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(71) Applicant
Exal Reservoir Services Limited

(Incorporated in the United Kingdom)

Phoenix House, Tyseal Base, Craigshaw Crescent, West Tullos, Aberdeen, AB1 4AW, United Kingdom

(72) Inventor
Andy Brown

(74) Agent and/or Address for Service
Urquhart-Dykes & Lord
8th Floor, Tower House, Merrion Way, Leeds, LS2 8PA, United Kingdom

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(56) Documents cited
GB 2192725 A GB 2161941 A EP 0031744 A1

(58) Field of search
UK CL (Edition K) **G1R RAB RBC RSA RSB**
INT CL[5] **G01F**
Online databases: WPI

(54) Hydro-carbon flow rate monitor

(57) A method of monitoring the rate of flow of hydrocarbons which are being conveyed along a production pipe 43 from an underground reservoir, using a drill string 42 having a tubular section 41 which incorporates a flow meter (40) having a flow restrictor and pressure monitoring points arranged at predetermined positions relative to the flow restrictor, and the method comprising running the drill string 42 down the production pipe 43 so as to bring the tubular section 41 to a suitable pressure monitoring position; causing the flow of hydrocarbons in the production pipe to pass upwardly through the drill string by way of the tubular section 41 after incorporation of the flow meter 40 therein; and measuring the pressures prevailing at the monitoring points in order to derive data indicative of the hydrocarbon flow rate. The flow meter may be incorporated in the tubular section prior to running of the drill string down the production pipe, or may be run downwardly via a wireline in order to snap fit into position after the drill string has been positioned. Preferably the flow meter has memory gauges arranged to gather down hold data, and which then can be monitored upon return of the flow meter to the surface. Individual flow rates of a two phase oil/water mix can be established.

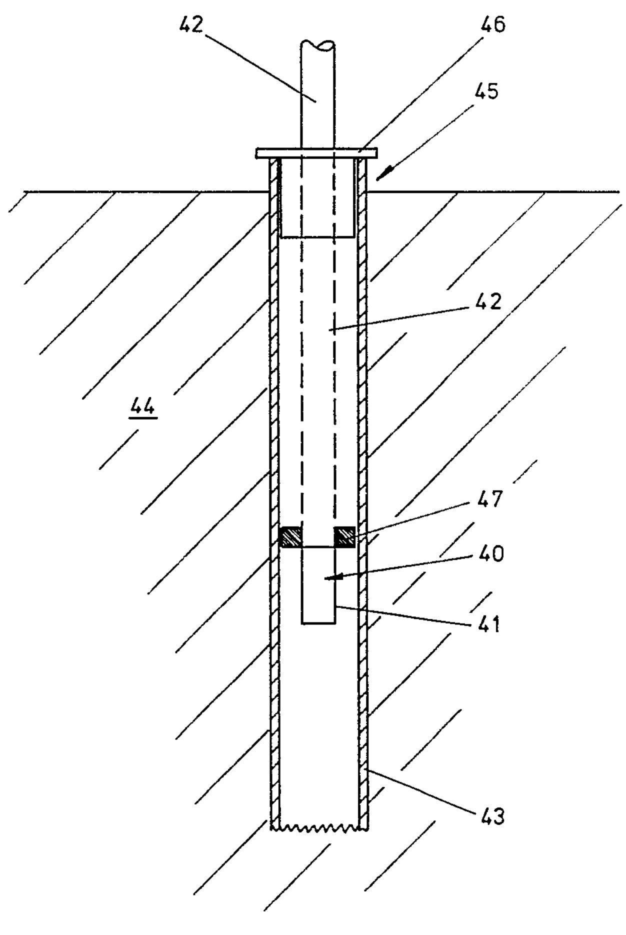

FIG. 4

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

This print takes account of replacement documents submitted after the date of filing to enable the application to comply with the formal requirements of the Patents Rules 1990.

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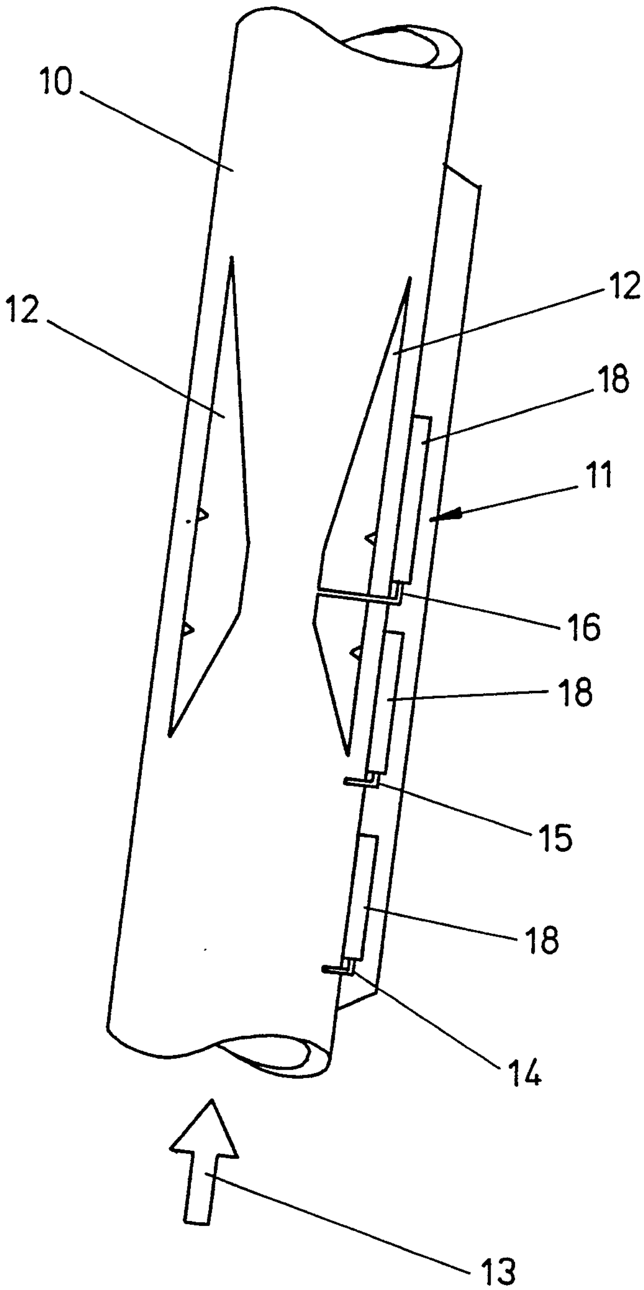

FIG. 1

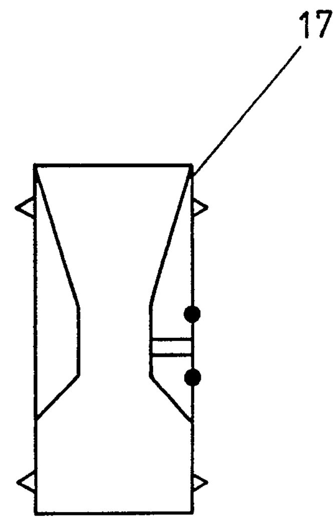

FIG. 2

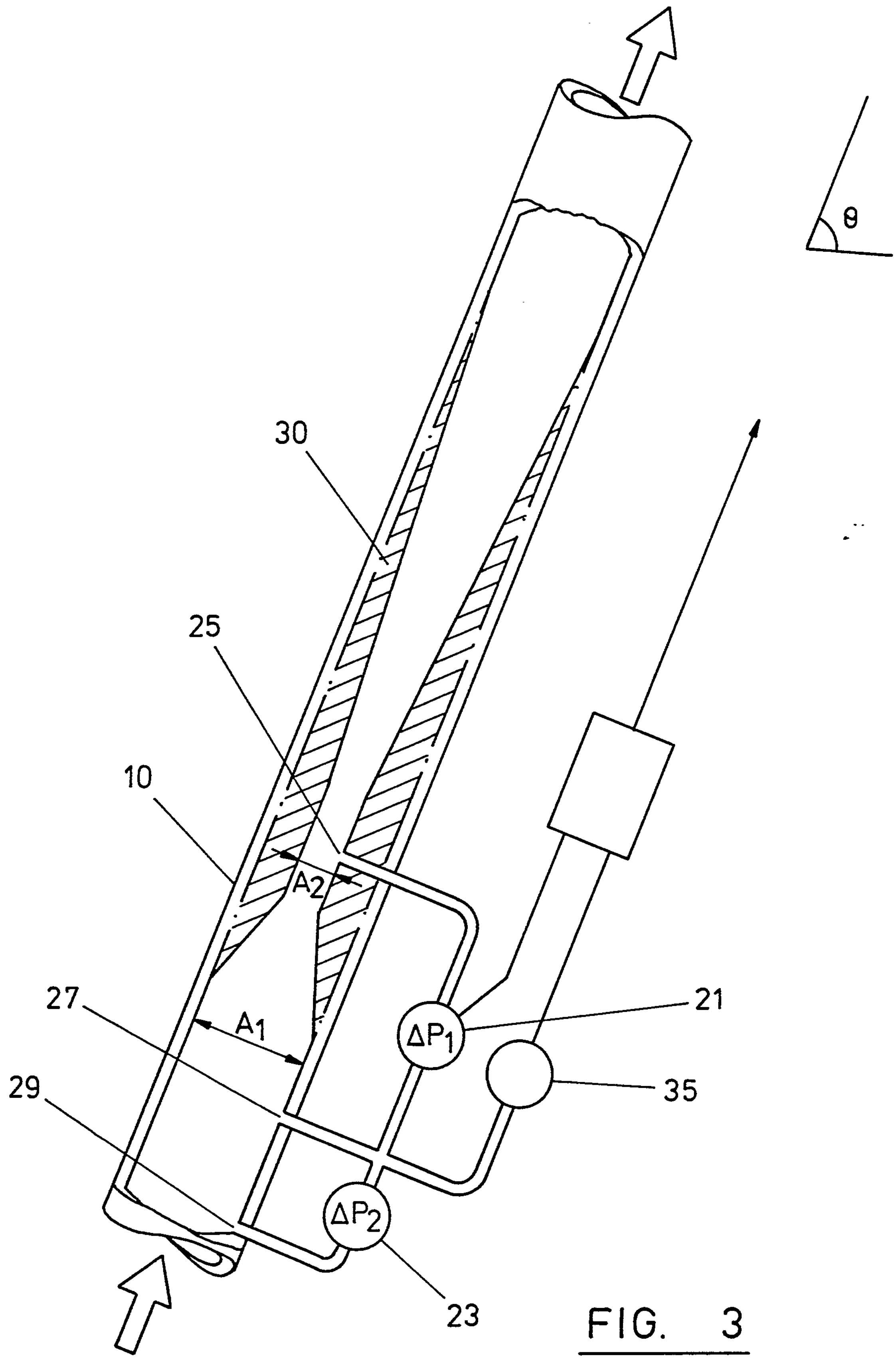

FIG. 3

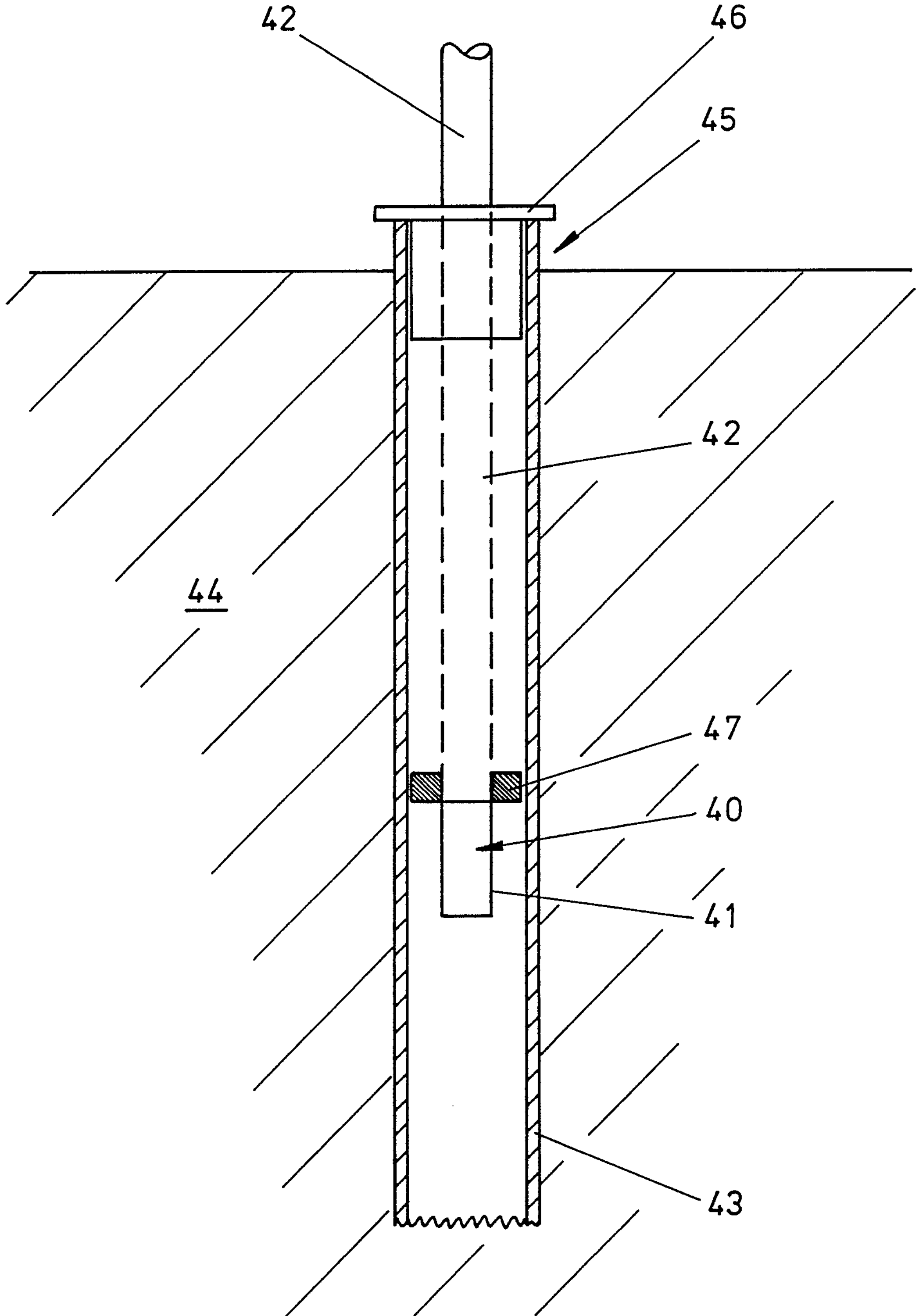

FIG. 4

HYDRO-CARBON FLOW RATE MONITOR

This invention relates to a hydro-carbon flow meter operable to monitor the rate of flow of hydro-carbons during extraction from a reservoir, and to a method of monitoring the flow rate.

In the extraction of hydro-carbons, such as oil or gas, from natural reservoirs, it is desirable to know the rate at which the fluid flows through the usual production pipe running upwardly from the reservoir to a collection and distribution point, from the point of view both of management of the extraction operation and of management of the reservoir.

These reservoirs are located underground, and often in environmentally hostile regions, such as a desert, or extraction from the sea bed of the North Sea, which makes the management of the extraction process hazardous. Another complication is that the hydro-carbons extracted are often co-existing in more than one phase, and in addition to monitoring the overall flow rate, it can be desirable to monitor the individual flow rates of the constituent phases of the extracted hydro-carbons.

This invention is concerned with an improved means and method of monitoring the flow rate of hydro-carbons being extracted via a production pipe and employs so-called drill string testing (DST) which involves the running of the string down the production pipe and blanking-off the entrance to the annular chamber defined between the inner surface of the production pipe and the outer surface of the string by a "packer" so that the extracted hydro-carbons are forced upwardly through the drill string.

Conventional monitoring of hydro-carbon flow rates using drill string testing is carried out either by mathematical extrapolation of surface derived data, or by running a production logging tool (PLT) down the drill string when this is possible. When utilising surface data and mathematical calculation, this does not give a true indication of "sand face" flow rate. This parameter would be a vital component of the mathematical balance equations required to calculate hydro-carbon flow rates.

In the case of intended use of a production logging tool, this is suspended on electrical cable and requires extra safety precautions to be taken when installing the tools. Also, it is not always possible to run a PLT due to down hole test tool restriction. Further, this causes a restriction in size of the impeller of the PLT (which is driven by the upwardly flowing hydro-carbon), which can give rise to certain inaccuracies.

Accordingly, in one aspect of the invention there is provided a method of monitoring the rate of flow of hydro-carbons which are being conveyed along a production pipe from an underground reservoir, using a drill string having a tubular section which incorporates a flow meter, having a flow restrictor and pressure monitoring points arranged at predetermined positions relative to the flow restrictor, and said method comprising:

running the drill string down the production pipe so as to bring said tubular section to a suitable pressure monitoring position;

causing the flow of hydro-carbons in the production pipe to pass upwardly through the drill string by way of the tubular section after incorporation of the flow meter therein; and

measuring the pressures prevailing at said monitoring points in order to derive data indicative of the hydro carbon flow rate.

The flow meter may be incorporated in the tubular section prior to running of the drill string down the production pipe, or alternatively it may be run downwardly via a wire line in order to snap-fit into position after the drill string has been positioned in the production pipe.

In a further aspect of the invention there is provided a drill string having a flow meter for monitoring the rate of flow of hydro-carbons along the production pipe from an underground reservoir and comprising a tubular section incorporating a flow meter to monitor the flow rate after the drill string has been run down the production pipe to bring the flow meter to a suitable pressure monitoring position, in which the flow meter has a flow restrictor and pressure monitoring points arranged at predetermined positions relative to the flow restrictor, whereby upon upward movement of the hydro-carbons through the drill string by way of the tubular section, the pressures prevailing at the monitoring points can be measured and data derived therefrom indicative of the hydro-carbon flow rate.

Accordingly, the invention enables "down hole" flow measurements to take place accurately using drill string testing equipment, and in which the flow meter incorporated in its own tubular section of the string can create a differential pressure between two monitoring points at certain flow rates. The differential pressure can then be used to calculate the flow rate of an oil well.

Preferably, the flow meter is provided with memory gauges arranged to gather the "down hole" data and which can then be monitored upon the return of the flow meter to the surface.

As indicated above, the flow meter may be incorporated in its own tubular section prior to running of the drill string down the production pipe. Alternatively, the flow meter may comprise a module which can be lowered down the drill string via a "wire line" arrangement until it reaches a mounting point in the tubular section at which preferably it can latch itself in position.

The flow meter module may comprise a wire line sleeve incorporating the flow meter and associated measuring components.

The flow meter may be arranged to be able to monitor down hole pressure and/or temperature values.

The following advantages can be achieved by preferred embodiments of the invention:

1. The flow rate information can be directly measured, which will lead to a more accurate calculation of hydro- carbons in place;

2. There are no moving parts in the system;

3. The flow rate measuring component of the system is an integral part of a standard DST string;

4. The system can be used for both down hole pressure and also temperature measurements.

Preferred embodiments of the invention will now be described in detail, by way of example only, with reference to the accompanying schematic drawing, in which:

Figure 1 is a perspective illustration of a tubular section incorporating a flow meter and forming part of a drill string testing system according to the invention for introduction down a production pipe, in order to monitor hydro carbon flow rates;

Figure 2 is a detail view of a further embodiment of a flow meter which may be incorporated in a dedicated tubular section of the drill string according to the invention;

Figure 3 is a schematic illustration of the way in which pressure measurement can be made in order to derive flow rate information; and,

Figure 4 is a schematic illustration of the flow meter installed as part of a drill string run down a production pipe.

Referring now to the drawings, they will be described a method and means of monitoring the rate of flow of hydro-carbons which are being conveyed along a production pipe from an underground reservoir, using a drill string, having a dedicated tubular section which incorporates a flow meter having a flow restrictor and pressure monitoring points arranged at predetermined positions relative to the flow restrictor.

The flow meter can be incorporated in the dedicated tubular section prior to the running of the drill string down the production pipe, or the flow meter may be of modular form, as shown in Figure 2, so as to be capable of being lowered by wire line techniques in order to latch into position in the dedicated tubular section.

The drill string will be run down the production pipe so as to bring the dedicated tubular section to a suitable pressure monitoring position, and the annular space surrounding the drill string and defined between the inner surface of the production pipe and the outer surface of the drill string will be blanked off by a "packer" in known manner. This can then cause the flow of hydro-carbons in the production pipe to pass upwardly through the drill string by way of the dedicated tubular section. The hydro-carbon flow passes by way of the flow restrictor of the flow meter, and the pressures prevailing at the monitoring points are then measured in order to derive data indicative of the hydro-carbon flow rate.

The dedicated tubular section is designated generally by reference 10 in Figure 1 and the flow meter incorporated therein is designated generally by reference 11. The flow meter 11 has a flow restrictor 12 through which an upward flow 13 of hydro-carbon passes, and the flow restrictor 12 effectively constitutes a differential pressure element.

Monitoring or tapping points 14, 15 and 16 are arranged at predetermined positions relative to the flow restrictor 12, and the pressure measurements made provide data from which flow rate calculations can be derived.

Figure 2 shows a wire line sleeve 17 which incorporates a flow meter 11, and which can be raised and lowered by wire line techniques if required. This can be latched into position in the dedicated tubular section 10 after the latter has been run down the production pipe, and pressure monitoring then take place.

The flow meter 11 is preferably provided with memory gauges 18 which can gather all the down-hole data, rather than having to cable this data back to the surface.

Flow rate information is therefore directly measured, which can lead to a more accurate calculation of the hydro-carbons in place. There are no moving parts in the flow measuring system, which forms an integral part of the DST string. The system can be used for down hole pressure and also temperature measurements if required.

Referring now to Figure 3, this shows a further construction of a flow meter which may be incorporated in the dedicated tubular section of the drill string.

Figure 3 shows a flow meter having a restriction 30, and pressure monitoring points 25, 27 and 29 spaced apart along the length of the tubular section 10.

Measurement of pressure between first point 25 at the constriction 30 by means of a first pressure change gauge 21 allows the rate of flow of fluid through the pipe section to be determined. The measurement of pressure change between the second point 27 and third point 29 , (both the second and third points 27 and 29 being upstream of the constriction and spaced apart vertically) by means of a second pressure, allows the relative proportion of two immiscible liquid components of products through the pipe section 10 to be determined.

An absolute pressure gauge 35 measures pressures at the second point 27.

When the product flowing through the pipe section 10 comprises two immiscible liquid phases and a gas component, the pipe section with associated gauges will be located such that the pressure under which products within its flow is greater than the bubble point, the gas components remain dissolved in the liquid phases. Its product flowing through the pipe section past the measurement points 25, 27 and 29 are therefore in liquid phases only. The pressure change measurement made by the first gauge 21 allows the rate of flow of the combined liquid phases to be measured. The pressure change measurement measured by the second gauge 23 allows the relative proportions of the immiscible phases of the liquid flowing through the pipe section to be calculated, provided that the densities of those phases are known. The information provided by the two pressure change measurements individually allows the individual flow rates of the immiscible phases of the liquid products to be calculated.

The relative proportions and flow rates of a two phase as follows, reference being made to Figure 3 of the accompanying drawing. The pipe section 10 is inclined at an angle to the vertical. Upstream of the constriction 23, the cross-section of the pipe is A1, and at the constriction, the cross-section of the pipe is A2. The first pressure change gauge 21 measures a pressure change P1 and the second pressure change gauge 23 measures a pressure change P2. The distance between the first and second points 25, 27 is L1, and the distance between the second and third points 27, 29 is L2.

As a first step in the calculation, one calculates the density of the two phase liquid which flows along the pipe, according to the formula:

The proportion of water (WF) in the mixture can be calculated

$$\rho = \frac{\Delta P_2}{L_2 . \sin\theta}$$

from knowledge of the density of the mixture, together with knowledge of the densities of water and oil, according to the formula:

$$WF = \frac{\rho - \rho_o}{\rho_w - \rho_o}$$

The overall flow rate (Q) can be calculated according to the following formula:

$$Q = \frac{CD . A_1 . A_2}{\sqrt{A_1^2 - A_2^2}} \sqrt{2g[\frac{\Delta P_1}{\rho} - L_1 . \sin\theta]}$$

In this formula, CD represents the discharge coefficient, and g has a value $9.8 m.s^2$.

From the overall flow rate Q, individual flow rates for the oil and water phases (Q and Q respectively) can be calculated as follows:

$$Q_o = Q.(1 - WF)$$

$$Q_w = Q.WF$$

Using the following values:

ΔP_2	287.1 $kg.m^{-2}$
ΔP_1	1055 $kg.m^{-2}$
ρ_o	761.3 $kg.m^{-3}$
ρ_w	1000 $kg.m^{-3}$
L_1	0.610 m
L_2	0.610 m
A_1	0.0195m^2
A_2	0.0046m^2
CD	0.98
θ	30°

the following values are arrived at:

ρ	941.3 $kg.m^{-3}$
WF	0.75
Q	0.0186 $m^3.s^{-1}$
Q_o	0.0046 $m^3.s^{-1}$
Q_w	0.0139 $m^3.s^{-1}$

Referring to Figure 4, this is a schematic illustration of a flow meter installed as part of a drill string which is run down a production pipe. The flow meter is illustrated schematically only, and designated by reference 40, and is installed in a dedicated tubular section 41 of a drill string 42 running up to the surface within a production pipe 43.

Production pipe 43 extends downwardly from the surface through earth formation 44, and will have at the well head 45 a suitable blow-out preventer 46 and other standard equipment usually provided.

To enable the well fluids flowing upwardly through production pipe 43 to be measured, the drill string 42 is run through the production pipe 43 to bring the flow meter 40 to a suitable measuring position, and then a packer, shown schematically by reference 47, is installed so as to blank-off the entrance to the annular chamber defined between the inner surface of the production pipe 43 and the outer surface of the string 42, so that the extracted hydrocarbons are forced upwardly through the flow meter 40 and through the drill string 42.

CLAIMS

1. A method of monitoring the rate of flow of hydrocarbons which are being conveyed along a production pipe from an underground reservoir, using a drill string having a tubular section which incorporates a flow meter, having a flow restrictor and pressure monitoring points arranged at predetermined position relative to the flow restrictor, and said method comprising:

running the drill string down the production pipe so as to bring tubular section to a suitable pressure monitoring position;

causing the flow of hydrocarbons in the production pipe to pass upwardly through the drill string by way of the tubular section after incorporation of the flow meter therein; and,

measuring the pressures prevailing at said monitoring points in order to derive data indicative to the hydrocarbon flow rate.

2. A method according to Claim 1, in which the flow meter is incorporated in the tubular section prior to running of the drill string down the production pipe.

3. A method according to Claim 1, in which the flow meter is run downwardly within the drill string via a wireline in order to snap-fit into position after the drill string has been positioned in the production pipe.

4. A drill string having a flow meter for monitoring the rate of flow of hydrocarbons along a production pipe from an underground reservoir and comprising a tubular section incorporating a flow meter to monitor the flow rate after the drill string has been run down the production pipe to bring the flow meter to a suitable pressure monitoring position, in which the flow meter has a flow restrictor and pressure monitoring points arranged at predetermined positions relative to the flow restrictor, whereby upon upward movement of the hydrocarbons through the drill string by way of the tubular section, the pressures prevailing at the monitoring

points can be measured and data derived therefrom indicative of the hydrocarbon flow rate.

5. A drill string according to Claim 4, in which the flow meter is provided with memory gauges arranged to gather "down hole" data and which can then be monitored upon the return of the flow meter to the surface.

6. A drill string according to Claim 4 or 5, in which the flow meter is incorporated into its own dedicated tubular section of the drill string, prior to running of the drill string down the production pipe.

7. A drill string according to any one of Claims 4 to 6, in which the flow meter comprises a module which is capable of being lowered down the drill string via a wireline arrangement until it reaches a mounted point in the tubular section at which it can latch itself into position.

8. A drill string according to Claim 7, in which the flow meter module comprises a wireline sleeve incorporating the flow meter and associated measuring components.

Patents Act 1977
Examiner's report to the Comptroller under Section 17 (The Search Report)

Application number

GB 9223258.6

Relevant Technical fields

(i) UK Cl (Edition L) G1R RSA,RSB,RBC,RAB

(ii) Int Cl (Edition 5) G01F

Databases (see over)

(i) UK Patent Office

(ii) ONLINE DATABASES: WPI

Search Examiner

J A WALLIS

Date of Search

17 DECEMBER 1992

Documents considered relevant following a search in respect of claims 1 AND 4 AT LEAST

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
X	GB 2192725 A (AMOCO CORP) see Figures	1 and 4 at least
X	GB 2161941 A (UNIVERSITY OF SURREY) see Figure	1 and 4 at least
A	EP 0031744 A1 (SOC PROSPECTION ETC) whole document	1 and 4 at least

Category	Identity of document and relevant passages	Relevant to claim(s,

Categories of documents

X: Document indicating lack of novelty or of inventive step.

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P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family, corresponding document.

Databases: The UK Patent Office database comprises classified collections of GB, EP, WO and US patent specifications as outlined periodically in the Official Journal (Patents). The on-line databases considered for search are also listed periodically in the Official Journal (Patents).

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