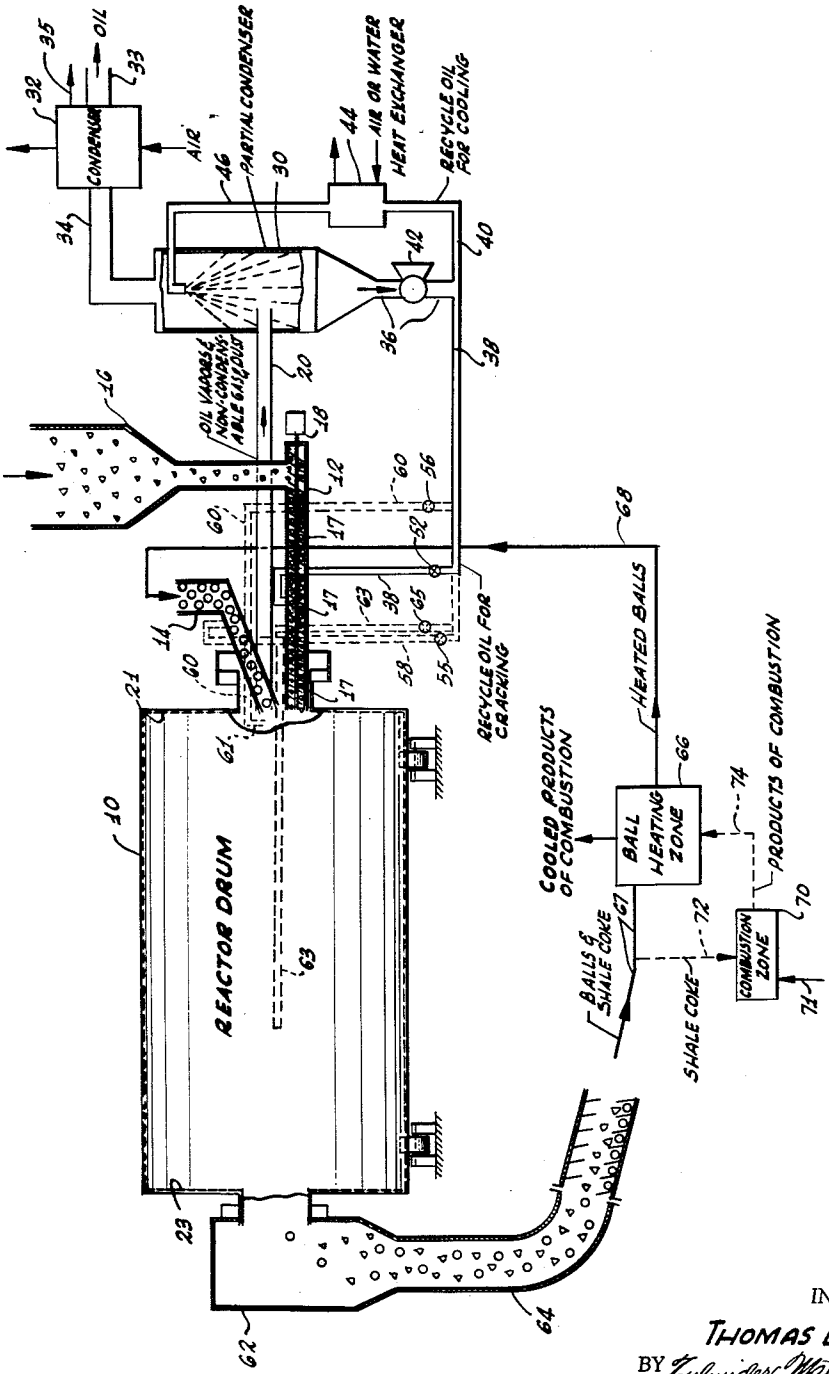
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PLANT AND PROCESS FOR PRODUCTION OF LOW TEMPERATURE PUMPABLE OIL FROM OIL SHALE AND THE LIKE

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PLANT AND PROCESS FOR PRODUCTION OF LOW TEMPERATURE PUMPABLE OIL FROM OIL SHALE AND THE LIKE

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This invention relates generally to a plant and process for the production of oil from solid substances leaving a carbonaceous residue, such as oil shale, peat, etc., and more specifically relates to a plant and process for the production of shale oil and the like having a low pour point and reduced viscosity. The term "carbonaceous residue" denotes a residue which includes fixed combustible carbon.

Inasmuch as the large deposits of solid materials, such as oil shale, are found some distance from refinery centers, it has heretofore been considered desirable to crack all the oil pyrolyzed from the solid materials in such a manner as to reduce its viscosity, and/or pour point prior to its introduction into a pipeline for ease in transportation. Such a thermal cracking is sometimes referred to as visbreaking, or if the cracking is prolonged, as coking. While the pour point of an oil is not the most accurate measure of its pumpability, the pour point test does give a fair indication, and generally speaking, the lower the pour point, the better the pumpability at the lower temperatures.

One plant and method wherein combined pyrolysis and cracking are advantageously employed to secure a lower temperature pumpability of shale oil is disclosed in my copending U.S. application, Serial No. 777,354 entitled Plant and Process for Production of Low Temperature Pumpable Oil From Oil Shale and the Like. In that application, a plant and process are disclosed for the production of oil having a low pour point and reduced viscosity wherein the amount of valuable oil loss in the form of non-condensable gases is substantially reduced over prior art processes known to me. Prior to that plant and method, the combined pyrolysis and cracking processes, while resulting in the lowering of pour point of the oil product, inherently produced a relatively high amount of oil loss in the form of non-condensable gases.

The basic concept involved in my copending application is the condensation of the heavier pyrolyzed oil vapors and the cracking thereof in a separate cracking unit, the cracked oil vapors and the uncracked oil vapors being then combined and condensed, the composite oil thereby produced being a low temperature pumpable oil having only approximately one-half or less the normal amount of oil loss. The process of my copending application and of other combined pyrolysis and thermal cracking processes known to me requires that a separate pyrolysis drum and cracking unit be employed.

The process of my above-identified and described copending application is extremely advantageous and desirable in many instances. For example, the thermal cracking operation may be conducted within wide temperature limits and within wide limits of residence time. However the equipment required to perform the process is relatively expensive since in addition to the pyrolysis unit or drum, a separate cracker must also be employed.

Bearing in mind the foregoing facts, the major object of the present invention is to provide a plant and process for the production of oil having a low pour point and reduced viscosity from solid material such as oil shale and the like wherein the amount of valuable oil loss in the form of non-condensable gases is substantially reduced, said plant and process being relatively simple and involving a relatively small initial capital investment.

Still another object of the present invention is to provide a process for the production of shale oil or other oil from oil shale and the like wherein an extremely simplified control of the cracking of pyrolyzed oil vapors and gases is accomplished over a wide range of temperatures and residence times.

Yet a further object of the present invention is to provide a plant and process for the production of oil from oil shale and the like wherein a low capital investment in plant equipment is required for both a pyrolysis and cracking operation, but with no sacrifice in ease and variation of control during both the pyrolysis and cracking phases of the process.

These, and other objects, of the present invention will become clearly understood by referring to the following description and to the accompanying figure in which the figure is a diagrammatic elevational view of one preferred embodiment of the invention showing the important parts of the plant and process of the invention.

In general, the plant and process therefor of my present invention includes operations which remove the lighter fractions of oil vapors and gases resulting from the pyrolysis (e.g. gas oil, gasoline and kerosene) prior to the cracking step, in much the same manner as in my copending application, since the cracking of these fractions contributes relatively little to the reduction in both pour point and viscosity of the resulting oil, but if cracked, they give rise to a relatively large loss of oil in the form of non-condensable gases. On the other hand, the cracking of the heavier oil fractions resulting from the pyrolysis does contribute considerably to the reduction in viscosity and the pour point of the resulting oil product but does not produce relatively large amounts of non-condensable gas.

More specifically, the process of my present invention comprises the steps of pyrolyzing oil shale or the like to produce effluent oil vapors and gases, cooling the effluent to a predetermined temperature to thereby condense the heavier fractions contained therein but not the lighter fractions, thermally cracking the heavier fractions within a certain predetermined period of residence time, by recycling at least a portion of the heavier fractions to the zone wherein the pyrolysis takes place, either indirectly, i.e. via one of the several material streams entering therein or directly to the zone of pyrolysis itself, all of which will be described in detail hereafter. The uncracked lighter fractions, as well as the thus cracked heavier fractions, are then condensed to thereby produce a composite oil product which has a pour point and viscosity comparable to, or slightly less than that of shale oil produced after the pyrolysis and cracking of all the effluent oil vapors and gases from the pyrolysis, the loss of oil by my present process being substantially less than in such prior art processes.

Referring now to the figure a solid material, such as oil shale, and generally spherical solid heat-carrying bodies, enter a reactor zone, which is preferably in the form of a rotatable drum **10**, via the conduits **12** and **14**, respectively. The oil shale enters the conduit from a hopper **16** communicating therewith. The conduit **12** has a conveyor means **17** mounted therein driven by a motor **18** to insure a proper rate of inflow of oil shale into the reactor drum **10**.

The oil shale usually enters the drum **10** at a low temperature, e.g. 50° F., although frequently it is desirable to preheat the oil shale to a temperature as high as 500° to 600° F. The heat-carrying bodies or balls are made of a hard-resistant material, such as alumina, or other ceramic material, or steel and preferably have a diameter somewhat larger than the average mesh size of the in-

coming cold or preheated oil shale. For example, the ball diameter usually ranges between one-half to one inch, whereas the average oil shale mesh size is usually minus one-quarter or minus one-half inch.

The heat-carrying bodies or balls preferably enter the reactor drum **10** at a temperature lying within the range of 1,000° to 1,400° F., and are preferably intermixed in parallel flow, with the oil shale. Counter-flow of balls and oil shale is also employed, although parallel flow is presently preferred. The ratio of the balls to oil shale generally ranges between 1:1 and 3:1, depending upon the inlet temperature of the oil shale being processed, the type of heat-carrying bodies being employd, and the rate of heat-transfer sought.

It should be noted that while other modes of preheating and pyrolyzing oil shale and the like can be employed, e.g. fluidized bed processes employing heated gases for the preheating and pyrolysis, the preferred method and means for such operations (and also for the thermal cracking) utilizes generally spherical solid heat-carrying bodies of the type above described. The advantages of such method and means are several, and are gone into in detail in a copending application Serial No. 702,150, entitled Method and Apparatus for Stripping Oil From Oil Shale, filed December 11, 1957.

On admixture of the heat-carrying bodies with oil shale in the rotating reactor drum **10**, heat is transferred from the bodies to the oil shale by solid to solid heat transfer. The hot bodies continually come into contact with all of the oil shale due to the rotation of the drum **10**. Pyrolysis of the oil shale then occurs and the effluent oil vapors and gases leave the drum **10** via a vapor outlet line **20** located at the oil shale-and-ball inlet end **21** of the pyrolysis drum **10**. Attention is drawn to the fact that the oil and gas vapors could be removed from the ball and shale coke outlet end **23** of the pyrolysis drum **10** instead of the ball and shale inlet end **21** (as shown) if desired. It is preferable, however, to remove the oil and gases from the ball and shale coke inlet end **21**. For it has been found that the majority of dust that is generated within the reactor drum **10** is generated at the ball and shale outlet end **23** during and after the shale is pyrolyzed and the entrainment of dust within the oil and gas vapors is minimized when the oil and gas vapors travel the length of the drum back to the inlet end **21** and through an area of less dust before they are removed.

The pyrolyzed oil vapors and gases have a temperature preferably lying between 750° F. to 950° F. They are passed into a partial condenser unit **30**, and are cooled therein to a temperature lying preferably between 500° F. and 800° F. in a manner described below. Those fractions of the oil vapors and gases which remain a vapor at 500° F. to 800° F., e.g. gas oil, kerosene and gasoline are, of course, not condensed and pass directly into a condenser **32** via overhead line **34**.

The partial condenser unit **30** also preferably functions as a combination dust scrubber and oil aerosol scrubber. Thus those liquified heavier fractions of the effluent oil vapors and gases, such as the high boiling tars, etc. include agglomerated aerosols and dust, all of this material being removed from the bottom of the partial condenser **30** by a pump **42**, capable of handling sludges, located in bottom discharge line **36**.

The oil vapors and gas sent into the partial condenser **30** preferably meet, and are cooled by, cool heavy oil (preferably uncracked heavy shale oil) having a temperature of between 400° and 750° F. The cool oil is preferably atomized counter-currently to the oil vapors and gases thereby liquefying and removing the heavier fractions and also causing the removal of dust and oil aerosols. The amount of cooling of the oil vapors obtained by this means is preferably between approximately 50° to 250° F. This means of condensing the heavier oil fractions is extremely advantageous inasmuch as dust and oil aerosol are substantially completely removed from the oil vapors and gases.

The condensed heavier oil fraction which usually comprises approximately 10% to 50% of the total collectible oil product is passed from conduit **36** into either or both recycle lines **38** and **40** by means of the pump **42**. This heavier oil fraction has a pour point usually in the range of 110° to 130° F. but is pumped easily by pump **42** since it is at a temperature of 500° to 800° F.

The heavier oil is sent into recycle lines **38** and **40** respectively in any desired proportion. For example, approximately 75% of the heavier fractions can be recycled through a heat exchanger **44**, thence to the top of the partial condenser **30** via line **46**. The heat exchanger **44** serves to cool the recycled oil from approximately 50° to 350° F. and it is then atomized countercurrently to the pyrolyzed oil vapors and gases to remove dust, agglomerated oil aerosol and the heavier oils therefrom, as described above.

That portion of the heavier fraction of oil not recycled for cooling purposes through line **40**, is recycled via line **38** to the reactor drum **10** for thermal cracking, by one of several of a number of different methods described below. It is important that the degree of thermal cracking be controlled to as great an extent as possible. This in turn requires a control of the temperature of the recycled heavier oil fraction and also a control of its residence time, while it is in the reactor drum **10**. The thermal cracking operations are found to be controlled to a very great degree by the manner in which the heavier oil fraction is introduced into the reactor drum **10**.

In order to obtain a relatively large amount of thermal cracking, the heavier oil fraction is sent from line **38** into line **58**, the valves **56**, **65** and **52** being closed, while the valve **55** is open. The heavier oil fraction is sent from line **58** directly into the hot incoming ball stream, entering via line **14**. As mentioned, the balls entering the drum have a temperature of approximately between 1,000° and 1,400° F. and the amount of cracking that the heavier oil fraction will undergo is substantial compared with the amount of cracking obtained by methods to be described.

To obtain a reduced amount of thermal cracking of the heavier oil fraction, the oil vapors may be sent to any one of a number of other locations. For example, they may be sent along line **38**, valve **52** located therein being opened and the valves **55**, **56** and **65** located in the auxiliary (dotted) lines **58**, **60** and **63** respectively being closed. The recycled heavier oil fraction is thus introduced directly into the shale inlet line **12**, which has a temperature of between 50° to 600° F.

If the heavy oil fraction is cracked to a point greater than desired by its introduction into the reactor drum **10** via the high temperature ball inlet line **14**, it may be desirable to introduce the recycled oil into the reactor drum just in front of the oil vapor take-off line **20** at a point designated by the numeral **61**. In this case, the recycled oil will pass from line **38** directly into line **60** through open valve **56**. The other valves **52**, **55** and **65** are, of course, closed. This mode of introducing the recycled heavy condensed oil fraction has the added advantage that the dust and oil aerosols in the effluent oil vapors and gashes are scrubbed or removed therefrom, by contact with the entering recycled oil, prior to their entry into the oil or vapor take-off line **20**. In this manner, the load of the partial condenser is appreciably reduced.

It is also frequently desirable to introduce the recycled oil fraction directly into the ball-oil shale mixture in the reactor drum **10**, as for example, via dotted line **63** and through open valve **65**. Valves **52**, **56** and **55** are closed. The line **63** may extend to any point axially located anywhere between ends **21** and **23** of drum. Thus, the line **63** may extend only to some point nearer the

inlet end **21** of the drum or could extend nearer the shale and ball outlet end **23** of the drum in order to reduce the residence time and thus reduce the amount of thermal cracking that is desired.

While all the oil recycled, via line **38**, may be sent to a single location for inlet into the reactor drum **10**, it is frequently desirable to introduce the recycled oil into the reactor drum at two or more different locations. For example, it has been found desirable to introduce a portion of the recycled oil to be thermally cracked into the line **60**, as above described, so as to remove an appreciable part of the dust and oil aerosols from the pyrolyzed effluent oil vapors and to send the remaining portion of the recycle heavy oil to the location in the reactor drum **10** where the optimum thermal cracking, for the particular heavy oil fraction, can be realized.

The cracked oil vapors and gases leave the reactor drum **10** with the pyrolyzed oil vapors and gases, via take-off line **20**, the lighter oil fraction passing, via overhead line **34**, to the condenser **32**. The oil product leaves condenser **32**, via line **33**, at a low temperature preferably, of the order of 100° F.

The oil product produced according to the above process is highly advantageous in that, for Colorado oil shale, the pour point generally lies in the neighborhood of 30° to 60° F.; and what is also extremely important, the loss of oil in the process typically amounts to approximately only 5% to 15% of the total oil collectible. In most prior art processes, wherein shale oil of such a pour point is produced, appreciably more oil loss occurs in the form of non-condensable gases and coke due to the cracking of all the pyrolyzed oil vapors and gases.

The amount of liquid oil sent to the reactor drum **10** is of the order of 1% to 2% of the total solids entering the drum. The tars in the heavy oil fraction, and the coke produced during the thermal cracking do not however gum up, or stick to, the walls of the reactor drum **10** because of the great proportion of solids to liquids sent to the reactor drum. Most of the coke and tar formation in the reactor drum **10** is picked up by the balls and/or shale coke and is later combusted to furnish additional heat for the reheating of the balls, as will be described hereafter.

After the pyrolysis of the oil shale in the reactor drum **10**, the carbonaceous residue (which, in the case of the carbonaceous shale residue, is hereinafter, and in the claims, termed "shale coke") passes, together with the balls, into the chamber **62**. The carbonaceous residue passes downwardly together with the balls, through the passageway **64** and into a ball-heating zone **66** via line **67**. The shale coke is then combusted by means of air or preheated air to furnish heat for the reheating of the balls, and the heated balls are then passed via line **68** into the ball-inlet line **14** for the pyrolysis and thermal cracking operations in the reactor drum **10**.

In many cases it is found desirable to combust the shale coke in a zone separate from that of the ball heating zone and to this end, the carbonaceous residue is separated from the larger balls in any convenient manner, such as, for example, by screening operations (not shown). In this connection, the carbonaceous residue is considerably reduced in size over the initial oil shale mesh size due to the grinding and crushing action of the hard balls on the oil shale in the reactor drum **10**. The separation of the carbonaceous residue from the balls is thus readily effected by screening means. It should also be understood that other methods of separation of balls from carbonaceous residue can also be employed, such as by magnetic or elutriation means, or trommels.

The separated shale coke is sent to the combustion zone **70** via dotted line **72**, air is provided for combustion, entering zone **70** via line **71**, and the products of combustion are sent to the ball heating zone **66** via dotted line **74**.

Mention has previously been made of the fact that the oil shale entering the reactor drum **10** may either be cold or preheated. A preferred method of preheating involves mixing fresh oil shale with hotter balls in either parallel or counterflow, as is disclosed in detail in the above-identified copending U.S. application of William J. Culbertson, Jr. The hot balls employed for the solid material preheating step are preferably those taken from the reactor drum **10**. After preheating the oil shale, the balls are sent through the ball-heating step previously described.

Attention is drawn to the fact that the thermal cracking operations made possible by the process of the present invention have an extremely wide range of temperature limits and also wide residence time limits within the reactor drum or chamber **10**. At one extreme, the initial cracking temperature can be as high as 1000° F. to 1400° F. (if the heavy oil fraction is introduced indirectly into the drum **10** via the ball inlet line **14**) or as low as 50° to 600° (if introduced indirectly into the drum **10** via te oil shale inlet line **12**). If initial temperatures desired are in the intermediate range, e.g. 750° F. to 950° F., the heavy oil fraction is introduced into the ball-oil shale admixture directly, at the appropriate point, in the reactor drum **10** corresponding to the period of residence time desired. In this connection, it is possible that the recycled heavier oil fraction in the reactor drum **10** can contact hot moving heat-carrying bodies for a period of time ranging between approximately several seconds to approximately five minutes.

A specific example of one preferred form of the process is set forth below:

A ton of Colorado oil shale, of approximately ¼ inch mesh size, having a Fischer assay of 22.5 gallons of oil per ton of shale, enters the drum **10** via line **12**, along with 1.2 tons of ⅝" aluminum oxide-containing ceramic balls, the balls entering the drum **10** via line **14**. The oil shale has an average inlet temperature of 500° F. and the balls have an average inlet temperature of 1300° F.

Approximately 180 pounds of oil vapors and 25 pounds of gases are produced during the pyrolysis in the reactor drum **10**, the oil vapors and gases (at a temperature of 850° F.) passing, via the oil vapor and gas takeoff line **20** to the partial condenser **30**. The oil vapors and gases are cooled in the partial spray condenser **30** to a temperature of approximately 700° F., about 60 pounds of oil being condensed thereby.

The 60 pounds of heavier oil fractions are pumped, by pump **42**, through line **36** and approximately 75% or 45 pounds, are recycled through line **40** for cooling purposes. The remaining 25%, or 15 pounds, is recycled into the reactor drum **10** for thermal cracking and revaporization. Actually, as much heavy oil eventually passes through line **38** as comes through line **20**. It is, however, split in the 3:1 ratio as between lines **38** and **40**.

The recycled oil for cooling is passed through an air or water heat exchanger **44**, then along line **46** to be then atomized counter-currently to the incoming oil vapors and gases thereby condensing the heavier portion of these, as well as agglomerating the oil aerosols, and bringing down substantially all the dust.

The lighter non-condensed fractions pass through the overhead line **34** and are sent to the condenser **32**, and are cooled to 100° F. The condensed oil is then sent to a storage tank for transportation at some later time, or may be directly transferred to a pipeline. The non-condensable gases pass from the condenser **32**, via line **35**, for processing or use.

The heavy oil fractions are recycled, via line **38**, into line **63** which leads into the reactor drum **10** at a point such that the residence time of the oil is approximately one minute and the temperature of the ball-shale admixture is in the neighborhood of 850° F. The heavy oil is thermally cracked and the cracked oil vapors are taken from the reactor drum **10** along with freshly pyrolyzed oil vapors to the condenser **30**. The lighter oil fraction,

including the thermally cracked oil, is drawn off the top of the unit **30**, via line **34**, into condenser **32**.

Approximately only 18 pounds or 10% of the maximum oil recovery is converted into non-condensable gases and coke. The pour point of the composite product is approximately 40° F.

Comparing the results of the process when all conditions are equivalent to those just described except that all the effluent vapors are cracked, the pour point of the resulting oil was 40° F. and the loss of oil was in the neighborhood of 36 pounds or 20% of the total oil collectible.

The balls and shale coke produced leave the reactor drum **10** via chamber **62** in line **64**, the balls being then reheated to a temperature of 1300° F. by directly contacting them with the hot product of combustion of the shale coke. The balls are then sent to the reactor drum **10** via line **68** to contact fresh incoming oil shale.

Attention is drawn to the fact that the eliminaion of a separate cracking unit, besides having the advantage of lower equipment costs and variation of controlled thermal cracking conditions, also has the advantage that fewer vapor or gas seals are required. The amount of piping is reduced and the number of connections between various pieces of equipment is also reduced. This is an important advantage in reducing the loss of gases from the system.

While several preferred embodiments of my invention have been shown and described herein, it will be understood that modifications and changes may be made herein that lie within the ordinary skill of those in the art. For this reason, I do not intend to be bound by the embodiment herein shown and described, but intend to be bound only by the appended claims.

I claim:

1. An continuous process for producing a low temperature pumpable oil from attritionable solid material which upon heating leaves a combustible carbonaceous residue which comprises contacting the solid material in particulate form in a heating zone in solid-to-solid milling contact with hot, solid, heat-carrying bodies larger in particle size than said combustible residue, to produce oil vapors and gases, said vapors containing a heavier oil fraction and a lighter oil fraction; condensing at least part of the heavier oil fraction in said oil vapors; returning at least a portion of said condensed heavier oil fraction to the heating zone to thermally crack and vaporize said fraction; condensing said thermally cracked oil vapors and said lighter oil fraction to produce at least one oil product; burning said combustible residue to produce hot products of combustion; and employing heat produced by the burning of said combustible residue to reheat said heat-carrying bodies.

2. A process according to claim 1 in which the oil vapors and gases produced in the heating zone have a temperature between about 750° and about 950° F. and are cooled during condensation to between about 500° and about 800° F.

3. A process according to claim 1 wherein a portion of the heavier condensed oil fraction is cooled and, after being cooled, is directly contacted with said oil vapors and gases to thereby condense heavier oil therefrom and to entrap and carry down dust.

4. A process according to claim 1 in which the condensed heavier oil fraction is introduced directly into the heating zone.

5. A process according to claim 1 in which the condensed heavier oil fraction is introduced into the heating zone in admixture with one of the solid materials fed to the heating zone.

6. A process according to claim 1 in which the attritionable solid material is oil shale.

7. A plant for producing oil from solid attritionable materials leaving a solid carbonaceous residue, which comprises: a continuously circulating load of heat-carrying solid bodies harder than the solid material and having a particle size greater than said carbonaceous residue; reactor means for heating said solid material to an elevated temperature and causing the evolution of oil vapors and gases therefrom, including inlet means for said solid material, inlet means for said heat-carrying solid bodies; outlet means for discharging from said reactor means said oil vapors and gases, said carbonaceous residue, and said heat-carrying bodies; partial condensation means, communicating with said outlet means for oil vapors and gases, for cooling the oil vapors and gases to a temperature such that a substantial portion of the heavier oil fractions contained therein, but not the lighter fractions, are condensed; means for recycling at least a portion of said heavier oil fraction to said reactor means for the cracking thereof; and means for condensing said cracked heavier oil fractions and said lighter fractions to produce a composite oil product.

8. The apparatus of claim 7 wherein said recycling means leads to said solid material inlet means.

9. The apparatus of claim 7 wherein said recycling means leads to said heat-carrying body inlet means.

10. The apparatus of claim 7 having a conduit means for recycling a portion of the heavier oil fraction to a cooling means, and having another conduit means for recycling the cooled oil fraction to said partial condensing means for condensing additional heavy oils from said oil vapors and gases by direct contact therewith.

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