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F. J. SANDERS

3,130,132

APPARATUS FOR RECOVERING OIL FROM OIL-BEARING MINERALS

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FIG. 1

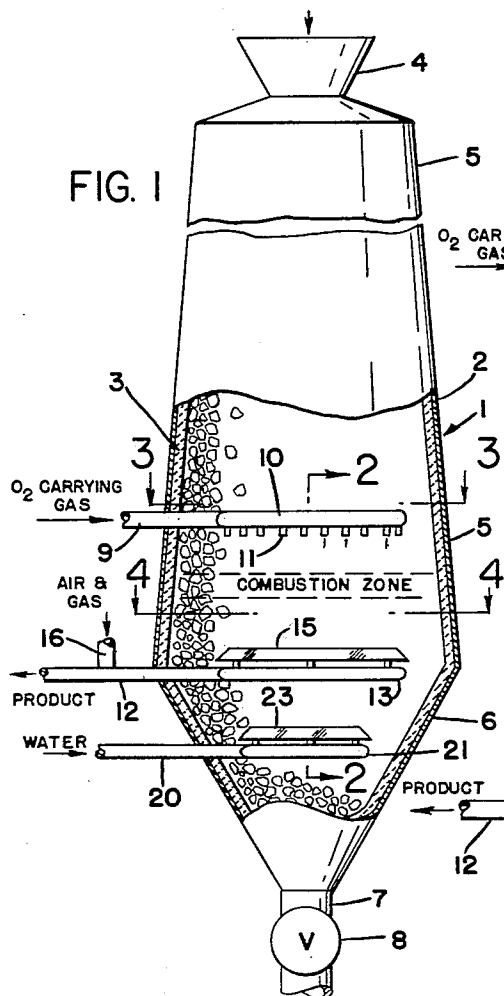


FIG. 3

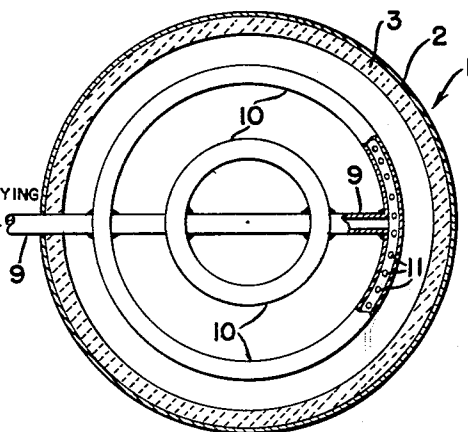


FIG. 4

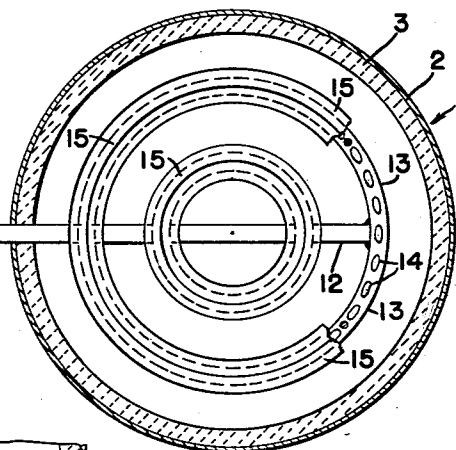
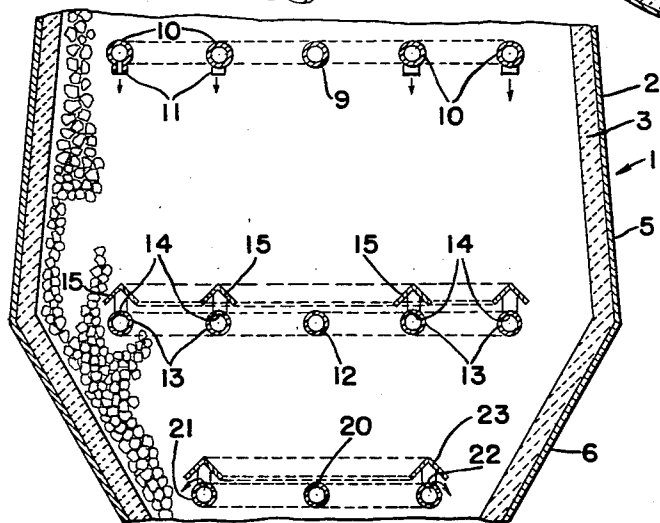


FIG. 2



INVENTOR.

FREDERICK J. SANDERS

BY

Robert R. Chapman

ATTORNEY

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APPARATUS FOR RECOVERING OIL FROM
OIL-BEARING MINERALS

Frederick J. Sanders, Shaker Heights, Ohio, assignor to
The Standard Oil Company, Cleveland, Ohio, a corporation of Ohio

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This invention relates to a method and apparatus for recovering oil from oil-bearing minerals. In particular, the present invention relates to a retorting process and a suitable apparatus for conducting such a process for the recovery of valuable hydrocarbon products from tar sands, oil shales, and the like.

Large deposits of oil-bearing minerals such as tar sands and oil shale have long been known to exist in the world and are found in great abundance particularly in this country and in Canada. Such deposits contain tremendous reserves of oil which are of great commercial significance in light of the diminishing world oil pool reserves, as well as of strategic importance since such deposits represent potential domestic source of petroleum products.

Due to the above considerations, there has been considerable interest in developing a commercially feasible process for recovering oil from such oil-bearing deposits. Various operational schemes have been proposed in the prior art to accomplish this objective and, in particular, retorting operations have been given wide attention.

Conceptually, the retorting of such oil-bearing solids is quite simple. Essentially it involves merely the step of heating the solids at sufficiently elevated temperatures to educt the oil and the step of recovering the products evolved. However, when it is desired to practice such operations commercially on oil-bearing deposits which typically contain only 10 to 20% of oil or oil-producing organic matter, it can be readily seen what large quantities of solids that must be handled and heated to relatively high temperatures in order to obtain comparatively small quantities of valuable oil products.

Obviously, therefore, in order to gain economic feasibility, retorting operations must be adapted to continuous operation so as to permit a high unit throughput or capacity. Furthermore, it is essential that the operation be substantially self-supporting so far as heat requirements are concerned, deriving, if possible, all the heat requirements by the direct combustion of part of the hydrocarbons present on the oil-bearing minerals with only the consumption of a minimum of valuable liquid and vapor oil products.

These basic considerations have been met by retorting operations long known in the prior art which suggest the recovery of oil products from oil-bearing minerals by passing the solids downwardly as a compact moving bed in countercurrent contact with hot gases rising from an internal combustion zone maintained in the lower regions of the retort so that the product oil vapors, together with the gaseous products of combustion, are removed from the top of the vessel while oil-free solids are removed at the bottom of the retorting vessel. This process, however, introduces other serious operational difficulties which makes such a retorting operation largely unattractive for commercially removing oil from tar sands or shale.

The oil present on tar sands is in its natural state but is found to be a very viscous oil, often with a kinematic viscosity in the range of 66 to over 6,000 centistokes at 210° F. Hence, when tar sands are treated by the afore-described process of the prior art, the oil, instead of being readily vaporized from the solids, tends to burn in

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place so that the gaseous recovery from the top of the retorting vessel is substantially low value combustion products including only slight yields of product oil vapors. This in-place burning of the oil also gives rise to coke formation on the mineral solids and increases the tendency of the solids to "bridge" within the retorting vessel which interferes with continuous operation of the process. Furthermore, if the combustion process of this retorting operation is controlled to be less severe so that the oil is not burned in-place on the solids, the oil on the particles near the combustion zone will not undergo sufficient vis-breaking or cracking to permit the oil to permeate the compact bed of colder solids in the retort above the combustion zone so that oil products may be effectively recovered from the upper regions of the retorting vessel.

Due to other operational difficulties, such a retorting process has also proved commercially unattractive for recovering oil from shale. It is well known that shale does not contain oil per se but rather contains an organic substance known as kerogen which, when heated at sufficiently high temperatures, converts into oil. Therefore, when shale is treated in the aforedescribed process of the prior art, the kerogen converts into an oil which in contradistinction to the viscous oil on tar sands is readily vaporized so as to be displaced from the residual mineral solids in the upward flowing stream of gases. However, with the practice of such a processing scheme, it will be obvious that substantial amounts of the product oil vapors carried upward from the retorting zone will be condensed during its contact with the incoming cold solids. These liquid products then flow by gravity downward in the retorting vessel toward the combustion zone, whereupon such products will be revaporized and rise again toward the top of the bed where the condensing action again occurs upon the cold solids. A refluxing condition is therefore developed with such overhead product recovery; and since these oil products for the most part are quite unstable thermally, such constant refluxing causes uncontrolled thermal cracking with a consequent high loss in potential oil yield. The presence of this refluxing condition also increases the tendency of the solid particles to agglomerate with the result that "clinkering" within the retorting and combustion zones is aggravated. Moreover, some other of the vaporized normally liquid hydrocarbons in contact with the cold solids condenses in the form of a fog which is not precipitated on the cold solids and therefore emerges from the retort in suspension in the gaseous product. This latter condition requires either that a substantial loss of liquid product be accepted or that unusually elaborate recovery equipment be provided to capture the suspended oil droplets. The prior art has recognized these undesirable conditions associated with this method of retorting shale and additional means have been suggested to remedy one or more of these difficulties. All such means involve either the introduction of extraneous materials in the retort or apparatus modifications, all of which either increase the cost of operation or make the operation more difficult of control.

A major object of this invention, therefore, is to provide a retorting method and apparatus for recovering oil from oil-bearing minerals so that the oil may be effectively removed from the solids and, furthermore, to avoid subjecting the product oil vapors to severe refluxing conditions with consequent overheating and loss in yield. Another object of this invention is to provide a retorting apparatus of compact and simple design adaptable to the continuous passage of oil-bearing solids downward through the vessel, thereby attaining a high throughput unit capacity. A still further object of this invention is to provide a process for recovering oil from oil-bearing minerals that is self-supporting in heat requirements for

retortation by utilizing direct internal combustion of part of the hydrocarbons present on such solids without appreciably affecting the potential yield of valuable liquid and vapor oil products.

The above and other objects of the invention are accomplished by a novel retorting operation and apparatus in which such operation may be suitably conducted whereby the hydrocarbon products educted from the oil-bearing solids are removed downstream from the hot combustion zone in a direction concurrent to the moving bed of solids in contradistinction to the usual direction of removing such hydrocarbon products. It is therefore contemplated in accordance with this invention to pass particulate oil-bearing solids downwardly by gravity as a compact moving bed through an elongated vertical vessel having a combustion zone maintained at a substantially fixed position in the lower regions of the retort wherein gaseous and liquid oil products resulting from the heating of the solids in the area of the combustion zone are removed from the retort downstream from the combustion zone. This reverse flow is accomplished by introducing an oxygen-containing gas, most conveniently air, in a downward direction within the retort at a level above the combustion zone and at a distance sufficiently remote from the top of the retort to facilitate the flow of gas downward and across the combustion zone. The oxygen-containing gas therefore supports the combustion process in the combustion zone as well as forcing the gaseous products of combustion and the oil products evolved from the solids immediately above the combustion zone downward from the combustion zone through the residual mineral matter present below said zone to be collected and removed by means of a product outlet conduit. It will be obvious, therefore, that the present method of retortation eliminates the operational difficulties heretofore discussed attendant to the retorting schemes of the prior art applied for the recovery of oil from tar sands or shale in which the hydrocarbon products are taken overhead countercurrent to the solid moving bed.

A better understanding of the method and apparatus of this invention will be gained from the following detailed description, taken together with the appended patent drawings, in which:

FIGURE 1 is an elevational view partly in section representing a schematic arrangement of the apparatus for carrying out the invention;

FIGURE 2 is a partial vertical section of FIGURE 1 taken along line 2—2 showing a detail of various of the elements within the retorting vessel;

FIGURE 3 is a transverse horizontal section taken along line 3—3 of FIGURE 1; and

FIGURE 4 is a transverse horizontal section taken along line 4—4 of FIGURE 1.

Referring now to the drawings, the reference numeral 1 refers generally to an elongated upright retorting vessel comprising a metal shell 2 suitably insulated with a refractory lining 3. A charge hopper 4 of any suitable construction is disposed at the top of the retort and is so adapted as to maintain a continuous feed of solid material into the top of the retorting vessel 1. The upper portion 5 of the retorting vessel 1 is substantially cylindrical in shape with the wall diverging outwardly in a downward direction to a maximum diameter for the vessel somewhat below the combustion zone of the unit so as to diminish the tendency of "bridging" or agglomeration of the particles within the combustion zone. The lower portion 6 of the retorting vessel 1 forms a frustum of a cone and converges into a central opening 7 in which is disposed a suitable valve means 8. The rate of flow of solids through the retort will, of course, be controlled by regulating the discharge of spent solids from valve 8 as will be described in greater detail hereinafter.

A series of conduits enter the retorting vessel 1 at various levels as shown in the drawings, extending horizontally across the unit. These conduits may be sup-

ported in any suitable manner within the retort, such as being directly supported from the walls of the retort. At the uppermost level is the oxygen-containing gas conduit 9. In order to achieve a uniform distribution of gas within the retort, conduit 9 is adapted with communicating circular tubes 10 which are arranged in a common horizontal plane with conduit 9 and are provided with openings 11 to supply gas in a downward direction. At a level lower in the retort is the product outlet conduit 12 adapted with communicating circular tubes 13. The topside of tubes 13 have slotted openings 14 to effect the removal of combustion gases and products from the retort in a manner to be described hereinafter.

Depending upon the size of the retorting vessel, conduits 9 and 12 each may be adapted with more or less than the two communicating circular tubes shown in the drawings. Furthermore, various other structural arrangements associated with conduits 9 and 12 will occur to those skilled in the art for supplying and removing, respectively, fluids from the retorting unit; and, consequently, there is no intention of limiting the invention to the exact details shown and described. It is only important that the structural arrangement associated with conduits 9 and 12 will provide for a uniform distribution of oxygen-containing gas from conduit 9 to the combustion zone and the even removal of products from the retort to the product outlet conduit 12.

Deflectors 15, which may conveniently be an angle bar positioned as an inverted V, is mounted above each of the tubes 13 and overlying the tubes 13 sufficiently to provide an angle of repose for the solids immediately above tubes 13 to prevent the entrainment of granular solid particles in the gases removed from the unit. Deflectors 15 may be mounted on tubes 13 in any suitable manner, such as by welding directly to tubes 13 or, if desired, deflectors 15 may be supported directly from the walls of the retort.

The level of conduit 9 in the retort is not critical. However, the position of conduit 9 will be somewhat determined by the relationship that must be observed between the height of the retort bed over conduit 9 to the distance in the retort between conduit 9 and conduit 12. For a fixed distance between the level of conduit 9 and conduit 12, the pressure drop from conduit 9 to conduit 12 will be inversely proportional to approximately the square of the distance from conduit 9 to the top of the retort. It therefore becomes obvious that in order to have the gases which are supplied through conduit 9 flowing substantially downward in the retort toward conduit 12, it is necessary to maintain the height of the retort above conduit 9 several times the distance between the levels of conduits 9 and 12. Consequently, in order to supply sufficient air in a downward direction within the retort for the effective removal of products by conduit 12 without the need for excessive pressures on the gas in conduit 9, it is desired to have the distance between conduits 9 and 12 to the height of the retort above conduit 9 maintained in a ratio of at least 1:4 and preferably 1:5 to 1:6. For example, if the retort height is to be 30 ft., conduit 9 would be located at a level 22 ft. from the top of the retort and conduit 12 would be located 26 ft. from the top of the retort so that the height above conduit 9 to the distance between conduit 9 and conduit 12 would be in the ratio of 5.5 to 1. Of course, a ratio of these distances less than 1:4 can be used if for other reasons it is desired to have a retort of relatively short over-all length if a corresponding adjustment of pressure on the oxygen-carrying gas supplied through conduit 9 is made.

Conduit 20 is positioned in the lower portion 6 of the retorting vessel 1. Conduit 20 supplies a cooling medium to the retort and is adapted with communicating circular tube 21 having openings 22 so as to introduce the cooling medium uniformly to this level in the retort. Deflector

23 is provided in the manner shown to protect the openings 22 from being clogged by solids.

The introduction of a cooling medium is not to be considered necessary for the successful operation of this process or apparatus but is advantageous in that the solids removed are more convenient to handle in a cool condition. Furthermore, when water is used as the cooling medium, the steam that is generated when the water contacts the hot solids is helpful in forming a seal against product leakage into outlet pipe 7 and is very helpful in stripping residual oil from the solid particles.

The operation of the retort will now be described in particular reference to the processing of tar sands. At the start of the operation, let it be assumed that the retorting vessel 1 has been filled from hopper 4 by gravity flow with tar sands crushed to a suitable particle size and that star valve 8 is closed. Hopper 4 contains an additional supply of crushed tar sands particles so that once valve 8 is opened the particles will pass continuously downward in an uninterrupted column. The size of the tar sands particles is not critical, but it is preferred that the particles will pass a 2-inch mesh sieve while being substantially free of silt and fines which might be entrained in the product gases and vapors leaving the retort. It may be desirable in initially starting the operation of the unit to fill the lower portion 6 of retorting vessel 1 with sand such as flint shot Ottawa ranging from 20 to 50 mesh in particle size, and filling the balance of the unit with the tar sands particles.

The retorting operation is started by igniting the hydrocarbons present on a horizontal strata of tar sands particles extending across the unit immediately above the level of conduit 9. To accomplish this, a mixture of a combustible gas and air may be temporarily injected through conduit 12 from conduit 16 and burned within the retort to heat the hydrocarbons to a temperature above their ignition temperature, which is approximately 500-600° F. When the combustion process is under way, the supply of gas is stopped while the supply of air is continued through conduit 12 to support combustion. As an alternate method of initiating the combustion process, an air-gas burner may be temporarily placed within the retort just above conduit 12 to again heat the hydrocarbons across this level of the retort to a temperature above their ignition temperature. When the combustion process is under way, the air-gas burner may then be removed from the side of the retort so as not to later interfere with the sustained operation of the process and air is temporarily supplied through conduit 12 to support combustion.

The combustion zone thus created is permitted to move upward a short distance from the original ignition level. It is most desirable that the combustion zone attains uniform depth across the bed as well as uniform temperatures. Thermal indicators well known to the art may be positioned within the retorting vessel to observe the conditions of the combustion zone so it will be possible to adjust air flow rates as required to reach desired conditions within the unit.

When the combustion zone reaches a level at least one-half the distance between the level of conduit 12 and the level of conduit 9 and has built up a uniform temperature across the bed in the range of 650 to 1100° F., the temporary supply of air through conduit 12 is stopped and a supply of air is introduced through conduit 9. This supply of air may be preheated if desired.

During the initial ignition period, the products of combustion move upward in the retort and are cooled by the unheated particles above the combustion zone. In this comparatively brief period of time, a small band of oil contained on the particles above is displaced by such gas flow; and when the reverse flow of air from conduit 9 reaches this area, these liquid products, together with products of combustion, flow downward in the retort toward product outlet conduit 12, and the combustion

process continues with relatively even temperatures throughout the combustion zone.

After the flow of air has been reversed, the temperature in the combustion zone is continued in the range of 650 to 1100° F. for sustained operation. At temperatures below 650° F. the viscous oil present on the tar sands is not effectively removed from the mineral particles. At temperatures substantially greater than 1100° F. the combustion reaction progresses too vigorously and the oil burns in-place, giving off substantially all combustion gases with very little yields of valuable oil products.

Valve 8 is now opened and the rate of discharge of residual solids from the retort is regulated so as to maintain the level of the combustion zone constant for the continued operation of the unit, and the rate of feed of fresh particles to restoring vessel 1 from hopper 4 is equal to said rate of discharge.

It is desirable that no more oxygen be introduced by way of conduit 9 than will be consumed in the reactions at the combustion zone. In this manner, no further combustion of the oil products can occur while these products pass downward in the retort toward conduit 12. Therefore, it will be obvious that when using air as the oxygen-containing gas that if the rate of air supplied through conduit 9 to attain the desired temperature level in the combustion zone is inadequate to effectively force the oil products and the combustion products to flow downwardly in the retort, then some extra non-combustible gas such as nitrogen must be added with the air to cause such a result.

The heat from the combustion zone is sufficient to educt the hydrocarbons from the oil-bearing solids immediately above the combustion zone as vapors and liquid. The actual distribution of product between the vapor and liquid states will depend in great part on the temperature level maintained in the combustion zone. The products are forced across the combustion zone and pass downwardly in the retort through the residual solids to the open areas found around tubes 13 due to deflectors 15. The liquid and vapor oil products entering these open areas are readily collected in tubes 13 by means of slots 14, together with the gaseous combustion products and steam which is rising from the lower portion of the retort. The products so entering tubes 13 are withdrawn from the retorting vessel by means of conduit 12 into a recovery system forming no part of this invention where they are to be cooled, condensed, and put in storage. The products, while passing through the residual solids below the combustion zone, do not cool or reunite to the solids in any appreciable degree since these solids are still hot from leaving the combustion zone. A slight vacuum of approximately 100 to 300 mm. may be placed on conduit 12 if desired to facilitate the removal of the products and combustion gases therethrough to the recovery system.

The residual solids flowing below conduit 12 are cooled by the introduction of water through conduit 20 and tube 22. The water is converted to steam on the hot solids which forms a seal against vapor leakage into outlet pipe 7. Some of the steam produced rises upwardly in the retort to be collected in tubes 13 and is quite helpful in stripping the descending solids of residual oil products and forcing these residual products upwardly in the retort to where they are also collected by tubes 13 and removed from the retort by means of conduit 12.

Although the method and apparatus described herein have been particularly directed to the recovery of valuable oil products from tar sands, the process may also be adapted with slight modifications which will be obvious to those skilled in the art for the recovery of oil from oil shale or any like solid substance.

It is therefore to be understood that the above description is merely illustrative of preferred embodiments of the invention, and hence Letters Patent is requested to

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cover these and such other variations which will remain within the spirit of the invention and the scope of the appended claims.

I claim:

1. In a retorting apparatus for recovering oil from oil-bearing mineral solids, the combination of a closed vertical retorting vessel having a substantially fixed combustion zone within a confined area of said vessel, a hopper means at the top of said retorting vessel for introducing crushed solids into said retorting vessel, an independent first inlet and first outlet conduit below said combustion zone for temporarily supplying an oxygen-containing gas to said combustion zone, an independent second inlet conduit above said combustion zone and down from the top of said retorting vessel equipped with a gas distributing means adapted to disperse an oxygen-containing gas uniformly over the cross-section of the mass of solids in a downwardly direction across said combustion zone when said temporary supply of oxygen-containing gas is discontinued through said first inlet conduit, said first outlet conduit for withdrawing a stream of combustion products and educted oil products from said retorting vessel, the height of the top of said retorting vessel above said second inlet conduit being maintained at several times the distance between said second inlet conduit and said first inlet and first outlet conduit an independent third inlet conduit below said first outlet conduit for introducing water into the lower regions of said retorting vessel uniformly over the cross-section of the mass of solids to cool oil-free solids after combustion thereof, and an independent second outlet conduit in the bottom of said retorting vessel for removing said oil-free solids therefrom.

2. In a retorting apparatus for recovering oil from tar sands particles, the combination of a closed elongated vertical retorting vessel having a substantially fixed combustion zone within a confined area of said vessel, a hopper means at the top of said retorting vessel for introducing crushed tar sands particles into said retort-

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ing vessel, an independent first inlet and first outlet conduit below said combustion zone for temporarily supplying an oxygen-containing gas upwardly in said retorting vessel to said combustion zone, an independent second inlet conduit above said combustion zone and down from the top of said retorting vessel equipped with a gas distributing means adapted to disperse an oxygen-containing gas uniformly over the cross-section of the mass of solids in a downwardly direction across said combustion zone when said temporary supply of oxygen-containing gas is discontinued through said first inlet conduit, said first outlet conduit below said combustion zone located at a distance from said second inlet conduit no greater than one-fourth the distance from the top of said retorting vessel to said second inlet conduit for withdrawing a stream of combustion products and educted oil products, an independent third inlet conduit situated below said first outlet conduit for introducing water into the lower regions of said retorting vessel uniformly over the cross-section of the mass of solids to cool oil-free solids after combustion thereof, and an independent second outlet conduit at the bottom of said retorting vessel for removing cool oil-free solids therefrom.

3. The apparatus according to claim 2 wherein the gas distributing means is a set of communicating circular tubes arranged in a common horizontal plane and provided with openings to supply gas in a downwardly direction.

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