourly capacity of 50,000 kg. of wet coal. The coal contains 60% water so that 20,000 kg. of dry coal substance, including 10% or 2,000 kg. of oil or hydrocarbons are to be processed.

The temperature during the de-watering of the coal is about 230° C. The petroleum oil introduced together with the soft coal has a boiling point above 380° C. A pressure of 30 atmospheres is maintained.

In describing the dimensions, etc. of parts of the apparatus, reference is made to Fig. 4:

Diameter of horizontal ring pipe (23) ____m__	0.65
Median diameter of pipe ring (23) ____m__	5.0
Number of riser pipes (1) connected with pipe ring (23) ____	6
Height of riser pipes (1) ____m__	6.0
Diameter of riser pipes (1) ____m__	0.6
Lengths of descending pipes (24) ____m__	3.0
Diameter of descending pipes (24) ____m__	0.6
Time required for passage of soft coal through ring pipe ____min__	1
Time required for passage of soft coal through riser and descending pipe ____min__	2½
Quantity of circulating oil ____m.³/h__	720
Temperature of oil at inlet (2) ____° C__	360
Temperature of oil at outlet point (10) __° C__	240
Quantity of steam of 30 atmospheres produced ____kg./h__	30,000

The following data refer to the second step, i.e. the removal of bitumen from the de-watered soft coal:

Temperature	About 400° C.
Diameter of riser pipe	1.0 m.
Height of riser pipe	6.0 m.
Time required for passage of coal	2 min.
Quantity of circulating oil	360 m.³/h.
Temperature of heating oil at inlet (14)	400° C.
Temperature of heating oil at outlet (20)	425° C.
Quantity of oil contained in coal	2,000 kg./h.

Due to reaction between the oxygen, the carbon and hydrogen of the coal, the temperature of the oil rises during the second step from 400° C. to 425° C. and the temperature of the coal rises from 240° C. to 425° C., corresponding to 5,600,000 kcal.

Subsequently, coal and oil are separated from each other and the coal is passed into decompression chamber 30.

Temperature in decompression chamber	425° C.
Pressure in decompression chamber	1 atm. overpressure.

Thus, pressure has been reduced from 30 atmospheres overpressure to 1 atmosphere overpressure.

Thereby the oil in the pores of the coal and the oil adhering to the surface thereof are vaporized. The thus obtained oil vapors are condensed and further processed in conventional manner.

A small portion of the circulating petroleum oil which has been described as being introduced together with the soft coal, is converted into light oil during the process and is replaced by a portion of the heavy oil separated from the coal.

In this manner the following yields are obtained:

In the first step or stage of the process.—	
Steam at 30 atmospheres ____kg./h__	30,000
Useful mechanical energy ____kwh__	7,000
In the second stage of the process.—	
Low temperature coke ____kg./h__	16,500
Light, medium and heavy oil ____kg./h__	2,000
Low temperature coal gas ____kg./h__	1,500

Example III

The data given herein relate to a process similar to the one described in Example II, however, using peat as the solid fuel.

The hourly capacity of the apparatus is 200,000 kg. of wet peat. The water content of the peat is 90%, so that per hour 20,000 kg. of peat dry substance containing 10% or 2,000 kg. of oil, are processed.

As first step, the water content of the peat is reduced from 90% to 60% as follows:

Operating pressure ____atm__	30
Temperature of heating water entering the apparatus ____° C__	232
Temperature of heating water leaving the apparatus ____° C__	180
Quantity of circulating heating water ___kg./h__	115,000
Medium diameter of pipe ring ____m__	5.0
Number of connected descending pipes ____	6
Number of connected riser pipes ____	6
Diameter of riser pipes ____m__	0.6
Height of riser pipes ____m__	6.0
Length of peat treatment ____min__	3

Thereafter, the peat is separated from the previously colloidally bound water as described further above.

There remain:

Peat containing 60% water____kg./h__	50,000
Circulating heating water at 180° C. ____kg__	115,000
Water removed from peat ____kg./h__	150,000

The heat contained in the thus removed water is conveyed to fresh peat being introduced into the apparatus. After thus utilizing the heat content of the removed water, the same may be disposed of in any desirable manner, for instance by being returned tot he peat pit.

The thus pre-dried peat is then further treated like the soft coal according to Example II.

Example IV

This example relates primarily to the treatment of petroleum oils containing only a small fraction of low boiling oils.

The treated oil has a boiling point above 380° C.

As carrier for the oil, a soft coal containing 60% water is used.

The oil content of the soft coal amounts (on dry basis) to 10% and the oxygen content to 22%.

The analysis of the coal ash is as follows:

	Percent
CaO	31
SiO_2	12.9
F_2O_3	10.8
Al_2O_3	21.9
MgO	4.6
SO_3	16.1

Due to the high calcium oxide content of the coal used according to the present example, which has a partially inhibiting effect on the catalytically active constituents, the process is adjusted so as to put relatively great weight

on thermal cracking at a temperature range around 600° C.

Capacity of the apparatus:

Wet soft coal	kg./h.	50,000
Water content of coal	kg./h.	30,000
Dry coal	kg./h.	20,000
Oil content of dry coal	kg./h.	2,000

The temperature during the first stage of the process is maintained at about 230° C.

Circulating petroleum oil, boiling range	° C.	380
Operating pressure	atm.	30
Steam temperature	° C.	232
Diameter of horizontal (circular) treatment conduit	m.	5
Diameter of circular pipe	m.	0.65
Number of riser pipes (7)		6
Diameter of riser pipes	m.	0.6
Length or height of riser pipes	m.	6.0
Number of descending pipes		6
Diameter of descending pipes	m.	0.6
Length of descending pipes	m.	0.3
Coal treating time	min.	3½

The second stage of the process is carried out at about 425° C.

Diameter of riser pipe	1.0 m.
Height of riser pipe	6.0 m.
Coal treating time	2 min.
Quantity of circulating oil	About 360 m.³ h.
Quantity of oil dissolved in coal (A small portion thereof, light oil, is separated in the second stage in the form of oil vapors.)	2,000 kg./h.
Coal gas produced	1,500 kg.
Heat consumption in stages 1 and 2	About 32,500,0000 kcal./h.

Of this amount of heat about 5,600,000 kcal. are accounted for by the reaction between the oxygen, carbon and hydrogen of the coal. Altogether, upon carrying out the process at great speed, about 400 kcal./kg. coal are released, or upon treatment of 20,000 kg. dry coal/h.:8,000,000 kcal.

The thus-formed coke is then separated from the circulating petroleum oil, and introduced into the second reaction means.

Of the originally introduced 20,000 kg. of dry coal/h., 2,000 kg. represented oil and 1,500 kg. of coal gas were formed. Thus, 16,500 kg./h. of coke are introduced into the second reaction means together with 8,000 kg. of added oil and 2,000 kg. of originally dissolved oil, so that a total quantity of 10,000 kg. of oil/h. is now to be treated.

The pressure in the second reaction means is 5 atmospheres, representing a pressure drop from 30 to 5 atmospheres.

Due to the thus reduced pressure, the oil adhering to the coke is vaporized. The coke and the oil in the pores of the same is then contacted with circulating coke having a temperature of about 700° C., and thereby heated to about 550° C.

The heat requirements for this step of the process, for heating coke and oil, vaporizing the oil and for maintaining endothermic cracking reactions, amount to about 4,200,000 kcal./h. During the reaction, about 2,400,000 kcal./h. are liberated, and the missing balance of about 1,800,000 kcal./h. is supplied by the addition of coke heated to 700° C.

Quantity of circulating heated coke	kg./h.	40,000
Dimensions of the reactor:		
Diameter	m.	3.0
Height	m.	5.0
Reaction time	min.	12

In the first stage:

Steam at 30 atm.	kg./h.	30,000
The steam is then super-heated with waste heat of the apparatus to a temperature of 400° C. and converted into mechanical energy	kwh.	8,000

In the second stage:

Low temperature coke	kg./h.	16,500
Low temperature coal gas	kg./h.	1,500
Oil originally contained in coal	kg./h.	2,000

In the reactor or third stage:

8,000 kg. of heavy oil introduced per hour and 2,000 kg. of oil contained in the coal are transformed into light and medium oils and coke. The latter is then removed together with the coke obtained from the original soft coal. Additional combustible gases are formed from the coke during heating in the above described third stage, in addition to the combustible gases resulting from the oil cracking process.

Residual heavy oil is used for heating the apparatus.

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. A process 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, comprising the steps of contacting said petroleum oil with said water-containing, particulate, soild carbonaceous fuel the same being capable to be partially converted into bitumen by application of heat, so as to form a mixture of said petroleum oil and said solid fuel; subjecting said mixture to a temperature of about 350° C. at an elevated pressure so chosen as to substantially prevent evaporation of oil from said mixture while allowing evaporation of water thereform, thereby forming steam and filling pores of said solid fuel with petroleum oil; withdrawing the thus formed steam; raising the temperature of the thus formed substantially water-free mixture to about 400° C. so as to convert a portion of said solid fuel into liquid bitumen, while maintaining a pressure sufficiently high to substantially prevent vaporization of the thus formed liquid bitumen; separating said oil-containing solid fuel from the remainder of the reaction mixture; subjecting said separated, oil-containing solid fuel to a temperature of at least about 500° C. while maintaining a pressure of about between 0.5 and 5 atmospheres, so as to crack the oil within the pores of said solid fuel thereby transforming said oil at least partially into lower molecular hydrocarbons; and separating the thus formed lower molecular hydrocarbons from the solid fuel, whereby steam at relatively high pressure and temperature, a dry solid carbonaceous fuel, bitumen and lower molecular hydrocarbons are formed from said petroleum oil and said water-containing carbonaceous solid fuel.

2. A process of treating a petroleum oil having a relatively low content of components boiling below 250° C. at normal pressure, such as the oily residue remaining after distillation of petroleum oils at temperatures of between 250 and 400° C., comprising the steps of contacting said petroleum oil with a substantially water-free, particulate, soild, carbonaceous fuel including bituminous substances capable of being converted into liquid bitumen by application of heat, so as to form a mixture of said petroleum oil and said solid fuel; subjecting said mixture to a temperature at which the bitu-

men in said solid fuel will liquefy, while maintaining a pressure sufficiently high to substantially prevent evaporation of said liquefied bitumen, while the pores of said solid fuel are being filled with at least a portion of said petroleum oil; separating said oil-containing solid fuel from the remainder of the reaction mixture; subjecting said separated, oil-containing solid fuel to a temperature of at least about 500° C. while maintaining a pressure of about between 0.5 and 5 atmospheres, so as to crack the oil within the pores of said solid fuel thereby transforming said oil at least partially into lower molecular hydrocarbons; and separating the thus formed lower molecular hydrocarbons from the solid fuel, whereby a dry solid carbonaceous fuel, bitumen and lower molecular hydrocarbons are formed from said petroleum oil and said carbonaceous solid fuel.

3. A process of treating a petroleum oil having a relatively low content of components boiling below 250° C. at normal pressure, such as the oily residue remaining after distillation of petroleum oils at temperatures of between 250 and 400° C., comprising the steps of forming in said petroleum oil a suspension of a substantially water-free, particulate, solid, carbonaceous fuel including bituminous substances capable of being converted into liquid bitumen by application of heat; subjecting said suspension to a temperature at which the bitumen in said solid fuel will liquefy, while maintaining a pressure sufficiently high to substantially prevent evaporation of said liquefied bitumen, while the pores of said solid fuel are being filled with at least a portion of said petroleum oil; separating said oil-containing solid fuel from the remainder of the reaction mixture; subjecting said separated, oil-containing solid fuel to a temperature of at least about 500° C. while maintaining a pressure of about between 0.5 and 5 atmospheres, so as to crack the oil within the pores of said solid fuel thereby transforming said oil at least partially into lower molecular hydrocarbons; and separating the thus formed lower molecular hydrocarbons from the solid fuel, whereby a dry solid carbonaceous fuel, bitumen and lower molecular hydrocarbons are formed from said petroleum oil and said carbonaceous solid fuel.

4. A continuous process of treating a petroleum oil having a relatively low content of components boiling below 250° C. at normal pressure, such as the oily residue remaining after distillation of petroleum oils at temperatures of between 250 and 400° C., comprising the steps of forming a flowing stream of said petroleum oil and of a substantially water-free, particulate, solid, carbonaceous fuel including bituminous substances capable of being converted into liquid bitumen by application of heat; subjecting said flowing suspension to a temperature at which the bitumen in said solid fuel will liquefy, while maintaining a pressure sufficiently high to substantially prevent evaporation of said liquefied bitumen, while the pores of said solid fuel are being filled with at least a portion of said petroleum oil; separating said oil-containing solid fuel from the remainder of the reaction mixture; subjecting said separated, oil-containing solid fuel to a temperature of at least about 500° C. while maintaining a pressure of about between 0.5 and 5 atmospheres; so as to crack the oil wthin the pores of said solid fuel thereby transforming said oil at least partially into lower molecular hydrocarbons; and separating the thus formed lower molecular hydrocarbons from the solid fuel, whereby a dry solid carbonaceous fuel, bitumen and lower molecular hydrocarbons are formed in a continuous manner from said petroleum oil and said carbonaceous solid fuel.

5. A process of treating a petroleum oil as defined in claim 4, wherein the mixture of said petroleum oil and said liquid bitumen remaining after separation of the oil-containing solid fuel is heated to an elevated temperature and contacted with subsequent portions of said substantially water-free, particulate, solid, carbonaceous fuel.

6. A process of treating a petroleum oil as defined in claim 1, wherein said remainder of the reaction mixture is used as said petroleum oil for contacting subsequent portions of said water-containing, particulate, solid, carbonaceous fuel.

7. A process of treating a solid, carbonaceous fuel containing water and at least one substance convertible into bitumen by application of heat, comprising the steps of forming a mixture of said solid fuel and a petroleum oil; subjecting said mixture to an elevated pressure of at least 12 atmospheres while maintaining said mixture at a first elevated temperature above the boiling point of water at said elevated pressure and below the vaporization point of said petroleum oil at said elevated pressure, so as to vaporize the water of said solid fuel; withdrawing the thus-formed steam; and subjecting the remainder of said mixture to a second elevated temperature higher than said first elevated temperature while maintaining substantially said elevated pressure, so as to transfer said convertible substances into bitumen and liquefy the same, thereby cracking at least a portion of the thus-formed bitumen in contact with said solid fuel under formation of petroleum oils and vaporizing the thus-formed petroleum oils.

8. A process of treating a solid, carbonaceous fuel containing water and at least one substance convertible into bitumen by application of heat, comprising the steps of forming a mixture of said solid fuel and a petroleum oil; subjecting said mixture to an elevated pressure of about 30 atmospheres while maintaining said mixture at a first elevated temperature above the boiling point of water at said elevated pressure and below the vaporization point of said petroleum oil at said elevated pressure, so as to vaporize water of said solid fuel; withdrawing the thus-formed steam; subjecting the remainder of said mixture to a second elevated temperature of about 400° C. being higher than said first elevated temperature while maintaining substantially said elevated pressure, so as to transfer said convertible substances into bitumen and liquefy the same, thereby cracking at least a portion of the thus-formed bitumen in contact with said solid fuel under formation of petroleum oils and vaporizing the thus-formed petroleum oils; and separating said vaporized petroleum oils from the remainder of said solid fuel.

9. A process according to claim 8, wherein said mixture is formed of said separated petroleum oils and subsequent portions of said solid fuel.

10. A process of treating a solid, carbonaceous fuel containing water and at least one substance convertible into bitumen by application of heat, comprising the steps of forming a mixture of said solid fuel in comminuted form and a petroleum oil; subjecting said mixture to an elevated pressure of at least 12 atmospheres while maintaining said mixture at a first elevated temperature above the boiling point of water at said elevated pressure and below the vaporization point of said petroleum oil at said elevated pressure, so as to vaporize the water of said solid fuel; withdrawing the thus-formed steam; and subjecting the remainder of said mixture to a second elevated temperature higher than said first elevated temperature while maintaining substantially said elevated pressure, so as to transfer said convertible substances into bitumen and liquefy the same, thereby cracking at least a portion of the thus-formed bitumen in contact with said solid fuel under formation of petroleum oils and vaporizing the thus-formed petroleum oils.

11. A process of treating a solid, carbonaceous fuel containing water and at least one substance convertible into bitumen by application of heat, comprising the steps of forming a suspension of said solid fuel in comminuted form in a petroleum oil; subjecting said suspension to an elevated pressure of at least 12 atmospheres while

maintaining said suspension at a first elevated temperature above the boiling point of water at said elevated pressure and below the vaporization point of said petroleum oil at said elevated pressure, so as to vaporize the water of said solid fuel; withdrawing the thus-formed steam; and subjecting the remainder of said suspension to a second elevated temperature higher than said first elevated temperature while maintaining substantially said elevated pressure, so as to transfer said convertible substances into bitumen and liquefy the same, thereby cracking at least a portion of the thus-formed bitumen in contact with said solid fuel under formation of petroleum oils and vaporizing the thus-formed petroleum oils.

12. A continuous process according to claim 7, in which said petroleum oil is separated from the solid fuel having been treated as defined in claim 7; and the thus-separated petroleum oil is re-introduced into said process for forming a mixture with subsequent portions of said solid fuel, said petroleum oil thus conveying the solid fuel and flowing in a closed cycle.

13. A process of treating a solid, carbonaceous fuel containing water and at least one substance convertible into bitumen by application of heat, comprising the steps of contacting a substantially horizontally flowing stream of petroleum oil with particles of said solid fuel; subjecting the thus-formed stream of solid fuel-carrying petroleum oil to an elevated pressure of at least 12 atmospheres while maintaining a first elevated temperature being above the boiling point of water at said elevated pressure and below the vaporization point of said petroleum oil, so as to vaporize at least the major portion of the water contained in said solid fuel, thereby causing said solid fuel upon loss of most of its water content to sink downwardly in said stream of horizontally flowing petroleum oil; thereafter directing said stream of petroleum oil conveying said fuel in an upward direction at least until substantially all of the remaining water of said solid fuel has evaporated so as to form a substantially water-free stream of flowing oil and solid fuel; subjecting said substantially water-free stream to a second elevated temperature higher than said first elevated temperature while maintaining substantially said elevated pressure, so as to transfer said convertible substances into bitumen and liquefy the same, thereby cracking at least a portion of the thus-formed bitumen in contact with said solid fuel under formation of petroleum oils and vaporizing the thus-formed petroleum oils.

14. A process according to claim 13 in which the particles of said solid fuel contacting said stream of petroleum oil are of varying size, so as to sink downwardly in said horizontal oil stream at different points after being carried by the same varying distance corresponding to the size of the particles, respectively; and whereby said particles of solid fuel are thereafter carried upwardly in one of a plurality of successively arranged upwardly flowing streams of said petroleum oil, each particle respectively being carried upwardly by a stream of petroleum oil emanating from said horizontally flowing petroleum oil at a point in the vicinity of sinking of said respective particle of solid fuel.

15. A process of treating a solid, carbonaceous fuel containing water and at least one substance convertible into bitumen by application of heat, comprising the steps of contacting a substantially horizontally flowing circular stream of petroleum oil with particles of said solid fuel; subjecting the thus-formed stream of solid fuel-carrying petroleum oil to an elevated pressure of at least 12 atmospheres while maintaining a first elevated temperature being above the boiling point of water at said elevated pressure and below the vaporization point of said petroleum oil, so as to vaporize at least the major portion of the water contained in said solid fuel, thereby causing said solid fuel upon loss of most of its water content to sink downwardly in said stream of horizontally flowing petroleum oil; thereafter directing said stream of petroleum oil conveying said fuel in an upward direction at least until substantially all of the remaining water of said solid fuel has evaporated so as to form a substantially water-free stream of flowing oil and solid fuel; subjecting said substantially water-free stream to a second elevated temperature higher than said first elevated temperature while maintaining substantially said elevated pressure, so as to transfer said convertible substances into bitumen and liquefy the same, thereby cracking at least a portion of the thus-formed bitumen in contact with said solid fuel under formation of petroleum oils and vaporizing the thus-formed petroleum oils.

16. A process of treating peat, comprising the steps of heating peat containing colloidally bound water, in water under pressure to a temperature sufficiently high to release the colloidally bound water of said peat; forming a mixture of the thus-treated peat and a petroleum oil; subjecting said mixture to an elevated pressure of at least 12 atmospheres while maintaining said mixture at a first elevated temperature above the boiling point of water at said elevated pressure and below the vaporization point of said petroleum oil at said elevated pressure, so as to vaporize water contoined in said peat; withdrawing the thus-formed steam; and subjecting the remainder of said mixture to a second elevated temperature higher than said first elevated temperature while maintaining substantially said elevated pressure, so as to transform a portion of said peat into bitumen and liquefy the same, thereby cracking at least a portion of the thus-formed bitumen in contact with said solid fuel under formation of petroleum oils and vaporizing the thus-formed petroleum oils.

17. In on apparatus for simultaneously de-watering water-containing, solid, carbonaceous fuel, and at least partially reducing the molecular weight of higher-boiling petroleum oil and the like, in combination, first reaction means for subjecting a mixture of water-containing, carbonaceous, solid fuel and petroleum oil to super-atmospheric pressure and to an elevated temperature sufficiently high to cause evaporation and steam formation of the water contained in said solid fuel while retaining said petroleum oil in unvolatilized conidtion, whereby petroleum oil will enter into the pores of the thus de-watered solid fuel; means for removing the formed steam from said first reaction means; hydrocyclone means operatively connected to and communicating with said first reaction means for separating free petroleum oil from the thus de-watered petroleum oil-containing solid fuel; conveying means communicating with said hydrocyclone means and with said first reaction means for conveying at least a portion of said free petroleum oil from said hydrocyclone means to said first reaction means; second reaction means operatively connected to said hydrocyclone means for receiving said de-watered petroleum oil-containing solid fuel and subjecting the same to a temperature sufficiently high to cause at least partial transformation of the petroleum oil contained in the solid carbonaceous fuel into lower molecular hydrocarbons, and at a pressure sufficiently low to volatilize the thus-formed lower molecular weight hydrocarbons; and means operatively connected to said second reaction means for separating the thus-formed volatilized hydrocarbons and water-free, solid, carbonaceous fuel.

18. In an apparatus for simultaneously de-watering water-containing, solid, carbonaceous fuel, and at least partially reducing the molecular weight of higher-boiling petroleum oil and the like, in combination, first reaction meons including a tubular, upwardly extending reaction vessel for subjecting a mixture of water-containing, carbonaceous, solid fuel and petroleum oil to superatmospheric pressure and to an elevated temperature sufficiently high to cause evaporation and steam formation of the water contained in said solid fuel while retaining said petroleum oil in unvolatilized conidtion, whereby petroleum oil will enter into the pores of the thus de-watered solid fuel; means for removing the thus formed

steam from said first reaction means; hydrocyclone means operatively connected to and communicating with said first reaction means for separating free petroleum oil from the thus de-watered petroleum oil-containing solid fuel; separating and conveying means communicating with said hydrocyclone means and with said first reaction means for separating a portion of said free petroleum oil from said hydrocyclone means and for conveying the remaining portion to said first reaction means; second reaction means operatively connected to said hydrocyclone means for receiving said de-watered petroleum oil-containing solid fuel and subjecting the same to a temperature sufficiently high to cause at least partial transformation of the petroleum oil contained in the solid carbonaceous fuel into lower molecular hydrocarbons, and to a pressure sufficiently low to volatilize the thus-formed lower molecular weight hydrocarbons; and means operatively connected to said second reaction means for separating the thus-formed volatilized hydrocarbons and water-free, solid, carbonaceous fuel.

19. In an apparatus for simultaneously de-watering water-containing, solid, carbonaceous fuel, and at least partially reducing the molecular weight of higher-boiling petroleum oil and the like, in combination, first reaction means including a tubular, upwardly extending reaction vessel for subjecting a mixture of water-containing, carbonaceous, solid fuel and petroleum oil to superatmospheric pressure and to an elevated temperature sufficiently high to cause evaporation and steam formation of the water contained in said solid fuel while retaining said petroleum oil in unvolatilized condition, whereby petroleum oil will enter into the pores of the thus de-watered solid fuel; means for removing the formed steam from said first reaction means; hydrocyclone means operatively connected to and communicating with said first reaction means for separating free petroleum oil from the thus de-watered petroleum oil-containing solid fuel; conveying a portion of means communicating with said hydrocyclone means and with said first reaction means for conveying said free petroleum oil from said hydrocyclone means to said first reaction means; second reaction means including a reaction chamber having arranged therein means for retarding the passage of solid, particulate fuel through said chamber and for displacing particles of said fuel relative to each other, operatively connected to said hydrocyclone means for receiving said de-watered petroleum oil containing solid fuel and subjecting the same to a temperature sufficiently high to cause at least partial transformation of the petroleum oil contained in the solid carbonaceous fuel into lower molecular hydrocarbons, and at a pressure sufficiently low to volatilize the thus-formed lower molecular weight hydrocarbons; and means operatively connected to said second reaction means for separating the thus-formed volatilized hydrocarbons and water-free, solid, carbonaceous fuel.

20. A process of treating of solid, carbonaceous fuel containing water and at least one substance convertible into bitumen by application of heat, comprising the steps of comminuting said solid fuel to a particle size of about 6 mm. forming a mixture of said comminuted solid fuel and a petroleum oil; subjecting said mixture to an elevated pressure of at least 12 atmospheres while maintaining said mixture at a first elevated temperature above the boiling point of water at said elevated pressure and below the vaporization point of said petroleum oil at said elevated pressure, so as to vaporize the water of said solid fuel; withdrawing the thus-formed steam; and subjecting the remainder of said mixture to a second elevated temperature higher than said first elevated temperature while maintaining substantially said elevated pressure, so as to transfer said convertible substances into bitumen and liquefy the same, thereby cracking at least a portion of the thus-formed bitumen in contact with said solid fuel under formation of petroleum oils and vaporization of the thus-formed petroleum oils.

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