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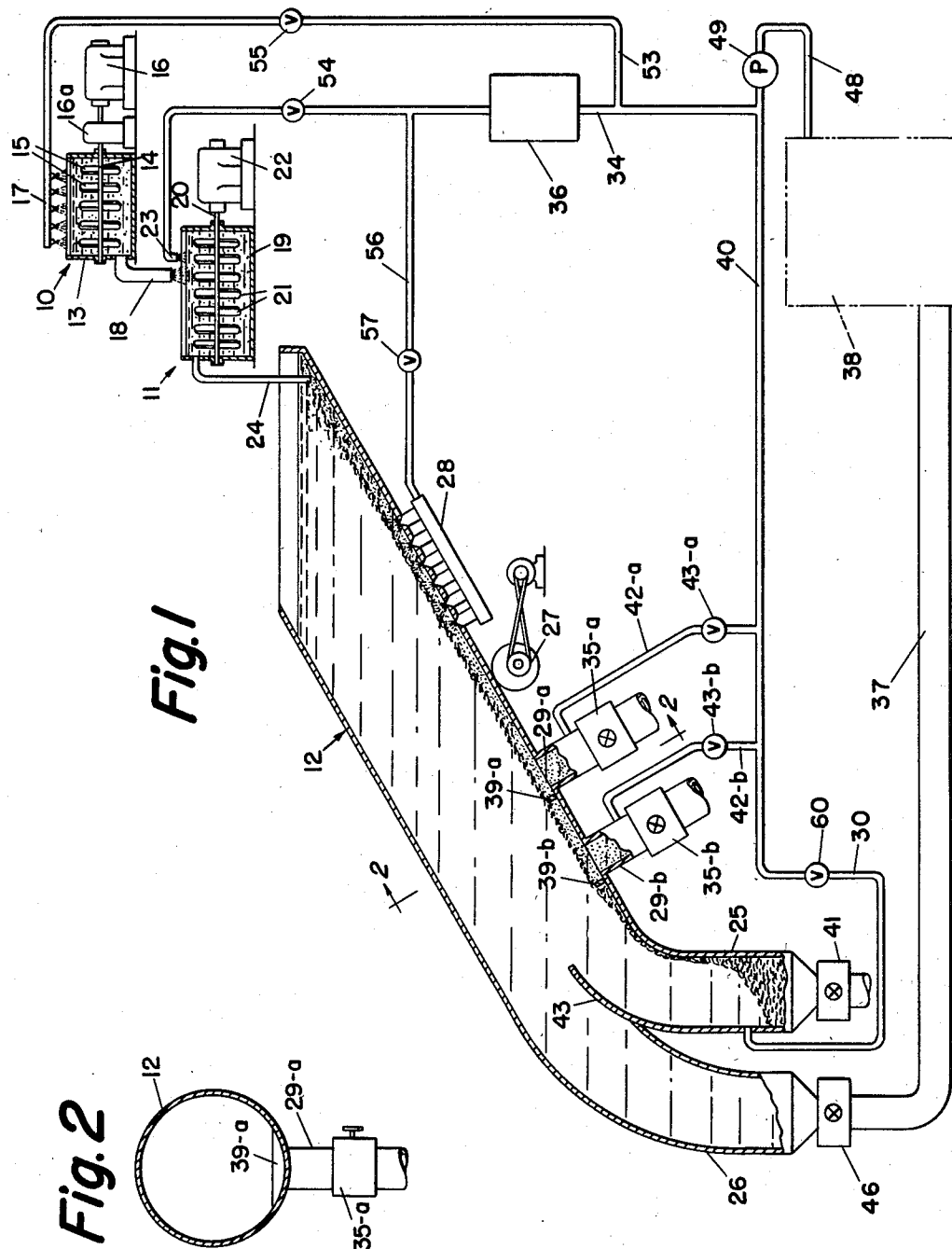
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2 Sheets-Sheet 1



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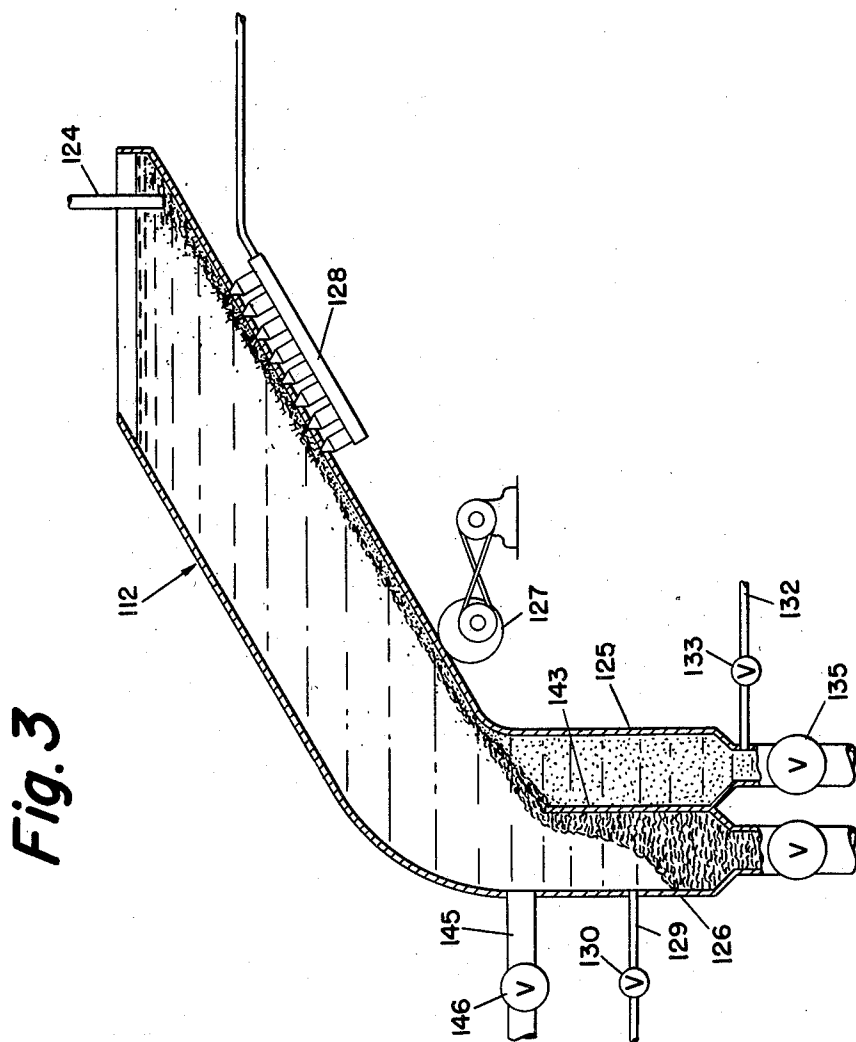
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RECOVERY OF OIL FROM BITUMINOUS SANDS

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13 Claims. (Cl. 196—1)

This invention relates to method and apparatus for the separation of oil from bituminous sands, such as Alberta tar sands, in which the oil has a higher density than water.

In various localities throughout the world, deposits of bituminous sands are found in which the oil or tarry matter has a density greater than 1.0. The most extensive and best known deposits of this type occur in the Province of Alberta in the Athabasca district. These Alberta tar sands extend for many miles and occur in thicknesses varying up to more than 200 feet, and probably constitute the largest presently known petroleum deposit of any type. The oil content of these sands typically is within the range of 10–20% by weight although sands with smaller and larger amounts of oil are not unusual, and the material generally contains a small proportion of water which is usually in the range of 1–5% by weight. The water is present in the form of films surrounding the individual sand grains and insulating them from the oil or tar which fills the interstices of the mass. The sand tends to have a preferential attraction for the oil and would be wetter by it rather than by water if given a suitable opportunity. The oil or tar generally has a specific gravity varying within the range of 1.00–1.04. The bituminous sands also generally contain clay or silt in varying amounts.

Various methods has been proposed heretofore for extracting the oil from bituminous sands such as Alberta tar sand, but none of these has had any substantial degree of commercial success. The oil obtained from these sands is a viscous tarry material and in its crude state does not command a high price; hence, any method suitable for recovering it must involve a minimum expense to be attractive for commercial practice. In the methods heretofore proposed operating costs have been sufficiently high so that the processes have not been economic for large commercial scale practice.

Practice of the methods heretofore proposed generally has involved either heating of the tar sands or the use of an oil solvent or both. The application of at least one of these procedures has been thought to be necessary in order to secure satisfactory extraction of the oil phase from the sand particles. However, either the use of heat in the extraction operation or the employment of an oil solvent which must thereafter be recovered for re-use in the process, entails expense which adds to the cost of the operation.

The two best known methods proposed for the separation of Alberta tar sands are known as the "hot water method" and the "cold water method." In the former the tar sand is jetted with steam and mulled with a small proportion of water at about 176° F.; and the pulp is then dropped into a turbulent stream of circulating water and carried to a separation cell maintained at about 185° F. wherein the oil rises to the top as a froth which is drawn off. Considerable expense is thus involved in

heating of the sand mass and maintaining the temperature of the circulating water.

The so-called "cold water method" does not involve heating the tar sand other than whatever heating might be required to conduct the operation at a temperature of 73–81° F. which is rather critical. The process involves milling a mixture of the tar sand, kerosene, water and soda ash and then settling at a temperature within the specified range. A mixture of oil and kerosene floats to the top of the settling zone and is removed. This process thus requires the use of an oil solvent which, for a commercially practicable operation, would have to be distilled from the extracted oil for re-use in the process. This distillation step adds to the expense by requiring additional equipment as well as heat.

The present invention is directed to the separation of bituminous sands in a manner such that no oil solvent is required and no heating is required to effect the separation. The invention thus provides a more economical procedure for treating bituminous sands such as Alberta tar sand. Furthermore, it achieves a better purification of the oil for the reason that the clay or silt, which is naturally associated with the bituminous sands, is more effectively removed than by the other processes which involve the use of elevated temperatures or oil solvents.

Briefly, the process of the present invention involves mulling the bituminous sand with a minor amount of water until the pulp has reached a certain state. The pulp is then vigorously mixed with a large volume of water and the mixture is fed into an inclined conduit which functions as the separating zone, the conduit being inclined at an angle of 28–35°. The dispersion of mulled tar sands in water is fed at a low temperature—below 50° F.—into the conduit which is maintained filled with liquid, and the conduit is subjected to vibrations to aid the flow of material down the inclined bottom of the conduit. This causes the mixture to separate effectively into a lower layer of sand particles, an intermediate layer of oil and an upper water layer containing the clay or silt which was present in the tar sands charged. The lower layer of sand is trapped and drawn off, while the oil and water layers are also separately withdrawn from the separation zone.

The invention is described more specifically in connection with the accompanying drawings in which:

Fig. 1 is a diagrammatic view, partly in section of one form of apparatus for practicing the invention;

Fig. 2 is a sectional view taken on the plane indicated by the line 2—2 in Fig. 1; and

Fig. 3 is a sectional view of another form of apparatus constituting the separation zone for operating according to the invention.

Referring to Figs. 1 and 2, the apparatus illustrated comprises agitating means for pulping the tar sands and then forming an aqueous dispersion of the pump, and a separating zone for resolving the dispersion into its constituent parts. The agitating means illustrated consists of a pug mill generally indicated as 10 and an agitator generally indicated as 11, each of these being of conventional construction. The separating zone comprises a sloping conduit generally indicated as 12. Means hereinafter described are provided for supplying water to the agitating and separating zones and for handling the materials withdrawn from the separating zone.

The pug mill 10 comprises a tank 13 in which a pair of parallel shafts 14 are journaled. (Only one shaft 14 is visible in Fig. 1.) The shafts each have a plurality of radial arms 15 and are rotated slowly in the same direction by a motor 16 through reduction gearing 16a. A pipe 17 from which water is sprayed is located above the tank 13. Near the bottom, the tank 13 has an outlet

18 through which the pulp passes to the agitator 11. The agitator comprises a tank 19 in which is disposed one or more shafts 20, having a greater number of radial arms 21 than the shafts 14 of the pug mill. Shafts 20 are rotated at a high speed by a motor 22 to effect vigorous mixing of the pulp with cold water. A water supply 23, through which a relatively large volume of water can be fed, is located adjacent the inlet 18. The tank 19 has an outlet 24 near the top, from which the aqueous dispersion of tar sand is passed to the settling zone 12.

The inclined conduit 12 which functions as the separating zone may have various cross-sectional shapes, but is shown in Fig. 2 in the form of a circular pipe. It is important that the bottom surface of the conduit be inclined at an angle within the range of 28–35°, more preferably 30–31°. If the angle of inclination is less than 28°, the sand and tar fed from pipe 24 will not flow properly down the incline, while with the angle greater than 35° the material tends to flow too fast to separate properly. Conduit 12 is resiliently supported, and a vibrator 27 is provided so that the conduit may be continuously vibrated to aid in maintaining flow of the sand layer. The vibrator is shown in the drawing as comprising a motor driven eccentric shaft, but it may be a solenoid-operated electrical vibrator or any other form of apparatus suitable for subjecting conduit 12 to vibrations.

As a further aid in facilitating flow of the sand along the bottom of conduit 12, it is preferable to provide a series of water injection lines 28 through which slow streams or trickles of water may be introduced into the flowing sand. This prevents the sand from packing and maintains it in a more or less quicksand state. It also aids in effecting separation of the oil from the sand layer.

Along the bottom of conduit 12 adjacent its downstream end, means are provided for trapping the sand so that it can be withdrawn separately. As shown in Figs. 1 and 2, such means may comprise lines 29-a and 29-b containing suitable valves 35-a and 35-b adapted to regulate the rate of withdrawal of the sand. Within the conduit 12 baffles 39-a and 39-b are positioned adjacent the downstream sides of sand outlets 29-a and 29-b to aid in trapping the sand. While the apparatus is illustrated in Fig. 1 with two sand outlets, it will be understood that the operation may be conducted with only one such outlet or with more than two outlets if desired.

In order to prevent the sand from packing firmly in draw-off lines 29-a and 29-b and to facilitate its withdrawal through valves 35-a and 35-b, water supply lines 42-a and 42-b, having valves 43-a and 43-b, are provided. Water is slowly introduced through these lines into the sand just above valves 35-a and 35-b to maintain it in slightly expanded state so that its removal through the valves can be more readily regulated. The sand thus removed is disposed of in any manner desired.

Beyond the last sand draw-off line, the apparatus is provided with means for collecting and withdrawing the tar layer as a separate stream. Conduit 12 has two downwardly extending chambers 25 and 26 at its lower end, which function as separate sections from which the oil and water are drawn off respectively. A baffle 43 extends upwardly from the junction of chambers 25 and 26 preferably to a height slightly above the top of baffle 39-b. The oil passes over baffle 39-b as a thin layer and flows along the curved bottom side of the conduit into chamber 25 where it is collected. A valve 41 is provided at the bottom of chamber 25 for removing the oil and passing it to a suitable receiving tank (not shown). A water line 30 containing valve 60 is connected with chamber 25 at a level above the normal oil level, so that a slow stream of water can be introduced above the oil. This is important in preventing clay or silt from settling in chamber 25 and thereby contaminating the oil which is withdrawn from it. The water introduced through line 30 causes a slow upward flow which carries the clay or silt over baffle 43 into chamber 26 along with the main

flow of water. By this arrangement, practically all of the clay or silt that was in the bituminous sand fed to the system is contained in the water layer which flows down into chamber 26.

The water layer from the separation zone is withdrawn through valve 46 at the bottom of chamber 26 and is sent through line 37 to a settling pond 38, indicated diagrammatically in Fig. 1 by dashed lines. A sufficiently large settling pond will provide adequate time to allow most of the clay or silt to settle from the water which can then be re-used. The supernatant water is recirculated through the system by means of line 48 and pump 49, the bulk of it flowing through line 34, cooler 36, valve 54 and line 23 to agitator 11. The purpose of including cooler 36 is explained hereinafter. The smaller amount of water required for the pug mill 10 is supplied by means of line 53, valve 55 and line 17. The slow flow of water for injection lines 28 on the lower side of conduit 12 is provided through line 56 and valve 57, while the water for sand draw-off lines 29-a and 29-b and for chamber 25 is supplied through line 40.

Fig. 3 illustrates a more simplified form of apparatus which can be utilized as the separating zone for the present process. The separator in this case comprises an inclined conduit 112 which terminates in a downwardly extending section which is divided by baffle 143 into two chambers 125 and 126. The conduit is provided with water inlets 128 adjacent its bottom wall for introducing slow streams of water at spaced points into the sand layer as previously described, and with a vibrator 127. In this case the downwardly extending section functions both as a sand trap and as a collector for the oil layer. As shown in Fig. 3, the feed mixture, which is introduced through line 124 from agitating apparatus as previously described, stratifies into the three layers; and the sand layer passes from the inclined conduit downwardly into chamber 125 while the oil layer accumulates above the sand and passes over baffle 143 into the other chamber 126. Chamber 125 has an outlet valve 135 for regulating the rate of sand removal. Water may be fed slowly through line 132 and valve 133 into the sand at the base of chamber 125 in amount sufficient to prevent packing of the sand. The oil collecting chamber 126 is provided with a water line 129 containing valve 130 for introducing a slow stream of water that will cause an upflow and prevent settling of clay or silt into the oil layer. The water layer, containing substantially all the clay or silt, is removed from a higher level by means of line 145 and valve 146.

There are several important conditions that should be established for successful or most efficient operation of the process according to the invention. In the pug milling operation only a minor amount of water should be present—for example, 5–25% based on the mixture, with about 10–15% being preferred—and the mulling should be done at a temperature above 50° F. but preferably below 100° F. The recommended procedure is as follows: Tar sand in its natural state, broken into particles of size suitable for handling, is placed in the pug mill 10 and water containing a detergent is gradually added up to the desired minor amount. The detergent can be any of the well known surface active agents which are commercially available for detergent use. Its purpose is to aid in breaking the film of oil from around the sand grains, but its presence is not essential for successful operation of the process. The mixture at ordinary temperature is milled in the pug mill without any heating other than that which occurs due to working of the mass. The temperature of the mass typically may rise to about 80° F. It is important that the mixture be milled for a time sufficient to break the oil film from around the sand grains, which time can be ascertained by the appearance of clean grains of sand in the mass and the presence of discrete oil particles. At this stage the mixture should be discharged from the pug mill, since further milling

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will tend to cause the oil to stick to the sand grains and make it impossible to attain the desired separation.

In the agitator 11 the pulp obtained from the milling step is vigorously mixed with a large volume of cold water, generally at least ten times its volume being used. A typical proportion is 20 volumes of water for each volume of the pulp. It is particularly important here that the temperature of the water be sufficiently low so that the resulting mixture will have a temperature between freezing and 50° F. I have found that at temperatures below 50° F., the oil or tar is in a more or less plastic condition whereby it will still flow and yet have little or no tendency to stick to the sand grains or the equipment. Under these conditions it is capable of stratifying in a layer and moving through the system. Hence such low temperature condition greatly improves the separating efficiency of the operation.

The cold mixture at a temperature below 50° F. is passed from the agitator to the separating zone and should be fed gently beneath the water level near the lower side of the inclined conduit in order to minimize agitation therein. As previously stated, an important factor is the angle of inclination of the conduit, or at least of its bottom wall, which angle should be in the range of 28-35°, preferably about 30-31°. The sand and tar accumulate along the bottom wall of the conduit; and with the aid of the vibrations to which the conduit is subjected and, by virtue of its angle of inclination, they flow along the wall at a rate which permits the oil particles to stratify as a layer above the sand. This is aided, as previously described, by the introduction of slow streams of water into the sand layer at spaced points along the bottom of the conduit. The resulting sand layer is trapped and diverted downwardly, while the oil layer which has formed on top of the sand flows along a path beyond that of the sand and is separately removed.

It is noteworthy that the foregoing procedure, which avoids any frothing of the oil as well as the use of any oil diluent as in other processes, is particularly effective in getting rid of the clay or silt, since this material is substantially all dispersed in and retained by the water layer. Re-use of the water, after the clay or silt has been settled from it in the settling pond avoids the loss of detergent and minimizes the amount of it used for continuous practice of the process.

The cooler 36, as illustrated in Fig. 1, is provided to insure that the water, which is used to disperse the mulled tar sand, will be cold enough so that the separating step will be conducted at a temperature below 50° F. as previously specified. However, in cold climates such as in the Athabasca district of Alberta, the use of such cooling means may not be necessary during most of the time, as the available water usually will have the desired low temperature. When necessary, cooling of the water, as schematically illustrated by cooler 36, may conveniently and economically be done by well known evaporation methods, although any other desired procedure may be employed.

The foregoing description is directed to illustrative embodiments of apparatus and procedure for practicing the invention, and it will be understood that various modifications may be made without departing from the scope of the invention. By way of example, while the inclined conduit has been illustrated as having a circular cross-section, it also may be ovate, rectangular, triangular, or the like.

What I claim is:

1. Method of separating oil from bituminous sands, such as Alberta tar sands, in which the oil has a density greater than that of water, which comprises: mulling the bituminous sand with a minor amount of water at a temperature above 50° F. for a time sufficient to break the oil film from around the sand particles but insufficient to cause the oil to stick to the sand; vigorously mixing the mulled material with a large volume of cold water;

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feeding the resulting mixture at a temperature above freezing but below 50° F. into a separating zone having a bottom wall inclined at an angle of 28-35° and subjected to vibrations; flowing the mixture along the bottom wall while maintaining a water level in the upper part of the separating zone, whereby sand particles separate as a lower layer, oil separates as an intermediate layer and water containing clay or silt separates as an upper layer; and separately removing said layers.

2. Method of separating oil from bituminous sands, such as Alberta tar sands, in which the oil has a density greater than that of water, which comprises: mulling the bituminous sand with a minor amount of water at a temperature in the range of 50-100° F. for a time sufficient to break the oil film from around the sand particles but insufficient to cause the oil to stick to the sand; vigorously mixing the mulled material with a large volume of cold water; feeding the resulting mixture at a temperature above freezing but below 50° F. into a separating zone having a bottom wall inclined at an angle of 28-35° and subjected to vibrations; flowing the mixture along said bottom wall while maintaining a water level in the upper part of the separating zone, whereby sand particles separate as a lower layer, oil separates as an intermediate layer and water containing clay or silt separates as an upper layer; diverting the sand layer downwardly along a path more nearly vertical than said bottom and thereby separately removing it; removing oil along a path beyond the path of the sand; and separately removing the water layer containing clay or silt.

3. Method of separating oil from bituminous sands, such as Alberta tar sands, in which the oil has a density greater than that of water, which comprises: mulling the bituminous sand with 5-25% by volume of water containing a detergent at a temperature in the range of 50-100° F. for a time sufficient to break the oil film from around the sand particles but insufficient to cause the oil to stick to the sand; vigorously mixing the mulled material with at least 10 times its volume of cold water; feeding the resulting mixture at a temperature above freezing but below 50° F. into a separating zone having a bottom wall inclined at an angle of 28-35° and subjected to vibrations; flowing the mixture along said bottom wall while maintaining a liquid level in the upper part of the separating zone, whereby sand particles separate as a lower layer, oil separates as an intermediate layer and water containing clay or silt separates as an upper layer; and separately removing said layers.

4. Method of separating oil from bituminous sands, such as Alberta tar sands, in which the oil has a density greater than that of water, which comprises: mulling the bituminous sand with 5-25% by volume of water containing a detergent at a temperature in the range of 50-100° F. for a time sufficient to break the oil film from around the sand particles but insufficient to cause the oil to stick to the sand; vigorously mixing the mulled material with at least 10 times its volume of cold water; feeding the resulting mixture at a temperature above freezing but below 50° F. into a separating zone having a bottom wall inclined at an angle of 28-35° and subjected to vibrations; flowing the mixture along the bottom wall while maintaining a liquid level in the upper part of the separating zone, whereby sand particles separate as a lower layer, oil separates as an intermediate layer and water containing clay or silt separates as an upper layer; diverting the sand layer downwardly along a path more nearly vertical than said lower surface and thereby separately removing it; removing oil along a path beyond the path of the sand; and separately removing the water layer containing clay or silt.

5. Method according to claim 4 wherein slow streams of water are introduced upwardly at spaced points along said bottom wall to aid in preventing packing of the sand particles and in separating the oil from sand.

6. Method according to claim 2 wherein a slow stream

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of water is introduced into the diverted sand adjacent its locus of removal to aid in preventing packing of the sand particles.

7. Method according to claim 6 wherein slow streams of water are introduced upwardly at spaced points along said bottom wall to aid in preventing packing of the sand particles and in separating the oil from sand.

8. Apparatus for separating oil from bituminous sands, such as Alberta tar sands, in which the oil has a density greater than that of water, which comprises: a conduit adapted to be filled with liquid and having a bottom wall inclined at an angle of 28-35°; means for introducing a dispersion of mulled bituminous sand in water into the conduit adjacent the upper end of said inclined bottom wall; means for regulating the temperature of said dispersion below 50° F. but above freezing; means for vibrating the conduit to aid in causing the introduced material to flow down said bottom wall and separate into a lower sand layer, an intermediate oil layer and an upper water layer; means for introducing slow streams of water upwardly at spaced points along and through said bottom wall to aid in preventing packing of the sand particles and in separating the oil from sand; and means for separately removing said layers.

9. Apparatus for separating oil from bituminous sands, such as Alberta tar sands, in which the oil has a density greater than that of water, which comprises: a conduit adapted to be filled with liquid and having a bottom wall inclined at an angle of 28-35°; means for introducing a dispersion of mulled bituminous sand in water into the conduit adjacent the upper end of said inclined bottom wall; means for regulating the temperature of said dispersion below 50° F. but above freezing; means for vibrating the conduit to aid in causing the introduced material to flow down said bottom wall and separate into a lower sand layer, an intermediate oil layer and an upper water layer; means for introducing slow streams

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of water upwardly at spaced points along and through said bottom wall to aid in preventing packing of the sand particles and in separating the oil from sand; sand trapping means for separately diverting the sand layer into a downward path; means for drawing-off sand from the sand trapping means; means for separately drawing-off oil from the intermediate layer; and means for separately drawing off the water layer.

10. Apparatus according to claim 9 including means for introducing a slow stream of water into the sand trapping means to aid in preventing packing of the sand particles.

11. Method according to claim 1 wherein slow streams of water are introduced upwardly at spaced points along said bottom wall to aid in preventing packing of the sand particles and in separating the oil from sand.

12. Method according to claim 4 wherein a slow stream of water is introduced into the diverted sand adjacent its locus of removal to aid in preventing packing of the sand particles.

13. Method according to claim 12 wherein slow streams of water are introduced upwardly at spaced points along said bottom wall to aid in preventing packing of the sand particles and in separating the oil from sand.

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