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(54) **Title:** HEATING CAPSULE FOR RECOVERING A HYDROCARBON FLUID FROM A SOLID HYDROCARBON-ACEOUS MATERIAL, RELATED INSTALLATION AND METHOD

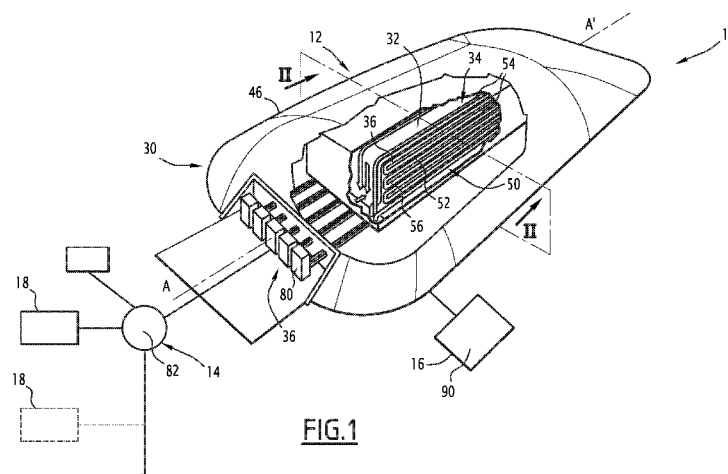


FIG. 1

(57) **Abstract:** The capsule (12) comprises an enclosure (30) having an impervious bottom wall, side walls and a cap defining an inner volume (32). It comprises a heating structure (34), comprising a plurality of pipe segments (54) received in the inner volume (32) and voids (52) delimited between the pipe segments (54) to receive solid hydrocarbonaceous material. It also comprises a circulation assembly (36) for circulating heating fluid through the pipe segments (54). The ratio of the total area of the pipe segments (54) outer surface to the total volume of the voids (52) is greater than 0.02 m²/m³, and is advantageously comprised between 0.04 m²/m³, and 0.12 m²/m³.



**Heating capsule for recovering a hydrocarbon fluid from a solid
hydrocarbonaceous material, related installation and method**

The present invention concerns a heating capsule for recovering a hydrocarbon fluid from a solid hydrocarbonaceous material, comprising:

- 5 - an enclosure having an impervious bottom wall, side walls, and a cap defining an inner volume;
- a heating structure, comprising a plurality of pipe segments received in the inner volume and voids delimited between the pipe segments to receive solid hydrocarbonaceous material;
- 10 - a circulation assembly for circulating heating fluid through the pipe segments.

Such a capsule is intended in particular for heating a solid material comprising oil shale or consisting of oil shale. The oil shale is advantageously produced from hydrocarbonaceous material mined in the ground.

15 More generally, the heating capsule applies to the heating of conventional, heavy or unconventional oils, mobile or stationary oils, either ex situ, i.e. at the surface of the ground, or in situ, directly in the ground, for example in a cavity or in a well bored in the ground.

 Oil shale is an organic rich fine-grained sedimentary rock. Oil shale contains immature kerogen in a mineral matrix. A retorting process can be carried out to heat the
20 kerogen and produce liquid oil and gas under an oxygen-free environment.

 As a consequence, oil shale can be a source of oil which could be a substitute for conventional liquid crude oil. Deposits of oil shale are located around the world, with major deposits in the United States of America. Estimates of global deposits are about 4 trillion barrels of equivalent crude oil.

25 In order to extract liquid oil with a good quality, the oil shale is preferably heated for long times at relatively low temperatures to obtain a higher hydrogen to carbon ratio and a higher API gravity degree. A preferred temperature for the treatment is around 320°C to 400°C.

30 An example of operation which can be carried out to extract liquid oil from oil shale solid material is disclosed in US 8,490,703.

 The method includes building a heating capsule comprising an impervious bottom wall, side walls and a cap delimiting an inner volume for receiving the oil shale solid material.

35 In order to heat the solid material, pipe segments of large diameters are inserted into layers of oil shale material. A heating gas circulates in the pipe segments to heat the solid material located in the inner volume of the capsule.

The gas circulating in the pipe segments is heated outside of the capsule by convective heating from hydrocarbon combustion under stoichiometric conditions. The heating gas is circulated through heating pipes of large diameter, having preferentially a corrugated surface to accommodate potential deformation of the mass of oil shale when the oil is extracted.

Once the liquid oil has been recovered, the capsule is cooled down and the metal pipe segments are left in the capsule.

Such a method is not entirely satisfactory. In order to limit the pressure drop when circulating the heating gas, the cross section of the heating pipes has to be significantly increased, for example to a diameter of more than 90 cm.

The use of heating gas may lead to corrosion of the tubes and possibly safety issues, if leaks occur. The produced gas from shale retorting can also contribute to the heating pipes corrosion.

Additionally, the heat stored in the capsule is almost unusable, since the heating gas circulates at very low pressure and has by nature a very low heat capacity. At least 40% of the energy used to heat the oil shale in the capsule would be lost if a heat recovery was tried.

One aim of the invention is to obtain a heating capsule for efficiently recovering hydrocarbon liquids and gases from solid hydrocarbonaceous material, which is easy to build and economical to operate.

To this aim, the subject-matter of the invention is a heating capsule as defined above, wherein the ratio of the total area of the pipe segments outer surface to the total volume of the voids is greater than $0.02 \text{ m}^2/\text{m}^3$, and is advantageously comprised between $0.04 \text{ m}^2/\text{m}^3$, and $0.12 \text{ m}^2/\text{m}^3$.

The capsule according to the invention may comprise one or more of the following features, taken solely or according to any technically possible combination:

- in a section transverse to at least one pipe segment, the minimal distance separating the center of the pipe segment and the center of the closest adjacent pipe segment is lower than 4.5 m and is advantageously comprised between 3.0 m and 4.3 m;
- each pipe segment comprises a metal tube with a smooth outer surface;
- the maximal transverse dimension of the metal tube is lower than 0.9 m;
- the wall thickness of the metal tube is greater than 2 mm and is advantageously comprised between 2 mm and 5 mm;
- each pipe segment comprises a tube and at least one fin protruding radially from the tube;

- for at least one pipe segment, the total area of the active surface of the fin(s) is lower than 0.6 times the total area of the outer surface of the tube;

- the assembly for circulating fluid comprises a heating liquid and at least a pump able to circulate the heating liquid in the pipe segments;

5 - the bottom wall and side walls comprise soil material and/or concrete ;

-it comprises at least a first row of longitudinal pipe segments and at least a second row of longitudinal pipe segments, the pipe segments from the first row being offset from the pipe segments of the second row.

The subject-matter of the invention is also an oil recovery installation comprising:

10 - a heating capsule as defined above;

- at least one heat recovering assembly able to recover heat from the heated capsule, the heat recovering assembly being in thermal exchange relationship with the heating fluid circulating in the heating structure.

The installation according to the invention may comprise the following feature:

15 - a second heating capsule as defined above, the heating fluid circulating in the second heating capsule being the fluid circulating in the first heating capsule or being in heat exchange relationship with the fluid circulating in the first capsule.

The invention also concerns a method for recovering hydrocarbon fluids from a solid hydrocarbonaceous material, comprising the following steps:

20 - providing at least a heating capsule as defined above;

- placing a solid hydrocarbonaceous material in the voids of the heating structure, in contact with the plurality of pipe segments;

- circulating heating fluid in the plurality of pipe segments to heat the solid hydrocarbonaceous material;

25 - recovering a hydrocarbon liquid at the bottom wall of the enclosure and/or gas.

The method according to the invention may comprise one or more of the following features, taken solely or according to any technically possible combination:

- the temperature of the fluid circulating into the plurality of pipe segments is lower than 800°C;

30 -the method comprises the following steps:

* recovering heat from the capsule;

* using the heat recovered from the capsule to pre-heat or heat the solid hydrocarbonaceous material in another capsule;

35 - the solid hydrocarbonaceous material is heated for at least 100 days, in particular between 200 days to 400 days.

The invention will be better understood upon reading of the following description, given solely as an example, and made in reference to the appended drawings, in which:

- figure 1 is a perspective view, with a partial opening, of a first heating capsule according to the invention;

- figure 2 is a partial section, taken in a transverse plane II-II, of the heating capsule of figure 1;

- figure 3 is a side view of a heating pipe comprising several parallel pipe segments in the heating capsule of figure 1;

- figure 4 is a transverse view of an arrangement of pipe segments in the heating capsule of figure 1;

- figure 5 is a view similar to figure 4 of an alternate arrangement;

- figure 6 is a transverse section of a pipe segment having fins;

- figure 7 is a variation of the pipe segment of figure 6;

- figure 8 is a view similar to figure 4 in a heating structure having pipe sections according to figure 6 or figure 7;

- figure 9 is a view similar to figure 8 of an alternate arrangement;

- figure 10 to figure 14 are schematic views of an installation comprising several capsules according to the invention, during successive steps of an oil recovery method;

- figure 15 is a graph illustrating the variation of temperature in several capsules of the installation of figure 10, as a function of time.

A first oil recovery installation 10 according to the invention is illustrated in figure 1. The installation 10 is intended for recovering a hydrocarbon fluid, in particular liquid and gaseous hydrocarbons, from a solid hydrocarbonaceous material 11 illustrated partially in figure 3.

The solid hydrocarbonaceous material 11 preferably comprises dispersed pieces of material such as crushed pieces of rocks, and/or powder.

The maximum dimension of each piece of material is generally lower than 0.3 m.

The solid material is preferably oil shale, as defined above. The oil shale has been mined and possibly crushed to be available in the form of a dispersed solid material.

The hydrocarbonaceous material preferentially contains kerogen, which is able to be heated to release liquid oil and/or natural gas, generally defined as hydrocarbon fluids.

In reference to figure 1, the installation 10 comprises at least a heating capsule 12, for receiving the solid hydrocarbonaceous material 11.

The installation 10 further comprises a heating device 14, an oil recovery assembly 16 and advantageously at least one heat recovering assembly 18 for recovering heat from

the heating capsule 12, connected to the heating capsule 12, for example through the heating device 14.

In a preferred embodiment, shown in figure 14, each additional structure 18 is another heating capsule 12A, 12B, 12C according to the invention.

5 As shown in figure 1, the heating capsule 12 comprises an enclosure 30 defining an inner volume 32 for receiving solid hydrocarbonaceous material 11, a heating structure 34 located in the inner volume 32 and a circulation assembly 36 for circulating fluid in the heating structure 34.

10 As shown in figure 2, the enclosure 30 comprises an inner part having a bottom wall 40, and side walls 42 extending at the periphery of the bottom wall 40 to define the inner volume 32. The enclosure comprises an upper cap 44, closing upwardly the inner volume 32.

Advantageously, in the present case, an outer protection cover 46 is located around the inner part.

15 The bottom wall 40 is preferably laid on the ground, for example in a cavity dug in the ground. It comprises an impervious layer, such as a clay layer, to prevent liquid hydrocarbons recovered in the inner volume 32 to permeate in the ground. In a preferred embodiment, the bottom wall 40 is inclined to allow a spontaneous flow of the liquid hydrocarbons towards the oil recovery assembly 16.

20 The side walls 42 protrude from the bottom wall 40, at the periphery of the bottom wall 40. They are preferably impervious to liquids.

The side walls 42 for example comprise soil material such as rocks and sediments, an impermeable liner and/or a concrete structure.

25 The cap 44 closes the side walls 42. It is made of a material impervious to gases. The cap 44 for example comprises an impervious layer such as clay, a liner or a metallic membrane.

The bottom wall 40, the side walls 42 and the upper cap 44 together define the inner volume 32.

30 Advantageously, the length of the inner volume 32, taken along a longitudinal axis A-A' of the capsule 12 is comprised between 100 m and 300 m. The width of the inner volume 12, taken transversely in relation with the axis A-A' is generally comprised between 100 m and 200 m and the height of the inner volume 32 is comprised advantageously between 20 m and 60 m.

35 The inner volume 32 is greater than 200,000 m³ and is generally comprised between 1,500,000 m³ and 2,000,000 m³.

As illustrated in figures 1 to 3, the heating structure 34 comprises at least one pipe 50, advantageously a series of parallel pipes 50, which are located in the inner volume 32, and voids 52 for receiving solid material 11, located between the pipes 50.

As shown in figures 1 and 3, each pipe 50 advantageously comprises a plurality of parallel pipe segments 54 running advantageously longitudinally along the inner volume 32 of the capsule 12.

Each pipe segment 54 has preferably a length which is comprised between 80 % and 95 % of the length of the inner volume 32.

Each longitudinal pipe segment 54 is connected to at least one other pipe segment 54 by a curved section of pipe 56 at an end of the pipe segment 54.

In the example shown in figure 3, at least one pipe segment 54 is connected at one end to an upper pipe segment 54 by a curved section 56 and is connected to a lower pipe segment 54 at another end, opposed to the first end, by another curved section 56.

At least one upstream pipe segment 54 (at the bottom of figure 3) is connected to the circulation assembly 36 for circulating fluid through a side wall 42 by an upstream segment 58 and at least one downstream pipe segment 54 (at the top of figure 3) is connected to the circulation assembly 36 for circulating fluid through a side wall 42 by a downstream segment 60.

In this example, each pipe 50 comprising a column of pipe segments 54 extends vertically and comprises between 2 and 15 parallel pipe segments 54 defining a coil.

The heating structure 34 comprises advantageously between 10 and 128 parallel pipes 50 laterally spaced apart one from another.

In a cross-section, such as defined in figure 2, the heating structure 34 therefore comprises a series of rows 62 of pipe segments 54 and a series of columns 64 of pipe segments 54.

In reference to figure 4, each pipe segment 54 comprises a tube 66 defining a circulation passage 68 for the heating fluid.

The tube 66 is preferably a metal tube, for example made of Class A or B steel. Each tube 66 has an outer diameter lower than 90 cm (35 inches), and is for example lower than 12.7 cm (5 inches) and comprised between 7.6 cm (3 inches) and 10.2 cm (4 inches).

The wall thickness of the tube is greater than 2 mm and advantageously comprised between 2 mm and 5 mm.

The tube 66 has a smooth outer surface of cylindrical shape.

According to the invention, the voids 52 are defined between the outer surfaces of the pipe segments 62, between each pair of adjacent pipe segments 54 in each row 62 and between each pair of adjacent pipe segments 54 in each column 64.

According to the invention, the ratio R1 of the total area of the outer surface of the pipe segments 54 to the total volume of the voids 52 located between the pipe segments 54 is higher than $0.02 \text{ m}^2/\text{m}^3$. The ratio R1 is advantageously comprised between $0.04 \text{ m}^2/\text{m}^3$ and $0.12 \text{ m}^2/\text{m}^3$.

Accordingly, when the voids 52 are filled with solid hydrocarbonaceous material 11, the ratio R2 of the total area of the outer surface of the pipe segments 54 to the mass of material is higher than 0.85 m^2 by ton of material, and is advantageously comprised between 0.9 m^2 by ton of material and 2 m^2 by ton of material.

The maximum distance Dmax transversely separating each pipe segment 54 from the closest adjacent pipe segment 54 is lower than 4.5 m, and is for example comprised between 4.0 m and 4.4 m.

The distance Dmax is taken as the distance in cross-section between the respective centers of the pipe segments 54.

In a cross section of the heating structure 34, the number of pipe segments 54 per square meter is greater than $0.03 \text{ pipes}/\text{m}^2$ and is generally comprised between $0.09 \text{ pipes}/\text{m}^2$ and $0.15 \text{ pipes}/\text{m}^2$.

In the embodiment of figure 4, in a transverse cross-section, each pipe segment 54 is vertically aligned with a pipe segment 54 located in the row 62 of pipe segments 54 located just above said pipe segment 54 and with a pipe segment 54 in the row 62 located just below said pipe segment 54.

The pipe segments 54 define a square pattern in a transverse cross section.

In a variation, shown in figure 5, the pipe segments 54 in a first row are shifted in reference to a horizontal axis with regard to the pipe segments 54 of the adjacent rows, defining a triangle pattern.

The triangle pattern minimizes the distance between each pair of adjacent pipe segments 54. This decreases the equivalent heat transfer surface by pipe segment 54 to a value lower than 5 m^2 by pipe segment 54, and comprised between 4 m^2 by pipe segment 54 and 5 m^2 by pipe segment 54.

In order to further increase the outer surface of each pipe segment 54, the pipe segment 54 may comprise at least one outer fin 70, preferably several outer fins 70, as shown in the embodiments of figure 6 to figure 9.

As shown in figure 6 and 7, the outer fins 70 protrude apart from the axis of each pipe segment 54 from the outer surface of the tube 66.

In the embodiment of figure 6, each outer fin 70 protrudes radially from the outer surface of the tube 66.

In a transverse cross section, the number of fins 70 is higher than 1, in particular higher than 3, for example comprised between 3 and 10. The fins 70 are preferably distributed angularly around the outer surface 70.

Preferentially, the total active area A_f of the fins 70, i.e. the area of the fins 70 able to enter in contact with solid hydrocarbonaceous material 11 is lower than 0.6 times the total outer surface area of the tube 66 to which they are connected. The total active area A_f of the fins 70 is advantageously comprised between 0.2 times and 0.5 times the total surface area of the tube 66.

In the examples of figures 8 and 9, the fins 70 are permanently fixed on the outer surface of the tubes 66 for example by welding. In a variation, the fins 70 are fixed by sticking, by crimping, and/or by riveting.

In the embodiment of figure 7, each pipe segment 54 comprises a cylindrical support sleeve 72 which has inner dimensions complementary to the outer surface of the tubes 66. The sleeves are mounted on the outer surface of the tubes 66.

The sleeves 72 bear the fins 70. In order to be mounted on the outer surface of a tube 66, the sleeve 72 is for example open longitudinally through a slot 74 or is made of several segments.

Advantageously, the fins 70 and the sleeve 72 are made of a heat conducting material such as metal.

The circulation assembly 36 comprises a heating liquid introduced into the heating passage 68 of each pipe segment 54 and at least one pump 80 (visible in figure 1) for circulating the heating fluid into the passages 68.

In the embodiment of figure 1, the circulation assembly 36 comprises several pumps 80 mounted in parallel.

The heating device 14 is connected to the pump(s) 80. It comprises for example a heating furnace 82 (see figure 10) able to heat the heating liquid by heat exchange. The heating furnace for example comprises a combustion device able to burn hydrocarbons to heat the heating liquid.

The heating liquid is for example an organic fluid, such as Therminol VP-1 or Syltherm 800 or equivalent. This organic fluid is able to be heated up to a temperature of about 400°C without substantial degradation.

In a variation, the heating liquid comprises melted salts, such as Hitech. It can then be heated up to a temperature of 800°C.

In another variation, different types of heat transfer liquids can be used such as oil, nanofluids, supercritical fluids, such as supercritical CO₂ with or without phase transition.

In reference to figure 1, the oil recovery assembly comprises at least a collection apparatus 92 connected to the bottom wall 40 of the enclosure 30.

5 The heat recovering assembly 18 is able to recover at least part of the heat conveyed by the heating liquid circulating in the capsule 12.

In a particular embodiment, disclosed for example in figures 10 to 14, the heat recovering assembly 18 comprise at least one other heating capsule 12A, 12B, 12C..., similar to the heating capsule 12 disclosed in figure 1.

10 A method for recovering hydrocarbon fluids from a solid hydrocarbonaceous material 11 will now be described.

Initially, the structure of the heating capsule 12 is built. The bottom wall 40 is constructed above the ground with an impervious layer.

15 The side walls 42 are also constructed to define an inner volume 32. The construction is for example made by digging a cavity in the ground.

An upper opening is left open for bringing the solid hydrocarbonaceous material 11 into the inner volume 32. The solid hydrocarbonaceous material 11 is mined and crushed if needed before being introduced in the inner volume 32.

20 Then, a first row 62 of pipe segments 54 is introduced at the bottom of the inner volume 32. The pipe segments 54 of the first row 62 are connected to the circulation assembly 36 for circulating fluid through an upstream pipe segment 58.

Then, a layer of solid hydrocarbonaceous material 11 made of pieces is introduced above the pipe segments 54. An additional row 62 of pipe segments 54 is laid on the layer of solid hydrocarbonaceous material 11.

25 Each pipe segment 54 of the additional row 62 of pipe segments is connected to a pipe segment 54 of the row 62 of pipe segments 54 located below, by assembling a curved section 56 at the ends of the pipe segments 54.

30 Then, an additional layer of solid hydrocarbonaceous material is introduced in the inner volume 32 to cover the additional row 62 of pipe segments 54 and the previous operations are repeated until the inner volume 32 is almost filled with material 11.

Each pipe segment 54 of the upper row 62 is then connected to the circulation assembly 36 through a downstream segment 60.

35 Then, the cap 44 is built above the side walls 42 to close the inner volume 32 of the enclosure 30. Advantageously, an outer protection cover 46 is placed around the enclosure 30.

Then, the pipe segments 54 are filled in with heating liquid. The heating furnace 82 is activated to heat the heating liquid at a temperature generally comprised between 380°C and 420°C, in particular around 400°C.

Heating fluid is circulated continuously through the pipe segments 54 to heat up the solid hydrocarbonaceous materials by conduction and convection.

When the temperature of the solid material 11 reaches above 250°C, kerogen conversion, also referred to as "maturation" occurs. Shale oil is released in the form of gas and liquid, liquid which flows down around the heating assembly 34 to the bottom wall 40 of the enclosure 30. The liquid is then collected in the oil recovery assembly 16.

Thanks to the very large outer surface area of the pipe segments 54, an extensive heat exchange occurs between the heating liquid and the pieces of solid hydrocarbonaceous material 11.

The solid material 11 can be then be heated during an appropriate time.

The appropriate time is for example in the order of more than 100 days, for example between 200 days and 400 days.

The use of heating liquid, coupled with the high surface area available for heat exchange in the capsule 12 avoid the generation of heat points which could be detrimental for the quality of the produced liquid oil. The liquid oil which is produced from the hydrocarbonaceous solid material 11 is therefore of optimal quality, with a API gravity comprised between 30 ° and 45 °, in particular of about 36°.

The result is obtained with a reasonable quantity of metal in the capsule 12, and hence, with an optimal construction cost.

The improvement is obtained in particular with pipe segments 54 located quite close one from another, or offset from one row to another, and/or comprising outer fins 70 to increase heat transfer. The use of small diameter metal tubes 66 also allows the circulation of a liquid without too much pressure drop, in the heating structure 34, with small wall thickness.

The assembly of the heating structure 34 on site is very easy. Indeed, mounting the heating structure 34 only requires laying a row of pipe segments 54, covering them with hydrocarbonaceous solid material 11, connecting a new layer of pipe segments 54 to the former layer of pipe segments 54 and repeating the previous operations.

The installation 10 according to the invention also allows a very efficient recovery of the heat stored in the capsule 12, after the liquid oil has been extracted.

Accordingly, the method according to the invention further comprises steps of heat recovery, depicted schematically in figures 11 to 14 as an example.

In a first step, the fluid circulating in a first heating capsule 12 is directed towards a second capsule 12A, in order to pre-heat the second capsule 12A to a first preheating temperature T2 (see figure 15).

This can be done by directly conveying the fluid circulating in the first capsule 12 into the second capsule 12A or by providing a heat exchange zone between the heating liquid circulating in the first capsule 12 and a distinct heating fluid circulating in the second capsule 12A.

As shown in figure 15, during phase 102, the pre-heating of the second capsule 12 decreases the inner temperature of the first capsule 12 (curve 103) and increases the temperature of the second capsule 12 (curve 104).

Subsequently, at the end of phase 102, the heating device 14 is connected to the second capsule 12A. The heating furnace 80 is activated to heat up the heating liquid circulating in the second capsule 12 to reach the threshold temperature Tt at the end of phase 106.

Simultaneously, the remaining heat stored in the first capsule 12 is sent to a third capsule 12B, as shown in figure 12, by means of the heating liquid circulating in the first capsule 12 to pre-heat the third capsule 12B to a second pre-heating temperature T3 which is lower than the first pre-heating temperature T2.

Then, once recovery of oil and gas from the second capsule 12B is finished, the heat stored in the second capsule 12B is also directed to the third capsule 12C and finalizes the pre-heating of the third capsule 12C, as shown in curve 107 in phase 108.

After this operation, the third capsule 12C is connected to the heating device 14 to complete the heating to the threshold temperature Tt. The heat stored in the second capsule 12B is subsequently directed to a fourth capsule 12D.

Hence, a large quantity of the energy supplied to each capsule 12 is recovered for pre-heating other capsules 12, which greatly diminishes the heating power necessary to carry out the liquid oil recovery.

The yield of the installation 10 is therefore greatly increased. Heat storage and recovery is now possible using a heating capsule 12 according to the invention, since the heat stored in the capsule 12 can be extracted out of the capsule by a heating liquid circulating in the heating structure 34.

The equipment for circulating the heating liquid is much simpler than the equipment used in prior art for gas circulation, since huge blowers are replaced by conventional pumps which have a lower energy consumption, a lower power, a reasonable size and cost.

The use of pipe segments 54 made of metal tubes, with diameters lower than 10 inches decreases the building cost, facilitates the welding of the pipe segments 54 and provides easier quality control. Additionally, corrosion issues are eased with the use of a heating liquid in combination with pipe segments 54 made of metal tubes 66.

5 The heating capsule 12 according to the invention is very safe to operate, since there are no more safety issues related to the possibility of oxygen ingress in the heating structure 34. The heating and cooling operations are also very simple to carry out.

10

15

CLAIMS

1.- Heating capsule (12) for recovering hydrocarbon fluids from a solid hydrocarbonaceous material (11), comprising:

5 - an enclosure (30) having an impervious bottom wall (40), side walls (42), and a cap (44) defining an inner volume (32);

 - a heating structure (34), comprising a plurality of pipe segments (54) received in the inner volume (32) and voids (52) delimited between the pipe segments (54) to receive solid hydrocarbonaceous material;

10 - a circulation assembly (36) for circulating heating fluid through the pipe segments (54);

 wherein the ratio of the total area of the pipe segments (54) outer surface to the total volume of the voids (52) is greater than $0.02 \text{ m}^2/\text{m}^3$, and is advantageously comprised between $0.04 \text{ m}^2/\text{m}^3$, and $0.12 \text{ m}^2/\text{m}^3$.

15 2.- Capsule (12) according to claim 1, wherein, in a section transverse to at least one pipe segment (54), the minimal distance separating the center of the pipe segment (54) and the center of the closest adjacent pipe segment (54) is lower than 4.5 m and is advantageously comprised between 3.0 m and 4.3 m.

20 3.- Capsule (12) according to any of claims 1 or 2, wherein each pipe segment (54) comprises a metal tube (66) with a smooth outer surface.

25 4.- Capsule (12) according to claim 3, wherein the maximal transverse dimension of the metal tube (66) is lower than 0.9 m.

 5.- Capsule (12) according to any one of claims 3 or 4, wherein the wall thickness of the metal tube (66) is greater than 2 mm and is advantageously comprised between 2 mm and 5 mm.

30 6.- Capsule (12) according to any one of the preceding claims, wherein each pipe segment (54) comprises a tube (66) and at least one fin (70) protruding radially from the tube (66).

7.- Capsule (12) according to claim 6, wherein, for at least one pipe segment (54), the total area of the active surface of the fin(s) (70) is lower than 0.6 times the total area of the outer surface of the tube (66).

5 8.- Capsule (12) according to any one of the preceding claims, wherein the assembly for circulating fluid (36) comprises a heating liquid and at least a pump (80) able to circulate the heating liquid in the pipe segments (54).

10 9.- Capsule (12) according to any one of the preceding claims, wherein the bottom wall (40) and side walls (42) comprise soil material and/or concrete.

15 10.- Capsule (12) according to any one of the preceding claims, comprising at least a first row (62) of longitudinal pipe segments (54) and at least a second row (62) of longitudinal pipe segments (54), the pipe segments (54) from the first row (62) being offset from the pipe segments (54) of the second row (62).

11.- Oil recovery installation (10), comprising :

20 - a heating capsule (12) according to any one of the preceding claims;
 - at least one heat recovering assembly (18) able to recover heat from the heated capsule (12), the heat recovering assembly (18) being in thermal exchange relationship with the heating fluid circulating in the heating structure (34).

25 12.- Installation (10) according to claim 11, wherein the heat recovering assembly (18) comprises a second heating capsule (12B) according to any one of claims 1 to 10, the heating fluid circulating in the second heating capsule (12B) being the fluid circulating in the first heating capsule (12) or being in heat exchange relationship with the fluid circulating in the first capsule (12).

30 13.- Method for recovering hydrocarbon fluids from a solid hydrocarbonaceous material (11), comprising the following steps:

 - providing at least a heating capsule (12) according to any one of claims 1 to 10;
 - placing a solid hydrocarbonaceous material (11) in the voids (52) of the heating structure (34), in contact with the plurality of pipe segments (54);
35 - circulating heating fluid in the plurality of pipe segments (54) to heat the solid hydrocarbonaceous material (11);

- recovering a hydrocarbon liquid at the bottom wall (40) of the enclosure (30) and/or gas.

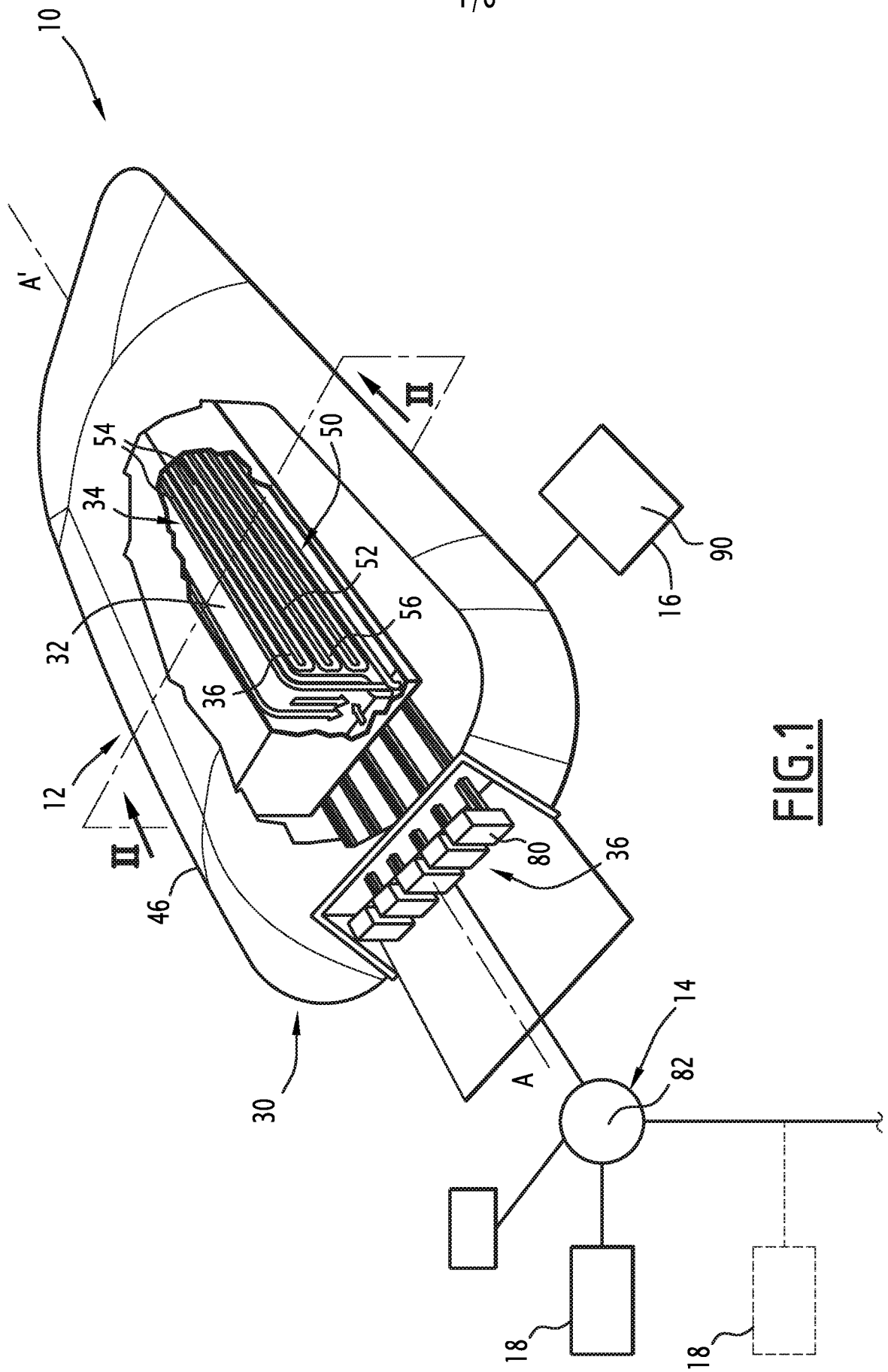
5 14.- Method according to claim 13, wherein the temperature of the fluid circulating into the plurality of pipe segments (54) is lower than 800°C.

15.- Method according to any one of claims 13 or 14, comprising the following steps:

- recovering heat from the capsule (12);

10 - using the heat recovered from the capsule (12) to pre-heat or heat the solid hydrocarbonaceous material in another capsule (12A, 12B, 12C).

16.- Method according to any one of claims 13 to 15, wherein the solid hydrocarbonaceous material (11) is heated for at least 100 days, in particular between 200 days to 400 days.



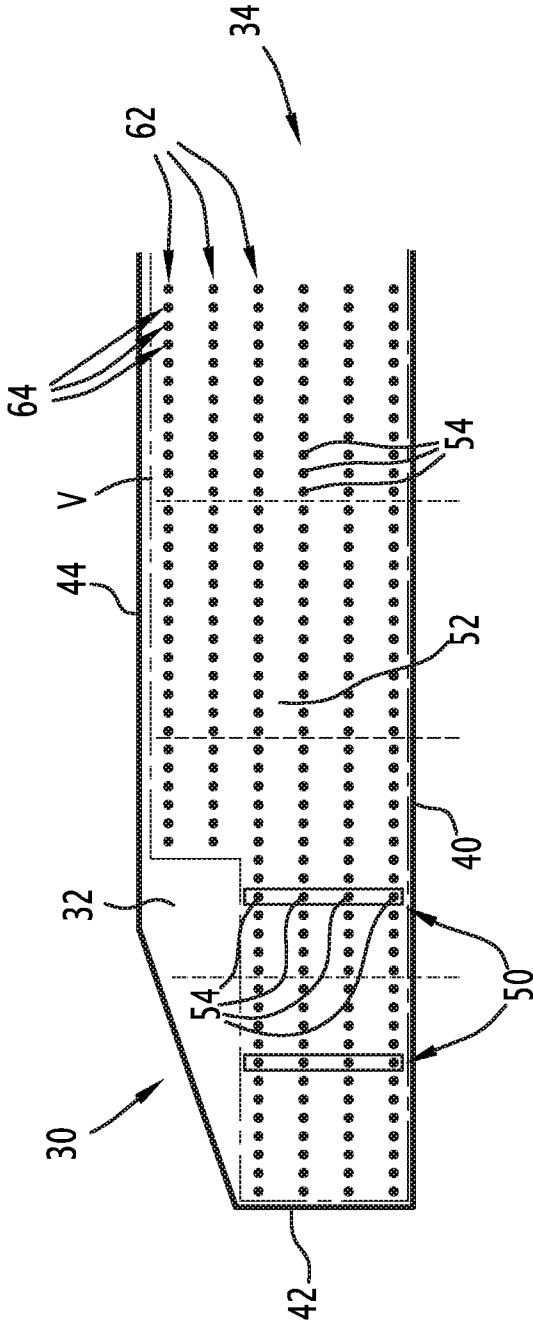


FIG. 2

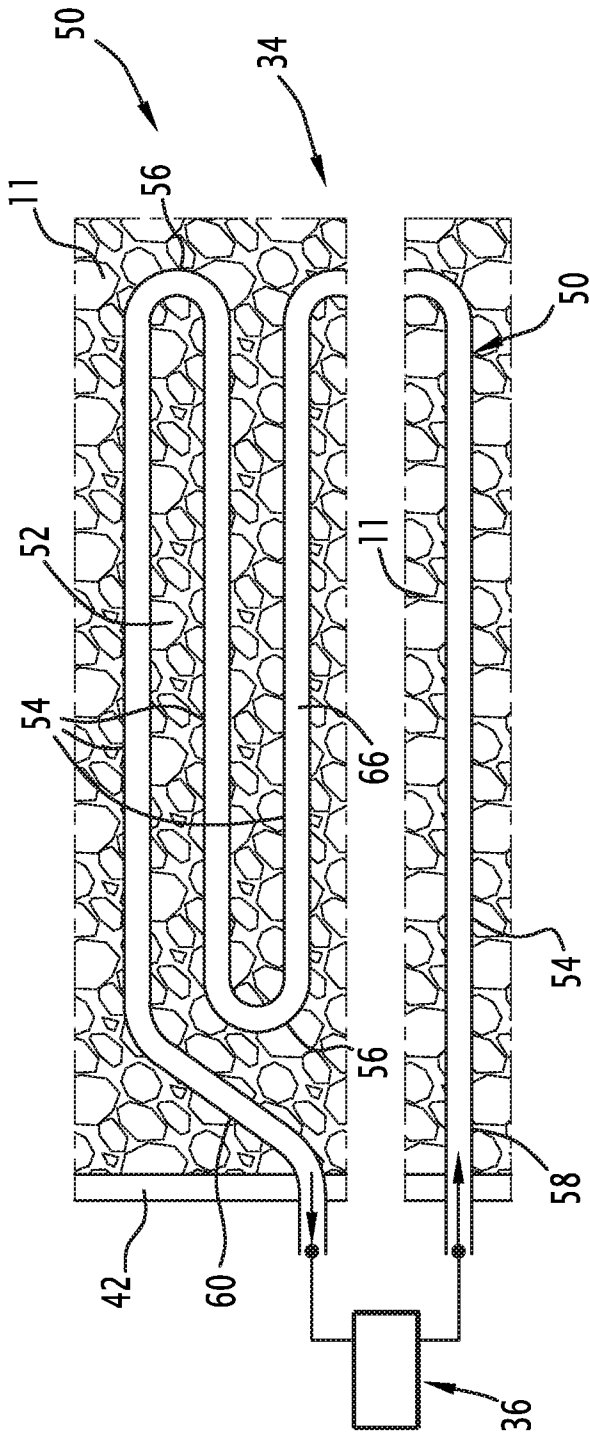
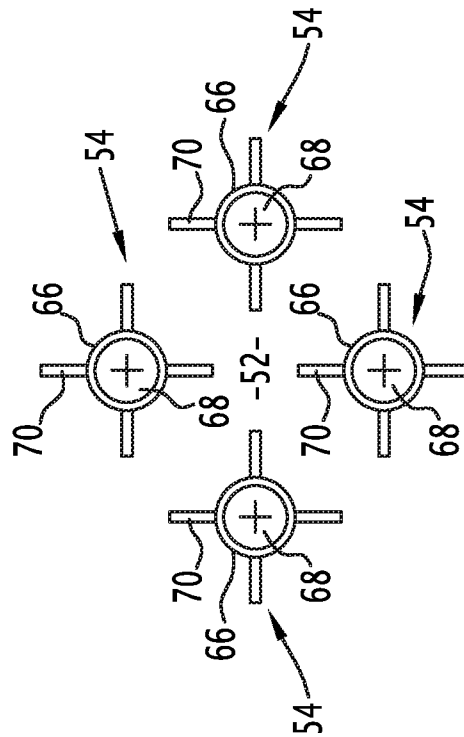
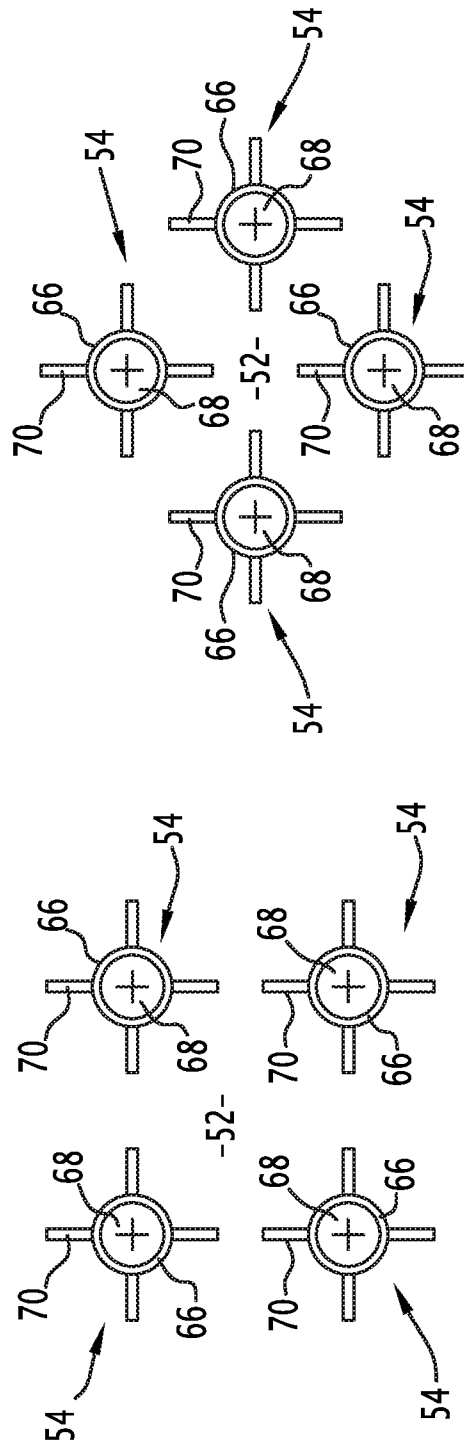
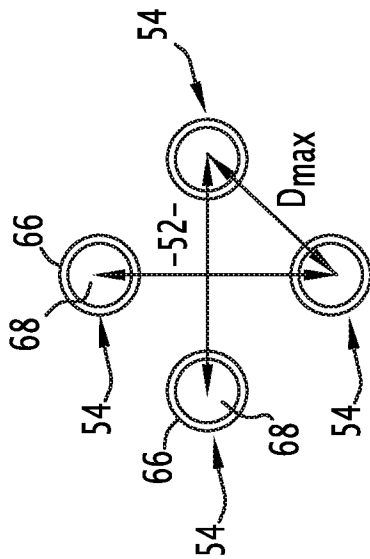
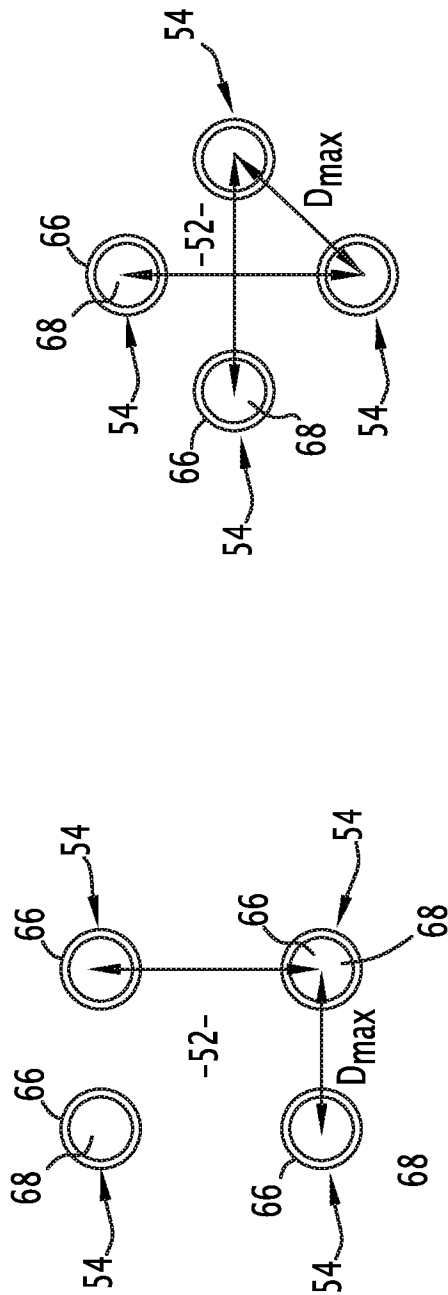


FIG. 3



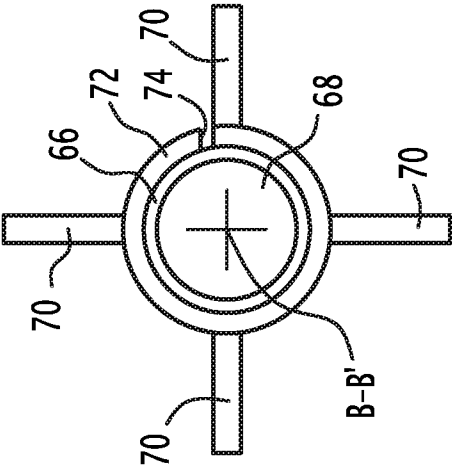


FIG. 7

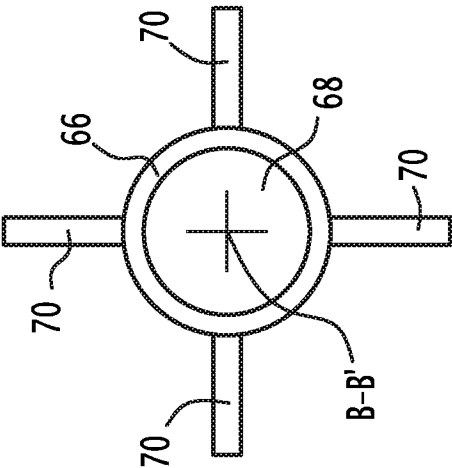


FIG. 6

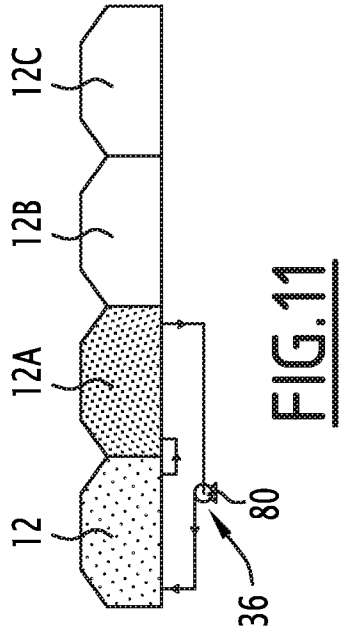


FIG. 10

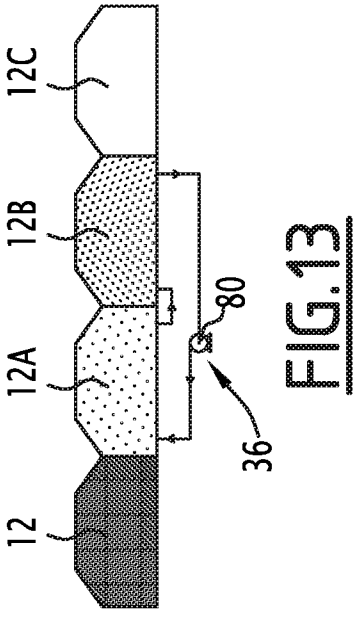


FIG. 11

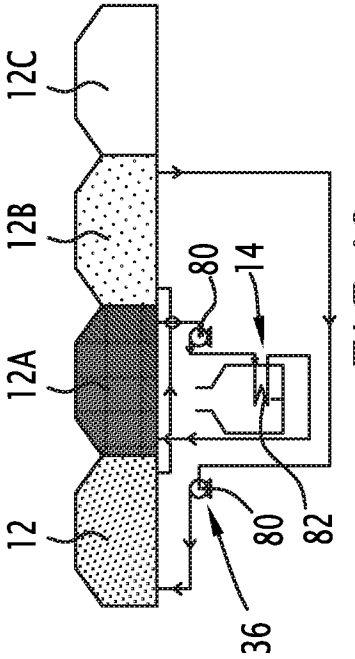


FIG. 12

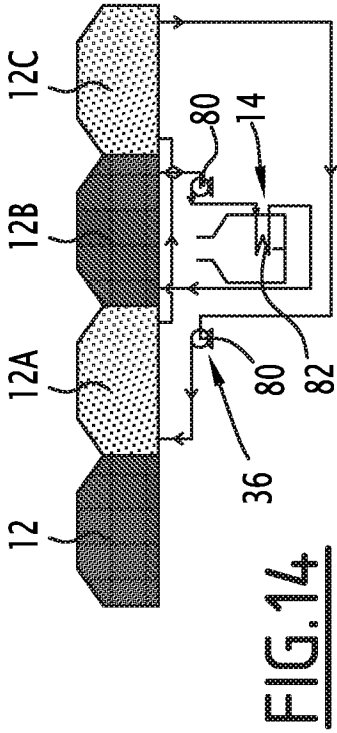


FIG. 13



FIG. 14

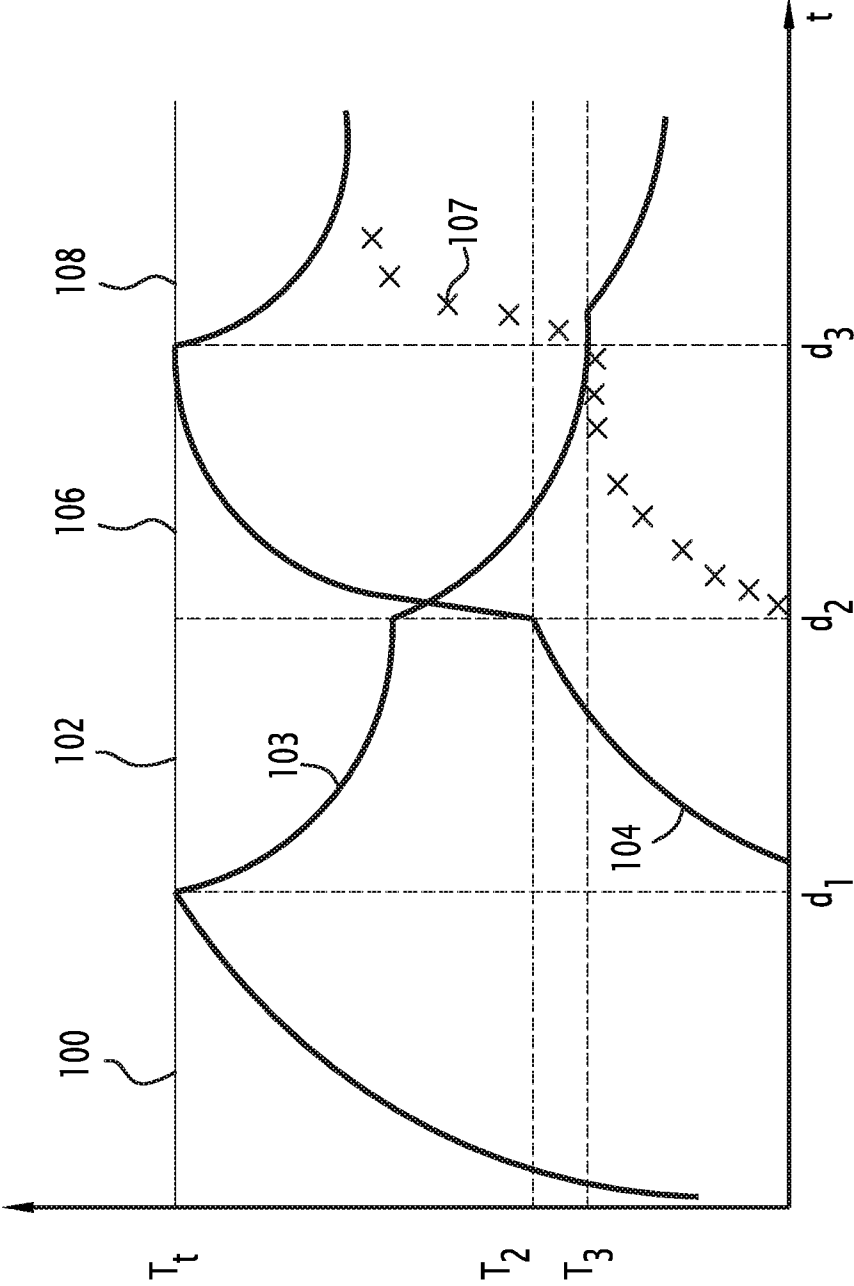


FIG.15

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2014/001533

A. CLASSIFICATION OF SUBJECT MATTER
INV. C10G1/02 F28D7/16
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C10G F28D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2013/025924 A2 (RED LEAF RESOURCES INC [US]; PATTEN JAMES W [US]; GHORBANI HAMID [CA];) 21 February 2013 (2013-02-21) page 10, line 22 - page 11, line 4; claims 1,4; figure 6 page 8, line 1 - line 6 page 8, line 20 - line 24 page 12, line 19 - line 28 page 16, line 22 - line 30 page 23, line 20 - line 27 page 15, line 5 - line 8	1-16
A	US 2009/007484 A1 (SMITH DAVID G [US]) 8 January 2009 (2009-01-08) paragraphs [0121], [0124] ----- -/--	1-16



Further documents are listed in the continuation of Box C.



See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search

12 March 2015

Date of mailing of the international search report

20/03/2015

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Fax: (+31-70) 340-3016

Authorized officer

Deurinck, Patricia

INTERNATIONAL SEARCH REPORT

International application No

PCT/IB2014/001533

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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