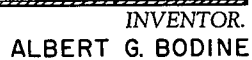


A. G. BODINE
ACOUSTIC METHOD FOR EXTRACTING HYDROCARBON
CONSTITUENTS FROM OIL-SANDS

3 Sheets-Sheet 1

Filed June 2, 1958



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CONSTITUENTS FROM OIL-SANDS

3,123,546

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3 Sheets-Sheet 2

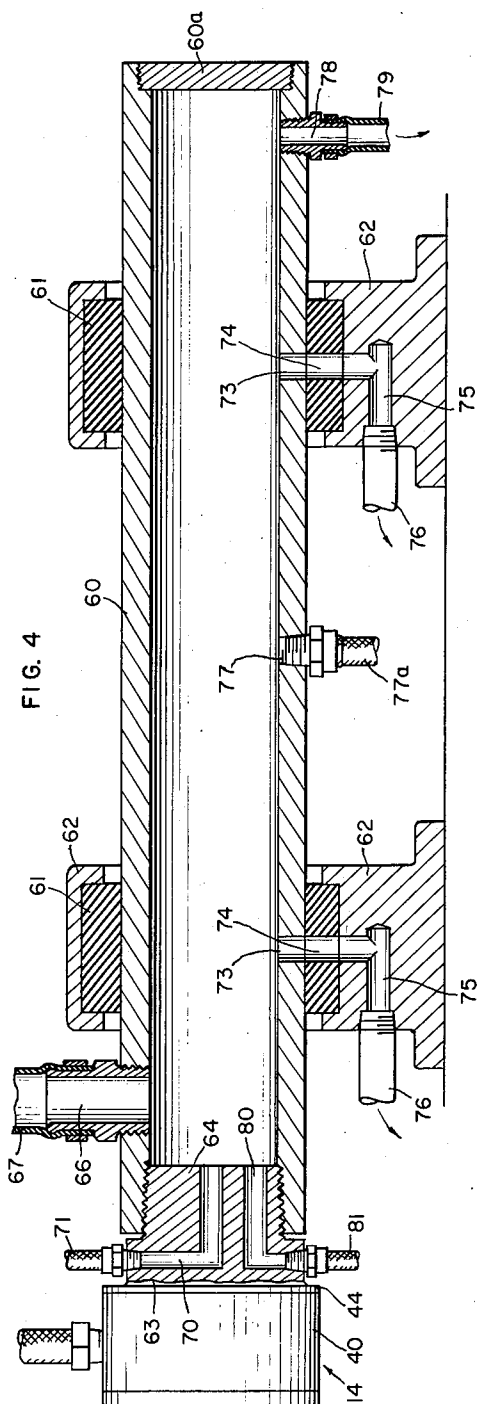


FIG. 3

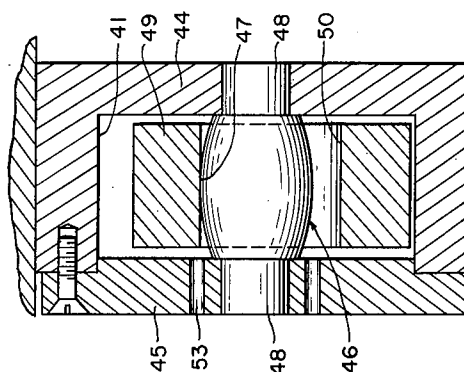


FIG. 2

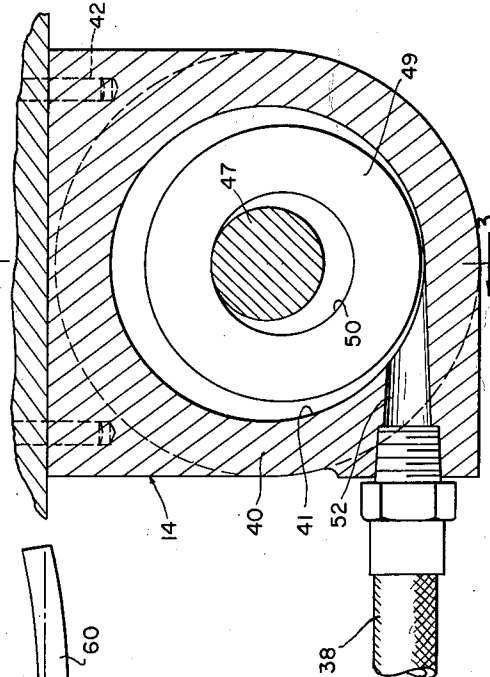
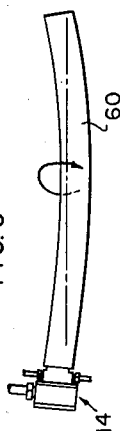


FIG. 5



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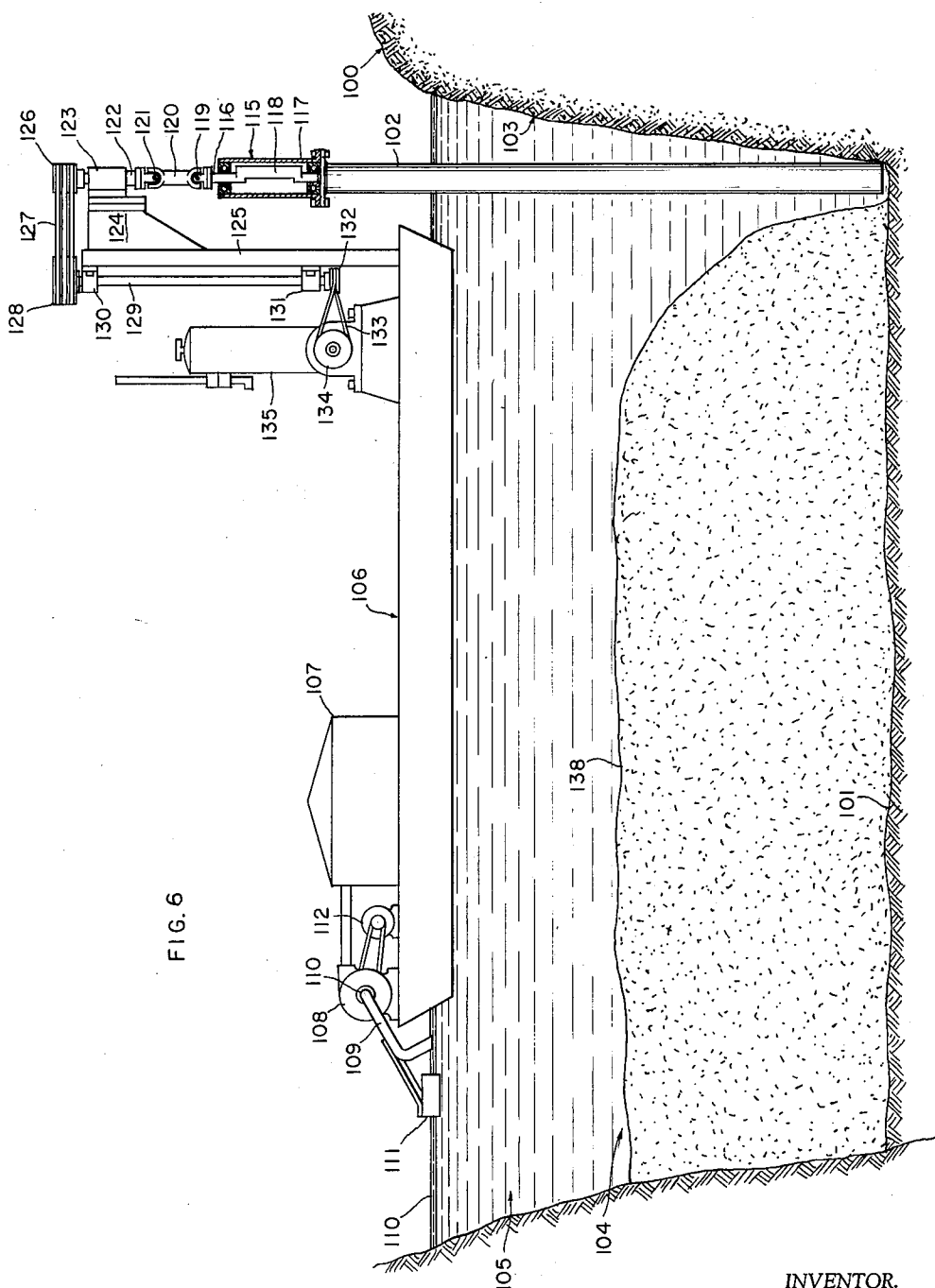


FIG. 6

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ACOUSTIC METHOD FOR EXTRACTING HYDRO-CARBON CONSTITUENTS FROM OIL-SANDS

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6 Claims. (Cl. 208—11)

This invention relates generally to processes and apparatus for extracting the hydrocarbon constituents from so-called tar-sands, and more particularly to a process and apparatus for accomplishing such purpose by use of high intensity sound waves.

There exist a number of petroleum reservoirs wherein the hydrocarbon content is held in a thick sandy mixture. Most of the known tar-sand structures are fairly shallow, dipping down usually only to some 1,000 to 2,000 feet, and in many regions occurring as outcrops for all practical purposes.

In most instances the oil and sand make up a somewhat pasty and viscous mixture, with the sand in a "free" form, rather than in a consolidated or sandstone type structure. In some regions the structure is almost solid in character, but in most such instances the solidity is more due to an almost solid form of the petroleum material itself, resulting from loss of volatile constituents over the ages. The mixtures encountered vary in all proportions from those which are mostly or largely sand to those which are mostly or largely petroleum.

All such petroleum material is valuable, and the only problem limiting or barring commercialization has been the lack of a good process for extracting and handling the material on a profitable commercial basis.

Attempts have been made from time to time to recover the petroleum from the large Athabasca tar-sands of Canada by scraping away the overburden and then scooping up the tar-sands for separation. Separation has been attempted by heating, centrifuging, etc. These separation processes have proved to be unduly expensive, and commercially uneconomic.

The general object of the present invention is accordingly the provision of a novel, economic process and apparatus for separating the petroleum constituent from such tar-sand mixtures by use of high intensity sound waves.

According to the present invention, the tar-sand material is subjected to high intensity sound waves. By sound waves, I do not imply the audible frequency spectrum, but, more broadly, waves of elastic compression and rarefaction travelling in the material at any suitable frequency, whether within, below or above the audible range. The applied sound waves set up elastic wave action in the tar-sand mixture, resulting in separation of the two ingredients. It might naturally be supposed that agitation of the mixed materials such as would occur through sound wave transmission therethrough would tend toward further mixture, rather than separation. The unexpected result of separation, which I have demonstrated, using treatment apparatus to be disclosed herein, may largely be attributed to peculiarly differing physical properties of the two ingredients contained in the tar-sand mixture. Thus, one ingredient, the tar, is of relatively low density, but high viscosity, meaning a complex acoustic impedance which is largely resistive, or of low phase angle; while the other ingredient, the sand, has relatively low resistive impedance, but because of substantial density, is of relatively large reactive impedance, and thus possesses a complex impedance of large phase angle. Other acoustic factors also appear to enter, in such a way as to favor separation of the materials, as will now be discussed.

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Sound wave action in the material results in the material experiencing high periodic accelerations, and such accelerations are very evidently a basic factor causing a separation of the petroleum from the sand, particularly since sonic acceleration is inversely proportioned to mass, and the densities of the sand and tar are substantially different. It may be noted at this point that acceleration varies with the square of the frequency of the sound wave, indicating increased effectiveness with increase in frequency.

Further, the sound wave transmission properties of tar and sand differ markedly. The velocity of a sound wave is proportional to the density of the material, and the velocity of propagation is accordingly markedly different for tar and sand, with the consequence that the vibratory responses of the tar and sand materials are different, and relative movement therebetween is compelled.

The situation may also be viewed from the standpoint of acoustic impedance, and mismatch of acoustic impedances between the sand and tar materials. Acoustic impedance of a material transmitting a sound wave may be considered to be the ratio of the sound pressure wave to the velocity (and amplitude) of particles of the material. Acoustic impedance also is related both to material viscosity and material density, and therefore differs greatly for tar and sand. When a sound wave successively traverses substances of markedly differing acoustic impedance such as tar and sand, the amplitude of particle oscillation thus differs for the sand material and the tar material, and the impedance mismatch therefore results in differential motion of the two materials, with resulting tendency for separation.

Also, as mentioned above, and possibly of even greater importance, I have further discovered that when a sound wave is propagated through a mixture of two materials whose acoustic impedances have substantially differing phase angles, phase shifts are introduced which result in substantial differential movements of the unlike materials. To be more specific, the tar material has a very high viscosity, and therefore a highly resistive impedance (low phase angle), while the sand material has low resistance, but, because of substantial density, has a high reactive impedance (large phase angle). The result is that the waves in the tar and sand material are of markedly differing phases. Relative movements of the two materials occur owing to such phase shift, and the materials accordingly are forced apart. Moreover, there is apparently an accompanying tendency for each of the two types of material to agglomerate. Thus, those portions of the mixture of like material, tending to oscillate in like phase, tend naturally not only to separate from materials oscillating at different phase, but to agglomerate with one another to form a wave transmission path of uniform impedance.

A further feature of the invention comprises the addition to the tar-sand of a suitable liquid, which may be water, before subjecting to the sound wave treatment. One typical treatment apparatus in accordance with the invention constitutes a batch container, with the walls functioning as a sound wave generation and/or transmission system. The liquid mentioned above may simply be added to the tar-sand in this container. The added water, or other liquid, is apparently helpful in that it provides a fluid medium of intermediate density and impedance. It is additionally very helpful and important in that it very greatly increases the degree of acoustic coupling between the sound wave source, e.g., the walls of the container, and the mixed sand and petroleum material.

In the operation of the process, assuming the tar-sand material to be placed in a container, and intense sound waves passed therethrough, the oil quickly migrates to the

surface of the sand. With liquid added to the batch, the material disintegrates as the sound wave action drives the liquid into the material, and the oil leaves the sand more completely, undoubtedly as a result of the sound waves being transmitted more effectively to and through the mass. The oil rises to the surface of the water (if water is used as the added liquid), and the sand collects in the bottom of the container. The sand settlement occurs no matter what the nature of the added liquid may be.

Suitable illustrative apparatus for carrying the invention into effect will now be described, reference being had to the accompanying drawings, in which:

FIG. 1 is a vertical longitudinal section through an apparatus in accordance with the invention;

FIG. 2 is a section taken through a vibration generator forming a part of the apparatus of FIG. 1;

FIG. 3 is a section taken on line 3—3 of FIG. 2;

FIG. 4 is a longitudinal section through an alternative form of the invention;

FIG. 5 is a diagram illustrating the type of elastic wave action undergone by the apparatus of FIG. 4; and

FIG. 6 shows a further application of the invention.

With reference now to the form of apparatus shown in FIG. 1, the numeral 10 designates generally a treatment chamber comprised of a cylindric sidewall 11, a thick bottom plate 12, and a flexible ring member 13 interconnecting the sidewall and bottom plate. A vibration generator or transducer 14 is mounted on the bottom of plate 12, and sets said plate into resonant vibration.

The cylindric sidewall 11 is suspended from a flat ring 15 which extends outwardly in a horizontal plane, and is mounted on a cylindric external casing 16. The latter is mounted at the bottom on a base ring 17, which is in turn mounted on a base consisting of a short cylindrical sidewall 18 and a bottom plate 19. For sound insulation purposes, there is preferably provided, midway between the treatment chamber 10 and the exterior casing 16, a cylindrical screen 20, and the space between this screen and the exterior casing 16 is packed with suitable sound insulation material 21, such as Micro-Lite. For the same purpose, a screen 22 extends across the top of the sidewall 18 of the base, and sound insulation material 23 is packed between this screen 22 and bottom plate 19. Also, preferably, the apparatus is provided with a sound insulated cover 24, comprised of a cylindric top and sidewall, and a screen 25 across the bottom thereof, sound insulation material 26 being packed therein, as indicated. This cover 24 may simply rest on ring 15, being prevented from dislodgement by the heads of assembly screws 27.

The bottom plate 12 of the treatment chamber 10 is suitably spaced above the base of the apparatus so as to accommodate the vibration generator 14, with sufficient space being provided to permit free access to generator 14 when desired. Access is had to this space through suitable openings 28 defined by sleeves 29 fitted between the exterior casing 16 and screen 20.

In the embodiment here shown, the flexible connecting ring 13 is designed in relation to the flexural sound wave pattern set up in the resonant bottom plate 12 by the vibration generator 14. The vibration generator, the details of an illustrative embodiment of which will be set forth presently, may be assumed to generate and apply to the bottom of plate 12, at its center, a vibration having a component of vibratory motion normal to the plate. Such vibration, when at the resonant frequency of the plate for a desired resonant mode of vibration, sets the plate into elastic vibration at substantial amplitude in the desired predetermined wave pattern. A desirable fundamental frequency wave pattern consists in an alternating upward and downward elastic "bowing" of the plate. In this action, there is an elastic vertical oscillation of the central area of the plate, a similar elastic vertical oscillation, but of opposite phase, of the rim portion of the plate, and an annular nodal region of minimized or zero oscillation between the two. The deflection amplitude of the central

area of the plate is maximum at the center, and tapers to zero at the nodal region. The deflection radially outward from the nodal region is of progressively increasing amplitude. In other words, the plate flexes elastically at the vibration frequency, deflecting upwardly in its central region while deflecting downwardly in its outer region, and then downwardly in the central region and upwardly in the outer region, while the intermediate nodal region remains substantially stationary.

The connecting ring 13 between the treatment chamber sidewall 11 and the bottom plate 12 has, as shown in the illustrative example, an inner flange 30 fastened to bottom plate 12, as by studs 31, and this mounting to the plate 12 is preferably located at, or just inside, the nodal region of plate 12. Rising from the outer periphery of flange 30 is the inner web 32 of an inverted box-section member 33, whose outer web is outwardly flanged for connection, as shown, to the lower end of chamber sidewall 11. The member 33 is fairly heavy and rigid, excepting for the web 32, which is relatively thin and adapted for flexure. This flexible web 32 is preferably located over the nodal region of the vibratory plate 12.

It will be seen that the vibratory plate 12 and vibration generator 14 are suspended through the ring 13 from the sidewall 11 of the chamber 10, which is in turn suspended by its top from the top of the exterior casing 16. In operation, the plate 12 vibrating in the resonant mode described hereinabove, bows alternately upwardly and downwardly, with its nodal region, just under the web 32, standing substantially stationary, at least as regards vertical displacement. However, certain vibratory rocking of the studs 31 and ring flange 30 in the nodal region will occur, and such motion is absorbed by flexure of the web 32, and so prevented from transmission to the side walls of the chamber. With the type of vibration generator 14 to be described, the plate 12 may also be vibrated in its own plane. Such component of vibration is also absorbed by the flexible web 32. Accordingly, the chamber stands substantially stationary, excepting for the described vibratory movement of the bottom plate 12.

Bottom plate 12 is provided with a discharge outlet 36, to which is coupled discharge hose 37, here shown as lead outwardly through opening 28. The vibration generator 14 is in this instance of an air-driven type, and air under pressure is conveyed thereto through air hose 38 lead in through one of the casing openings 28, as shown. The raw tar-sand material to be treated is generally available in lumps or chunks up to four or five inches in diameter, with a proportion of loose or fairly finely divided material. Ordinarily, this material is fairly dry. Such material is introduced into the chamber 10, and with this material I introduce a certain amount of liquid, which may be water, or hydrocarbon solvent, in an amount sufficient to bathe the material and to form a good coupling contact with the walls of the treatment chamber as well as between the chunks of material. The amount of liquid used is not critical and enough may be used to nearly or substantially cover the material to be treated. In some cases, where the material contains a large proportion of oil, the oil itself may furnish adequate coupling to the chamber walls and between the chunks or particles of material. This coupling liquid is of primary importance; and without a liquid coupling to the chamber, particularly to the lower vibratory plate 12, effective sonic wave transmission from the plate 12 through the material cannot be achieved. In my work with this apparatus, I have indeed found that the main part of the sound wave pattern transmitted through the batch is within the liquid. The vibratory plate 12, thus coupled intimately to the liquid, acts as a radiator of longitudinal sound waves which are transmitted upwards through the liquid and act upon the mixture of sand and tar contained therewithin. The high sonic accelerations, and other sonic influences mentioned above, resulting from this sound wave transmission cause the oil and sand to separate from one another, so that the contents of the

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chamber become and remain a sort of turbid mixture. This mixture is conducted from the lower end of the treatment chamber via the hose 37 to a settling vessel, not shown, wherein the sand readily settles to the bottom.

This process thus consists in radiating a longitudinal sound wave through the mix of tar-sand raw material and added liquid, so that the combined material is subjected to a longitudinal sound wave pattern generated by and radiated from the plate 12. Observing the process in operation, oil may be seen to quickly migrate to the surface of the material as the treatment is started. The lumps of material progressively disintegrate as the operation proceeds, apparently as the sound wave action drives the liquid into the material. As before indicated, the sound wave transmission path is from the sonic radiator plate 12 primarily through the liquid, so that sound wave action occurs in the liquid and is transmitted from the liquid into the material. Good sonic coupling is attained from the liquid to the particles of material, and substantial sound wave transmission thus occurs also within the body of tar-sand material. The sound wave action in the liquid appears to drive the liquid into the lumps of material, promoting disintegration, and consequently additional coupling between the liquid and the material. This disintegration probably also ensues directly from sound wave transmission directly through the bodies of material. The high sonic accelerations experienced by the material, as described heretofore, and the other sonic wave influences mentioned in the foregoing, cooperate to break up the material, and to break or separate the sand from the tar.

As mentioned heretofore, the sound wave generator or transducer 14 may be of any suitable type capable of producing vibration in the desired frequency range at adequate power. One simple illustrative form of generator is shown in FIGS. 2 and 3, and will now be described. The generator comprises a housing 40 formed with a cylindrical chamber 41, the housing being secured to plate 12 as by means of studs 42. The housing is formed with one integral side closure wall 44, and its opposite side is fitted with a removable closure wall 45. A center pin of axle 46 of circular cross-section, preferably formed with a central crowned or barrel-shaped portion 47, has reduced end portions 48 set tightly into walls 44 and 45. The crowned periphery of this axle 46 provides a roller bearing surface, which is surrounded by a roller in the form of an inertia ring 49, having a circular central opening 50 of substantially larger diameter than that of the portion 47 of the pin 46, the outer periphery of the ring having a suitable clearance with the periphery of the chamber 41 when hanging on the pin 46, or spinning thereabout.

The inertia ring 49 is caused to roll or spin about the pin 46 by a fluid jet, either air under pressure, steam, or liquid, introduced through an injection nozzle 52 formed in the housing 40 tangential to the periphery of the circular chamber 41, such fluid being introduced to the nozzle 52 via the aforementioned hose 38. The spent driving fluid may be discharged from chamber 41 as by way of orifices 53 formed in closure plates 45 as close to the center of the chamber 41 as possible.

The tangentially-introduced fluid causes the inertia ring 49 to roll or spin on the axle 46, and the centrifugal force exerted by the spinning ring on the axle and thence transmitted to the housing 40 and from there to the plate 12, applies vibratory forces to the plate, with a component of vibration normal to the plate. The spin frequency of the inertia ring depends upon the pressure of the air supply, and may be readily regulated to match or approximate the desired resonant frequency of the plate 12.

FIG. 4 shows a modified form of apparatus for carrying the process of the invention into effect. In said figure numeral 60 designates generally an elastic gyratorially vibratory tube, typically composed of steel or Duraluminum, closed at one end, as by a threaded plug 60a, and at the other by the presently described vibration gen-

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erator 14, is carried by spaced supports, here shown as rubber blocks or sleeves 61 supported by mountings 62, and these supports, while placed at the nodes of the standing wave generated in the tube, are preferably such as will permit a substantial degree of elastic vibration in all directions in planes transverse of the tube. The tube does not rotate bodily, but portions thereof spaced from the nodal points of the standing wave set up in the tube gyrate in circular paths by elastic bending of portions of the tube from its neutral position (see the exaggerated diagram of FIG. 5). Such circular motion or gyration is a form of harmonic vibration, and may be analyzed as the resultant of two component linear transverse harmonic vibrations occurring at right angles to one another with 90° phase difference. The rubber blocks 61 will be seen to comprise compliant mountings permitting such gyratory action as may occur at the velocity nodes of the wave.

The vibration generator, generally designated by numeral 14, and which may be essentially the same as the generator 14 of the first-described embodiment, has secured to its sidewall 44 a flanged fitting 63 formed with a threaded projection 64 screwed into the end of tube 60.

In operation, fluid under pressure introduced into the generator causes the inertia ring 49 (see FIGS. 2 and 3) to roll or spin on the axle 47, and the centrifugal force exerted by the spinning ring on the axle, and thence transmitted to the housing 40 and from there to the end of the tube 60, elastically bends the end portion of the tube and moves it bodily about in a circular path. Each point on the tube describes a small circle in a plane transverse to the tube. As earlier mentioned, this gyratory motion of the end portion of the tube is a form of harmonic vibration, being the resultant of two perpendicular transverse linear harmonic vibrations in quadrature.

FIG. 5 shows, with some degree of exaggeration, the tube 60 undergoing gyratory elastic motion characteristic of a standing wave for fundamental resonant frequency of the tube for longitudinally propagated transverse elastic waves. It will be understood that the standing wave diagrammatically indicated at FIG. 5 results from the transmission longitudinally along the tube, from the generator 14, of elastic deformation waves whose components of vibration are in transverse planes. These waves are reflected from the far end of the tube, and through interference with a succeeding forwardly propagated wave, the standing wave is established as indicated. Nodal points occur at sections of the tube approximately one quarter of its length from each of its ends, while the two ends of the tube and its center are at antinodes of the standing wave. In each transverse plane of the tube, the tube thus undergoes a gyratory motion, and the amplitude of this motion is maximized at the nodal points where the tube is supported by the rubber blocks 61, and is maximized at the antinodes.

The speed of rotation of the inertia ring 49 about the axle 47 depends at first upon the fluid jet which drives it. However, as the inertia ring is driven at a number of revolutions per second which approaches or approximates the resonant frequency of the tube for the described transverse mode of standing wave vibration, the inertia ring 49 then locks in or synchronizes at that frequency, and thereafter spins about its axle at a number of circuits per second equal to the resonant frequency for the tube 60 and housing 40.

The tube may be equipped with various intake and discharge openings. I have shown in FIG. 4 an inlet nipple 66 connected into tube 60 approximately midway between the tube support 61 and the generator 14, or in other words, approximately midway between a velocity node and a velocity antinode of the standing wave. This nipple receives material to be separated via a flexible hose 67.

A liquid inlet passageway 70, fed from a hose 71, extends downwardly into plug 64 and thence turns to discharge into the end of tube 60.

At each of the velocity nodal points of tube 60, the tube

is formed with a downwardly extending discharge port 73, registering with a port 74 in block 61, and the latter leads to passageway 75 in mounting 62 and thence to discharge hose 76.

At the midpoint of the tube 60, on the bottom side thereof, there is formed a discharge port 77 leading to a flexible discharge hose 77a. A similar discharge port 78 is formed in the bottom of tube 60 near the right hand end thereof and communicates with flexible discharge hose 79. Finally, there may be a discharge passageway 80 at the generator end of the tube 60, leading out through plug 64 to a hose 81.

The tar-sand material to be separated is introduced through the inlet 66, so as to fill, or partially fill, the tube 60. Liquid sufficient to afford good sonic coupling is introduced via passageway 70. Operation of the gyrator vibration generator 14 establishes the previously described gyratory acoustic standing wave in the tube 60, and the latter acts as a sonic wave radiator to transmit sound waves to and through the material, the introduced liquid serving as a coupling medium with the walls of the tube, as a wave transmission path to and around the tar-sand material, and also as a coupling to and between the particles of material to be treated. The particles of material are thus subjected to intensive sound waves, and because of the high accelerations involved in the sound wave action, and the other sonic influences mentioned in the foregoing, particularly the effects owing to differences of acoustic impedance of the two components of the material, the sand and tar rapidly disintegrate and separate from one another. With an apparatus of the character of FIG. 4, there is a tendency for separated materials of one density to migrate toward the nodes of the tube, and separated materials of another density to migrate toward the antinodes. By the provision of separate outlets at the nodes and antinodes, one material may be circulated out via the nodal outlets, and the other via the antinodal outlets. If with the materials in hand such separation is not satisfactory, or necessary, the materials may be drawn off through a single outlet, and later separated in a settling tank. The apparatus of FIG. 4 will be seen to be a continuous flow apparatus, as distinguished from the batch process apparatus of FIG. 1.

FIG. 6 shows an application of the invention wherein the process is performed directly within an outcrop or uncovered body of the tar-sand material, the material being continuously sonically mined within a pit, and also sonically treated for separation by the same sonic equipment directly within the pit formed by the mining operation. An outcrop of the tar-sand material is designated generally at 100, and this material has been mined to a depth or floor indicated at 101 by operation of a sonic vibratory bar 102 moved against the wall 103 of the formation, thus forming a pit 104. The process may be initiated by first excavating a pit large enough to accommodate the equipment to be described, and the pit is then enlarged by working the equipment against its sidewall.

The pit is filled with water, as indicated at 105, and floated therein is a barge 106, equipped with any suitable propelling means, not shown, which carries the sonic mining equipment, and which may also, if desired, carry a storage vessel 107 into which oil recovered in the operation of the process may be pumped. To this end, the barge may be equipped with a pump 108 to which an oil suction pipe 109 is coupled by means of a swing joint at 110, the pick-up end of pipe 109 being properly positioned to take up oil forming in a surface layer 110 by means of a float 111. Pump 10 is shown driven by an electric motor 112.

The sonic vibratory bar 102 may comprise a solid steel shaft, hung in a vertical position, and to the upper end of which is coupled a sonic vibration generator 115. Generator 115 may take various forms within the scope of the invention, but is here shown in a simple embodi-

ment comprising a vertical shaft 116 journaled at its upper and lower ends in suitable bearings mounted within a housing 117, and provided with an eccentric mass 118 adapted to produce a substantial centrifugal force when the shaft is rotated at suitable speed.

The upper end of shaft 116 is coupled by means of a universal joint 119 to the lower end of a link 120 whose upper end is coupled by means of another universal joint 121 to a shaft 122 journaled in a bearing 123 mounted on a bracket 124 projecting laterally from a post 125 erected at one end of barge 106. Shaft 122 has at the top a multiple grooved pulley 126 connected by belts 127 to a multiple grooved pulley 128 on the upper end of a vertical drive shaft 129 journaled at the top in a bearing 130 and at the bottom in a bearing 131, both bearings being mounted on post 125, as shown. The lower end of shaft 129 carries a pulley 132 connected by belt 133 to a pulley 134 on the drive shaft of a variable speed internal combustion engine 135. Generator 115 is thus driven at a selected speed from engine 135. Bar 102 sometimes tends to rotate slowly, but this is easily compensated by adjusting the engine speed.

Rotation of the eccentrically-weighted shaft 116 of vibration generator 115 produces a centrifugal force which is exerted through the shaft bearings of the generator to its housing, and thence applied to the upper end of shaft 102, to which the generator housing is securely fastened. Thereby, a gyratory elastic deformation wave is set up in the elastic shaft or bar 102, of the same nature as described previously in connection with the embodiment of FIGS. 2-5. Generator 115 is preferably driven, by proper speed regulation of prime mover 135, to set up a resonant standing wave within and along the bar 102, and this standing wave may be of half-wave-length, if generator 115 is operated at the fundamental resonant frequency of member 102, or at higher harmonic modes. Since the upper end portion of bar 102 will be located at a velocity antinode of the standing wave, the generator housing undergoes gyratory motion, which is accommodated by the universal joints at 119 and 121 in the suspension.

In operation, barge 106 is manipulated to bring the vibratory shaft 102 to bear against the sidewall 103 of the formation. The vibratory action of shaft 102 is very powerful, and readily breaks down the formation, crumbling it into pieces suitably sized for sonic treatment to separate the oil therefrom.

The sonically vibratory bar or shaft 102 has the function not only of breaking down the formation, crumbling it and causing it to fall into the lower portion of the pit, but also the function of transmitting high intensity sound waves through the water 105 to the crumbled tar-sand material. Thus, such sound waves act on the crumbled formation, resulting in separation of the oil from the sand by the action fully described in connection with the earlier embodiments of the invention. In FIG. 6, numeral 138 designates the waste sand material, the separated oil rising and forming a layer 110 at the top of the water body, where it is picked up by suction pipe 109, as already described.

The invention has now been described in certain present illustrative forms, but is obviously capable of modification, and of being carried into practice in various other forms of treatment apparatus, without departing from the spirit and scope of the appended claims.

I claim:

1. The method of recovering hydrocarbon liquid from a tar-sand raw material in lump form, that includes: disintegrating the lumps of raw material by subjecting said material to sonic waves, whereby the petroleum tar is released from the sand in the physical form of a hydrocarbon liquid, and separating the released hydrocarbon liquid from the sand residue.

2. The method of mining petroleum tar-sand material from an exposed body thereof in the earth and ex-

tracting the hydrocarbon liquid content therefrom, that includes: forming a pit within the exposed material, introducing a liquid into said pit, and mechanically engaging against the sidewall of said pit, beneath the liquid level therein, a sonic vibrator, in a manner to break lumps of the material from said sidewall, and to subject the lumps of material which have fallen into the pit to sonic wave action transmitted through said liquid and thereby effect their disintegration and release of hydrocarbon liquid content from said sand.

3. The method of de-sanding solid or semi-solid earthen petroleum raw material comprised of unconsolidated sand particles intermixed and bound within petroleum, that comprises: providing the raw material in the form of a plurality of extended bodies, disintegrating said extended bodies of said raw material sonically by applying thereto sonic waves for transmission therethrough, such that sonic waves are transmitted partly through petroleum and partly through a multiplicity of sand particles, to thereby induce differential relative sonic activity of the sand particles and the petroleum in which they are bound, sustaining such sonic wave application and differential sonic activity to and within the disintegrating raw material until the initially bound sand particles are released from their initial bound state in said petroleum and are free for migration therein.

4. The subject matter of claim 3, including immersing the bodies of raw material in an acoustic coupling liquid,

and transmitting the sound waves applied to said bodies of raw material through said coupling liquid.

5. The method of recovering hydrocarbon liquid from a natural deposit of oil-sands in an earthen petroleum reservoir, that includes:

transmitting sonic vibrations to the material being removed from said reservoir so that said material is subjected to said vibrations, whereby the petroleum oil is released from the sand in the physical form of a hydrocarbon liquid, and separating the released hydrocarbon liquid from said sand.

6. The method of claim 1 wherein said raw material is in the form of oil-sands as it comes from a deposit thereof in the earth,

and wherein said step of subjecting said material to sonic waves consists of passing said material through a zone having a predetermined boundary surface, and transmitting said sonic waves in said zone while said material is passing therethrough.

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