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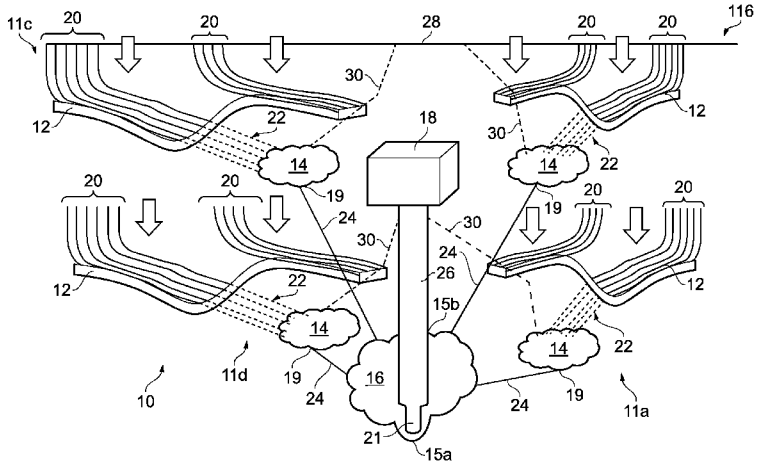


FIG. 1

(57) Abstract: In an embodiment of the present invention there is provided a system for exploiting a hydrocarbon reserve, the system comprising a subsurface hydrocarbon reserve and a subsurface reservoir in fluid communication with the subsurface hydrocarbon reserve via one or more manufactured flowlines. The subsurface reservoir is below the subsurface hydrocarbon reserve, and the hydrocarbons are flowable, in use, from the subsurface hydrocarbon reserve to the lower subsurface reservoir, under the influence of gravity to gather and store hydrocarbons for production. An advantage of embodiments of the present invention is that only one hydrocarbon production facility, and thus only one primary point of hydrocarbon production, is required because the need for a large surface infrastructure may be minimised or eliminated, thus helping to minimise the environmental impact of the operation. Moreover,capital investment, for example, in terms of drilling and excavation of the subsurface gathering cavern(s) and/or subsurface storage chamber, may be significantly offset by the elimination of multiple hydrocarbon production facilities at the surface.

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HYDROCARBON EXPLOITATION

The present invention relates to the exploitation of hydrocarbons and more specifically, although not exclusively, to a system and a method for gathering and/or storing and/or producing hydrocarbons from subsurface hydrocarbon reserves of conventional or unconventional hydrocarbon resources that may be otherwise commercially unfeasible or less feasible for exploitation using conventional techniques.

Unconventional resources are subsurface hydrocarbon reserves that have low permeability and porosity, that are trapped in rock formations or pockets, i.e. in volumes not appreciably consistent with a recognizable conventional reservoir, thus making the hydrocarbons more difficult to produce than conventional hydrocarbon resources. The exploitation of these reserves however has increased in recent years, especially in the United States where production of unconventional hydrocarbons such as light, tight oil and shale gas, has increased rapidly.

Unfortunately high productivity unconventional resources, such as shale, are limited in their global extent. Their depletion rates are also typically very high and existing wells targeting hydrocarbon bearing zones in an area of unconventional resource reserves become increasingly unproductive, which forces the industry to drill more wells in an attempt to offset these declines. Unconventional resources typically require many more completed wells and associated surface facilities than conventional resources, and have more widespread operational activities, thus exploitation can be met by a significant amount of resistance due to the potential negative impact on the environment. Furthermore, the large number of completed wells involved could make the exploitation of unconventional resources impractical in places with high population densities.

The collapse of the world oil price in 2014 has been attributed at least in part to the result of over production of such unconventional hydrocarbons in the United States along with a slowing demand. The economics involved in this scenario has led to a significant need for increased operational efficiencies, including more efficient drilling of wells and increased production and recovery efficiencies, all whilst minimizing the environmental impact arising from increased numbers of wells.

The inventor of the present invention has devised a system and method that aims to address or at least mitigate at least one of the above issues.

In accordance with one aspect of the present invention there is provided a system for exploiting a hydrocarbon reserve, the system comprising a subsurface hydrocarbon reserve and a subsurface reservoir in fluid communication with the subsurface hydrocarbon reserve, for example via one or more flowlines that may be manufactured, such that hydrocarbons are flowable, in use, from the subsurface hydrocarbon reserve to the subsurface reservoir, e.g. to gather and/or store hydrocarbons for production.

The subsurface reservoir may comprise a subsurface gathering chamber or cavern, for example wherein the system comprises a system for gathering hydrocarbons.

The subsurface reservoir may comprise a subsurface storage chamber, for example wherein the system comprises a system for storing hydrocarbon reserves. The system may comprise one or more subsurface gathering chambers or caverns, for example wherein the subsurface hydrocarbon reserve is in fluid communication with the subsurface storage chamber via at least one subsurface gathering chamber or cavern. The or each subsurface gathering chamber or cavern, hereinafter subsurface gathering cavern, may be in fluid communication with the subsurface hydrocarbon reserve via one or more flowlines that may be manufactured. The or each subsurface gathering cavern may be in fluid communication with the subsurface storage chamber via one or more flowlines that may be manufactured.

The system may comprise two or more subsurface hydrocarbon reserves each of which may be in fluid communication, for example via one or more flowlines that may be manufactured, with the subsurface reservoir. For example, the system may comprise two or more subsurface hydrocarbon reserves each of which may be in fluid communication, for example via one or more flowlines that may be manufactured, with the subsurface storage chamber via one or more subsurface gathering caverns, e.g. via a respective subsurface gathering cavern. Additionally or alternatively, the system may comprise two or more subsurface hydrocarbon reserves each of which may be in fluid communication, for example via one or more flowlines that may be manufactured, with one subsurface gathering cavern.

The system may comprise a system for producing hydrocarbons. The system may comprise a production connector accessible aboveground, which may be fluidly connected to the subsurface reservoir and/or for fluidly connecting, in use, for example via a pipe,

borehole or well that may be manufactured, the subsurface hydrocarbon reserve to a hydrocarbon production facility. Additionally or alternatively, the system may comprise a hydrocarbon production facility fluidly connected, for example via a pipe, borehole or well that may be manufactured, to the subsurface reservoir. The hydrocarbon production facility may be fluidly connected to the production connector if present.

At least one or each flowline is preferably at least partially manufactured or manmade, for example formed by a manufacturing process, such as a boring, drilling or fracturing process. In embodiments, at least one or each flowline is at least partially formed in addition to or as an extension of, wells created, e.g. drilled or hydraulically fractured, primarily for the purpose of access to hydrocarbon bearing zones of existing reserves.

In accordance with another, more specific aspect of the present invention there is provided a system for producing hydrocarbons, the system comprising:

a plurality of subsurface hydrocarbon reserves;

one or more subsurface gathering caverns each of which is in fluid communication with at least one of the subsurface hydrocarbon reserves;

a subsurface storage chamber in fluid communication with the or each subsurface gathering cavern; and either

a production connector accessible aboveground for fluidly connecting the subsurface hydrocarbon reserves to a hydrocarbon production facility; or

a hydrocarbon production facility;

wherein the hydrocarbons are flowable from the subsurface hydrocarbon reserves to the subsurface gathering cavern(s), e.g. where the hydrocarbons are gatherable; and

wherein the hydrocarbons are further flowable from the subsurface gathering cavern(s) into the subsurface storage chamber, e.g. where the hydrocarbons are storable and/or from which the hydrocarbons are producible, in use, by a hydrocarbon production facility.

There may be at least one subsurface hydrocarbon reserve. The or each subsurface hydrocarbon reserve may be commercially unfeasible, or at least somewhat commercially unfeasible, for exploitation using known technologies, for example due to insufficient volume and/or difficulty of extraction and/or ongoing production operations costs. In embodiments, one or more of the subsurface hydrocarbon reserves comprises a partially depleted hydrocarbon reserve or a conventional hydrocarbon reserve that is of insufficient volume for commercially feasible exploitation using known techniques. In embodiments,

one or more of the subsurface hydrocarbon reserves comprises an unconventional subsurface hydrocarbon reserve, for example one or more of a shale formation or any other unconventional subsurface hydrocarbon reserve as would be appreciated by the skilled person. Alternatively or additionally, the exploitation of the or each subsurface hydrocarbon reserve may be unfeasible due to the environmental and/or social impact of operations and/or surface equipment associated with known technologies.

Shale formations can be unconventional hydrocarbon sources because they are both a source rock and typically have not formed an appreciable conventional reservoir, with the generated hydrocarbons remaining in place due to the extremely low permeability of the shale. The hydrocarbons within the shale formations may comprise oil and/or gas. The oil is typically referred to as tight oil, shale oil or light, tight oil (LTO). Henceforth, the oil will be referred to as LTO. The gas may comprise natural gas (methane), and is henceforth referred to as shale gas.

At least one or each subsurface hydrocarbon reserve may comprise at least one bearing zone, for example a bearing zone of commercially feasible reserve and/or which may be in fluid communication with the subsurface reservoir. The system may comprise two or more, such as a plurality of hydrocarbon bearing zones, e.g. in a commercially feasible reserve, each of which may be in fluid communication with the subsurface reservoir.

The subsurface reservoir may be below at least one subsurface hydrocarbon reserve, for example such that liquid, e.g. liquid hydrocarbons, or oil or LTO flows or is able to flow from the at least one subsurface hydrocarbon reserve to the lower subsurface reservoir, e.g. by or under the influence of gravity. In embodiments comprising one or more subsurface gathering caverns and a subsurface storage chamber, these may all be below the at least one subsurface hydrocarbon reserve.

The subsurface reservoir may be above at least one subsurface hydrocarbon reserve, for example such that gas or natural gas or shale gas flows or is able to flow from the at least one subsurface hydrocarbon reserve to the subsurface reservoir. In embodiments comprising one or more subsurface gathering caverns and a subsurface storage chamber, these may all be above the at least one subsurface hydrocarbon reserve.

The subsurface reservoir may be in part above and in part below at least one subsurface hydrocarbon reserve, for example such that liquid and/or gas flows or is able to flow from

the at least one subsurface hydrocarbon reserve to the subsurface reservoir. In embodiments comprising one or more subsurface gathering caverns and a subsurface storage chamber, one or more or at least some of these may be above the at least one subsurface hydrocarbon reserve and one or more or at least some of these may be below the at least one subsurface hydrocarbon reserve.

The system may comprise a first subsurface reservoir below at least one subsurface hydrocarbon reserve and a second subsurface reservoir thereabove. The system may comprise a first subsurface storage chamber below at least one subsurface hydrocarbon reserve and fluidly connected thereto via one or more subsurface gathering caverns also below the at least one subsurface hydrocarbon reserve. The system may also comprise a second subsurface storage chamber above the at least one subsurface hydrocarbon reserve and fluidly connected thereto via one or more subsurface gathering caverns also above the at least one subsurface hydrocarbon reserve.

In embodiments, the configuration or relative positions of the or at least one subsurface hydrocarbon reserve and/or the or at least one subsurface gathering cavern and/or the storage chamber is or are such that liquid, e.g. liquid hydrocarbons, or oil or LTO flows or is able to flow from the or at least one subsurface hydrocarbon reserve to the subsurface storage chamber via the or at least one subsurface gathering cavern(s), e.g. by or under the influence of gravity.

Additionally or alternatively, the configuration or relative positions of the or at least one subsurface hydrocarbon reserve and/or the or at least one subsurface gathering cavern and/or the subsurface storage chamber is or are such that gas or natural gas or shale gas flows or is able to flow from the or at least one subsurface hydrocarbon reserve to the subsurface storage chamber via the or at least one subsurface gathering cavern. In some embodiments, the or a portion of the shale gas may rise via at least one surface flowline extending from the or each associated subsurface gathering cavern and/or subsurface storage chamber to the surface, where the shale gas is subsequently flared.

When, for example, LTO and shale gas are producible from one or more, or at least some or all, subsurface hydrocarbon reserves, there may be two subsurface storage chambers, for example a liquid subsurface storage chamber, hereinafter a central liquid chamber, and a gas subsurface storage chamber, hereinafter a central gas chamber. The central liquid chamber may be below one or more or at least some or all subsurface gathering

cavern(s). The central gas chamber may be located above one or more or at least some or all subsurface gathering cavern(s). In some embodiments there may be two or more, such as three or more, such as a plurality of, subsurface storage chambers.

The central liquid chamber may have a larger volume than the or an associated central gas chamber. Typically the central liquid chamber is up to 5 times larger than the or an associated central gas chamber.

At least one of the flowlines fluidly connected to the or each subsurface gathering cavern may comprise an input flowline and/or at least one of the or each subsurface gathering cavern may comprise an output flowline. The or each input flowline and/or the or each output flowline may be sloped. The or each input flowline may be sloped in a downwardly or downhill direction or an upwardly or uphill direction, depending at least in part on the configuration or relative positions of the subsurface hydrocarbon reserve(s), subsurface gathering cavern(s) and/or subsurface storage chamber. In embodiments where LTO is producible, the or each or some or all output flowline(s) may be sloped in a downwardly or downhill direction due at least in part to the or each subsurface gathering cavern being located above the central liquid chamber. In embodiments where shale gas is producible, the or each or some or all output flowline(s) may be sloped in an upwardly or uphill direction due at least in part to the or each subsurface gathering cavern being located below the central gas chamber. In use, the or each input flowline may allow hydrocarbons in the or each subsurface hydrocarbon reserve to flow downwardly or downhill into the or each subsurface gathering cavern, and the or each output flowline may allow the hydrocarbons in the or each subsurface gathering cavern to flow one or more of downwardly or downhill and/or upwardly or uphill into the or each subsurface storage chamber.

The or each, or some or all input flowline(s) and/or output flowline(s) may comprise downhole equipment and instrumentation such as flow controls and/or meters. Flow controls may include valves to control the flow between the subsurface hydrocarbon reserve(s) and the subsurface gathering cavern(s), and/or between the subsurface gathering cavern(s) and the subsurface storage chamber, and/or the production connector or the hydrocarbon production facility. At least one, each or every flowline may comprise a meter associated therewith, e.g. for measuring flow therethrough. Meters may be provided for measurement of flow between the subsurface hydrocarbon reserve(s) and the subsurface gathering cavern(s), and/or between the subsurface gathering cavern(s)

and the subsurface storage chamber, and/or the production connector or the hydrocarbon production facility. The design of the flow controls may take into account the effect and degree of the downward and/or upward slopes, changing flowline diameters and/or widths, and other such variables utilised in connecting the flowline(s) between system components which can impact flow efficiency.

The subsurface gathering cavern(s) and/or subsurface storage chamber may be man-made or naturally occurring, or a combination thereof. Both a chamber and a cavern may be defined as a subsurface cavity. The subsurface storage chamber and/or the or each subsurface gathering cavern may be manufactured to a size capable of containing a volume (m^3) at least consistent with the anticipated production volume from all associated input cavities and/or flowlines over a single production cycle. For example the subsurface storage chamber may be manufactured to a size capable of containing a volume (m^3) at least consistent with the combined volume (m^3) of the subsurface gathering chamber(s), and/or the input and/or output flowline(s) over a single production cycle. A production cycle may be defined as the time interval between which extracted hydrocarbons previously gathered into the subsurface gathering cavern(s) and/or subsurface storage chamber, are then brought to the surface to be available as commercial product(s). Bringing the hydrocarbons to the surface may include moving the hydrocarbons to a point of transportation. The time interval may depend on factors including well flow rates, hydraulic balance of the system and use of hydraulic lift for final production.

The hydrocarbon production facility may be fluidly connected to the subsurface reservoir by a production pipe. In embodiments comprising one or more subsurface gathering caverns and a subsurface storage chamber, the hydrocarbon production facility may be fluidly connected to the subsurface storage chamber by a production pipe. The system or hydrocarbon production facility may further comprise a water tank fluidly connected to the subsurface reservoir or subsurface storage chamber, for example by a water pipe, which may extend to a position below the end of the production pipe and/or to a lower or lowermost portion of the subsurface reservoir or subsurface storage chamber. The water tank may comprise or contain water and/or brine and/or another hydraulic fluid. The system or hydrocarbon production facility may comprise a pumping means, which may be operable to pump, in use, water and/or brine from the tank into and/or out of the subsurface reservoir or subsurface storage chamber. The production pipe may be retractable, in use, e.g. during production and/or in response to a rising water or brine level within the

subsurface reservoir or storage tank or subsurface storage chamber. In some embodiments, the water pipe is concentric with the production pipe.

The volume of hydrocarbons contained within the subsurface storage chamber and/or the or each subsurface gathering cavern may be measured in barrel of oil equivalent (BOE), and the volume of oil produced in a single production cycle may be measured in barrel of oil equivalent per day (BOE/d). The production cycle however may not necessarily operate on a daily basis. As an example, since 1 barrel of oil is approximately 0.16m^3, a system designed to produce 20,000 BOE/d of LTO would require a subsurface storage chamber of at least 3,200m^3, while a system designed to produce 100,000 BOE/d of LTO would require a subsurface storage chamber of at least 16,000m^3.

The or each subsurface gathering cavern may be designed and manufactured to a combined volume (m^3), such that their combined output to the subsurface storage chamber and/or production connector and/or hydrocarbon production facility, is at least equal to the anticipated hydrocarbon production volume via the subsurface storage chamber and/or production connector and/or hydrocarbon production facility.

The system, such as the subsurface gathering cavern(s) and/or subsurface storage chamber, may be designed and manufactured to accommodate a production volume over and above the anticipated hydrocarbon production cycle volume.

The shape of the subsurface gathering cavern(s) and/or the subsurface storage chamber may be designed and manufactured to avoid creating potential traps in order to ensure their effective drainage to either below subsurface gathering cavern(s) and/or subsurface storage chamber for LTO, and/or above subsurface gathering cavern(s) and/or subsurface storage chamber for shale gas.

The subsurface storage chamber and/or subsurface gathering cavern(s) may be up to 7,000m below the surface, as permitted by one or more of available drilling capabilities, inherent geological constraints, the depth required for the system to capture hydrocarbons released from the subsurface hydrocarbon reserve(s), and the upward and/or downward slopes required for the input and/or output flowline(s).

The subsurface storage chamber and/or the subsurface gathering cavern(s) is/are preferably fillable with a BOE volume of LTO and/or shale gas that is commercially feasible

after all capital investment and projected operating expenditures are calculated. Various sizes, depths and/or production volumes of the system may be useful, depending on the production requirements and/or characteristics of the subsurface hydrocarbon reserve(s) and/or as practicable or constrained by the available manufacturing methods, equipment and materials.

In accordance with another aspect of the present invention there is provided a method of forming a system for exploiting a hydrocarbon reserve, e.g. a system as described above, the method comprising fluidly connecting a subsurface hydrocarbon reserve to a subsurface reservoir, for example via one or more flowlines that may be manufactured.

The method may comprise fluidly connecting the subsurface reservoir to a hydrocarbon production facility, or to a production connector accessible aboveground for fluidly connecting the subsurface hydrocarbon reserve to a hydrocarbon production facility. The method may comprise fluidly connecting the subsurface hydrocarbon reserve to the subsurface reservoir, which may comprise a subsurface storage chamber, via a subsurface gathering cavern.

The method may comprise fluidly connecting two or more such as a plurality of subsurface hydrocarbon reserves to the subsurface storage chamber, for example via two or more such as a plurality of subsurface gathering caverns.

The method may comprise forming or creating, at least in part, the subsurface storage chamber and/or the subsurface gathering cavern(s). One or more or at least some or all subsurface gathering cavern(s) and/or the subsurface storage chamber may be manmade and/or formed or created by one or more or any combination of leaching the subsurface gathering cavern(s) and/or subsurface storage chamber in salt domes, excavating by rotary machines, and/or surface etching by acids and/or heat. Salt domes can be particularly suitable because they are dry and geologically stable, thus the hydrocarbons can typically be safely isolated and stored. The subsurface gathering cavern(s) and/or the subsurface storage chamber may be leached in salt domes by drilling at least one borehole from the surface to the or each salt dome.

Additionally or alternatively, naturally formed geological cavities, such as depleted natural gas reservoirs, where available, may be used for one or more or at least some or all subsurface gathering cavern(s) and/or the subsurface storage chamber.

To ensure the structural integrity, established mining practices such as propping up the top of the or each subsurface gathering cavern and/or the subsurface storage chamber, may be used.

The subsurface storage chamber may be fluidly connected to the subsurface hydrocarbon reserve(s) by forming or creating one or more flowlines, for example through the use of a boring or drilling process such as extended reach drilling (ERD) which incorporates directional drilling technologies that may permit very accurate placement of the drilled flowlines. Such drilling or boring may be in addition to conventional well formations created and hydraulically fractured in order to access the subsurface hydrocarbon reserve(s).

The subsurface hydrocarbon reserve(s) may be fluidly connected to the subsurface storage chamber via the subsurface gathering cavern(s). In such embodiments, the or each input flowline between the subsurface hydrocarbon reserve(s) and the subsurface gathering cavern(s), and the or each output flowline between the subsurface gathering cavern(s) and the subsurface storage chamber, may be formed or created. To create the or each input flowline and/or the or each output flowline, the angle of drilling may be varied.

Alternatively or additionally, the or each input flowline and/or the or each output flowline may be formed or created using the at least one borehole drilled from the surface to the or each salt dome. The or each borehole may be extended, preferably using ERD, from the or each subsurface gathering cavern to the subsurface storage chamber.

The method may comprise forming or creating two output flowlines from the or each subsurface gathering cavern, for example where both LTO and shale gas are producible from the or each subsurface hydrocarbon reserve. A first output flowline may be connected between the lower 50%, preferably the lower 25%, more preferably the lower 10%, of the or each subsurface gathering cavern and the central liquid chamber, and a second output flowline may be connected between the upper 50%, preferably the upper 25%, more preferably the upper 10%, of the or each subsurface gathering cavern and the central gas chamber. The first output flowline may be used when LTO is producible and the second output flowline may be used when shale gas is producible.

In some embodiments, it may be advantageous to form or create the first output flowline such that it is connected to the lower half of the or each subsurface cavern and/or the second output flowline such that it is connected to the upper half of the or each subsurface cavern. This may help to prevent any LTO and shale gas being trapped within the subsurface gathering cavern(s).

Once the system has been created using the above method, one or more wells may be formed or created or drilled, e.g. substantially vertically from the surface and/or to a predetermined depth above the or each subsurface hydrocarbon reserve. The or each well may then be turned at an increasing angle, for example until it or they run(s) substantially parallel within the subsurface hydrocarbon reserves, e.g. before being drilled to a selected length. Such drilling methods, known as horizontal or directional drilling, may permit very accurate placement of the drilled wells thus typically allowing maximum contact with the subsurface hydrocarbon reserve(s), and may also permit accurate positioning of the input and/or output flowline(s) between the subsurface hydrocarbon reserve and/or the subsurface gathering cavern(s) and/or the subsurface storage chamber.

After drilling, each well may be completed using known equipment and techniques. Flow control equipment, such as a flow control valve, may be installed in a portion of the or each well, such as prior to the subsurface hydrocarbon reserve(s), for example to prevent the direct flow of hydrocarbons up the well(s) to the surface.

The subsurface hydrocarbon reserve(s) may be stimulated by various methods, such as hydraulic fracturing, acidizing or explosive fracturing. The hydrocarbons may then be able to flow from the subsurface hydrocarbon reserve(s) to the subsurface gathering cavern(s), and/or the subsurface storage chamber, by or under the influence of gravity. This may be referred to as gravity drainage, and may be the preferred primary reservoir driver in the present invention.

Closing the flow control valve(s) in the portion of the well(s) prior to the subsurface hydrocarbon reserve(s) may create a back pressure, and along with the pressure created by the flow of LTO, the shale gas may also be driven out of the subsurface hydrocarbon reserve(s) and flow via the input flowline(s) towards the subsurface gathering cavern(s) and via the output flowline(s) towards the subsurface storage chamber.

The hydrocarbons may be stored in the subsurface storage chamber for example from one day up to one month, which may be the length of one production cycle. The hydrocarbons may be stored for multiple production cycles to enable longer, more effective or more economically attractive production cycles, in such cases the hydrocarbons may be stored for up to one year. Produced hydrocarbons are typically reported on at least a monthly basis for regulatory and fiscal purposes, but they may be subsequently stored subsurface for an unlimited period of time.

In some embodiments the hydrocarbons may be stored until the subsurface storage chamber reaches a pre-determined capacity, such as full capacity, or until transportation is available to remove the hydrocarbons from storage. It may be an advantage of embodiments of the present invention that the flow rate of hydrocarbons may be controlled and that the hydrocarbons may be gathered and/or stored, because this can help to mitigate capacity issues, such as full transportation tankers, which significantly constrains production in conventional operations and which can lead to well shut-ins.

It may be a further advantage of embodiments of the present invention that the hydrocarbons may be gathered and/or stored because the natural temperature difference between the top and the bottom of the or each subsurface gathering cavern and/or subsurface storage chamber encourages the hydrocarbons to circulate, thus helping to maintain their quality.

The subsurface storage chamber may be used as the primary source of production. The hydrocarbon production facility is normally located aboveground, preferably at the surface. The hydrocarbon production facility typically comprises a well and wellhead equipment, including a surface pump to extract the hydrocarbons and deliver them into adjacent surface facilities. The system may further comprise a production connector accessible aboveground for fluidly connecting the system, in particular the subsurface storage chamber, to the hydrocarbon production facility. In use, the hydrocarbons are produced by the hydrocarbon production facility fluidly connected to the production connector.

The production connector may be a production well which fluidly connects the hydrocarbon production facility to the subsurface storage system. At least one production well may be drilled from the hydrocarbon production facility to the subsurface storage chamber. In cases where there are two subsurface storage chambers, that is a central gas chamber and a central liquid chamber, there may be two production wells drilled from the

hydrocarbon production facility; one production well for the central gas chamber and one production well for the central liquid chamber. The production wells may be in fluid communication with each other via the hydrocarbon production facility. The hydrocarbons may be produced from the or each subsurface storage chamber by various means, such as water injection, which will be described in more detail later.

In a preferred embodiment, the hydrocarbons may flow freely from the subsurface hydrocarbon reserve(s) to the subsurface gathering cavern(s) and/or to the subsurface storage chamber. The subsurface storage chamber typically fills with hydrocarbons first. When the subsurface storage chamber is full, the subsurface gathering caverns(s) may then fill with hydrocarbons. Typically the subsurface gathering cavern at the lowest depth will fill first after the subsurface storage chamber. Producing the hydrocarbons from the subsurface storage chamber by water injection may prevent the further flow of hydrocarbons from the subsurface gathering cavern(s) to the subsurface storage chamber, at least until the water is removed from the subsurface storage chamber. In such embodiments, the hydraulic lift may act as a flow control, thus mitigating the need for installing extra flow control equipment which can be costly, although sometimes necessary.

Alternatively or in addition to the above preferred embodiment, at least one input flowline and/or at least one output flowline may also be completed. Downhole equipment and instrumentation such as flow controls and/or meters, may be installed in the at least one input flowline and/or the at least one output flowline. There may be at least one flow control valve and/or meter installed in one, or more than one, or all input flowline(s) and/or output flowline(s). At least one or each valve may have an open position whereby the flow of hydrocarbons is permitted, and a closed position whereby the flow of hydrocarbons is prevented. In such embodiments, the method of producing hydrocarbons may comprise closing or opening one or more or each valve to enable a pre-determined volume of hydrocarbons to accumulate in the or each subsurface gathering cavern and/or the subsurface storage chamber. The hydrocarbons may gather in the subsurface gathering cavern(s) when the valve(s) in the output flowline(s) are in the closed position and the valve(s) in the input flowline(s) ae in the open position. Alternatively, when all valve(s) are in the open position, the hydrocarbons may be able to flow from the subsurface hydrocarbon reserve(s) and/or the subsurface gathering cavern(s) to the subsurface storage chamber.

The present invention may comprise several hydrocarbon production facilities or a single hydrocarbon production facility. This is in contrast with traditional systems which typically require many hydrocarbon production facilities, and as such they require an extensive surface infrastructure.

It may be an advantage of embodiments of the present invention that only one hydrocarbon production facility, and thus only one primary point of hydrocarbon production, is required because the need for a large surface infrastructure may be minimised or eliminated, thus helping to minimise the environmental impact of the operation. Consequently the present invention may be more suitable for use in areas with a higher population density such as Europe, and in environmentally sensitive or tightly regulated regions such as Australia.

It may be a further advantage of embodiments of the present invention that having only one hydrocarbon production facility could help to reduce the efforts and costs involved with decommissioning and abandoning fields.

In accordance with another aspect of the present invention there is provided a system for accessing a modified well, the system comprising:

a modified well connecting a subsurface hydrocarbon reserve to a port accessible aboveground;

a production well fluidly connecting a subsurface hydrocarbon reservoir or subsurface storage chamber to a hydrocarbon production facility;

wherein the modified well is accessible during hydrocarbon production from the subsurface hydrocarbon reservoir or subsurface storage chamber via the production well.

The system for accessing a modified well may comprise or be used in combination with the above described system for producing hydrocarbons.

An initial well may be used for drilling a borehole from the surface to one or more subsurface hydrocarbon reserve(s) and/or at least in part creating the system for producing hydrocarbons as described above. After creation of the system, the hydrocarbons stored in the subsurface hydrocarbon reservoir or subsurface storage chamber may be produced via the production well, thus potentially rendering the initial well redundant for production purposes. However, embodiments of the present invention may permit the well to be modified for subsequent use and/or access for other means

and/or operations, for example isolation operations, plugging, workovers, maintenance, pigging, well testing, sampling, extending drilling of the borehole and/or further hydrocarbon reserve stimulation, such as further fracturing of the shale formation.

The present invention may allow the initial well, hereinafter modified well, to be used and/or accessed for at least the above mentioned means and/or operations at the same time as the production well is producing hydrocarbons from the subsurface storage chamber. In traditional operations, the well or modified well and the production well are one and the same, therefore it is not typically possible to carry out at least the above mentioned means and/or operations in the well without first ceasing production operations. The resulting production downtime may result in significant time and financial losses. It may be an advantage of embodiments of the present invention that the modified well and production well may be accessed and used simultaneously because this may minimise the impact on the production operation, and thus mitigate or at least minimise any time and/or financial losses.

The modified well may comprise well completion equipment, such as casing, valves, gauges and isolation devices. The isolation device may be, for example, one or more of a plug, packer, mud and cement. The isolation device may be one or more of mechanical, expandable, threadable and chemical, and may be permanent or semi-permanent. It may be an advantage of embodiments of the present invention to include at least one isolation device in the modified well, as this may help to prevent the back flow of hydrocarbons from the subsurface hydrocarbon reserve(s) to the surface.

The modified well may further comprise a connection port and/or a collar. The collar may be a flange. The connection port and/or the collar may be attachable and/or connectable to equipment, for example, a wellhead. The wellhead may be used for well operations such as, but not limited to, well servicing, workovers, reserve stimulation and/or well testing and/or further operations other than production which would be known to a person skilled in the art.

Typically the connection port and/or the collar is at the surface or below the surface, such as up to 1m below the surface. It may be an advantage of embodiments of the present invention that the connection port and/or the collar is at or below the surface because this may allow the connection port and/or the collar to be covered and/or buried, such as by

soil and/or turf. This may allow the connection port and/or the collar to be hidden from sight, which may help to minimise the impact on the environment.

In accordance with a further aspect of the present invention there is provided a method of operating a system for exploiting a subsurface hydrocarbon reserve and/or for producing hydrocarbons, for example as described above.

The method may comprise providing one or more subsurface hydrocarbon reserves, wherein the or each or some or all of the subsurface hydrocarbon reserve(s) is/are owned by different commercial sources, for example different oil companies and/or different infrastructure companies and/or different transportation companies. The method may further comprise transferring the hydrocarbons from one commercial source to another, or from one location to another, either subsurface or aboveground, for example between the subsurface reservoir or subsurface storage chamber to a tanker. The method may also comprise metering the hydrocarbons.

At any point where the hydrocarbons are transferred, for example from the subsurface storage chamber to a tanker, or from one owner to another, it is a legal requirement that the volume of hydrocarbons transferred is measured to the highest level of accuracy possible, such as within ±0.25%, to help minimise significant financial gains or losses. For example, the extraction, gathering, storage, production and transport elements of the described system may be performed by one or more contributing and/or commercial sources, such as one or more different companies. In such cases, it is necessary to accurately allocate the volume of hydrocarbons produced amongst the contributing and/or commercial sources as appropriate and/or as agreed. The volume of hydrocarbons being transferred and/or allocated may be measured by metering, such as by a flowmeter. Flowmeters may therefore be installed at one or more locations in the system, particularly in the hydrocarbon production facility. Alternatively or additionally, the volume of hydrocarbons transferred may be metered virtually by modelling the system using appropriate computer software. In such embodiments, sensors, such as pressure and/or temperature sensors, may be installed in the system. The sensors may be coupled to wireless or wired transmitters which, in use, transmit the sensor data to the surface for inputting into the model. The virtual model may then track the volume of hydrocarbons being transferred and/or allocated. The virtual model may be used alone, or in addition to the flowmeters for the purpose of corroborating the flowmeter measurements.

Within the scope of this application it is expressly intended that the various aspects, embodiments, examples and alternatives set out in the preceding paragraphs, in the claims and/or in the following description and drawings, and in particular the individual features thereof, may be taken independently or in any combination. That is, all embodiments and/or features of any embodiment can be combined in any way and/or combination, unless such features are incompatible. For the avoidance of doubt, the terms "may", "and/or", "e.g.", "for example" and any similar term as used herein should be interpreted as non-limiting such that any feature so-described need not be present. Indeed, any combination of optional features is expressly envisaged without departing from the scope of the invention, whether or not these are expressly claimed.

Embodiments of the invention will now be described by way of example only and with reference to the accompanying figures, in which:

Fig. 1 is a schematic view of a system for gathering, storing and producing light, tight oil from a plurality of subsurface hydrocarbon reserves in accordance with one embodiment of the present invention;

Fig. 2 is a schematic view of a system for gathering, storing and producing light, tight oil and shale gas from a subsurface hydrocarbon reserve in accordance with a further embodiment of the present invention; and

Fig. 3 is a schematic view of a modified well in accordance with one aspect of the present invention.

Fig. 1 shows a system (10) comprising four subsystems (11a, 11b, 11c & 11d). Each subsystem (11a, 11b, 11c & 11d) is identical. Only one subsystem will be described here, but the details will apply to all subsystems (11a, 11b, 11c & 11d).

The subsystem (11a) comprises a subsurface hydrocarbon reserve, such as a shale formation (12), and a subsurface gathering cavern (14). In this embodiment, the shale formation (12) produces light, tight oil (LTO). The subsurface gathering cavern (14) is located below the shale formation (12). The system (10) comprises a central liquid chamber (16) located below the subsurface gathering cavern (14) of each subsystem (11a, 11b, 11c & 11d).

The system (10) has a three-tier design which allows the system (10) to span over a much larger area. For example, a single tier system at 10 km in length could span an area of around 315km^2, but the corresponding system over two tiers could span an area of around 1260km^2, and the corresponding system over three tiers could span an area of around 2830km^2. The radius of the system may be limited by the extended reach drilling limitations and/or the economic feasibility of the one or more subsurface hydrocarbon bearing shale formation(s). Typically extended reach drilling can reach lengths of from 10km to 12km. It may be an advantage of embodiments of the present invention that the one or more subsurface gathering cavern(s) may be either below (for LTO) and/or above (for shale gas) the one or more subsurface hydrocarbon bearing shale formation(s) and/or may be correspondingly above and/or below the subsurface storage chamber, because such a tiered approach may allow the potential area of the system to span thousands of km^2.

In this example, the subsurface gathering cavern (14) is approximately spherical, and has a capacity of at least 25% of the central liquid chamber (16). The central liquid chamber (16) is also approximately spherical. Preferred shapes are approximately spherical or cylindrical, at least in part due to the formation or creation methods used. The shapes may otherwise be random, but preferably avoiding the creation of traps.

The volume of the subsurface gathering cavern (14) and the central liquid chamber (16) is, in this instance, approximated by the equation $V = \frac{4}{3}\pi r^3$, where r is the radius of the subsurface gathering cavern (14) or the central liquid chamber (16) respectively. For example, with 1 barrel of oil being approximately 0.16m^3, if the central liquid chamber (16) has a capacity of 100,000 BOE of LTO, the central liquid chamber should be created with a volume of at least 16,000m^3, and each subsurface gathering cavern (14) will deliver 25,000 BOE of LTO to the central liquid chamber (16), and so should be created with a volume of at least 4,000m^3. The total storage capacity of the system, that is the total volume capable of being stored in both the subsurface gathering caverns (14) and the subsurface storage chamber (16), is 200,000 BOE.

Shale formation (12) is approximately 2,000m below the surface. Wells (20) are shown adjacent to shale formation (12) and the subsurface gathering cavern (14) is located below the shale formation (12) at a depth determined by the distance and slope of boreholes (22) fluidly connecting shale formation (12) to subsurface gathering cavern (14). The central liquid chamber (16) is located, at least partly, below the subsurface gathering

cavern (14) at a depth again determined by the distance and slope of borehole (24) fluidly connecting subsurface gathering cavern (14) to the central liquid chamber (16). The depth of the lowest point (15a) of the central liquid chamber (16) will determine the depth of drilling from the surface for liquid production pipe (26).

The boreholes (22) are input flowlines (22) and the borehole (24) is an output flowline (24). The output flowline (24) is fluidly connected with the lowest point (19) of the subsurface gathering cavern (14).

A single hydrocarbon production facility (18) is located at the surface (28) above the central liquid chamber (16). A liquid production pipe (26) extends from the hydrocarbon production facility (18) into the central liquid chamber (16). The hydrocarbon production facility (18) comprises a water tank (not shown) fluidly connected to an input and/or output water pipe (21). The preferred input and/or output water pipe (21) is concentric and/or coaxial with the liquid production pipe (26). The input and/or output water pipe (21) extends to the lowest point (15a) of the central liquid chamber (16), and thus extends to a greater depth than the liquid production pipe (26) In alternative embodiments, an input and/or output water pipe independent of the liquid production pipe is fluidly connected to the water tank, and also extends to the lowest point (15a) of the central liquid chamber (16).

The liquid production pipe (26) is retractable, that is lowerable and raiseable. The input and/or output pipe (21) is fixed, that is it remains at a fixed depth.

To create the subsystem (11a) and the system (10), depending on the geology of the area surrounding the shale formation (12), the subsurface gathering cavern (14) and the central liquid chamber (16) are first created by leaching the subsurface gathering caverns (14) and the central liquid chamber (16) in salt deposits (not shown). This is usually done by drilling a borehole (30) from the surface (28) down to the salt deposit, injecting water to dissolve the salt, creating the cavity, and then pumping the salt solution out. The subsurface gathering cavern (14) and the central liquid chamber (16) are finished by spraying with, for example, a polymer spray coating, for protection and support.

Following this, the wells (20) are drilled substantially vertically from the surface (28) and then substantially horizontally, using directional drilling technology, which is routinely capable of reaching from 3km to 4.5km in depth and can span up to 7.5km in length. The

wells (20) are then extended horizontally, using Extended Reach Drilling technologies, which allows the wells (20) to reach a larger area from a single surface drilling location, and also helps to keep the wells in a hydrocarbon bearing zone within the shale formation (12) for a longer distance in order to maximize productivity and drainage capability. Using this technology, the wells (20) may reach a depth of up to 12.5km, and a horizontal length extending up to 11.5km. The wells (20) are then further extended down to the subsurface gathering caverns (14), thus creating the input flowlines (22). The output flowline (24) is created by further extending a single well (22) from the subsurface gathering cavern (14) towards the central liquid chamber (16). This may be either the initial well or an optimally placed well, depending on the configuration of the system. The trajectories of the wells (20), input flowlines (22) and output flowline (24) may be designed and/or planned and/or tracked to avoid clashes and/or intersection of the trajectories.

The input flowlines (22) and the output flowline (24) are designed for optimal contact and flow therethrough, and are able to cope with, for example, the expected flow volumes, pressures, temperatures and corrosivity. Both the input flowlines (22) and the output flowline (24) are created to slope in a downhill direction to facilitate the flow of LTO from the shale formation (12) into the central liquid chamber (16).

Concurrently with drilling the wells (20), a liquid production borehole to accommodate the liquid production pipe (26) is drilled from the hydrocarbon production facility (18) down to the central liquid chamber (16). Alternatively, the liquid production borehole can be created before the wells (20) or even some time after the drilling of the wells (20).

Once the wells (20) have been drilled, they are then completed, for example by installing casing and/or a flow control valve (not shown) and/or meters. Each input flowline (22) and each output flowline (24) may also comprise a flow control valve (not shown) depending on factors such as ease of adjusting the hydraulic balance in the system by other means and/or if a choked flow is required where flow rates are too high and/or difficult to control by other means.

Preferably, the flow of hydrocarbons from the shale formation (12) through to the central liquid chamber (16) is controlled by appropriately designing the degree of slope of the flowlines (22, 24), and/or constriction of one or more or some or all borehole diameter(s), in combination with hydraulically balancing the system using the hydraulic lift effect provided during production by water injection methods, as described below.

In use, the shale formation (12) is hydraulically fractured via the wells (20) to stimulate the reservoir and thus release the LTO. The LTO flows freely out of the fractures in the shale formation (12) and into the subsurface gathering cavern (14) via the input flowlines (22) by gravity drainage. Gravity drainage is based on the working principle of a siphon, whereby as the LTO flows from the shale formation (12) downhill to the subsurface gathering cavern (14), a low pressure area is created at the top of each input flowline (22). This low pressure area causes the LTO to flow from the higher pressure shale formation to the lower pressure area where the force of gravity takes over and moves the LTO downhill to the subsurface gathering cavern (14) and then into the subsurface storage chamber (16) where they accumulate first. After the subsurface storage chamber (16) is full, the subsurface gathering cavern (14) will fill with hydrocarbons.

The LTO can be stored in the central liquid chamber (16) for a period of time influenced by factors such as the demand for LTO. Once it is deemed appropriate, such as if demand for LTO increases, the LTO in the central liquid chamber (16) is produced by water injection. Water injection methods involve injecting water, or brine, from the water tank into the central liquid chamber (16) via the input and/or output water pipe (21) to hydraulically displace the LTO up the liquid production pipe (26) towards the hydrocarbon production facility (18) at the surface (28).

The water, often referred to as bottom fed water, is pumped into the lowest point (15a) of the central liquid chamber (16), in part to minimise or avoid the trapping of LTO in the central liquid chamber (16). As the water is pumped into the central liquid chamber (16), the LTO is lifted in an upwards direction towards the surface (28) via the liquid production pipe (26). In use, the liquid production pipe (26) is initially extended within the central liquid chamber (16), albeit it is extended to a depth which is higher than the input and/or output water pipe (21). As the water is pumped into the central liquid chamber (16), the water level rises as the LTO is lifted out, therefore the liquid production pipe (26) is retracted with the rising water level so that it remains above the water level at all times. This ensures that the liquid production pipe (26) continues to produce LTO, and does not start producing water. When the central liquid chamber (16) is full of water, the liquid production pipe (26) is fully retracted such that it is located at the highest point (15b) of the central liquid chamber (16). The production cycle normally ceases before the production of water.

The process of lifting the LTO from the central liquid chamber (16), will cause a portion of the LTO to be forced back into the subsurface gathering cavern (14) via the output flowline (24). Once the central liquid chamber (16) is full of water, the pressure exerted by the water prevents the LTO in the subsurface gathering cavern (14) from freely flowing into the central liquid chamber (16), thus controlling the flow of hydrocarbons without the need for installing flow control valves. However LTO still continues to freely flow from the shale formation (12) into the subsurface gathering cavern (14).

On completion of the production cycle, the injected water is removed via the water input and/or output pipe (21) by means of a pump (not shown) attached to the water input and/or output pipe (21) and is returned to the water tank. The injection water may be re-used multiple times, for example as long as the water quality permits. The injection water may be mechanically treated to maintain the necessary quality, and/or the injection water may be chemically treated by means of additives, for example corrosion inhibitors, via facilities provided at the surface (28) and/or at the hydrocarbon production facility (18).

The production cycle correctly balanced ensures that the central liquid chamber (16) empties before the subsurface gathering cavern (14) is full. Once the central liquid chamber (16) is empty of water, the LTO can then freely flow from the subsurface gathering cavern (14) to the central liquid chamber, and the above process, or production cycle, repeats.

In some embodiments, the liquid production pipe may be fixed at a depth above the water input and/or output pipe. In such embodiments, the liquid production pipe may be located at the highest point of the central liquid chamber at all times.

It may be an advantage of embodiments of the present invention that the water, or brine, can be re-used because this helps to minimise environmental impact and it also helps to minimise the demand for supplies of water.

During the production operation or cycle, typical well operations such as well-tests may still be carried out on the wells (20), as will be described in more detail in Fig. 3. Well-tests typically help to determine how much LTO, or other hydrocarbons, are likely to be produced, and how fast the subsurface hydrocarbon reserve(s) can produce.

Fig. 2 shows a further embodiment of the system (110) which includes like parts with the Fig. 1 embodiment and these are not described again in detail. The reference numerals of the like parts share the same latter two digits in both embodiments, but differ in that they are prefixed with a '1' in this second embodiment.

In contrast with Fig.1, the Fig. 2 embodiment shows a central gas chamber (117), a second output flowline (123) extending from subsurface gathering cavern (114) to central gas chamber (117), and a gas production pipe (125). Fig.2 shows only one shale formation (112), but in use the system (110) typically contains multiple shale formations (112). In this embodiment, the shale formation (112) produces both LTO and shale gas. The primary use for all aspects of the present invention is for extracting and producing liquid hydrocarbons, e.g. LTO, however it is inevitable that gaseous hydrocarbons, e.g. shale gas, will also be released from the subsurface hydrocarbon reserve(s) and the system must be able to accommodate this.

The subsurface gathering cavern (114), central liquid chamber (116), wells (120), input flowline (122) and output flowline (124) are created as described in Fig. 1.

The central gas chamber (117) is also created by leaching a salt deposit (not shown) via borehole (130), as previously described in Figure 1, and is located above the subsurface gathering cavern (114) and the central liquid chamber (116).

The second output flowline (123) is created in the same way as output flowline (124). A gas production borehole is provided to accommodate the gas production pipe (125). The gas production borehole is created in the same manner as liquid production borehole. The second output flowline (123) is created to slope in an uphill direction to facilitate the flow of shale gas from the subsurface cavern (114) into the central gas chamber (117).

The second output flowline (123) is connected to the highest point of subsurface gathering cavern (114). In use, this prevents any shale gas being trapped within the subsurface gathering cavern (114). The second output flowline (123) may also comprise a flow control valve (not shown).

Once the shale formation (112) is hydraulically fracked the hydrocarbons freely flow out of the fractures in the shale formation (112) and into the subsurface cavern (114) via the input flowlines (122) by gravity drainage. The shale gas flows out of the fractures in the

shale formation (112) and into the subsurface cavern (114) via the input flowlines (122) due to the back pressure in the wells (120) and the pressure created by the flow of LTO, as previously described. At this point, the production of LTO continues as described in Fig. 1.

Since shale gas is less dense than LTO it rises to the top of the subsurface gathering cavern (114), and then up through the second output flowline (123) into the central gas chamber (117). In other embodiments, the shale gas rises from subsurface gathering cavern (114) directly to the surface (128) via borehole (130) where it is subsequently flared.

The shale gas can be stored in the central gas chamber (117) for a period of time, and produced at a later time. Alternatively, the shale gas (and also the LTO) can be produced without first undergoing a period of storage.

The shale gas can typically be produced from the central gas chamber (117) via the gas production pipe (125) by means of natural pressure. The gas production pipe (125) is separate to, and runs adjacent to, the liquid production pipe (126). The gas production pipe (125) and the liquid production pipe (126) are both connected to and in fluid communication with the hydrocarbon production facility (118).

Within the central liquid chamber (116) and the central gas chamber (117), the hydrocarbons, and any other fluids, may be stratified depending on the inherent properties of the fluids present. In some embodiments of the present invention, the gas production pipe and/or the liquid production pipe may have multiple extraction points to target the various strata and extract individual fluids.

In some embodiments, the LTO may be stored in the central liquid chamber at the same time as the shale gas is stored in the central gas chamber. Alternatively, the shale gas may be produced from the central gas chamber whilst the LTO is stored in the central liquid chamber, or vice versa. It may be an advantage of embodiments of the present invention that the LTO and/or shale gas can be stored because this will help to mitigate problems with overproduction. This is especially beneficial if demand decreases.

In alternative embodiments, the gas production pipe may be located over the central gas chamber instead of adjacent to the liquid production pipe. In other embodiments, the gas

production pipe may connect with the liquid production pipe below the surface, so that there is only one production pipe connected to and in fluid communication with the hydrocarbon production facility for both liquid and gas.

Conventional means of producing hydrocarbons normally involves using the initial limited reservoir drive pressure and then pumping to pull any remaining hydrocarbons up out of the well. These conventional methods may involve significant equipment and/or energy usage costs, as well as in-the-field operation and/or maintenance efforts and/or costs. As such, the longer, low production phase of many wells may not be economic and so they may be abandoned, with remaining hydrocarbons not recovered. It may therefore be an advantage of embodiments of the present invention that the production of hydrocarbons is typically by water injection because this may help to mitigate the above problems associated with conventional methods, and production and recovery operations may be more efficient and economic because more hydrocarbons may be recovered over the life of the subsurface hydrocarbon reserve(s). Furthermore, the improved economics may increase the number of otherwise marginal fields that may be exploited.

It may be a further advantage of embodiments of the present invention that production efficiencies over the life of the subsurface hydrocarbon reserve(s) may be up to 95%, compared to conventional systems and operations which typically have production efficiencies in the range of from 40% to 60%. This may have an appreciable effect on the operating costs over the life of the subsurface hydrocarbon reserve(s), as well as an improved capital efficiency. Moreover, any additional capital investment, for example, in terms of drilling and excavation of the subsurface gathering cavern(s) and/or subsurface storage chamber, may be significantly offset by the elimination of multiple hydrocarbon production facilities at the surface.

Having a single hydrocarbon production facility may permit only a single industrial scale pump for water injection and/or water removal to be used, and also a single point of access to the hydrocarbons for transportation, either by pipeline or ground and/or sea transport, thus helping to minimise the environmental impact of the production operation. It may be an advantage of embodiments of the present invention that there is a single point of access to the hydrocarbons for transportation because this may help to minimise transportation costs, which can typically form a large proportion of the production costs.

In some embodiments of Fig.1 and Fig. 2, flow control valves may be the primary method for controlling the hydraulic balance in the system, although where possible use of the hydraulic lift effect as described above is preferred. In use, flow control valves in the input flowlines (22) and the output flowline (24) are initially in the closed position to prevent the flow of fluid. The flow control valve in the output flowline (24) remains in a closed position as the valves in the input flowlines (22) are opened, allowing the subsurface gathering cavern (14) to fill with fluid. When the subsurface gathering cavern (14) reaches full capacity, the valves in the input flowlines (22) are closed and the valve in the output flowline (24) is opened, both via command signals sent from the surface. The fluid can then flow from the subsurface gathering cavern (14), through the output flowline (24) under the influence of gravity, and into the central liquid chamber (16). No further fluid can flow from the shale formation (12) into the subsurface gathering cavern (14) whilst the valves in the input flowlines (22) are closed. Once the subsurface gathering cavern (14) is empty, command signals sent from the surface instruct the valve in the output flowline (24) to close, and the valves in the input flowlines (22) to open, and the process described above is repeated. Once the central liquid chamber (16) is full of fluid, or once a pre-determined volume of fluid has accumulated in the central liquid chamber (16), the valves in the input flowlines (22) and the output flowline (24) are instructed to close via a command signal sent from the surface, thus preventing any further fluid to flow. Alternatively, once the central liquid chamber (16) is full of fluid, or once a pre-determined volume of fluid has accumulated in the central liquid chamber (16), the valve in the output flowline (24) is instructed to close via a command signal sent from the surface, thus preventing any further fluid to flow from the subsurface gathering cavern (14) to the central liquid chamber (16). The valves in the input flowlines (22), however, may remain open to allow the subsurface gathering cavern (14) to fill with fluid from the shale formation (12) again.

Fig. 3 shows a well (220) comprising a connection port (240), a flange (242), an access port (244), a packer (248) and a borehole (246).

The well (220) was initially used as a drilling well to access the shale formation and create the system for producing hydrocarbons, as described above. Traditionally the well (220) would also be used to produce hydrocarbons, however, the hydrocarbons stored in the central gas and/or liquid chamber(s) are produced by the hydrocarbon production facility via the hydrocarbon production pipe(s), thus potentially rendering the well redundant. An aspect of the present invention however modifies the well, thus minimising or removing any redundancies in the system.

The flange (242) is threadably connected to the connection port (240), and both are located below the surface (228). The drilling wellhead connected to the connection port (240) has been removed, thus leaving the connection port (240) and flange (242) hidden beneath the surface (228). The surface (228) above the connection port (240) may be restored to the conditions found pre-drilling, or it can be converted into a new aesthetically pleasing environment, such as a park. However the location of the well (220) is known, and at any time the surface (228) can be removed to reveal and access the connection port (240).

The connection port (240) is typically accessed for well operations such as well tests or further hydraulic fracturing of the shale formation. Shale formations may require periodic stimulation, for example every 12 to 18 months, to maintain the flow of hydrocarbons. Therefore, periodically over the life of the well (220) the connection port (240) is uncovered and a suitable wellhead is connected.

The access port (244) provides access to the borehole (246). The access port (244) is opened after the wellhead is connected to the connection port (240), and the appropriate equipment is lowered into the borehole (246) to perform the required operations in the well (220). Certain operations may be carried out at the same time as production operations at the hydrocarbon production facility. Where isolation is necessary, the well (220) may be returned to production and reinstated within a reduced time period, with minimal effort.

The packer (248) is a permanent expandable packer. The packer (248) can be expanded during operations requiring isolation of at least a part of the well (220), or the packer (248) can be fully expanded at all times as a safety measure to help prevent the back flow of hydrocarbons from the subsurface hydrocarbon reserve(s) to the surface (228) via the borehole (246).

Modifications and improvements can be incorporated without departing from the scope of the invention. For example, the number and/or configuration of each of the elements described in relation to the specific embodiments may be varied in any manner that is consistent with the claims and/or the aforementioned aspects of the invention.

CLAIMS

1. A system for exploiting a hydrocarbon reserve, the system comprising a subsurface hydrocarbon reserve and a subsurface reservoir in fluid communication with the subsurface hydrocarbon reserve via one or more manufactured flowlines, wherein the subsurface reservoir is below the subsurface hydrocarbon reserve; and wherein hydrocarbons are flowable, in use, from the subsurface hydrocarbon reserve to the lower subsurface reservoir by or under the influence of gravity to gather and/or store hydrocarbons for production.

2. A system as claimed in claim 1 further comprising either

a production connector accessible aboveground and fluidly connected to the subsurface reservoir for fluidly connecting, in use, the subsurface hydrocarbon reserve to a hydrocarbon production facility; or

a hydrocarbon production facility fluidly connected to the subsurface reservoir.

3. A system as claimed in claim 1, wherein the subsurface reservoir comprises a subsurface storage chamber and the system further comprises a subsurface gathering cavern, wherein the subsurface hydrocarbon reserve is in fluid communication with the subsurface storage chamber via the subsurface gathering cavern.

4. A system for producing hydrocarbons, the system comprising:

a plurality of subsurface hydrocarbon reserves;

one or more subsurface gathering caverns each of which is in fluid communication with at least one of the subsurface hydrocarbon reserves via one or more manufactured flowlines;

a subsurface storage chamber in fluid communication with the or each subsurface gathering cavern via one or more flowlines; and either

a production connector accessible aboveground and fluidly connected to the subsurface storage chamber for fluidly connecting, in use, the subsurface hydrocarbon reserves to a hydrocarbon production facility; or

a hydrocarbon production facility fluidly connected to the subsurface storage chamber;

wherein the subsurface storage chamber is below at least one of the subsurface hydrocarbon reserves and fluidly connected thereto via one or more of the subsurface gathering caverns also below the at least one of the subsurface hydrocarbon reserves;

such that the hydrocarbons are flowable from the at least one subsurface hydrocarbon reserve to the lower subsurface gathering cavern(s) by or under the influence of gravity where the hydrocarbons are gatherable; and

wherein the hydrocarbons are further flowable from the subsurface gathering cavern(s) into the lower subsurface storage chamber by or under the influence of gravity where the hydrocarbons are storable and/or from which the hydrocarbons are producible, in use, by a hydrocarbon production facility.

5. A system as claimed in claim 3 or claim 4, wherein the flowlines slope in a downward direction.

6. A system as claimed in claim 3 or claim 4, wherein the or at least one subsurface gathering cavern and the subsurface storage chamber are above the or at least one subsurface hydrocarbon reserve and the flowlines slope in an upward direction.

7. A system as claimed in any one of claims 3 to 6 comprising a liquid subsurface storage chamber and a gas subsurface storage chamber, wherein at least one subsurface gathering cavern and the liquid subsurface storage chamber are below at least one subsurface hydrocarbon reserve and at least one subsurface gathering cavern and the gas subsurface storage chamber are above at least one subsurface hydrocarbon reserve.

8. A system as claimed in any preceding claim further comprising a meter associated with at least one flowline for measuring flow therethrough.

9. A system as claimed in any preceding claim further comprising a liquid storage tank and a pumping means in fluid communication with the subsurface reservoir or subsurface storage chamber for pumping liquid therein to produce hydrocarbons therefrom.

10. A system as claimed in any preceding claim, wherein one or more of the subsurface reservoir, the subsurface gathering cavern(s) and/or the subsurface storage chamber(s) is or are at least partially man-made.

11. A system as claimed in any preceding claim, wherein one or more of the subsurface reservoir, the subsurface gathering cavern(s) and/or the subsurface storage chamber(s) is or are at least partially naturally occurring.

12. A system according to any preceding claim comprising a hydrocarbon production facility, a water tank and a pumping means, wherein the hydrocarbon production facility is fluidly connected to the subsurface reservoir by a production pipe, the water tank is fluidly connected to the subsurface reservoir by a water pipe extending to a position below the end of the production pipe and the pumping means is operable to pump, in use, water or brine from the tank into and/or out of the subsurface reservoir.

13. A system according to claim 12, wherein the production pipe is retractable, in use, during production and/or in response to a rising water or brine level within the subsurface reservoir or storage tank.

14. A method of forming a system for producing hydrocarbons, the method comprising fluidly connecting a subsurface hydrocarbon reserve to a subsurface reservoir below the subsurface hydrocarbon reserve via one or more manufactured subsurface flowlines such that the subsurface flowlines slope in a downward direction and such that hydrocarbons are flowable, in use, from the subsurface hydrocarbon reserve to the lower subsurface reservoir by or under the influence of gravity.

15. A method as claimed in claim 14 further comprising fluidly connecting the subsurface reservoir to a hydrocarbon production facility, or to a production connector accessible aboveground for fluidly connecting the subsurface reservoir to a hydrocarbon production facility.

16. A method as claimed in claim 14 or claim 15 further comprising forming or creating, at least in part, the subsurface reservoir.

17. A method as claimed in any one of claims 14 to 16, wherein the subsurface reservoir comprises a subsurface storage chamber, the method comprising fluidly connecting the subsurface hydrocarbon reserve to the subsurface storage chamber via one or more subsurface gathering caverns.

18. A method as claimed in claim 17, wherein the subsurface storage chamber is the primary source of production, and the hydrocarbons are produced by the or a hydrocarbon production facility.

19. A method as claimed in claim 18, wherein the hydrocarbons are producible by water injection.

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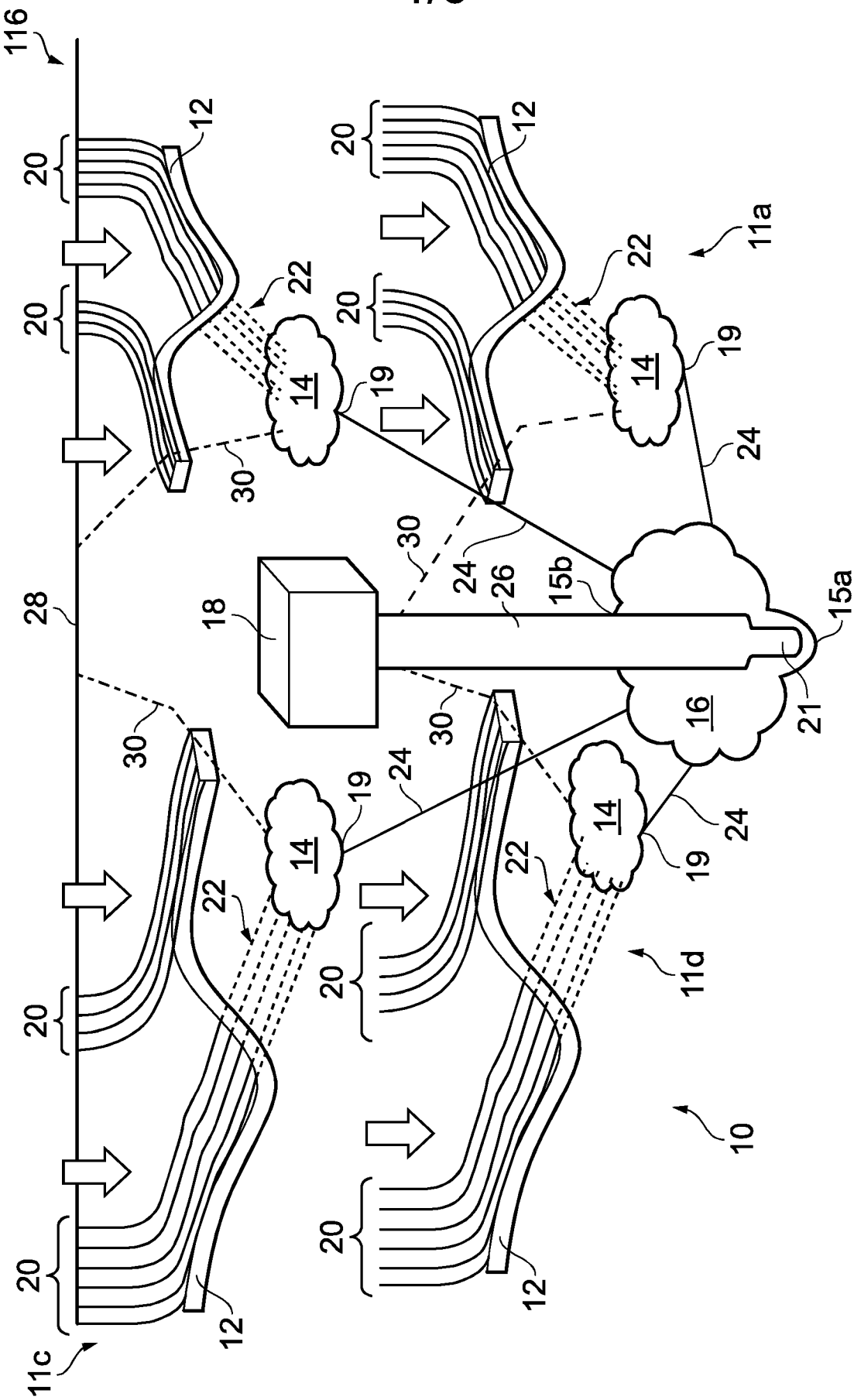


FIG. 1

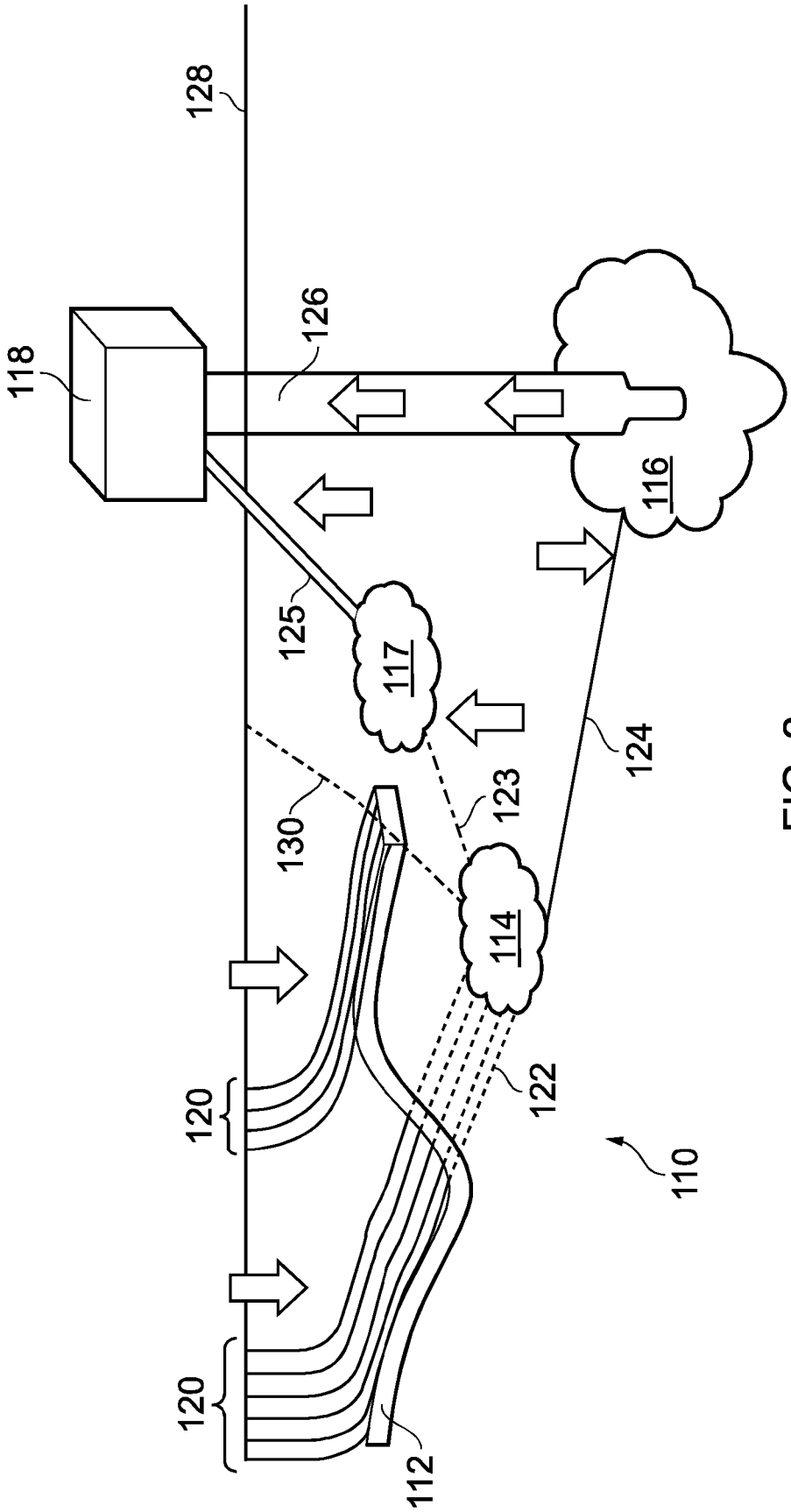


FIG. 2

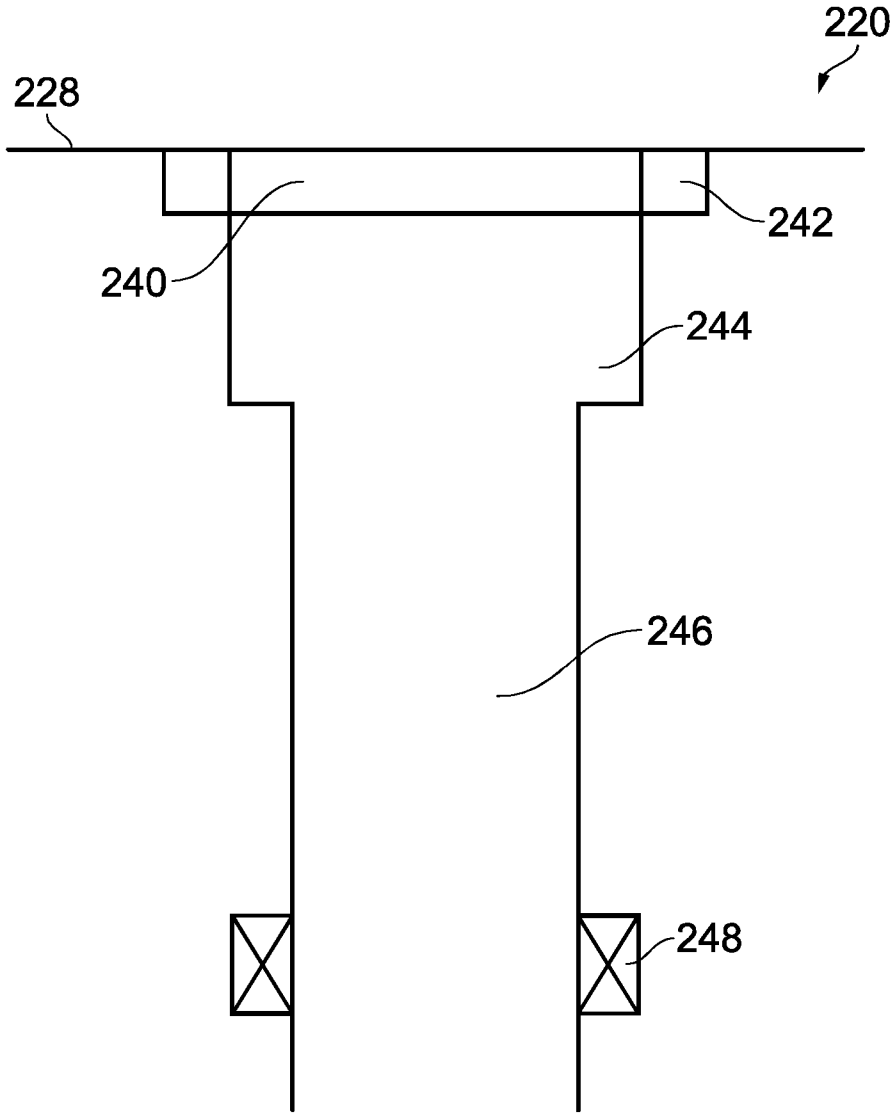


FIG. 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2016/052122

A. CLASSIFICATION OF SUBJECT MATTER
INV. E21B43/28
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)
E21B

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

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X	US 2014/338921 A1 (BARRY MICHAEL D [US] ET AL) 20 November 2014 (2014-11-20) paragraphs [0050], [0053], [0057], [0060], [0062], [0067], [0068], [0072], [0073]; figure 4	1-19
A	EP 0 212 692 A1 (SHELL INT RESEARCH [NL]) 4 March 1987 (1987-03-04) figure 1	1-19
A	US 4 182 128 A (GARDNER JAMES H [US]) 8 January 1980 (1980-01-08) figure 1	1-19
A	US 3 385 067 A (EEK WOUTER H VAN) 28 May 1968 (1968-05-28) figure 1	1-19

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
7 October 2016	14/10/2016

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Georgescu, Mihnea

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INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2016/052122

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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