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(54) Titre : PROCEDE POUR EXTRAIRE DES COMPOSES HYDROCARBONES, NOTAMMENT DU PETROLE BRUT, DE GISEMENTS DE SABLES PETROLIFERES SOUTERRAINS
(54) Title: METHOD FOR EXTRACTING HYDROCARBON COMPOUNDS, ESPECIALLY CRUDE OIL, FROM UNDERGROUND OIL SANDS DEPOSITS

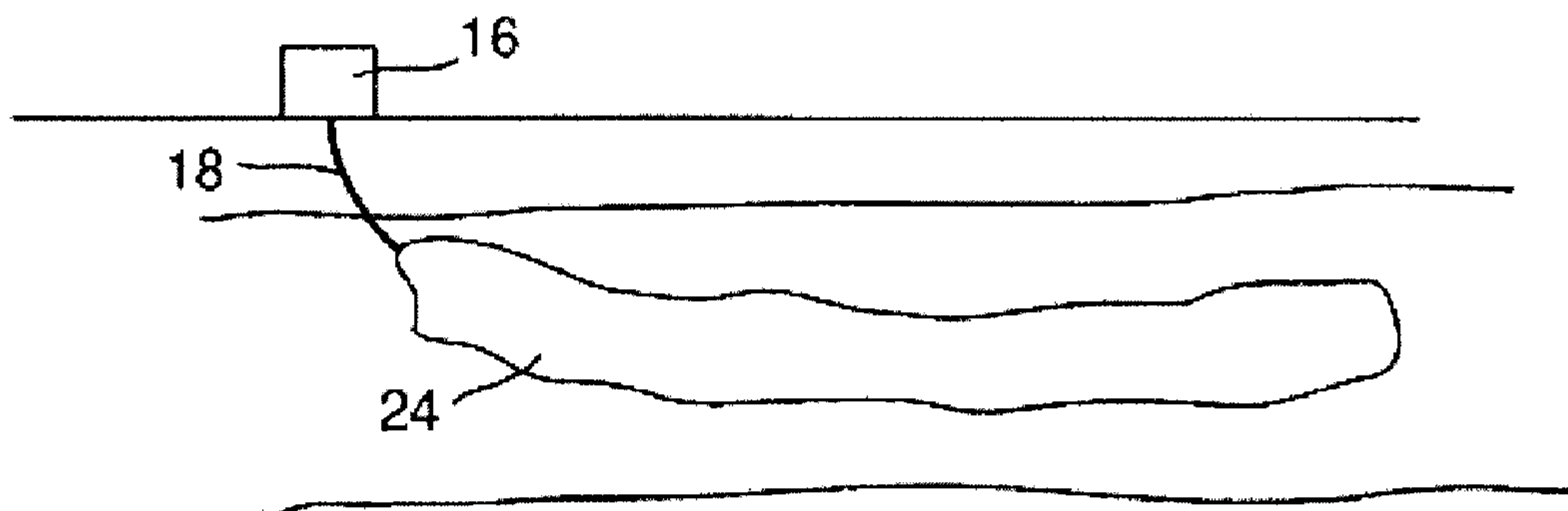


Fig. 3

(57) **Abrégé/Abstract:**

The invention relates to a method for extracting hydrocarbon compounds, especially crude oil, from underground oil sands deposits, comprising the following steps: at least two parallel boring sections are created in the oil sands deposits; at least some areas of the boring sections are filled with an explosive material; the explosive material is ignited in order to enlarge the boring sections; the combustible material is ignited in at least one of the boring sections in order to convert the hydrocarbon compounds in the oil sands deposit into a liquid and/or gaseous state; the hydrocarbon compounds in a liquid and/or gaseous state are collected; and auxiliary substances such as water and atmospheric oxygen are optionally introduced and removed for desired material conversions for the refining of hydrocarbons.



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[Fortsetzung auf der nächsten Seite]

(54) Title: METHOD FOR EXTRACTING HYDROCARBON COMPOUNDS, ESPECIALLY CRUDE OIL, FROM UNDERGROUND OIL SANDS DEPOSITS

(54) Bezeichnung : VERFAHREN ZUM FÖRDERN VON KOHLENWASSERSTOFFVERBINDUNGEN, INSBESONDERE ERDÖL, AUS UNTERIRDISCHEN ÖLSAND-LAGERSTÄTTEN

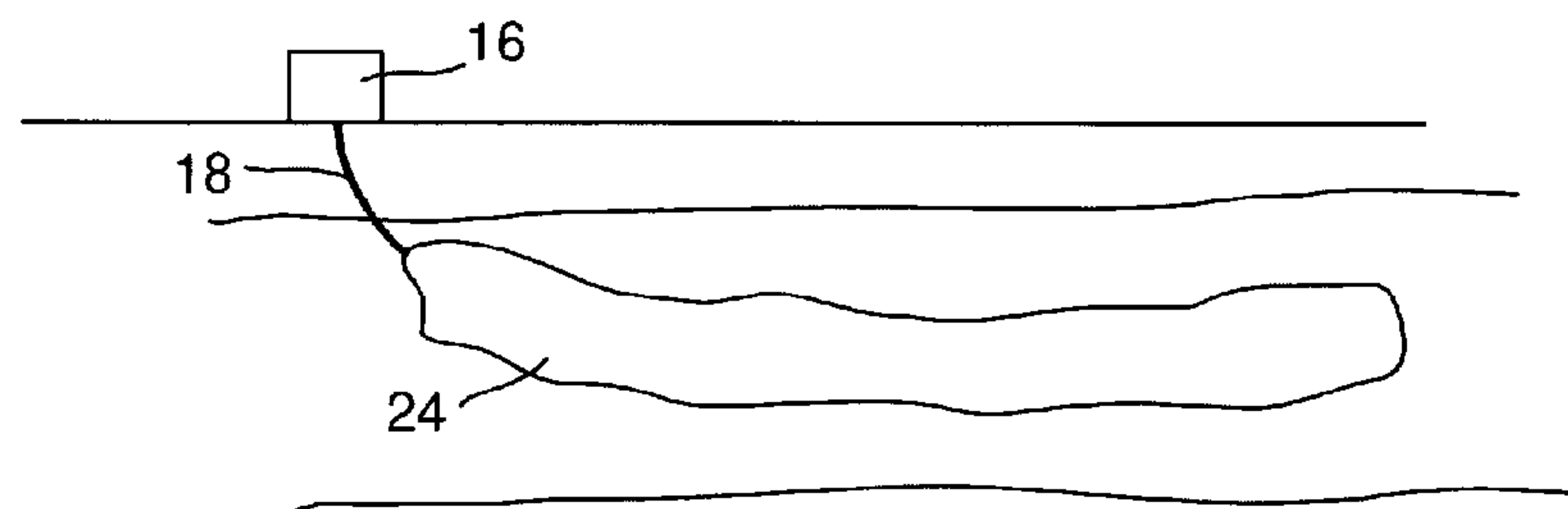


Fig. 3

(57) Abstract: The invention relates to a method for extracting hydrocarbon compounds, especially crude oil, from underground oil sands deposits, comprising the following steps: at least two parallel boring sections are created in the oil sands deposits; at least some areas of the boring sections are filled with an explosive material; the explosive material is ignited in order to enlarge the boring sections; the combustible material is ignited in at least one of the boring sections in order to convert the hydrocarbon compounds in the oil sands deposit into a liquid and/or gaseous state; the hydrocarbon compounds in a liquid and/or gaseous state are collected; and auxiliary substances such as water and atmospheric oxygen are optionally introduced and removed for desired material conversions for the refining of hydrocarbons.

(57) Zusammenfassung: Die Erfindung betrifft ein Verfahren zum Fördern von Kohlenwasserstoffverbindungen, insbesondere Erdöl, aus unterirdischen Ölsand-Lagerstätten, mit den Schritten Einbringen von wenigstens zwei zueinander parallelen Bohrungsabschnitten in die Ölsand-Lagerstätte, wenigstens abschnittsweises Füllen der Bohrungsabschnitte mit einem explosionsfähigen Material, Zünden des explosionsfähigen Materials zum Erweitern der Bohrungsabschnitte, Entzünden brennbaren Materials in wenigstens einem der Bohrungsabschnitte zum Überführen der in der Ölsand-Lagerstätte vorhandenen

[Fortsetzung auf der nächsten Seite]



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— vor Ablauf der für Änderungen der Ansprüche geltenden Frist; Veröffentlichung wird wiederholt, falls Änderungen eingehen (Regel 48 Absatz 2 Buchstabe h)

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Kohlenwasserstoffverbindungen in einen flüssigen und/oder gasförmigen Zustand und Sammeln der in einem flüssigen und/oder gasförmigen Zustand befindlichen Kohlenwasserstoffverbindungen sowie gegebenenfalls Einbringen und Entzug von Hilfsstoffen wie Wasser und Luftsauerstoff für gewünschte Stoffumwandlungen zum Veredeln der Kohlenwasserstoffe.

DescriptionMethod for extracting hydrocarbon compounds, especially crude oil, from
underground oil sands deposits

5 **[0001]** The invention relates to a method for extracting hydrocarbon compounds, especially crude oil, from underground oil sand deposits.

10 **[0002]** Processes known as ISC (in situ-combustion) processes are known for the subterranean separation of low-fluidity bitumen from oil sand. In this process, the bitumen present in the oil sand is partly combusted and, for this purpose, air is injected into the porous oil sand, via a bore introduced into the oil sand deposit, in order to enable such combustion. The high-viscosity bitumen made fluid by the combustion is then pumped off via drainage pipes. In such processes, a firefront is produced within the oil sand deposit, and moves through the deposit. Controlling the firefront presents problems.

15 **[0003]** Alternative processes are based on the introduction of hot steam into the oil deposit, in order to make the high-viscosity bitumen fluid and allow it to be pumped off.

[0004] The aim of the invention is to improve a method for extracting hydrocarbon compounds, especially crude oil, from underground oil sand deposits.

20 **[0005]** According to the invention, a method is provided, for this purpose, for extracting hydrocarbon compounds, especially crude oil, from underground oil sand deposits, with the steps of introducing at least two bore sections parallel to one another into the oil sand deposit, of at least sectionally filling the bore sections with an explosive material, of detonating the explosive material to enlarge the bore sections, of igniting combustible material in at least one of the bore sections, to
25 convert the hydrocarbon compounds present in the oil sand deposit into a liquid and/or gaseous state, and of collecting the hydrocarbon compounds present in a liquid and/or gaseous state.

30 **[0006]** The method of the invention permits improved in situ bitumen extraction and also improved upgrading of the hydrocarbon compounds with a higher and more rapid yield than in the case of the prior art described. By creating an underground cave system or cavern system through the introduction and enlargement of bore

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sections, the hydrocarbon compounds can be collected more easily and completely. Moreover, it is possible, for example, to blow in air, steam, or the like with substantially greater control and simplicity, since enlarged bore sections are available. In accordance with the invention, bores are sunk in the oil sand by means
5 of a suitable drilling apparatus. After the bores have been introduced into the oil sand, bore sections lying within the oil sand are filled, at least sectionally, with an explosive material, and this explosive material is detonated. As a result, a stable, approximately cylindrical cavern is formed in the oil sand. At least two such caverns are produced parallel to one another. Then, in at least one of the caverns,
10 combustible material or ignitable mixture is provided, for example, by the pumped introduction of additional air, and this material or mixture is then ignited by means, for example, of pyrotechnic detonating charges. The combustion is then maintained. Hot combustion gases then penetrate the porous oil sand and liquefy the bitumen in the sand. The combustion then progresses also preferably in the radial direction into the
15 surrounding oil sand. In the cavern itself, liquid and/or gaseous bitumen and/or other hydrocarbon compounds then collect, and can then simply be pumped off. Through targeted, blown introduction of air and water/steam or other substances, temperature conversions and physical conversions within the caverns can be influenced. When the bitumen source is exhausted, i.e., the combustion zones and/or the liquefaction
20 zones, which advance in the radial direction from the two caverns, come together, the supply of air is shut off. Optionally, CO₂ may be pumped in to halt the combustion reliably. The bore sections can be enlarged underground without problems, by detonation of the explosive material, and this enlargement represents the precondition for a decisive improvement in the method of the invention, as has
25 already been the case in particular with regard to the more rapid, more complete, and more secure collecting of liquid or gaseous hydrocarbon compounds, and also in respect of the more controlled propagation of a flame front in the oil sand.

[0007] In development of the invention, there is compacting of the oil sand material surrounding the outer surface of the bore sections, by means of the enlarging of the
30 bore sections after detonating of the explosive material.

[0008] Compacting the oil sand material produces stable caverns which can be utilized for the passage of gaseous and liquid hydrocarbon compounds and also of additives, and also for the combustion of combustible material. Especially in the case of porous and plastically deformable oil sand, such compaction may take place very
35 easily by detonation of explosive material in a bore section.

[0009] In development of the invention, air is supplied to the bore sections to promote the combustion of the combustible material, and off-gases formed during combustion are drawn off under suction.

[0010] In this way it is possible to maintain controlled combustion with predetermined parameters in the enlarged bore sections. Since the enlarged bore sections form caverns, such control or regulation of combustion can take place reliably, since physical exchange is possible comparatively rapidly in the volume of the caverns, in any case significantly more rapidly than would be the case for the blown introduction of air or gases in porous oil sand.

[0011] In development of the invention, water, steam, oxygen, carbon monoxide and/or carbon dioxide is supplied to or targetedly withdrawn from the bore sections in order to influence temperature and physical conversions in the region of the bore sections; in this case, carbon monoxide and/or carbon dioxide may also come from the combustion itself.

[0012] In this way it is possible to design an underground refinery with controllable combustion parameters, physical conversion (upgrading) parameters, mass transport parameters, and heat transport parameters in the caverns formed by enlargement of the bore sections. For example, with the aid of gravity and of the flow regime of gases, more particularly air, combustion gases, pyrolysis vapors or smolder vapors, hydrocarbon vapors, etc., and liquids (hot bitumen and crude oil) can be specifically influenced. Temperature zones can be influenced in just the same advantageous way. In addition, as in the case of above-ground upgrading processes, specific physical conversions can be achieved and therefore partially cracked bitumen also upgraded by hydrogen hydrotreating (synthetic crude oil) can be synthesized underground. This is accomplished, for example, by occasional (intermittent) or continuous injection of water or steam into a cavern filled with combustion gases and bitumen vapors. In a manner similar to steamcracking or thermal cracking, long-chain hydrocarbon molecules are split, and subsequently, using synthesis gas (CO and H₂ from steam and pyrolysis coke), unsaturated, short-chain hydrocarbon molecules are saturated with resultant hydrogen, also called hydrotreating. In order to control combustion or to extinguish the combustion zone, after the end of exploitation of the deposit, using CO₂ introduced by pumping, carbon dioxide, for example, can be pumped in. In this way it is also possible to a certain extent to store CO₂.

[0013] In development of the invention, the hydrocarbon compounds present in the oil sand deposit are split by means of the combustion into hydrocarbon chains of different lengths and different aggregate states, with short-chain, lighter and/or gaseous chain components rising upward, and long-chain, heavier and/or liquid chain components falling downward. In specific secondary reactions, hydrogen is formed from water, in order to upgrade the hydrocarbons by hydrotreating.

[0014] In this way, by means of the geometry of the enlarged bore sections and the skillful arrangement of a plurality of enlarged bore sections, physical partition within the caverns can be influenced.

[0015] In development of the invention, the combustion of the combustible material is extinguished by the pumped introduction of an extinguishant, more particularly by means of an extinguishing gas, CO₂ for example.

[0016] Combustion within the oil sand deposit or else only within the enlarged bore sections can be fully or partly extinguished in this way, in order to be able to control combustion rate and temperature, for example.

[0017] In development of the invention, provision is made for introducing a first, substantially vertical bore section down into the oil sand deposit, for introducing a second, substantially horizontal bore section into the oil sand deposit, starting from the first, vertical bore section, for introducing at least one third, substantially horizontal bore section into the oil sand deposit, starting from the first, vertical bore section or starting from a fourth, vertical bore section, the third, horizontal bore section being arranged with a vertical and/or horizontal offset from the second, horizontal bore section and running substantially parallel thereto, for at least sectional filling of the second, horizontal bore section and of the third, horizontal bore section with an explosive material, and for detonation of this explosive material, to enlarge the second, horizontal and third, horizontal bore sections, for ignition of combustible material in the second and/or third, horizontal bore section(s), to convert the hydrocarbon compounds present in the oil sand deposit into a liquid and/or gaseous state, and for collection of the liquid and/or gaseous hydrocarbon compounds.

[0018] In this way a particularly advantageous arrangement of the individual enlarged bore sections with respect to one another is achieved.

[0019] In development of the invention, two or more second, horizontal bore sections and two or more third, horizontal bore sections are arranged in planes which each run parallel to one another.

5 **[0020]** In this way, a matrix of enlarged bore sections can be formed within the oil sand deposit, this being extremely advantageous for controlled propagation of a flame front in the oil sand deposit and also for the creation of defined sinks or collecting basins for liquid and/or gaseous hydrocarbon compounds. The oil sand deposits can be exploited more completely and also more environmentally as a result, since, for example, combustion processes can be extinguished completely by
10 blown introduction of CO₂.

[0021] In development of the invention, two or more second, horizontal bore sections and two or more third, horizontal bore sections are arranged in a plane at a predetermined distance from one another.

15 **[0022]** In development of the invention, provision is made for introducing at least one first, substantially vertical bore section down into the oil sand deposit, for introducing at least one fourth, substantially vertical bore section down into the oil sand deposit, substantially parallel to the first, vertical bore section, for at least sectional filling of the first and/or fourth vertical bore section(s) with an explosive material, and for
20 detonating this explosive material, to enlarge the first and/or fourth vertical bore section(s), for igniting combustible material in the first and/or fourth vertical bore section(s), to convert the hydrocarbon compounds present in the oil sand deposit into a liquid and/or gaseous state, and for collecting the liquid and/or gaseous hydrocarbon compounds.

25 **[0023]** In this way, enlarged bore sections or caverns arranged vertically can be provided. Then, as in the case of rectifying columns, gases, vapors, and liquids can be fed in and tapped off at different heights. In this way as well it is possible to design an underground refinery.

30 **[0024]** In development of the invention, the first and fourth vertical bore sections are connected by means of horizontal bore sections, with at least one horizontal bore section connecting the vertical bore sections in an upper region, and at least one horizontal bore section connecting the vertical bore sections in a lower region.

[0025] In this way it is possible to enable a targeted flow regime in the underground caverns.

[0026] In development of the invention, at least one bore section is sealed off from the atmosphere. For example, connections between the underground caverns and the atmosphere are sealed off provisionally, at least partly, by means of an expandable or inflatable plug. An expandable plug casing is first expanded, for example, with air and/or with a fluid, resulting in an impervious seal in the borehole. Alternatively or additionally to air, for example, water, bentonite slurry, or flowable concrete can also be used for filling. This plug can thereafter be backfilled, for example with sand, gravel, bentonite slurry and/or concrete. In this way a cavern can be sealed off from the atmosphere or else from other caverns, in order to create an underground system of caverns and connections that can be utilized as an underground refinery.

[0027] Further features and advantages of the invention will become apparent from the claims and from the following description of preferred embodiments of the invention, in connection with the drawings. Individual features of the different embodiments shown may be combined arbitrarily with one another, without exceeding the scope of the invention. In the drawings:

fig. 1 shows a schematic representation of a first step in the method of the invention,

fig. 2 shows a schematic representation of a further step in the method of the invention,

fig. 3 shows a schematic representation of a further step in the method of the invention,

fig. 4 shows a schematic representation of a further step in the method of the invention,

fig. 5 shows an arrangement of underground bore sections in accordance with the method of the invention in a second embodiment,

fig. 6 shows the arrangement of underground bore sections in accordance with the method of the invention in a third embodiment,

fig. 7 shows the arrangement of underground bore sections in accordance with the method of the invention in a fourth embodiment,

fig. 8 shows the arrangement of underground bore sections in accordance with the method of the invention in a fifth embodiment,

5 fig. 9 shows a schematic representation of a further step in the method of the invention,

fig. 10 shows an arrangement of underground bore sections in accordance with the method of the invention in a sixth embodiment, and

10 fig. 11 shows an arrangement of underground bore sections in accordance with the method of the invention in a seventh embodiment.

[0028] The representation in fig. 1 shows, schematically, a section through the uppermost region of the Earth's crust. Arranged beneath a surface 10 of the Earth is, first of all, an intermediate layer 12, followed then by an oil sand deposit 14. The oil sand deposit 14 is situated, for example, at a depth of more than 75 m, corresponding to the thickness of the layer 12, and so the exploitation of the oil sand deposit 14 by open-cast mining is no longer rational. The oil sand deposit 14 must therefore be exploited using what is called an in situ method. In accordance with the invention, for this purpose, a drilling apparatus 16 is first used to drill vertically through the layer 12, with a first, substantially vertical bore section 18, down into the oil sand deposit 14, and then, subsequent to the substantially vertical section 18, a substantially horizontal, second bore section 20 is disposed running within the oil sand deposit 14. This second, substantially horizontal bore section 20 is then filled sectionally, over a length indicated by means of the double-ended arrow 22, with a gellike explosive.

25 **[0029]** This gellike explosive is then detonated - see fig. 2. The underground explosion within the oil sand deposit 14 causes the second, horizontal bore section 20 to be enlarged in a radial direction, thus producing an underground cavern 24, as shown in fig. 3. This underground cavern 24 runs substantially horizontally. The walls of the underground cavern 24 are composed of compacted oil sand, which as a consequence of the underground explosion is displaced radially outward from the

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bore section 20 and, as a result, compacted. The cavern 24 is therefore stable and communicates with the drilling apparatus 16 via the bore section 18.

[0030] In accordance with fig. 3, a second drilling apparatus 26 is used to introduce a third, substantially vertical bore section 28 through the layer 12 down into the oil sand deposit 14, which is then continued, as shown in fig. 1, through a fourth, substantially horizontal bore section. As elucidated using figs. 1 to 3, this fourth, horizontal bore section is then likewise filled sectionally with gellike explosive and then enlarged by the explosion of this gellike explosive. This produces a second underground cavern 30 running substantially horizontally within the oil sand deposit 14. The two underground caverns 24 and 30 are arranged substantially at the same height within the oil sand deposit 14, and run approximately parallel to one another. The representation in fig. 4 is schematic, but is intended to show perspective, and so the two underground caverns 24 and 30 are arranged parallel to one another and roughly at the same height or same depth within the oil sand deposit.

[0031] Arranged beneath the two caverns 24 and 30 is a pumping pipe 32, which communicates with a pumping station 34 on the Earth's surface 10.

[0032] Into both the underground cavern 24 and the underground cavern 30, combustible material is next either introduced, or combustible material is formed within the caverns 24 and 30 by the introduction of additives, as for example the blown introduction of air. The combustible material then present within the caverns 24 and 30, combustible gas for example, is then ignited by pyrotechnic means, for example, so that combustion develops and a flame front propagates, starting from the two caverns 24 and 30. One such flame front is indicated in the case of the cavern with the reference numeral 36. The pressure produced as a result of the combustion within the caverns 24 and 30 ensures a flow of gas in the direction of the arrows 38 and 40, in other words from the cavern 24 toward the cavern 30, and in the opposite direction. The oil sand deposit 14 consists of porous material, and so combustion and an associated flow of gas can propagate within the oil sand deposit 14. The progress of the flame front 36 between the two caverns 24 and 30, with a flame front surrounding the cavern 24 not being shown, ensures heating of the oil sand situated between the two caverns 24 and 30, and, consequently, ensures liquefaction of the bitumen situated between the two caverns 24 and 30. This liquefied bitumen can then be pumped off via the bore 32; however, the liquefied bitumen will also collect within the caverns 24 and 30 and can then easily be pumped

off from these caverns. The same applies to gaseous hydrocarbon compounds, which will preferably collect within the caverns 24 and 30.

5 **[0033]** Following depletion of the oil sand deposit 14 in the region between the caverns 24 and 30, combustion can be extinguished by pumping CO₂ into the caverns 24 and 30. This CO₂ will then spread, starting from the caverns 24 and 30 and likewise in the direction of the arrows 38 and 40, toward the respective opposite cavern 30 or 24, and the combustion of the oil sand deposit will be completely extinguished as a result. This pumped introduction of CO₂ may be used not only to
10 CO₂.

15 **[0034]** The representation in fig. 5 shows an arrangement of underground caverns 42, 44, and 46 in accordance with the method of the invention, in a further embodiment. The caverns 42, 44, and 46 are arranged within the oil sand deposit 14 and, as described with reference to figs. 1 to 3, are formed by arranging first vertical, then horizontal bore sections and then by enlarging the horizontal bore sections by
20 inserting and detonating gellike explosive. Respective vertical bore sections are merely indicated in fig. 5 with the reference numerals 48. The vertical bore sections 48 may be permanently sealed with concrete, for example. The representation in fig. 5 is merely the schematic representation of the arrangement of the underground caverns 42, 44, and 46, but not of their production by the sinking of suitable bores. The vertical bore sections 48 should therefore be understood purely schematically and illustratively.

25 **[0035]** The underground caverns 42, 44, and 46 arranged horizontally, roughly at the same height, and parallel to one another within the oil sand deposit 14 are connected to one another by means of horizontal bores 50 and 52. The horizontal bore sections 50 and 52 are arranged roughly flush and/or offset from one another and are continued in the form of substantially vertically running bore sections 54 and 56 and taken to pumping stations 58 and 60 at the Earth's surface. Starting from the pumping station 58, a substantially vertical bore section 54 leads to the cavern 42,
30 and is then continued by means of the bore section 50 to the cavern 44. Starting from the cavern 44, a flow connection exists via the bore section 52 to the cavern 46, and from there the substantially vertical bore section 56 leads to the pumping station 60. The arrangement in fig. 5 shows the geometrical arrangement of the caverns 42, 44, and 46 after the enlargement of corresponding bore sections by means of explosive.

[0036] The arrangement shown schematically in fig. 5 represents an underground refinery. Accordingly, via the pumping station 58 and the bore section 54, air and other substances are introduced into the cavern 42. In the cavern 42 there is a combustion zone, and here, water is supplied, as well as air, in order, with pyrolysis coke, to form hydrogen and carbon monoxide (synthesis gas) for the hydrotreating and for the cracking of the hydrocarbon compounds from the oil sand deposit 14. Upgrading of the bitumen, or cracking, takes place in the cavern 44. In the cavern 46, crude oil and light gas are deposited. Off-gas as well is collected in the cavern 46, and then off-gas, crude oil, and gaseous hydrocarbon compounds as well can be pumped off via the pumping station 60. Within the cavern arrangement in fig. 5 there is therefore a flow direction from the cavern 42 via the cavern 44 into the cavern 46. The cavern 42 forms a heating zone, the cavern 44 a conversion zone, and the cavern 46 a suction-withdrawal or pumping-off zone.

[0037] The representation in fig. 6 shows an arrangement of underground bore sections in accordance with the method of the invention, in a further embodiment. Three underground caverns 62, 64, and 66 are arranged here in parallel to one another within an oil sand deposit, but also at different depth levels. The caverns 62, 64, and 66 are connected to one another by bore sections 68 and 70. In the cavern 62 there is a heating zone, in which combustion takes place. In the middle cavern 64 there is a conversion zone, and in the uppermost cavern 66 there is a suction-withdrawal zone. The embodiment of fig. 6 is intended for the exploitation of gaseous hydrocarbon compounds, and ensures quick combustion and quick conversion, since the light, gaseous hydrocarbon compounds will rise rapidly along the bore sections 68 and 70 into the uppermost cavern 66, from which they can be pumped off. This predominant flow direction is indicated in fig. 6 by the arrow 72.

[0038] Fig. 7 shows an arrangement of underground bore sections in accordance with the method of the invention, in a further embodiment. Three underground caverns 74, 76, and 78 are arranged parallel to one another but at different depths in the oil sand deposit, and are connected to one another by means of bore sections 80 and 82. In the uppermost cavern 74 there is a combustion zone, in the middle cavern 76 there is a conversion zone, and in the lowermost cavern 78 there is a pumping-off zone. A predominant flow direction between the caverns 74, 76, and 78 is indicated by means of the arrow 84. The arrangement according to fig. 7 ensures slow propagation of the combustion gases, starting from the heating zone in the cavern 74. Liquid hydrocarbon compounds will preferably collect in the lowermost cavern 78, which

they reach as a result of gravity. On account of the slow process, in which the hot combustion gases spend a long time in the respective regions of the oil sand deposit, good and thorough separation of light and heavy crude oil can take place.

[0039] The representation in fig. 8 shows an arrangement of underground bore sections in accordance with the method of the invention, in a further embodiment. Three underground caverns 86, 88, and 90 are arranged parallel to one another and at different depths within an oil sand deposit. The cavern 86 on the left in fig. 8 is arranged the lowest, the cavern in the middle in fig. 8 the highest, and the cavern on the right in fig. 8 at a depth which lies roughly between the depths of the caverns 86 and 88. The caverns 86 and 88 are connected by a bore section 92, which runs upward at a slope, and the caverns 88 and 90 are connected by a bore section 94, which runs downward at a slope.

[0040] In the deepest cavern 86, on the left in fig. 8, there is a combustion zone, which then propagates, as indicated with the reference numeral 96, within the oil sand deposit toward the middle cavern 88. As a result, in accordance with the arrow 98, combustion gases rise preferably toward the middle cavern 88. The middle cavern 88 represents a conversion zone and, since the pumping-off zone, in the form of the cavern 90 on the right in fig. 8, is situated lower than the middle cavern 88, a higher residence time is achieved in the conversion zone, corresponding to the cavern 88.

[0041] The representation in fig. 9 shows the arrangement of the caverns 86, 88, and 90 from fig. 8, with the sealing of a connection between the cavern 88 and the atmosphere being shown, by way of example, above the Earth's surface 10. A connection 101 between the drilling apparatus 100 and the cavern 88 is then to be sealed, the connection 101 having served originally for the drilling of connection 92. For this purpose, an inflatable, elastic plug 102 is first introduced into the bore, adjoining the cavern 88, and is expanded using air, water, bentonite slurry, or flowable concrete, for example, until the bore section is fully filled and thus sealed off. This expandable plug 102 is then backfilled between the drilling apparatus 100 and the plug 102, with sand, gravel, bentonite slurry, concrete or the like, for example. A connection between the cavern 88 and the atmosphere can be fully closed in this way. This can be done in order to produce defined flow conditions between the caverns 86, 88, and 90 during operation. This may also take place after the end of the exploitation of the oil sand deposit. For example, after the end of exploitation,

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CO₂ is passed into the caverns 86, 88, and 90 in order to halt the combustion and to a certain extent to deposit CO₂. After introduction of the plug 102 and the backfilling 104, the caverns 86, 88, and 90 are then separated from the atmosphere, and so the deposited CO₂ is no longer able to escape.

5 **[0042]** The representation in fig. 10 shows a further arrangement of underground bore sections in accordance with the method of the invention, in a further embodiment. Arranged beneath the Earth's surface 10 and within an oil sand deposit 14 there is a matrix of bore sections, which exhibits a total of four planes 106, 108, 110, and 112 at in each case eight caverns arranged parallel to one another and at
10 the same height. The number of four planes and also the number of in each case eight caverns arranged parallel to one another and at the same height is merely exemplary. The caverns in each plane 106, 108, 110, and 112 are each connected to one another by means of a horizontal bore 114, 116, 118, and 120.

15 **[0043]** The arrangement of underground bore sections and caverns shown in fig. 10 forms an underground refinery, by means of which it is possible not only to exploit the oil sand deposit 14 but also, at the same time, to convert the hydrocarbon compounds still within the oil sand deposit 14.

[0044] The representation in fig. 11 shows an arrangement of underground bore sections in accordance with the invention, in a further embodiment.

20 **[0045]** According to fig. 11, three vertical bores 122, 124, and 126 have been introduced in parallel to one another in the Earth's surface 10 down into the oil sand deposit 14. Bore sections situated within the oil sand deposit 14 have been enlarged by explosion, thus forming three vertically arranged underground caverns 128, 130, and 132. In the region of their top end, the underground caverns 128, 130, and 132
25 are connected to one another by means of horizontally running bores 134 and 136, and in the region of their lower end by means of horizontal bores 138 and 140. The caverns 128 and 130 communicate via the bores 134 and 138, and the caverns 130 and 132 communicate with one another via the bores 136 and 140. An arrow 142 symbolizes the introduction of air or other substances into the cavern 128 on the left
30 in fig. 11. This is done via one or more bores, which for clarity are not shown in fig. 11. The pumping-off of liquid hydrocarbon compounds from the cavern 132 on the right in fig. 11 is indicated by means of an arrow 144. Liquid hydrocarbon compounds collect in the cavern 132, in accordance with gravity, at its bottom end, and so liquid

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hydrocarbon compounds are also pumped off from there. The pumping-off of gaseous hydrocarbon compounds from the cavern 132 is indicated by means of an arrow 146. Gaseous hydrocarbon compounds collect in the cavern 132 preferably in the region of its upper end, and so gaseous compounds are also pumped off from there.

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[0046] The arrangement of the underground caverns 128, 130, and 132 that is shown in fig. 11 also forms an underground refinery with a heating zone in the region of the left-hand cavern 128, a conversion zone in the region of the middle cavern 130, and a pumping-off zone in the region of the right-hand cavern 132.

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Claims

1. A method for extracting hydrocarbon compounds, especially crude oil, from underground oil sand deposits, with the steps of
 - 5 • introducing at least two bore sections parallel to one another into the oil sand deposit,
 - at least sectionally filling the bore sections with an explosive material,
 - detonating the explosive material to enlarge the bore sections,
 - 10 • igniting combustible material in at least one of the bore sections, to convert the hydrocarbon compounds present in the oil sand deposit into a liquid and/or gaseous state, and
 - collecting the hydrocarbon compounds present in a liquid and/or gaseous state.
- 15 2. The method as claimed in claim 1, characterized by compacting of the oil sand material surrounding the outer surface of the bore sections, by means of the enlarging of the bore sections after detonating of the explosive material.
- 20 3. The method as claimed in one of the preceding claims, characterized in that the explosive material is a gellike explosive.
- 25 4. The method as claimed in any of the preceding claims, characterized in that air is supplied to the bore sections to promote the combustion of the combustible material, and in that off-gases formed during combustion are drawn off under suction.
- 30 5. The method as claimed in any of the preceding claims, characterized in that water, steam, oxygen, more particularly atmospheric oxygen, carbon monoxide and/or carbon dioxide is supplied to or targetedly withdrawn from the bore sections in order to influence temperature and physical conversions, such as cracking and upgrading, for example, in the region of the bore sections.
- 35 6. The method as claimed in any of the preceding claims, characterized in that the hydrocarbon compounds present in the oil sand deposit are split by means of the combustion into hydrocarbon chains of different lengths and different aggregate states, with short-chain, lighter and/or gaseous chain components

rising upward, and long-chain, heavier and/or liquid chain components falling downward.

5 7. The method as claimed in any of the preceding claims, characterized in that the combustion of the combustible material is extinguished by the pumped introduction of an extinguishant, more particularly by means of an extinguishing gas, CO₂ for example.

10 8. The method as claimed in any of the preceding claims, characterized by sealing off at least one bore section from the atmosphere.

15 9. The method as claimed in any of the preceding claims, with the steps of

- introducing a first, substantially vertical bore section down into the oil sand deposit,
- introducing a second, substantially horizontal bore section into the oil sand deposit, starting from the first, vertical bore section,
- introducing at least one third, substantially horizontal bore section into the oil sand deposit, starting from the first, vertical bore section or starting from a fourth, vertical bore section, the third, horizontal bore section being arranged with a vertical and/or horizontal offset from the second, horizontal bore section and running substantially parallel thereto,
- at least sectionally filling the second, horizontal bore section and the third, horizontal bore section with an explosive material, and detonating this explosive material to enlarge the second, horizontal and third, horizontal bore sections,
- igniting combustible material in the second and/or third, horizontal bore section(s), to convert the hydrocarbon compounds present in the oil sand deposit into a liquid and/or gaseous state, and
- collecting the liquid and/or gaseous hydrocarbon compounds.

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35 10. The method as claimed in claim 9, characterized in that two or more second, horizontal bore sections and two or more third, horizontal bore sections are arranged in planes which each run parallel to one another.

11. The method as claimed in any of the preceding claims, characterized in that two or more second, horizontal bore sections and two or more third, horizontal

bore sections are arranged in a plane at a predetermined distance from one another.

12. The method as claimed in claim 1, with the steps of

- introducing at least one first, substantially vertical bore section down into the oil sand deposit,
 - introducing at least one fourth, substantially vertical bore section down into the oil sand deposit, substantially parallel to the first, vertical bore section,
- characterized by
- at least sectionally filling the first and/or fourth vertical bore section(s) with an explosive material, and detonating this explosive material to enlarge the first and/or fourth vertical bore section(s),
 - igniting combustible material in the first and/or fourth vertical bore section(s), to convert the hydrocarbon compounds present in the oil sand deposit into a liquid and/or gaseous state, and
 - collecting the liquid and/or gaseous hydrocarbon compounds.

13. The method as claimed in claim 12, characterized by connecting the first and fourth vertical bore sections by means of horizontal bore sections, with at least one horizontal bore section connecting the vertical bore sections in an upper region, and at least one horizontal bore section connecting the vertical bore sections in a lower region.

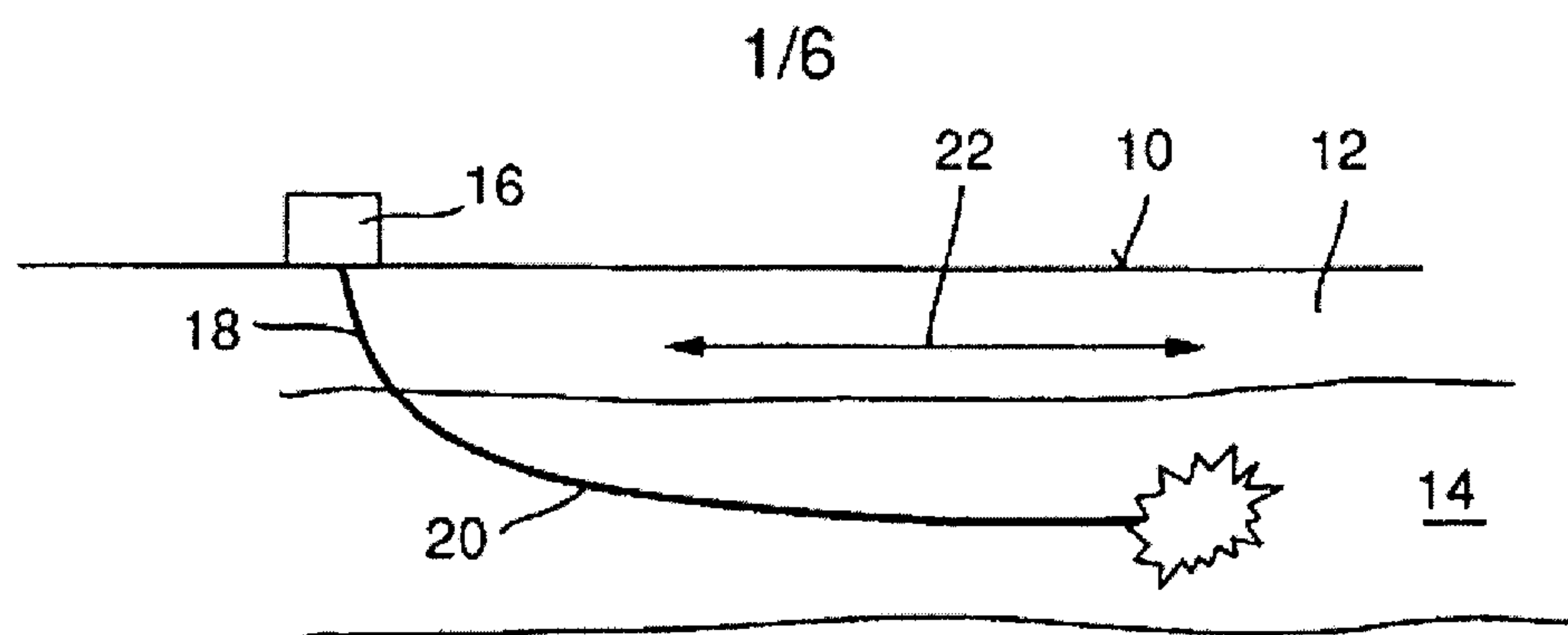


Fig. 1

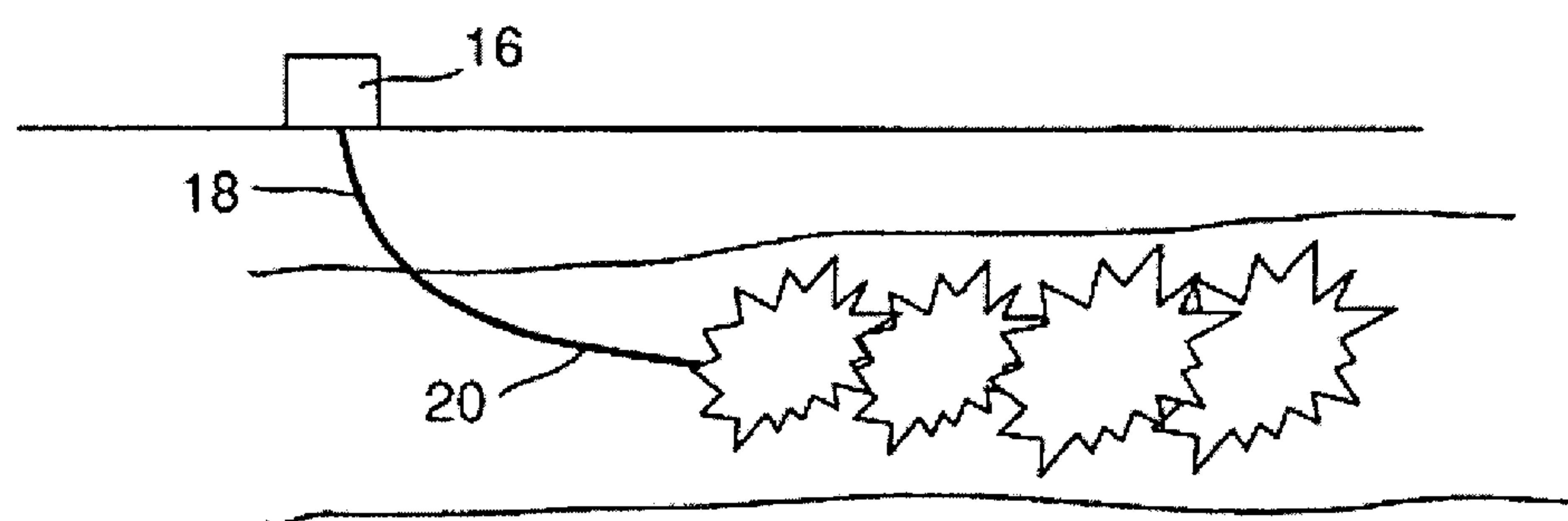


Fig. 2

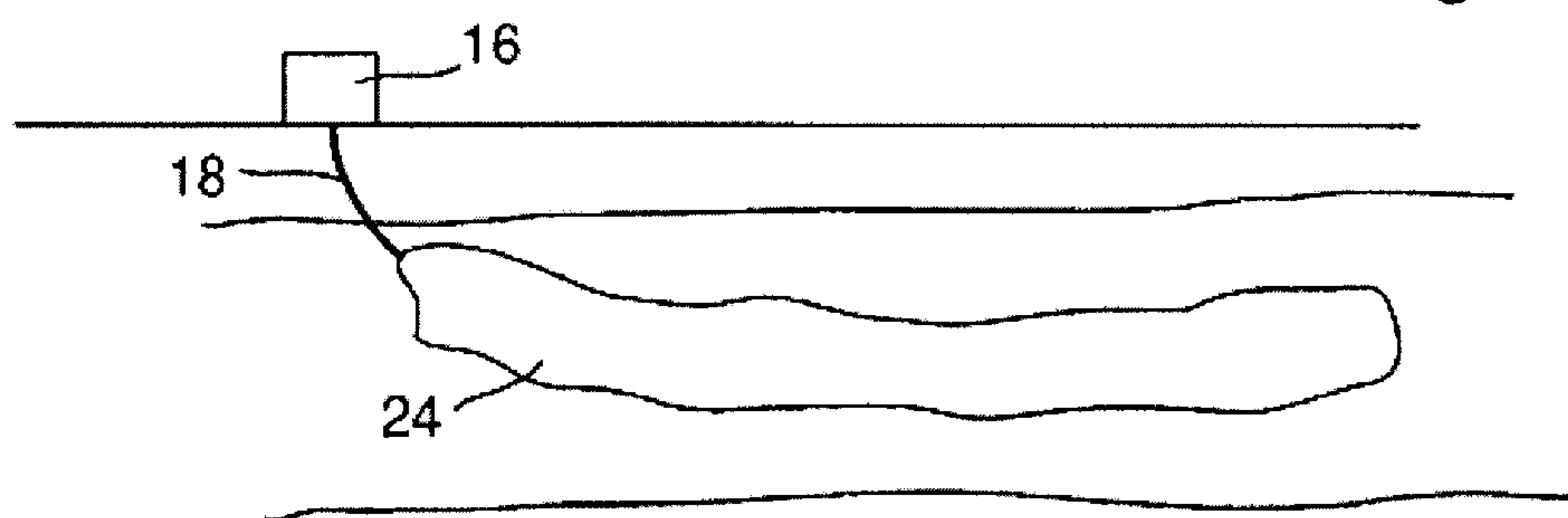


Fig. 3

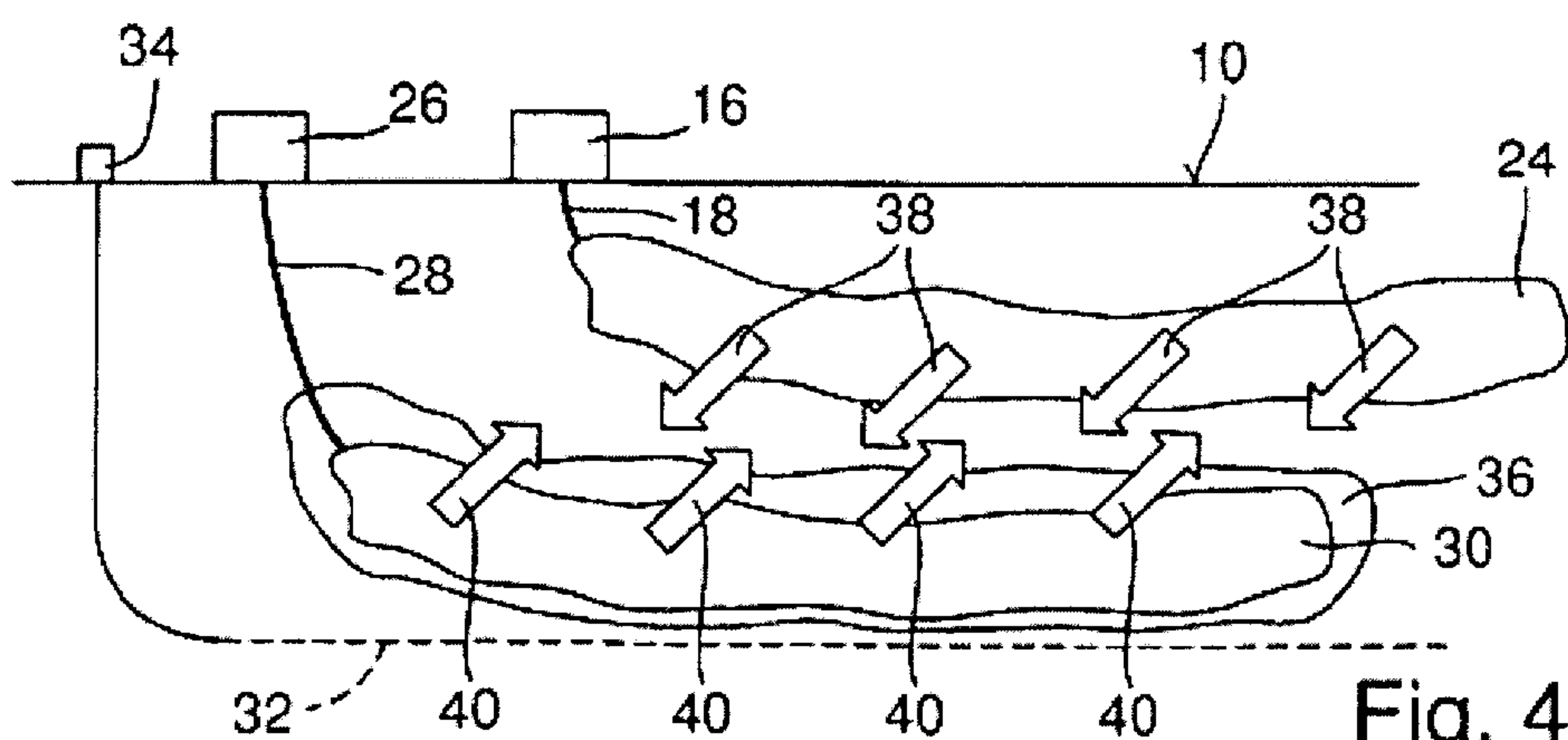


Fig. 4

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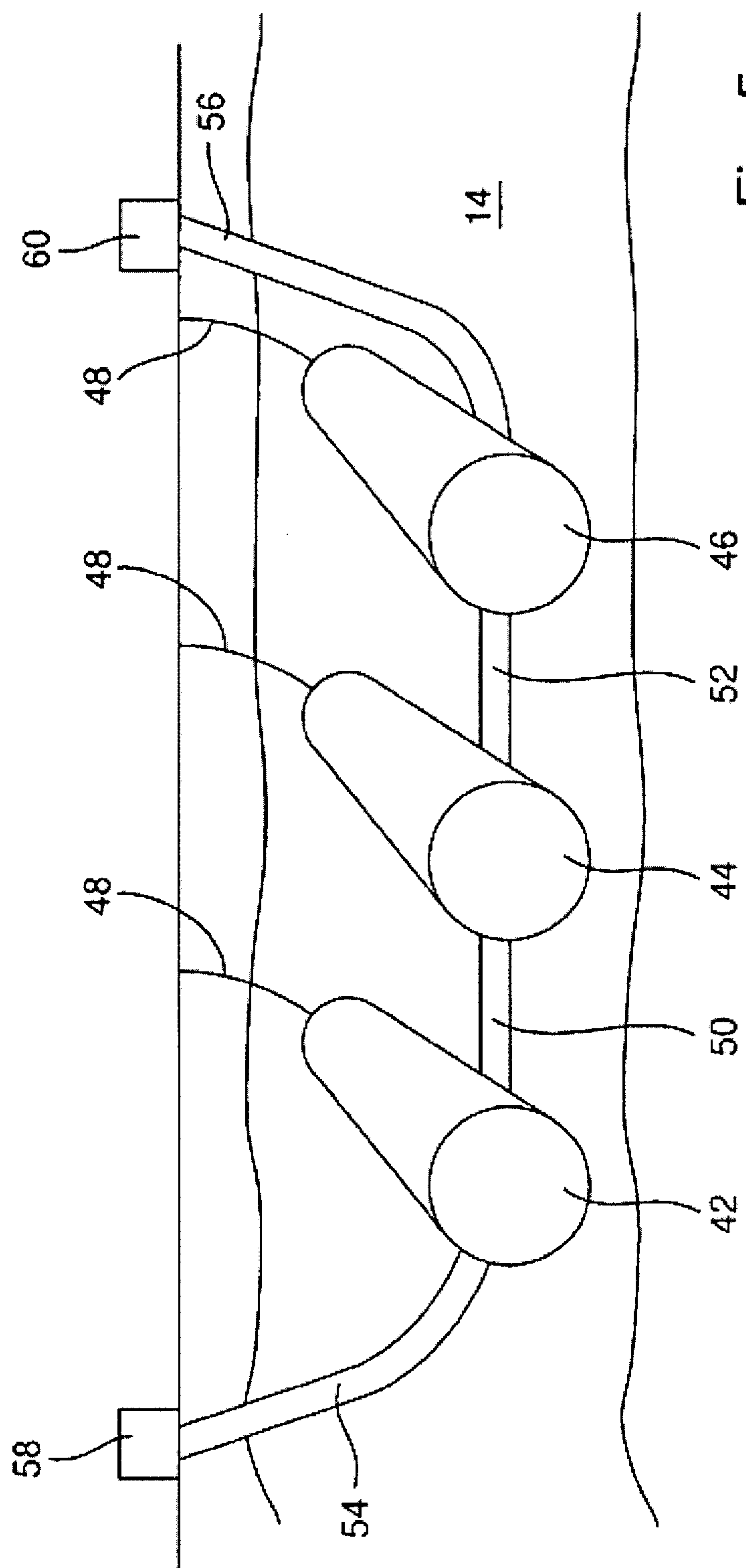


Fig. 5

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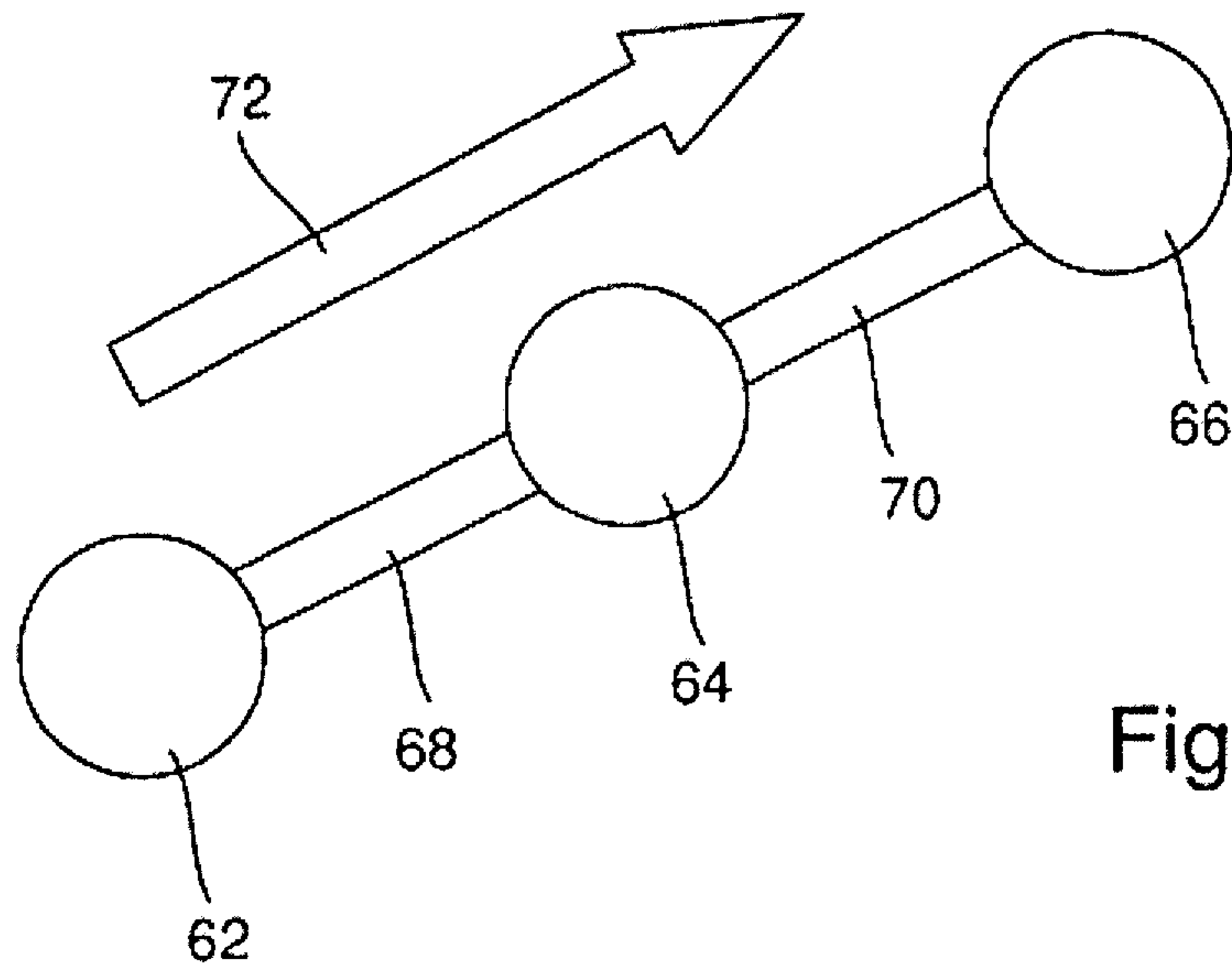


Fig. 6

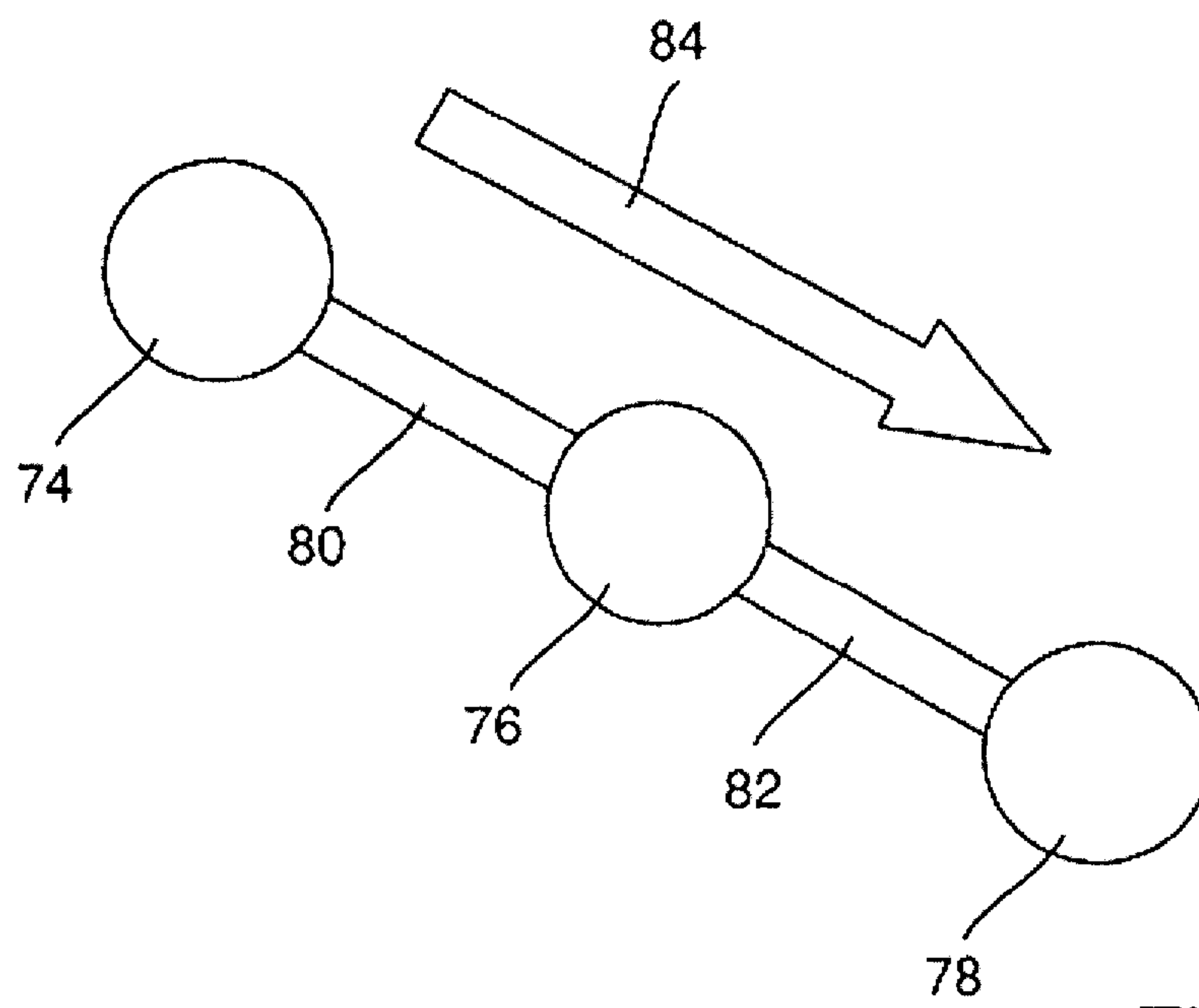


Fig. 7

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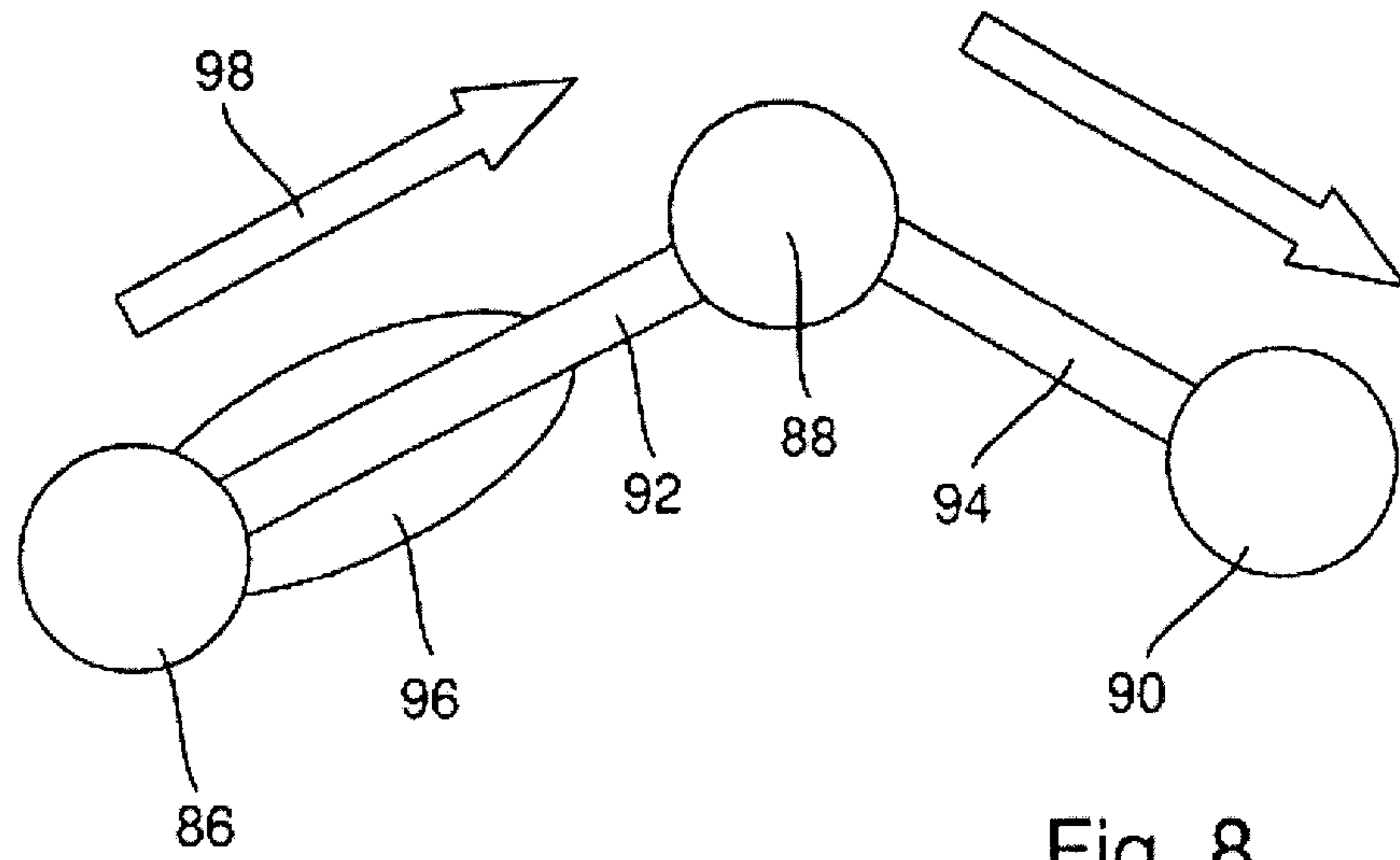


Fig. 8

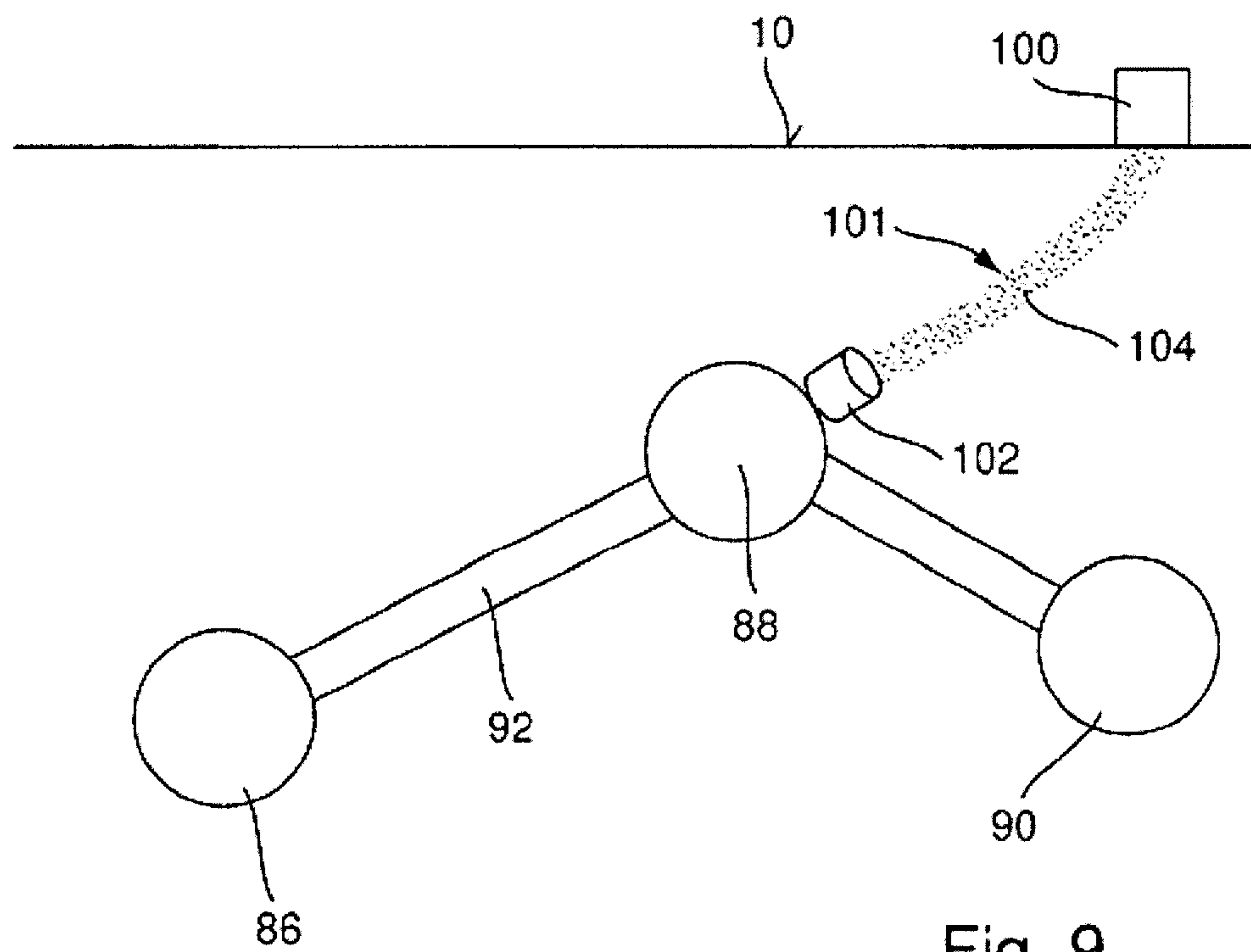


Fig. 9

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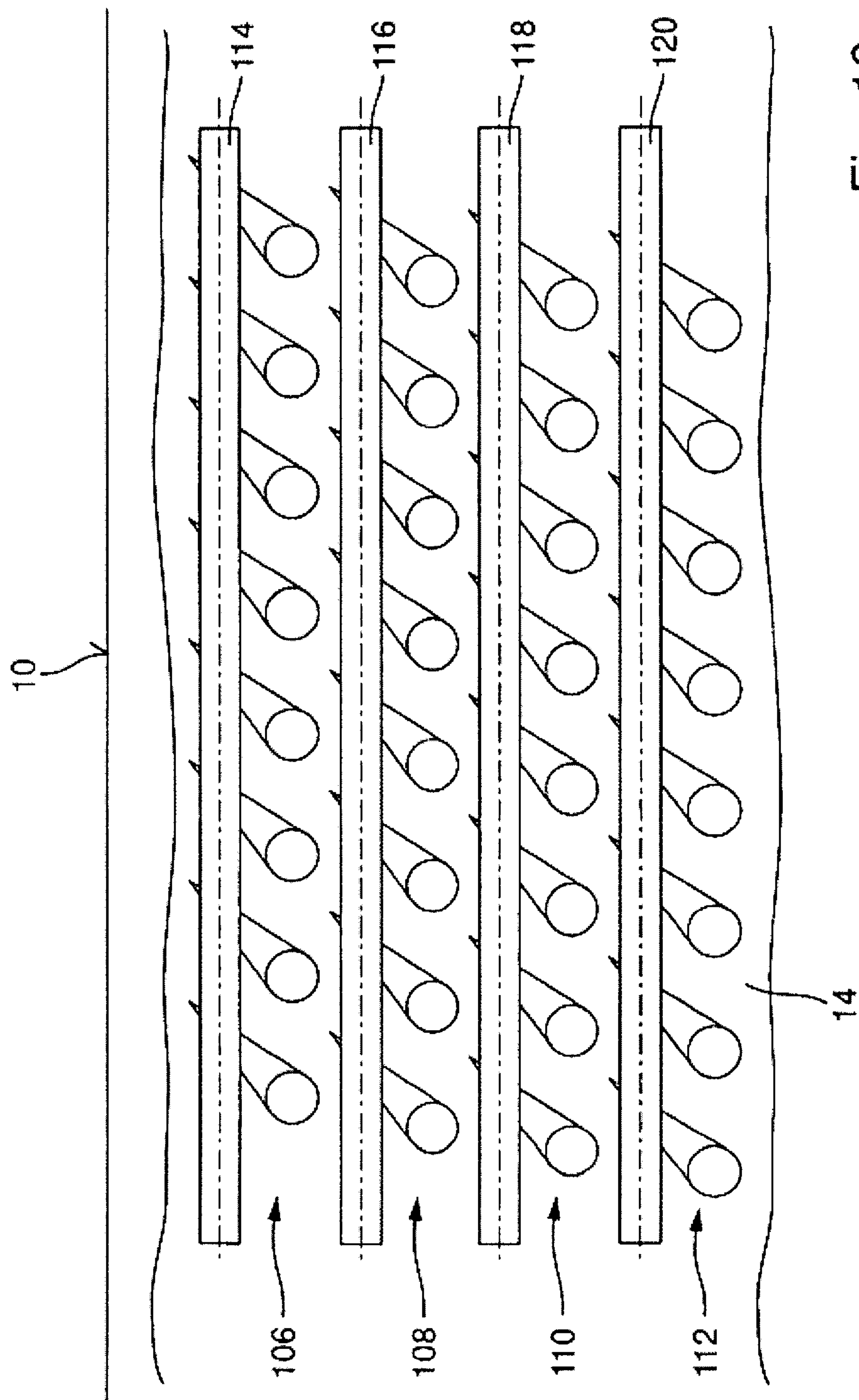


Fig. 10

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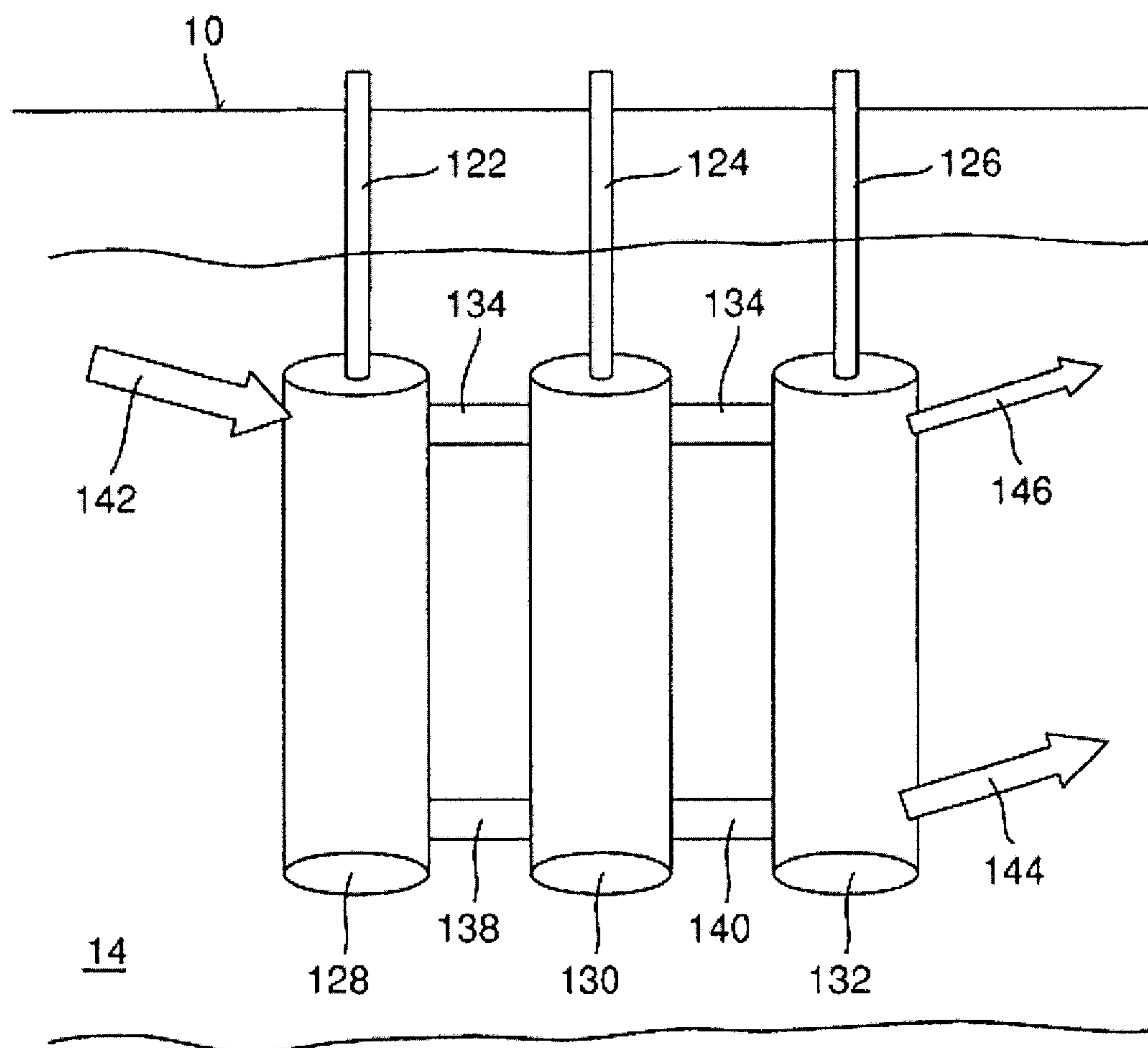


Fig. 11

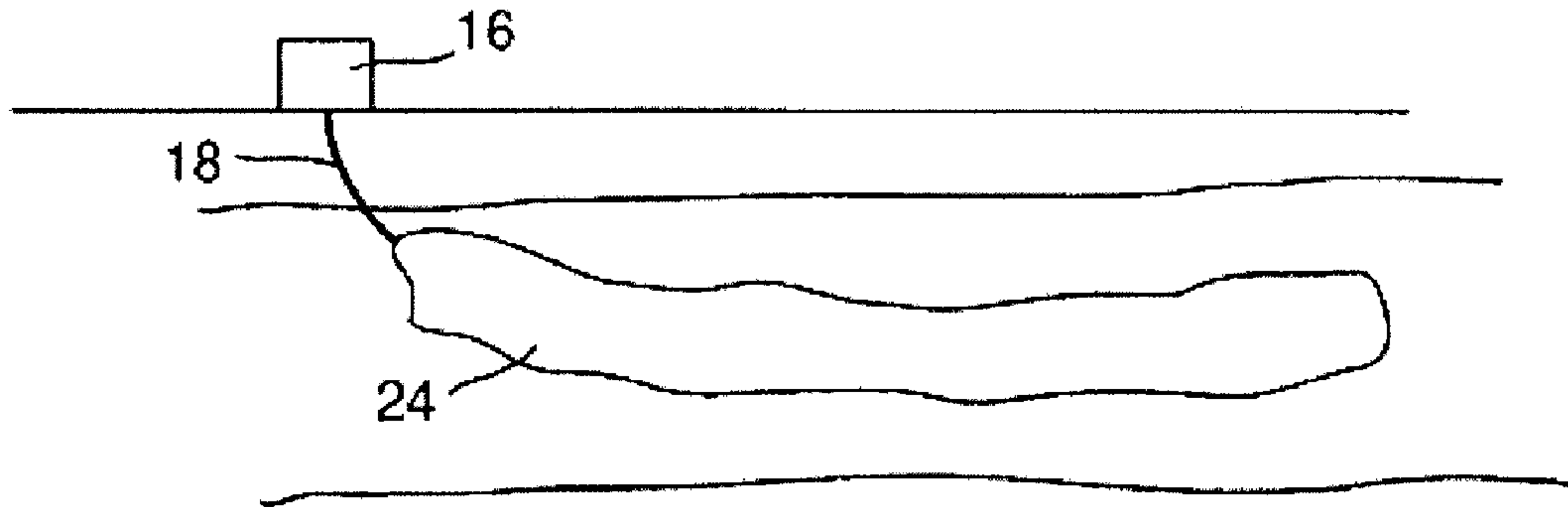


Fig. 3