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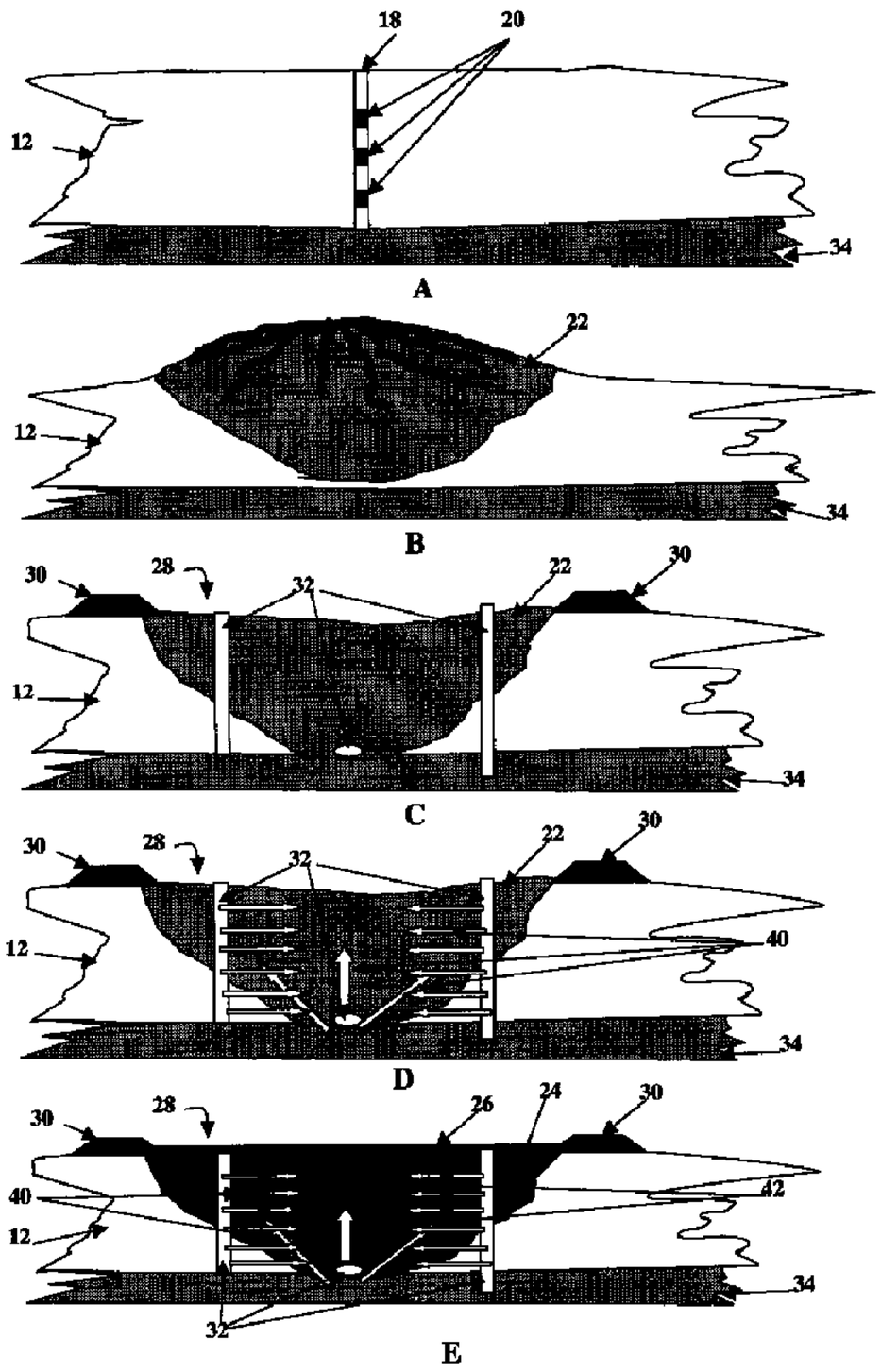
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(54) Titre : METHODE DE RECUPERATION DE PETROLE LOURD EN PLACE DANS DES GISEMENTS SOUTERRAINS

(54) Title: METHOD FOR THE IN PLACE RECOVERY OF HEAVY OIL FROM A SUBTERRANEAN DEPOSIT



(57) Abrégé/Abstract:
A method for extracting bitumen from a subterranean oil sand deposit comprising: a) removing an overburden from a subterranean deposit; b) blasting the subterranean deposit to fragment the subterranean deposit thereby forming a blasted deposit, the blasted

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(57) Abrégé(suite)/Abstract(continued):
deposit being operable to permit a flood volume of fluid to admix with the blasted deposit, to ablate and then release the heavy oil off an inert material so that the heavy oil floats on the flood volume of fluid forming a froth composed of the flood volume and the released bitumen up through and then above the blasted deposit; c) flooding the blasted deposit using the fluid , thereby forming a flooded deposit; d) recovering the heavy oil with the flood volume of fluid in the flooded deposit; and e)removing the fluid from the flooded deposit, thereby forming a treated deposit, the treated deposit being compacted by removing a fluid from the flooded deposit so that the treated deposit is not sufficiently permeable to accept a second flood volume of fluid from an adjacent blasted deposit, is provided.

ABSTRACT

A method for extracting bitumen from a subterranean oil sand deposit comprising: a) removing an overburden from a subterranean deposit; b) blasting the subterranean deposit to fragment the subterranean deposit thereby forming a blasted deposit, the blasted deposit being operable to permit a flood volume of fluid to admix with the blasted deposit, to ablate and then release the heavy oil off an inert material so that the heavy oil floats on the flood volume of fluid forming a froth composed of the flood volume and the released bitumen up through and then above the blasted deposit; c) flooding the blasted deposit using the fluid , thereby forming a flooded deposit; d) recovering the heavy oil with the flood volume of fluid in the flooded deposit; and e)removing the fluid from the flooded deposit, thereby forming a treated deposit, the treated deposit being compacted by removing a fluid from the flooded deposit so that the treated deposit is not sufficiently permeable to accept a second flood volume of fluid from an adjacent blasted deposit, is provided.

METHOD FOR THE IN PLACE RECOVERY OF HEAVY OIL FROM A SUBTERRANEAN DEPOSIT

TECHNICAL FIELD

This invention relates to the field of mining. More particularly, to recovering heavy oil from a subterranean oil sand deposit.

BACKGROUND

US patent 4,037,657 to Lekas describes a process for recovering carbonaceous material from a deposit by retorting. Lekas teaches that the deposit must be sealed and that a deposit should be blasted in a graded fashion so that smaller particles occur at one area and larger particles occur at another area. Other patents such as US 4,047,760 to Ridley and CA 1,123,728 to Rom *et al.* also describe retorting techniques.

U.S. patent 4,333,684 to Ricketts, *et al.*, U.S. 4,545,622 to Yang, U.S. 4,489,983 to Ricketts describe methods of blasting subterranean deposits, including oil shale deposits for providing *in situ* retorting zones.

U.S. patent 4,101,172 to Rabbitts describes an *in situ* method of extracting bitumen from oil sand using a bitumen flotation method. Rabbitts describes a method where the overburden is not disturbed and a sealed or closed reservoir is provided.

U.S. patent 4,302,051 to Bass *et al.* describes an *in situ* method for the separation of crude oil from a reservoir whereby the deposit is drilled and flushed with hot water and steam.

International patent application WO 03/060285 to Drake, *et al.* describes a mechanical device designed to excavate a hydrocarbon containing deposit with a cutter head and separating the hydrocarbon component in an enclosed vessel that is in communication with the cutter head. U.S. Patent 6,152,356 to Minden also describes a mechanical excavation of a tar sand deposit, termed hydraulic removal, and describes hot water/steam injection for the recovery of bitumen.

CA patent application 2,434,329 to Walsh describes a method of barge mining tar sand. The method describes flooding an oil sand deposit and dredge mining the flooded deposit with barges. A floating plant is provided for the dredged product to be processed and the bitumen extracted.

U.S. Patent 3,762,771 to Livingston provides a mine layout for the natural resources development of a broad region. The layout is particularly applicable to the recovery of ore from oil shale and tar sand.

U.S. patent 4,270,609 to Choules describes a tar sand extraction process. An *in situ* or *ex situ* method for separating and recovering bitumen from tar sand by heating the tar sand in an aqueous mixture of floating agent containing ammonia, a transfer agent containing a phosphate or silicon ion and a strong monovalent base.

U.S. patent 4,034,812 to Widmyer discloses a method whereby viscous petroleum may be recovered from a subterranean deposit, such as tar sand. Widmyer describes injecting hot fluid, such as hot water or steam, into the deposit and maintaining a pressure on the deposit so as to heat the deposit.

U.S. patent 4,406,499 to Yildirim describes that bitumen is recovered from an underground tar sand formation by an *in situ* percolation process. The process includes drilling a bore hole and enlarging the hole by radially hydraulic jetting to form a slurry. The resulting slurry is then treated *in situ* with hot alkaline water to separate the bitumen from the sand matrix.

U.S. patent 4,475,592 to Pachovsky describes an *in situ* recovery process whereby bitumen is recovered from a subterranean formation of heavy oil sand traversed by at least one injection well and at least one associated production well in fluid communication with the injection well. Injection of hot fluids, such as low quality steam, are injected into the injection wells to release the bitumen from the heavy oil sand.

SUMMARY

In various aspects, there is provided a method comprising: a) removing overburden from a subterranean deposit; b) blasting the subterranean deposit; c) flooding the blasted deposit using a fluid under pressure; d) recovering a heavy oil from the flooded deposit; and e) removing the fluid from the flooded deposit. The flooding and the recovering may be repeated at least once. The heavy oil may be bitumen and the subterranean deposit may be a subterranean oil sand deposit.

In another aspect, there is provided a method comprising: a) removing an overburden from a subterranean deposit; b) blasting the subterranean deposit to maximize the fragmentation of the subterranean deposit thereby forming a blasted deposit, the blasted deposit being operable to permit a first flood volume of fluid to admix with the blasted deposit, to release a heavy oil from an inert material so that the heavy oil floats within the flood volume of fluid in the blasted deposit; c) flooding the blasted deposit with the first flood volume of fluid thereby forming a flooded deposit; d) recovering the heavy oil floating within the first flood

volume of fluid in the flooded deposit; and e) removing the fluid from the flooded deposit, thereby forming a treated deposit, the treated deposit being compacted by removing a fluid from the flooded deposit so that the treated deposit is less permeable than a newly or freshly blasted adjacent deposit. The flooding and the recovering may be repeated at least once. The heavy oil may be bitumen and the subterranean deposit may be a subterranean oil sand deposit.

In another aspect, the blasting may comprise: i) drilling at least one blasthole into the subterranean deposit; ii) loading the at least one hole with at least one explosive charge per hole; iii) detonating the at least one explosive charge in such a manner that the explosive charge nearest the top surface of the subterranean deposit explodes before the explosive charge closer to the bottom surface of the subterranean deposit. This creates progressive relief for the lower and later detonating explosives charges by breaking and lifting, by explosive gas expansion from the upper and earlier detonating explosive charges.

In another aspect, methods described herein may further comprise defining a limit to the zone to be processed by creating a fractured or loosened plane on pre-determined limit lines through the use of a closely spaced line of blastholes which are lightly charged with explosives.

In another aspect, the flooding may comprise: i) drilling at least one well into the blasted deposit; ii) inserting into the at least one well at least one perforated casing per well; iii) pumping the fluid under pressure into the at least one perforated casing. The at least one well may be a substantially horizontal well, a substantially vertical well, comprise at least two wells where a first well is substantially horizontal and a second well is substantially vertical. The substantially horizontal well may be closer to a bottom surface of the blasted deposit when compared with a top surface of the blasted deposit. The at least one vertical well may be drilled into a stable layer immediately below the blasted deposit.

In another aspect, the recovering may comprise collecting a reservoir of heavy oil that has formed on a top surface of the flooded deposit.

In another aspect, the fluid may be selected from at least one of the group consisting of: water, steam, air, carbon dioxide and light hydrocarbon solvents and may further comprise an additive that facilitates release of the heavy oil from the blasted deposit. The additive may be selected from at least one of the group consisting of: surfactants, ant-acids, caustics and light hydrocarbon solvent.

In another aspect, methods described herein may further comprise shaping the blasted deposit prior to the flooding. An explosive charge, a machine or a combination of an explosive charge and a machine may be used for shaping the blasted deposit. The explosive charges used

for shaping may be at least a portion of a set of explosive charges used for blasting the subterranean deposit. The sequence in which a group of explosive charges are detonated, as well as the relative depths of these charges from the top surface of the subterranean deposit, can be adjusted to control the expansion characteristics of the deposit after blasting. The shaping may provide an incline down which the heavy oil will flow or a reservoir into which the heavy oil may accumulate.

The term "subterranean deposit" as used herein is defined as a volume of material that is at least partly underground and contains a mixture of unwanted materials and desired heavy oil. Examples of subterranean deposits include oil sand, and tar sand. In some cases the oil sand has no overburden an d this should be considered a subterranean deposit as described herein.

The term "substantially vertical" as used herein is defined as within five degrees of completely vertical.

The term "substantially horizontal" as used herein is defined as within five degrees of completely horizontal.

The term "maximally fragmented", or like phrases as used herein means the smallest fragments possible formed from a single starting piece. The term "maximum fragmentation" as used herein means to produce the smallest fragments possible from a single starting piece. This typically provides or produces the largest amount of surface area and the highest quantity of new pieces or fragments from the single starting piece.

The term "heavy oil" as used herein is defined as a material containing carbon that has a gravity of not more than 25.7° on the American Petroleum Institute (API) Scale. As used herein "heavy oil" comprises both heavy and extra heavy oil. Examples of heavy oil include, but are not limited to, bitumen and crude oil. Crude oil is commonly classified as light, medium, heavy or extra heavy, referring to its gravity as measured on the API scale. The API gravity is measured in degrees and is calculated using the formula API

Gravity = (141.5/S.G.) - 131.5.

Light oil has an API gravity higher than 31.1° (lower than 870 kilograms/cubic metre), medium oil has an API gravity between 31.1° and 22.3° (870 kilograms/cubic metre to 920 kilograms/cubic metre), heavy oil has an API gravity between 22.3° and 10° (920 kilograms/cubic metre to 1,000 kilograms/cubic metre), and extra heavy oil (e.g. bitumen) has an API gravity of less than 10° (higher than 1,000 kilograms/cubic metre). The Canadian government has only two classifications, light oil with a specific gravity of less than 900

kilograms/cubic metre (greater than 25.7° API) and heavy oil with a specific gravity of greater than 900 kilograms/cubic metre (less than 25.7° API).

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a cross-section of a subterranean deposit.

Figure 2A is a cross-section of a subterranean deposit that has been prepared for blasting.

Figure 2B is a cross-section of a blasted deposit.

Figure 2C is a cross-section of a shaped and prepared blasted deposit.

Figure 2D is a cross-section of a deposit being flooded. The white lines indicate fluid being released into the deposit.

Figure 2E is a cross-section of a flooded deposit. The white arrows indicate fluid being released into the deposit and the thick black arrows indicate the direction of a released heavy oil and fluid mixture.

Figure 3A is a plan view of adjacent deposits at different stages of methods described herein.

Figure 3B is a cross-section of adjacent deposits at different stages of methods described herein.

Figure 3C is a cross-section of adjacent deposits during a flooding step of methods described herein.

DETAILED DESCRIPTION

In various aspects, there is provided a method for the recovery of a heavy oil from a subterranean deposit 12 comprising the steps of A) pre-production, site drainage and topsoil and/or muskeg 14 removal; B) removing an overburden 16; C) drilling and blasting; D) shaping and production preparation; E) in place flooding and recovery of the heavy oil; F) lean froth and froth treatment and tailings treatment; and G) reclamation.

A) Pre-Production, Site Drainage and Topsoil/Muskeg Removal

Referring to Figure 1, a topsoil and/or muskeg 14 are often found above a subterranean deposit 12. If required, trees and shrubs are removed from the muskeg and/or topsoil 14. Surface drainage of the topsoil and/or muskeg 14 is then established in order to dry the material overlying the subterranean deposit 12. Muskeg drainage may be achieved using standard

backhoe ditching techniques. For example, a series of finger ditches may be dug into the muskeg to a depth just slightly into the overburden, below the muskeg. These drainage ditches may be sloped so that they drain to a common settling pond where a runoff water is held until small sediment settles out. When the runoff water meets government regulations it can be released to the environment. Muskeg is known to be suitably dried when it reaches a state that it can be handled with backhoe/truck combinations or other suitable mining equipment types. When the muskeg and/or topsoil 14 is dry enough to allow access to heavy mining equipment it and an overburden 16 may be removed and stockpiled or placed on an area that is ready for reclamation materials.

The Overburden 16 and the subterranean deposit 12 may also need a ground water control system. These systems are well know to the skilled practitioner in the art and may comprise a series of wells established around the perimeter of the site to assist in the control of the ground water.

Ground water is water that is naturally occurring and may be controlled by a series of perimeter wells established around the subterranean deposit 12. The ground water may be drawn down below the subterranean deposit 12, by a network of wells that are located along the perimeter of the subterranean deposit 12, prior to blasting. The water level may be kept below the subterranean deposit 12 so as to not interfere with a method described herein. Ground water may be released into the environment if acceptable or incorporated into a method described herein if acceptable. This reduces the demand for water from surrounding major water systems.

B) Removing Overburden

The material on top of the subterranean deposit 12 is called the overburden 16. The overburden 16 is often composed of coarse sands, silts, shale and clays. The overburden 16 may range in thickness from a few centimeters to many hundreds of meters.

Methods for removing the overburden 16 are well known to the skilled practitioner in the art. Typically, trucks and shovels are used to remove the overburden 16. Other methods may include draglines, and bucket wheel excavators. Drilling and blasting may be used to facilitate the overburden 16 removal. If the subterranean deposit 12 does not have the overburden 16 above it, then the step of removing the overburden 16 is unnecessary and may be skipped.

The removed overburden 16 and the topsoil/muskeg 14 may be stockpiled on top of an

area that does not have the subterranean deposit 12, or any other convenient place. A lack of the subterranean deposit 12 in an area may be attributed to the subterranean deposit 12 never having been there, or because the area has already been processed by a method described herein, a portion of a method described herein, or any other method known for removing the heavy oil from a subterranean deposit 12. The removed overburden may also be placed on an area that is un-economic for surface mining activities.

Removing the overburden 16 provides a space above the subterranean deposit 12. The space provided allows the subterranean deposit 12 room to expand. The room to expand facilitates the blasting of the subterranean deposit 12. In particular, blasting the subterranean deposit 12 into smaller fragments is improved by the removal of the overburden 16.

C) Drilling and Blasting

Referring to Figures 2A and 2B, the subterranean deposit 12 lying below the overburden 16 may range in thickness from a few centimeters to hundreds of meters.

Once the overburden 16 is removed, the subterranean deposit 12 is drilled to produce at least one bore hole 18. The number and the depth of the bore holes 18 will be determined by the depth of the subterranean deposit 12 to be blasted and the diameter of the bore hole 18. The bore hole 18 may extend as far down as the bottom of the subterranean deposit 12, lower than the bottom of the subterranean deposit 12 or to a desired distance above the bottom of the subterranean deposit 12. At least one explosive charge 20 is placed into the bore hole 18. The at least one explosive charge 20 is detonated and the subterranean deposit 12 is fragmented to become a blasted deposit 22.

Blast design may be based on one or a combination of standard blasting techniques, including crater blasting and choke (or buffer) blasting.

Crater blasting may be used when only one free surface is provided for relief and displacement of the blasted material by the expanding detonation gasses. In such a blast geometry, short concentrated charges are used. It is desired to approximate an ideal spherical charge geometry to obtain a uniform distribution of stress on the surrounding material in all directions using this technique.

Choke (or buffer) blasting may be used when at least two free faces are provided for relief and displacement of the blasted material by the expanding detonation gasses. In this blast geometry, relatively long cylindrical charges may be used and distributed in such a way as to break the material into a previously blasted, and therefore loosened, zone.

Water resistant explosive charges, or explosive charges encapsulated in water proof containers may be used in methods described herein. The explosive charge may also be detonable under high hydrostatic pressures. Explosive charges that have a relatively low shock energy and a high gas generation property may be better suited to the fragmentation and displacement required by methods described herein. Propellants may also be used in place of common commercial explosives.

The blasting techniques described herein are merely examples to explain possible blasting methods. Any blasting technique known to the skilled practitioner in the blasting art may be used. In particular, the blasting techniques known to provide maximum fragmentation of a subterranean oil sand deposit are preferred.

The subterranean deposit 12 is blasted to maximize fragmentation of the blasted deposit 22. To achieve maximum fragmentation the subterranean deposit 12 must have a space into which it may expand. Such a space is generally provided by the removed overburden 16, although any space, including naturally occurring spaces and spaces dug to the side of the subterranean deposit 12 may also assist with maximum fragmentation of the subterranean deposit 12.

Maximum fragmentation of the blasted deposit 22 provides greater permeability of the blasted deposit 22 for a flooding step. Maximum permeability allows a greater yield of a heavy oil to be released and recovered.

Maximum fragmentation of the blasted deposit 22 also provides maximum compacting of the blasted deposit 22 after a fluid from a flooding is removed from a flooded deposit 24. Maximum compacting of the blasted deposit 22 provides a zone which is less permeable to the fluid, thereby reducing leakage of the fluid from an adjacent flooded deposit. Furthermore, maximum compacting provides a more stable surface and a larger workable area on which to stockpile overburden and other materials.

A geometric distribution of the blast holes 18 and the elevations and masses of the explosive charges 20 in single or multiple blast holes 18 may be adjusted to create an optimum overlap of the radii of influence to maximize the fragmentation of the blasted deposit 22 and tailor the expansion of the subterranean deposit 12. Furthermore, a line of closely spaced blast holes 18 lightly charged with explosive charges 20 may be used to control the size of the area of fragmentation of the blasted deposit 22.

Blasting and blasting techniques known to those in the art may also be practiced in order to provide a desired shape and fragmentation of the blasted deposit 22. For example, the

distance from the bottom of the subterranean deposit 12 of the lower most explosive charge 20 in each bore hole 18 may be staggered to maximize the fragmentation of the blasted deposit 22.

Alternatively, special drilling techniques in which clusters of smaller diameter bore holes 18 may be used to concentrate explosives charges 20 in a deep location to simulate single large explosion may be used. This technique may be applied to a primary drilling and blasting step, after which a smaller diameter blast holes 18 may be distributed and charged in the choke (or buffer) blasting configuration as previously described.

Additional blasting may be done at any time after the blasted deposit 22 is flooded to assist in the agitation of the blasted deposit 22 and assist in the release of the heavy oil.

D) Shaping and Production Preparation

Referring to Figure 2C, the blasted deposit 22 may then be shaped, or further shaped if already shaped using blasting techniques, to prepare the blasted deposit 22 for in place flooding and heavy oil recovery. Large mining equipment, for example D10 Caterpillar™ dozers or large Caterpillar™ graders, may also be used to shape the blasted deposit 22. Shaping the blasted deposit 22 may be done to control the movement of the heavy oil and fluid, the fluid or a combination of the fluid and heavy oil called a froth 26. For example, a collection reservoir 28 at the top of the blasted deposit 22 may be provided as a collection area for the froth 26. A collection reservoir 28 may comprise a perimeter of the blasted deposit 22 shaped to be higher than a central area of the blasted deposit 22. An alternative collection reservoir 28 may comprise a portion of the blasted deposit 22 shaped to be lower than the rest of the blasted deposit 22. Furthermore, a slope may be provided in the blasted deposit 22 so that the heavy oil, the fluid or the froth 26, moves in a planned direction down the slope to a desired location from which it is collected and then transported to another facility like a large tank farm prior to being sent for further enhancement.

Removed overburden 16 may be used in the shaping of the blasted deposit 22. For example removed overburden 16 may be positioned around the blasted deposit 22 to act as a wall 30 for the collection reservoir 28. Alternatively some overburden 16 may be left in place to act as a wall 30 for the collection reservoir.

One or a plurality of fluid wells 32 are drilled into the blasted deposit 22. The drilled angle of the fluid well 32 may vary. For example, the fluid well 32 may be substantially horizontal, substantially vertical, or at an angle in between horizontal and vertical. A plurality of fluid wells 32 may be provided so that some or all of the fluid wells 32 may be substantially

horizontal, substantially vertical, or at an angle in between horizontal and vertical.

Once the fluid well 32 is drilled, a perforated casing is inserted into the fluid well 32. The drilling and inserting may be done concurrently. In a particular embodiment, a first substantially horizontal fluid well 32 is drilled and the perforated casing is inserted concurrently. In this embodiment, substantially horizontal means parallel to the bottom of the blasted deposit 22. The first fluid well 32 and perforated casing may be placed near the bottom of the blasted deposit 22.

Vertical fluid wells 32 may be drilled and perforated casings may be inserted into a stable layer 34 that lies below the blasted deposit 22. In one embodiment, the stable layer 34 is a limestone layer. These may also act as support posts or pillars for a shelter 36 on the top of the blasted deposit 22, flooded deposit 24 or a treated deposit 38. If required for a structure the vertical wells will be anchored into the limestone using the appropriate civil engineering techniques known to the skilled practitioner.

After the fluid wells 32 and perforated casings have been provided in the blasted deposit 22, fluid injection equipment, pumping equipment and heating equipment can be installed. A froth sump may also be installed to collect the recovered heavy oil in the form of the froth 26.

E) In Place Flooding and Recovery of the Heavy Oil

Referring to Figure 2D, at least one fluid is pumped into the fluid wells 32 and the perforated casings and the fluid is released into the blasted deposit 22 via perforations in the perforated casings (direction of flow of the fluid is illustrated by white arrows 40) thereby forming a flooded deposit. The fluid will cause the release of the heavy oil from the blasted deposit 22. The blasted deposit 22 may be fully or partially saturated with the fluid. The fluid may be under pressure and may be hot water, hot steam, hot compressed gas, or (e.g., air or CO_2). The flooding of the blasted deposit 22 may accomplish: conditioning of, agitation of, and heavy oil extraction and flotation from the blasted deposit 22.

The blasted deposit 22 may be flooded or soaked using a fluid that may have a temperature greater than 50 degrees Celsius. Flooding or soaking time may be partially dependent on the fluid temperature used. The longer the blasted deposit 22 is flooded or soaked the lower the fluid temperature that may be used.

The heavy oil is released from the flooded deposit 24 by the heat and agitation effect of the injected fluid as well as the chemical and mechanical properties of the injected fluid. When

the fluid contacts the heavy oil in the blasted deposit 22. the hot fluid raises the temperature of the heavy oil and reduces the viscosity such that the heavy oil may detach from the inert material. This combined with the mechanical and chemical properties of the fluid will facilitate the release of the heavy oil and/or bitumen.

The blasted deposit 22 may be agitated using the high pressure agitation effect of the injected fluid which may also be injected using a pulsating process. A range of pressures will be used and may include pressures from ambient pressure to over 500 PSI in order to condition, agitate and release the heavy oil and/or bitumen from the blasted deposit 22.

The fluid injected into the blasted deposit 22 may also provide a plethora of fluid and/or gas bubbles that facilitate and assist in the floatation of the heavy oil and/or bitumen droplets to the surface. Local fluidization may also be used to create passage for the bitumen droplets to rise. The froth 26 that floats to the surface may be continuously taken away from the top surface.

Additives like surfactants, ant-acids, acids, solvents and caustics may be used to assist in the releasing of the heavy oil from the inert materials or to improve the floating of the heavy oil on the surface of the fluid. Such additives are known to the skilled practitioner in the art.

As the heavy oil is released from a flooded deposit 24 it moves towards the top of the flooded deposit 24 in the form of froth 26 (movement of the froth 26 is indicated by thick black arrows 42). The froth 26 is also moved by the fluid in a direction of flow of the fluid. When the froth 26 appears on a top surface of the flooded deposit 24, the heavy oil is recovered and collected as froth 26. The froth 26 may be collected by pumping or draining the froth 26 into holding structures. Collected froth 26 may be sent to a storage facility or for further treatment at a treatment facility. A flood volume of fluid is typically the amount of fluid required to maximize and optimize the flooding and/or soaking and agitation of the blasted deposit 22 so that the heavy oil and/or bitumen is released and combined with the fluid to become a froth 26 which floats to the surface of the flooded deposit 24.

The specific volume of fluid in a flood volume for the blasted deposit 22 will vary depending on a number of factors including size dimensions of the blasted deposit 22, degree of fragmentation of the blasted deposit 22 and volume of heavy oil contained in the blasted deposit 22, as well as time required for proper soaking, ablation and subsequent release of the heavy oil and/or bitumen from the subterranean deposit.

In place pressure flooding and heavy oil recovery steps may be repeated any number of times to maximize the recovery of the heavy oil. Additional blasting steps may be carried out before repeating the flooding step.

Instead of bringing the oil sand from a subterranean deposit to a separation vessel, where fluids are added, fluids are brought to the subterranean deposit and the processing is done in the ground. The ground in effect becomes the separation vessel. The sand sinks to the bottom and the water and heavy oil and/or bitumen float to the surface. The released bitumen is skimmed off the top and sent to storage and/or for further processing.

The main difference between using the ground as a separation vessel and traditional separation vessels is that materials to be treated in a traditional separation vessels are often supplied by a pipeline. Traditional separation vessels often need to process the materials provided to it in a short amount of time, in order to accommodate materials arriving from the pipeline. Using methods described herein, the duration of time for which the flooded deposit is flooded with fluid (that is the materials being treated) may range from minutes to hours to days to weeks. As the duration of time for which the flooded deposit is flooded with fluid increases, the amount of heavy oil recovered from the deposit will also increase.

Additional blasting may be done after the blasted deposit 22 is flooded to assist in the agitation of the blasted deposit 22 and assist in the release of the heavy oil.

F) Lean Froth and Froth Treatment and Tailings Treatment

During the in place recovery of the heavy oil, the heavy oil will be released from the inert material and with the fluid it will form the froth 26. Depending on how many times the blasted deposit 22 has been flooded the percentage by weight of heavy oil in the froth 26 will vary. For example, the froth 26 released by a first flooding may have a higher percentage of heavy oil than the froth 26 that is released by a subsequent flooding from the same blasted deposit 22. This may be because more of the heavy oil is available to be released in the first flooding of a blasted deposit 22 than in the second flooding of the same blasted deposit 22. The froth 26 that is released in the subsequent flooding may be called lean froth because it does not have as much heavy oil as the froth 26 released by the first flooding.

The first flooding may be composed of two separate fluid injections that are executed at separate times. For example, the blasted deposit 22 may be flooded by injecting a fluid that is primarily hot water to a level that is near the top of the blasted deposit 22, followed by an injection with a fluid that is mostly comprised of compressed air or steam. The compressed air

or steam may release a plethora of tiny bubbles that assist in the release of the heavy oil from the inert material.

The froth 26 collected may need to be dewatered. Froth dewatering techniques known to the skilled practitioner, such as cyclones, de-aerators, inclined plate separators and multi stage settling vessels may be used to reduce the fluid content (i.e. the fluid used to flood the blasted deposit 22, for example water and air/gas) of the froth 26. This provides a more pure heavy oil. Secondary floatation techniques may also be used to produce more pure heavy oil. Once the fluid content of the froth 26 has been reduced to acceptable levels further upgrading may be achieved using techniques known to the skilled practitioner. The fluid removed from the froth 26 may be recycled and used again. Froth 26 may have a composition of from 10% to 70% heavy oil, 10% to 70% water and 0% to 30% solids. Typical froth 26 has a composition of approximately: 60% heavy oil, 30% water and 10% solids. Lean froth may have a composition of approximately: 10% bitumen, 89% water and 1% solids.

The dewatering of the froth 26 produces a waste or tailings that are often composed of fine sands, silts and clays. The quantity of tailings produced by in place methods are small when compared to conventional *ex situ* methods. Typically, the sand and/or fines and/or mineral portion of an oil sand deposit accounts for over 80% by weight of the oil sand deposit. Some present surface mining techniques mine or dig up the entire oil sand deposit. The oil sand is then processed to release the heavy oil and then the rest of the material, composed mostly of the sand, is pumped as a fluid or slurry to massive tailings ponds.

In methods described herein, the oil sand does not need to be mined or dug up and consequently the large tailings structures or ponds do not have to be constructed. The tailings storage required for methods described herein may consist only of the finer sand and fines material that are released with the heavy oil and/or bitumen during flooding or floatation.

Tailings may be treated using techniques that are known by a practitioner in the art and may include the use of a thickener, inground thickener or tailings flocculants. Tailings may be placed on top of a treated deposit 38 or in a conveniently located designated tailings area.

G) Reclamation

After in place flooding and heavy oil recovery is complete, the fluid wells 32 may be used to assist in the removal of fluid from the flooded deposit 24 by pumping the fluid in the reverse direction. Additional pumps and wells for providing artificial lift of the fluid to the surface may be used to maximize fluid recovery. When flooding has stopped and fluid is

removed the remaining materials from the deposit sink and compact providing a treated deposit 38. The compacted materials in the treated deposit 38 provides a less permeable surface which may be used to reduce or prevent the fluid flowing into the treated deposit 38 from an adjacent blasted deposit 22 that is being flooded or an adjacent flooded deposit 24.

Pipe and equipment are salvaged from the treated deposit 38 for future use. After equipment salvage, the treated deposit 38 may be further compacted by the use of machinery.

When the treated deposit 38 is dry enough for placement of sand or overburden on top of the treated deposit to allow heavy equipment to move onto the treated deposit, the tailings and/or the removed overburden 16 and/or the topsoil/muskeg 14 may be placed on top of the treated deposit 38. The removed overburden 16 and topsoil/muskeg 14 may be taken from above the next subterranean deposit 12 to be blasted. Alternatively sand may be placed hydraulically over the treated deposit to act as a more stable foundation for subsequent overburden placement. Seeding and vegetation planting may be done to return the surface of the land to its original or better condition.

Deposit Treatment Planning

Referring to Figures 3A and 3B, a plurality of subterranean deposits 12 may be adjacent to one another and methods described herein may be repeated several times, carried out simultaneously, or carried out with staggered starting and finishing times to optimize the recovery process. Staggering the time at which a method described herein is started and combining this with selecting the next subterranean deposit 12 to treat may be used to maximize heavy oil production and facilitate an orderly development of the resource.

Referring to Figure 3C, a substantially horizontal fluid well 32 may be provided so that the fluid well 32 may be used for a plurality of subterranean deposits 12. This may require blasting a plurality of subterranean deposits 12 prior to flooding.

Ex situ methods known to the skilled practitioner for the recovery of heavy oil from subterranean deposits 12 may be used to recover heavy oil from a top portion of the subterranean deposit 12 and the remaining, bottom portion of subterranean deposit 12 may then be treated by a method described herein. . For example, if a subterranean deposit 12 is 100m deep and conventional methods are used to remove 50m of the subterranean deposit 12 for *ex situ* processing, then the remaining 50m of the subterranean deposit 12 may be treated using a method described herein.

Alternatively, moving the top portion of the subterranean deposit to an area that can be treated using methods described herein it is possible to eliminate any problems that may be encountered when the subterranean deposit is too thick or deep for the blasting techniques described herein.

EXAMPLES

Example 1 - Bench scale testing:

50 kilograms samples of oil sand from Fort McMurray were placed in a clear reservoir in such a manner as to simulate the density of a blasted oil sand deposit. Water having a temperature greater than 50°C and compressed air were injected into the reservoir at various locations over a period of 1 hour. Bitumen froth and hot water floated to the surface and was decanted into a secondary reservoir. The injection with hot water and compressed air was repeated four times. The remainder of the fluid was drained off the reservoir and the balance of the oil sand sample sank to the bottom of the reservoir and compacted to a specific gravity of 1.70.

Example 2 - Bench scale testing:

A bench scale test was conducted where 100 kilograms of oil sand from Fort McMurray was placed in a semi clear reservoir in such a manner as to simulate the density of a blasted oil sand deposit. Fluid having a temperature greater than 50°C and compressed air were injected into the reservoir at various locations over a period of 2 hours.

Bitumen froth and hot water floated to the surface and was decanted into a secondary reservoir. The injection with hot water and compressed air was repeated a number of three times.

The remainder of the fluid was drained off the reservoir and the balance of the oil sand sample sank to the bottom of the reservoir and compacted to a specific gravity of approximately 1.72.

Although the foregoing invention has been described in some detail by way of illustration and example for purposes of clarity of understanding, it will be readily apparent to those of skill in the art in light of the teachings of this invention that changes and modification may be made thereto without departing from the spirit or scope of the appended claims.

What is claimed is:

1. A method comprising:

a) removing an overburden from a subterranean deposit;

b) blasting the subterranean deposit to maximize the fragmentation of the subterranean deposit thereby forming a blasted deposit, the blasted deposit being operable to permit a first flood volume of fluid to admix with the blasted deposit, to release a heavy oil from an inert material so that the heavy oil floats within the flood volume of fluid in the blasted deposit;

c) flooding the blasted deposit with the first flood volume of fluid thereby forming a flooded deposit;

d) recovering the heavy oil floating within the first flood volume of fluid in the flooded deposit; and

e) removing the fluid from the flooded deposit, thereby forming a treated deposit, the treated deposit being compacted by removing a fluid from the flooded deposit so that the treated deposit is not sufficiently permeable to accept a second flood volume of fluid from an adjacent blasted deposit.

2. The method of claim 1 wherein the blasting comprises:

i) drilling at least one hole into the subterranean deposit;

ii) loading the at least one hole with at least one explosive charges;

iii) detonating the explosive charge.

3. The method of claim 1 wherein the blasting comprises:

i) drilling at least one hole into the subterranean deposit;

ii) loading the at least one hole with at least two explosive charges;

iii) detonating the at least two explosive charges such that an explosive charge nearest the top surface of the subterranean deposit explodes before an explosive charge that is further from the top surface of the subterranean deposit.

4. The method of any one of claims 1 to 3 further comprising defining a limit to the blasted deposit by creating a fractured plane using a closely spaced line of bore holes which are lightly charged with explosives.

5. The method of any one of claims 1 to 4 wherein the flooding comprises:

i) drilling at least one well into the blasted deposit;

ii) inserting into the at least one well at least one perforated casing per well;

iii) pumping the fluid into the at least one perforated casing.

6. The method of claim 5 wherein the at least one well is a substantially horizontal well.

7. The method of claim 5 wherein the at least one well is a substantially vertical well.

8. The method of claim 5 wherein the at least one well comprises at least two wells and a first well is substantially horizontal and a second well is substantially vertical.

9. The method of claim 6 or 8 wherein the substantially horizontal well is closer to a bottom surface of the blasted deposit when compared with a top surface of the blasted deposit.

10. The method of claim 7 wherein at least one vertical well is drilled into a stable layer, the stable layer being immediately below the blasted deposit.

11. The method of any one of claims 1 to 10 wherein the recovering comprises collecting a reservoir of heavy oil that has formed on a top surface of the flooded deposit.

12. The method of any one of claims 1 to 11 wherein the fluid is selected from at least one of the group consisting of: water, steam, air, compressed air, carbon dioxide, light oil, light solvent, or oxygen.

13. The method of any one of claims 1 to 11 wherein the fluid is compressed air.

14. The method of any one of claims 1 to 11 wherein the fluid is water.

15. The method of any one of claims 1 to 11 wherein the fluid is steam.

16. The method of any one of claims 12 to 15 wherein the fluid further comprises an additive that facilitates release of the heavy oil from the blasted deposit.

17. The method of claim 16 wherein the additive is selected from at least one of the group consisting of: surfactants, ant-acids, acids, caustics, light oils, or light solvents.

18. The method of any one of claims 1 to 17 wherein method further comprises shaping the blasted deposit prior to the flooding.

19. The method of claim 18 wherein at least one explosive charge is used for shaping the blasted deposit.

20. The method of claim 18 wherein the at least one machine is used for shaping the blasted deposit.

21. The method of claim 18 wherein at least one explosive charge and at least one machine are used for shaping the blasted deposit.

22. The method of claim 19 or 21 wherein the at least one explosive charge is at least a portion of a set of explosive charges used for blasting the subterranean deposit.

23. The method of any one of claims 18 to 22 wherein the shaping provides a reservoir into which the heavy oil will accumulate.

24. The method of any one of claims 1 to 23 wherein the flooding and the recovering are repeated at least once.

25. The method of any one of claims 1 to 24 wherein the heavy oil is bitumen.

26. The method of any one of claims 1 to 25 wherein the subterranean deposit is a subterranean oil sand deposit.

Application number/numéro de demande: 2520223

Figures: 2E-3A-3B-3C

Pages: 2-34

DRW-IP

Unscannable items
received with this application
(Request original documents in File Prep. Section on the 10th Floor)

Documents reçus avec cette demande ne pouvant être balayés
(Commander les documents originaux dans la section de préparation des dossiers au 10ième étage)

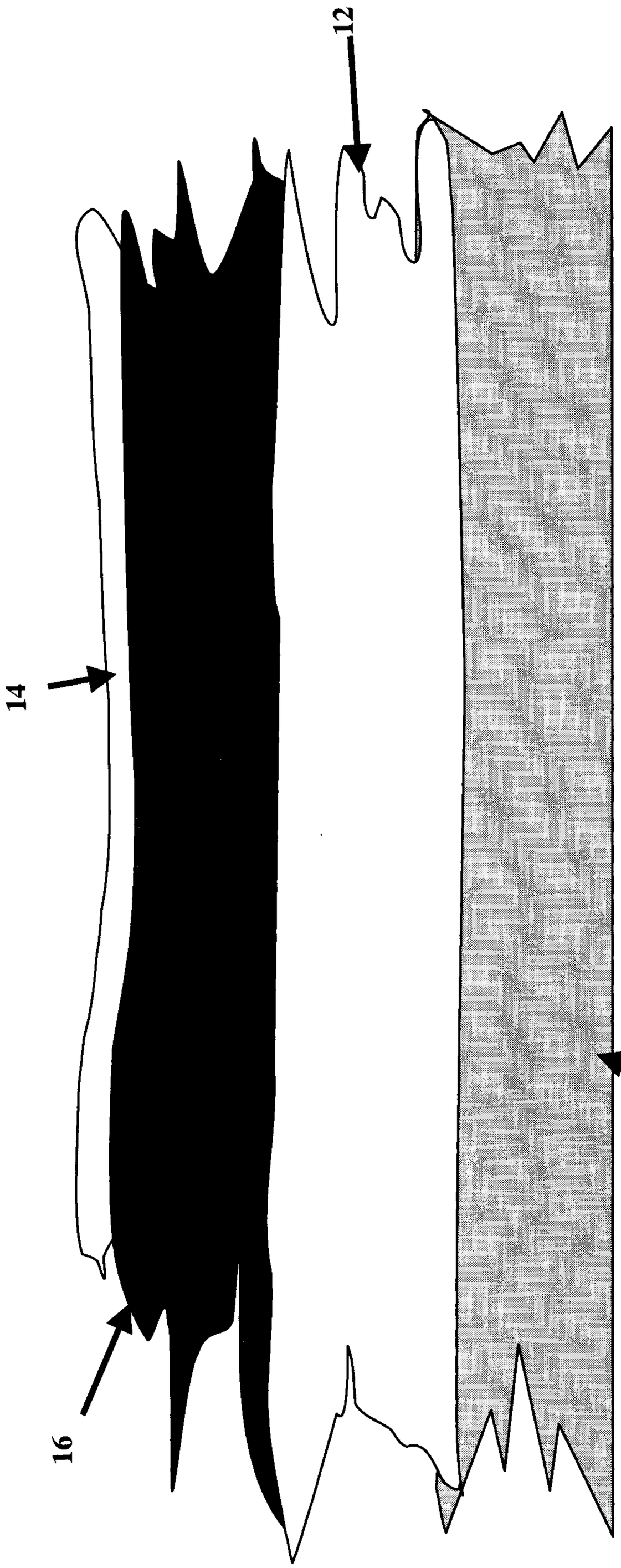


FIG. 1

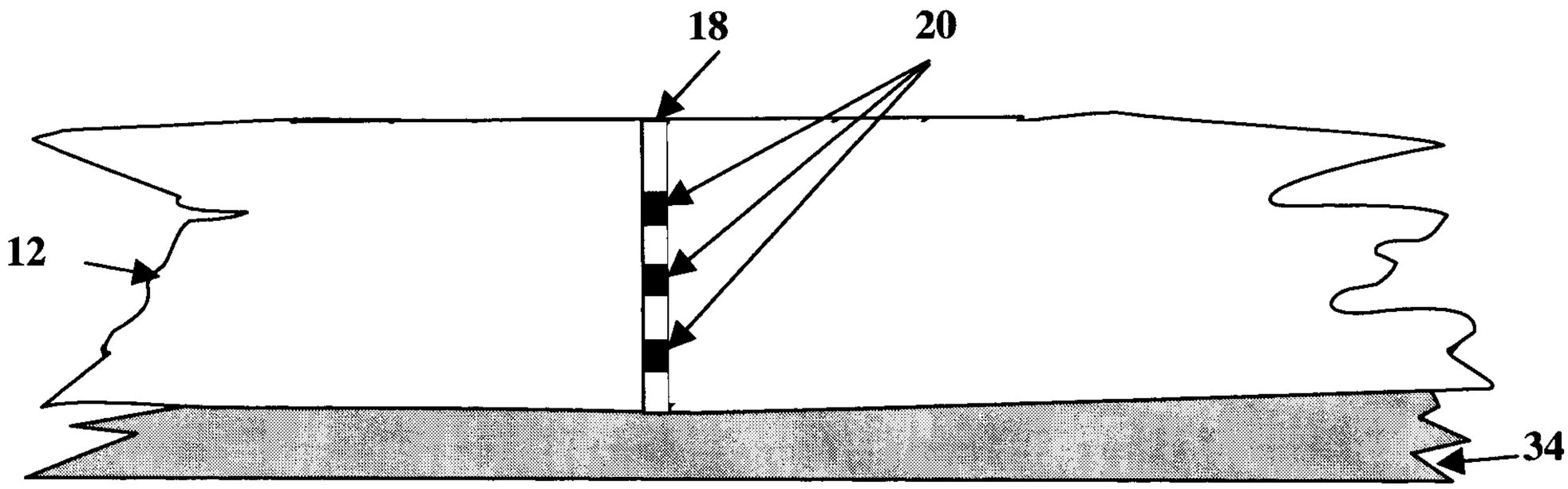


FIG. 2A

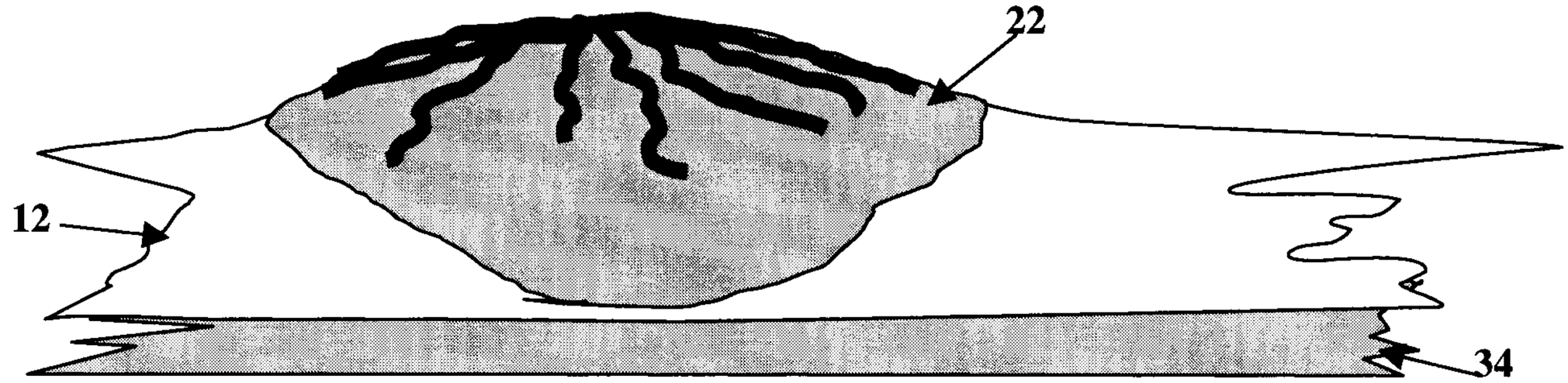


FIG. 2B

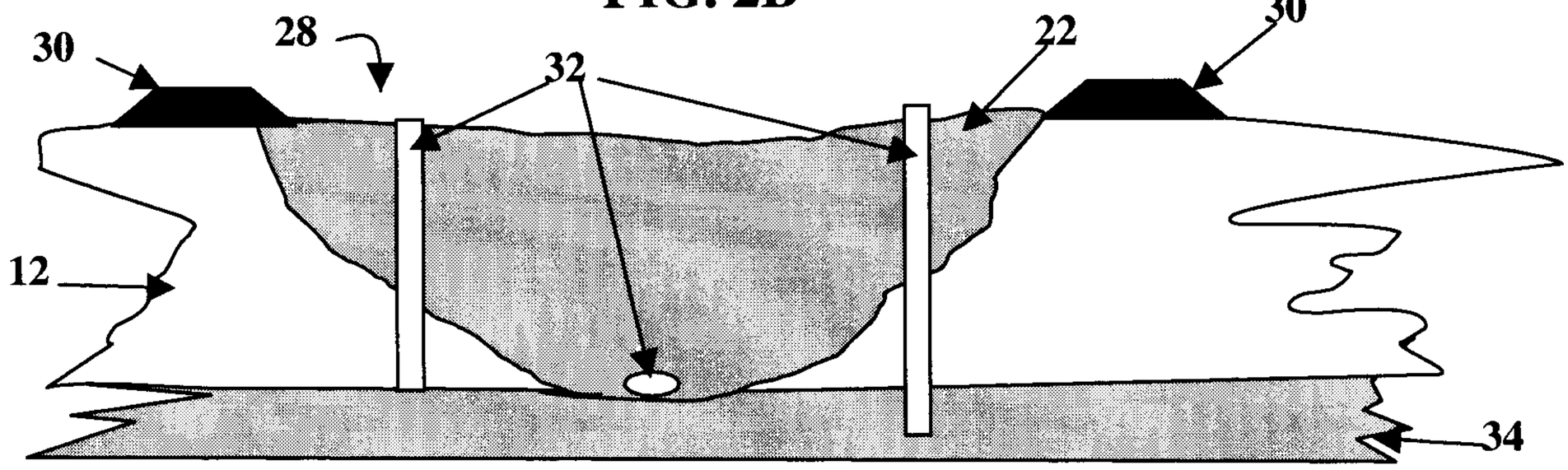


FIG. 2C

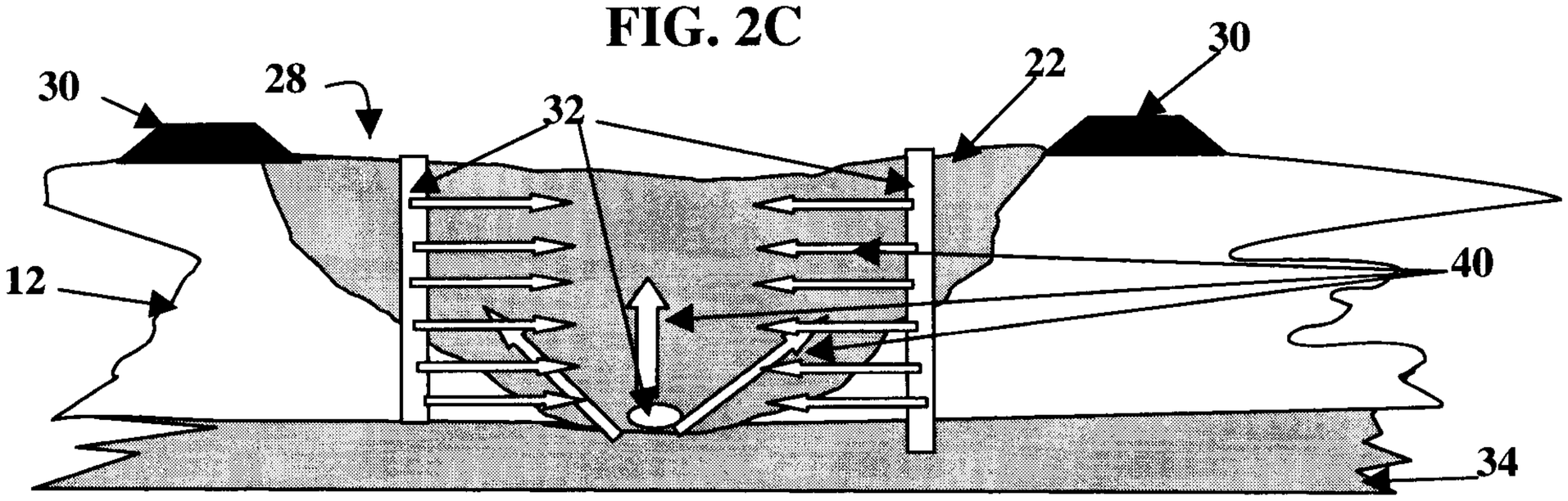


FIG. 2D

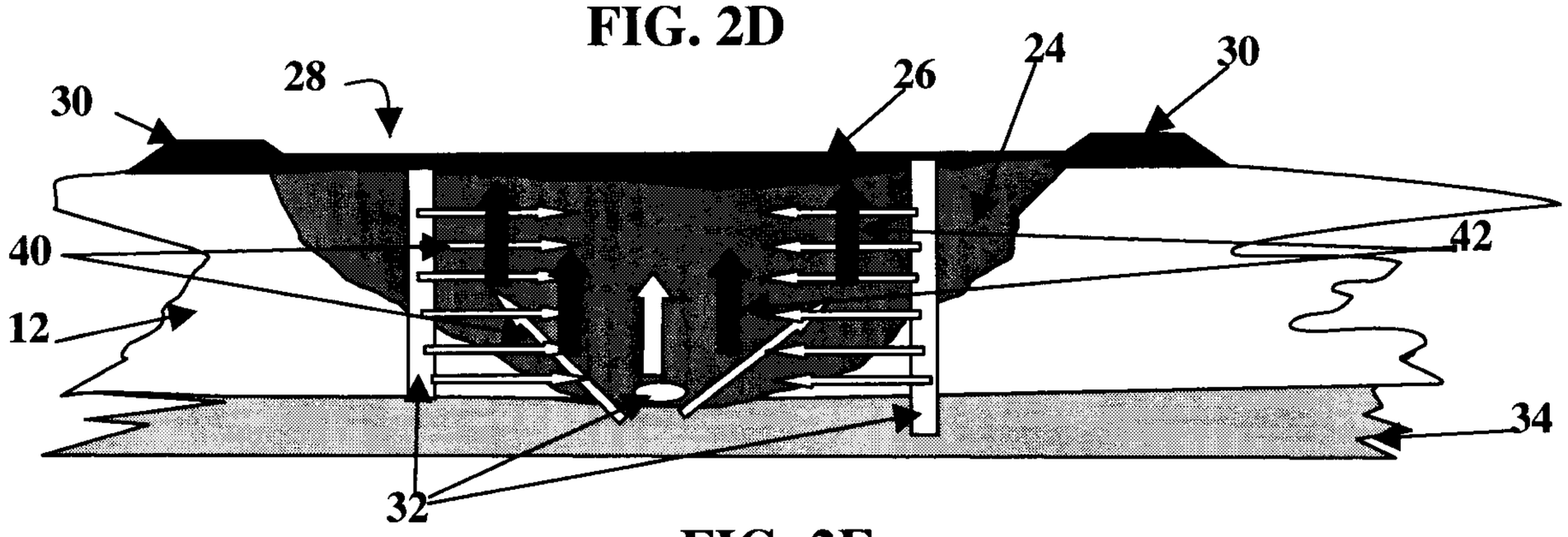
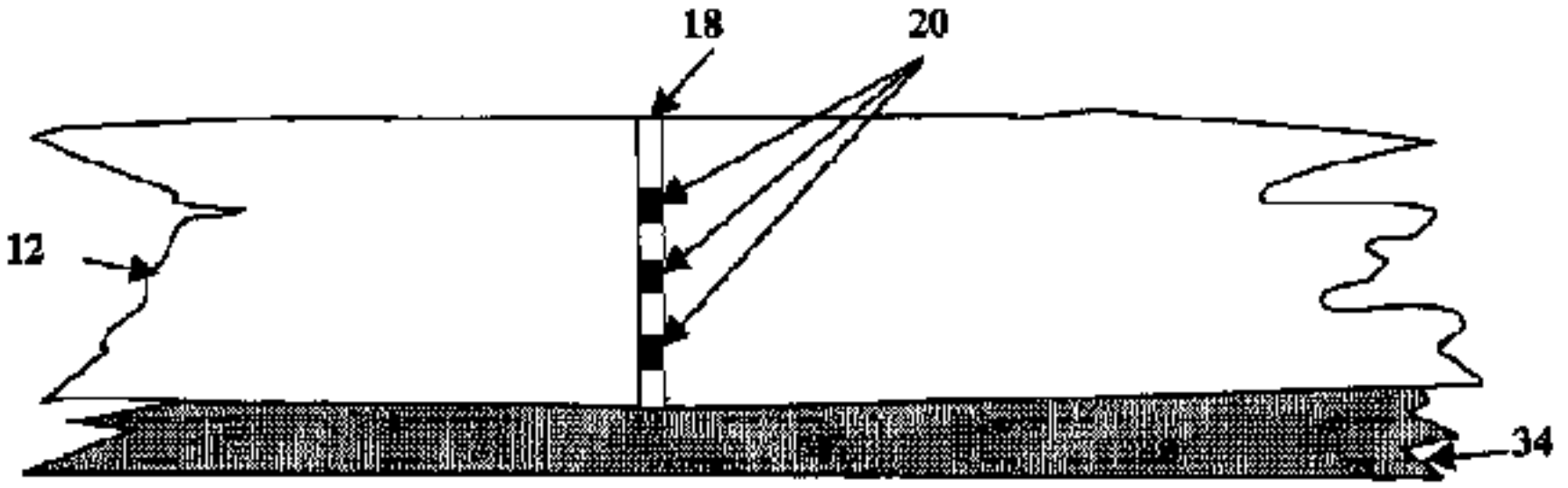
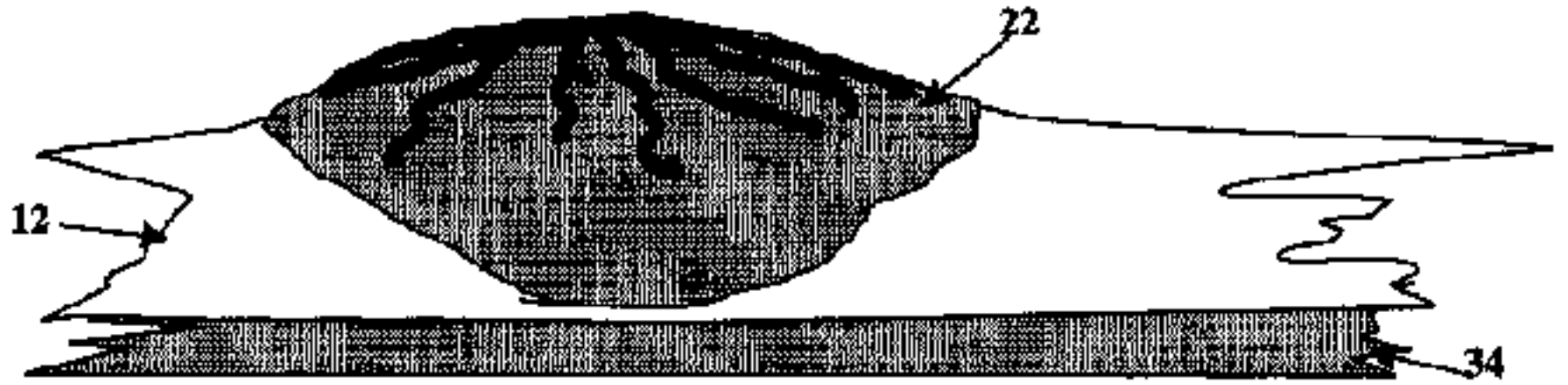


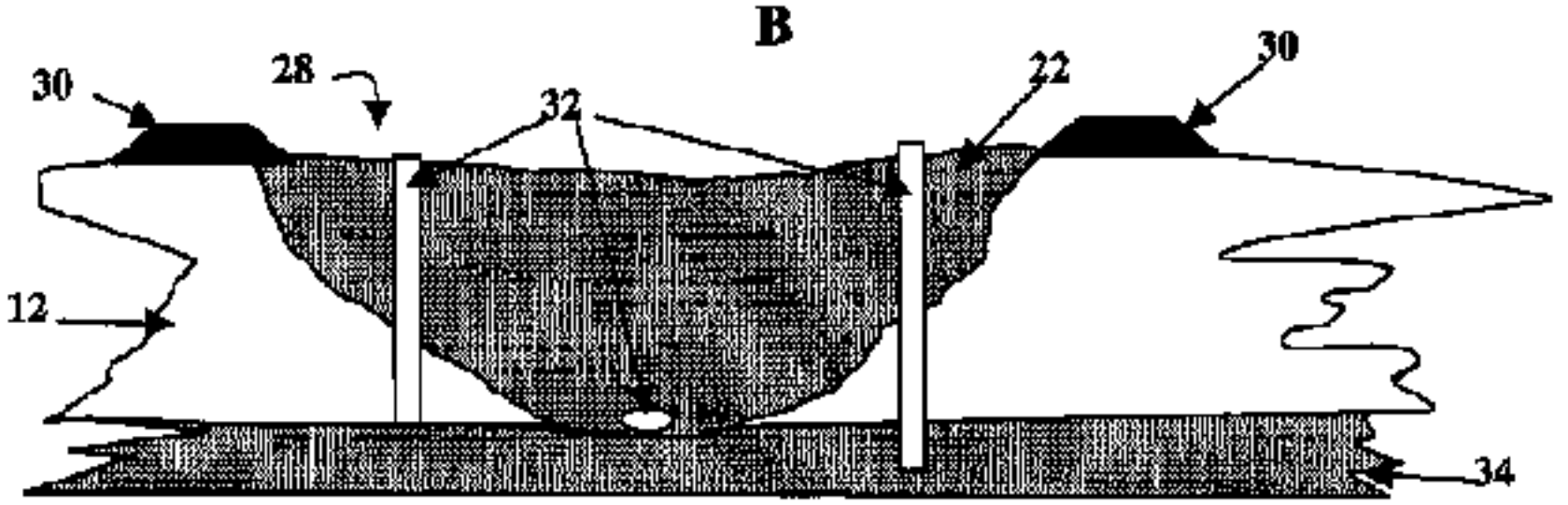
FIG. 2E


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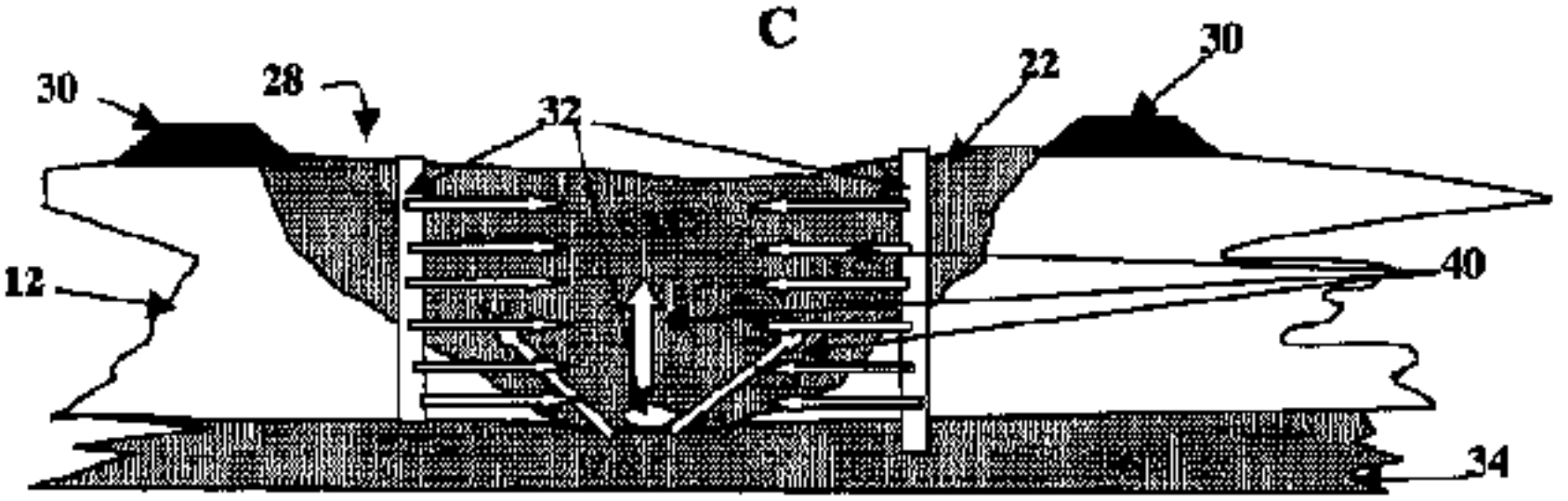
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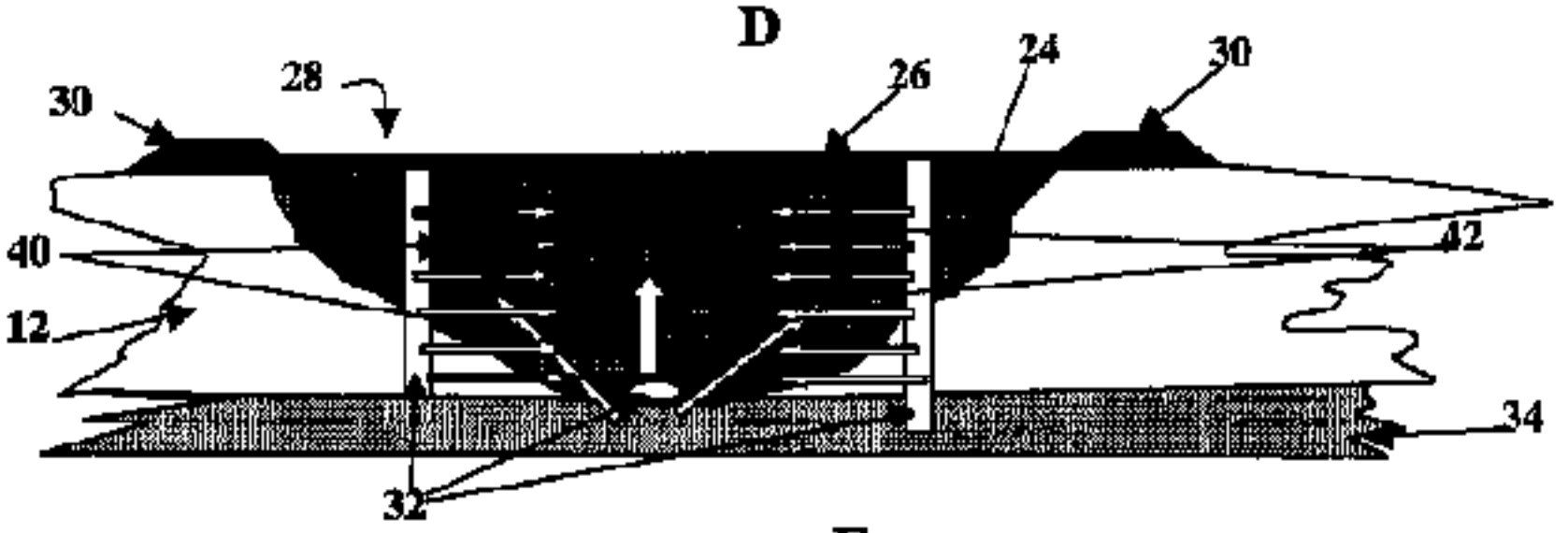
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