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(54) **Underbalance drilling downhole choke**

(57) A method for underbalance drilling in a reservoir comprises operating a variable aperture of a downhole choke located at a downhole extremity of a drill string. The variable aperture allows to control a pressure differential between a drilling fluid pumped down the drill string from surface and flowing into the variable aperture of the choke, and the drilling fluid flowing out of the variable aperture, in order to achieve a negative differential pressure between a reservoir pressure and a bottom hole pressure at the downhole extremity of the drill string.

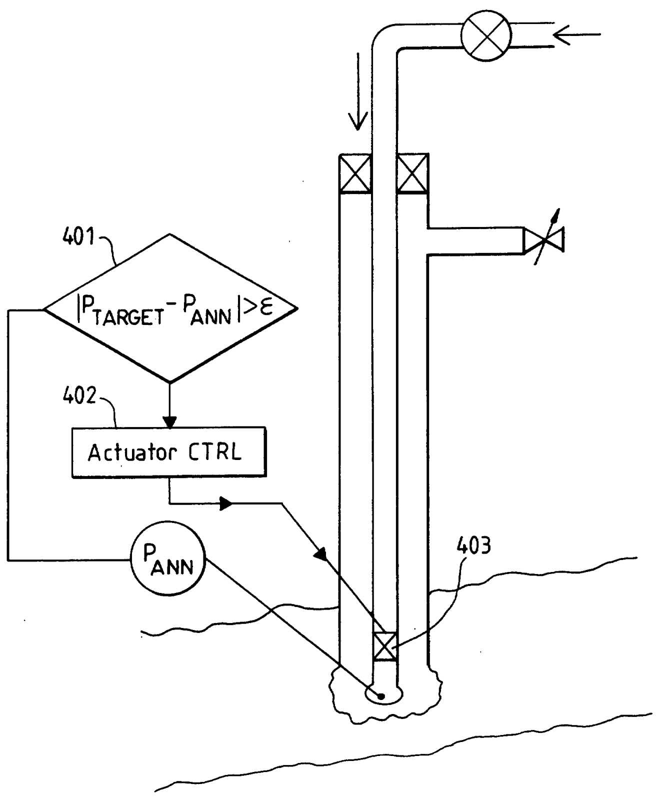

FIG. 4

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Description

Field of the invention

[0001] The present invention relation relates to drilling oil and gas wells. More particularly the invention relates to a technology known as underbalance drilling.

Background of the invention

[0002] Underbalance drilling is a technique that enables oil and gas wells to be drilled with a negative differential pressure between the reservoir pressure P_R *and* the well bore *pressure* P_{wb}, also called bottom hole pressure P_{ANN}, i.e., $P_R > P_{ANN}$. To conduct this operation efficiently, the driller endeavors to keep the bottom hole pressure P_{ANN} below the reservoir pressure P_R.

[0003] It is known to achieve a targeted underbalance pressure P_{TARGET} by acting on a surface casing back pressure and/or on drilling fluid injection pressure in a drilling string, and/or acting on the fluid density or drilling fluid flow rate. The pressure(s) may be adjusted as a function of the bottom hole pressure P_{ANN}.

[0004] The bottom hole pressure P_{ANN} may for example be monitored in real-time. Alternatively, if real-time monitoring is not available it may be inferred from fluid friction losses of drilling fluids injected in the drilling string and returning to the surface, and hydrostatic head.

[0005] The technique of inferring bears a number of drawbacks.

[0006] One drawback is due to the nature of the reservoir fluid which makes up the fluid column returning to the surface. There is a time lag between the surface pressure change and the effects causing it to change at the level of the bottom hole pressure. This time lag is estimated to be 1 second per 1000' of well depth when the fluid column is non-compressible. In underbalance situations, the fluid column will contain an undetermined and variable amount of compressible fluid providing from the reservoir. This results in a significant and difficult to predict increase of the time lag.

[0007] A further drawback in prior art relates to real time monitoring and lies in the fact that the transmission of the bottom hole pressure information may not take place instantaneously. The transmission delay may be as high as 30 seconds in the case of an electro-magnetic telemetry.

[0008] The described drawbacks are thus in fact due to time lags which are experienced between measurement of pressure conditions and adjustment of control parameters for drilling. The situation is even more difficult when considering that both drawbacks are combined, and are a source of over corrections and oscillations in the resulting bottom hole pressure.

[0009] It is an aim of the invention to overcome the described problems.

Summary of the invention

[0010] In a first aspect the invention provides a method for underbalance drilling in a reservoir comprising operating a variable aperture of a downhole choke located at a downhole extremity of a drill string, to control a pressure differential between a drilling fluid pumped down the drill string from surface and flowing into the variable aperture of the choke, and the drilling fluid flowing out of the variable aperture, in order to achieve a negative differential pressure between a reservoir pressure and a bottom hole pressure at the downhole extremity of the drill string.

[0011] In a preferred embodiment the method comprises measuring the bottom hole pressure and adjusting automatically the variable aperture in order to keep the bottom hole pressure in a determined range.

[0012] In a further preferred embodiment the values in the determined range are smaller than the reservoir pressure.

[0013] In another preferred embodiment the measuring of the bottom hole pressure is performed using a bottom hole instrument assembly located at the downhole extremity of the drill string.

[0014] In yet another preferred embodiment the method comprises measuring a momentary bottom hole pressure, and computing a target pressure depending at least on the measured momentary bottom hole pressure. The variable aperture is automatically adjusted in order to keep the bottom hole pressure in a predetermined range around the target pressure value.

[0015] In yet a further preferred embodiment the method comprises increasing the variable aperture in case the bottom hole pressure is smaller than the target pressure value, thereby increasing the bottom hole pressure. The variable aperture is decreased in case the bottom hole pressure is greater than the target pressure value, and the bottom hole pressure thereby decreased.

[0016] In a second aspect the invention provides a system for performing underbalance drilling in a reservoir using a drill string into which drilling fluid is pumped from the surface using a drilling fluid pump, the system comprising at a downhole extremity of the drill string a choke having a variable aperture through which the drilling fluid flows.

[0017] In a preferred embodiment the system further comprises an actuator for varying the variable aperture and a controller that computes and sends a control signal to the actuator depending on a value of a bottom hole pressure in order to adjust the bottom hole pressure.

[0018] In a further preferred embodiment the system comprises a pressure sensor to measure the bottom hole pressure and output a value of the bottom hole pressure to the controller.

[0019] In another preferred embodiment the system comprises storage means for storing a value of a target pressure, the controller using the target pressure to compute the control signal in order to adjust the bottom hole pressure in a determined range around the target pressure.

[0020] In a third aspect the invention provides a choke device for use in a drilling string, having a variable aperture through which drilling fluid pumped into the drill string may flow.

Brief description of the Figures

[0021] The invention will now be described in greater detail with reference to the accompanying drawings, in which :

Figure 1 contain a schematic representation of a well bore ;

Figure 2 contains a schematic representation of a drill string extremity comprising a variable aperture choke according to the invention ;

Figure 3 contains a schematic representation of a variable aperture choke according to the invention; and

Figure 4 illustrates a working principle of the invention.

Description of the preferred embodiments

General overview

[0022] Referring to Fig. 1 a schematic representation shows a well bore 100, as used to drill an earth formation 101 for oil and gas extraction.

[0023] A drill string 102 comprises an elongated tube-like body that is terminated by a drill bit and a bottom hole instrument assembly (not shown in Fig. 1).

[0024] Drilling fluid 103 is pumped down the drill string 102, inside the tube, and from the surface by means of a drilling fluid pump 104. As the drilling fluid 103 exits the drill string it is returned to the surface mixed together with formation fluids, by flowing between the outer surface of the drill string 102 and a casing 105 of the well bore 100. Eventually the drilling fluid may be collected at a surface outlet 106.

[0025] Referring to Fig. 2 a magnified view of the downhole drill string extremity contained in the dotted circle of Fig. 1 is shown. The schematic representation contains a drill bit 200 and a bottom hole instrument assembly 201. The bottom hole instrument assembly 201 includes at least a bottom hole pressure sensor (not shown in Fig. 2). A variable choke 202 is located at the bottom of the drill string, inside of the tube of the drill string 102 at proximity of the drill bit. The variable choke comprises a variable aperture 203 through which fluid inside the drill string may flow according to arrow 204.

[0026] As the drilling fluid passes through the variable aperture 203 of the variable choke, a pressure drop ΔP occurs between an input and an output of the variable choke. The pressure drop ΔP may be influenced by altering a size of the aperture.

Bottom hole pressure

[0027] The bottom hole pressure P_{ANN} is the pressure at the downhole extremity of the drill string (see Fig. 1). The bottom hole pressure P_{ANN} may be measured using a pressure sensor of the bottom hole instruments assembly.

[0028] Formally, the bottom hole pressure P_{ANN} may be expressed as follows:

$$P_{ANN} = P_S + \rho \bullet g \bullet h \, P_{drop} - \Delta P \qquad (1)$$

or

$$P_{ANN} = P_R - \Delta P_{UBD} \qquad (2)$$

in which

- P_S is a surface pressure applied to the drill string drilling fluid by means of a drilling fluid pump (see Fig. 1);
- $\rho \bullet g \bullet h$ represents a hydrostatic pressure exerted by the drilling fluid column. ρ is the density of the drilling fluid, g the gravitation coefficient and h the height of the drilling fluid column from the bottom hole up to the surface ;
- P_{drop} represents a pressure drop due to friction losses of the drilling fluid flowing down the drill string ;
- P_R represents a reservoir fluid pressure (see Fig. 1); and
- ΔP_{UBD} represents an underbalance pressure difference, i.e. a negative pressure difference between the bottom hole wellbore pressure and the reservoir pressure.

[0029] The comparison of both equations (1) and (2) shows that any change of ΔP in equation (1) influences the term ΔP_{UBD} in equation (2), assuming that all other terms in the equations remain constant. The term $P_S + \rho \bullet g \bullet h - P_{drop}$ in equation (1) may be kept constant as long as the density ρ and the pumping rate of the drilling fluid are constant.

Variable choke

[0030] It has been described that the variable choke comprises a variable aperture. Referring to Fig. 3 the variable aperture 203 of choke 202 is controlled by an actuator 300 that is powered either from the surface in case hardwire communication is available (not shown in Fig. 3), or from a downhole power source, e.g. a battery 301.

[0031] The actuator 300 of the variable aperture is controlled by a logic circuit 302 of the bottom hole instrument assembly. The logic circuit 302 continuously compares the bottom hole pressure P_{ANN} to a target value P_{TARGET}. The value of P_{ANN} is monitored using the pressure sensor 304.

[0032] The target value P_{TARGET} is stored in the logical circuit and periodically updated from the surface operator. The update can for example be done using downwards telemetry using a communication module 303.

[0033] The surface operator is periodically informed of the actual values of the bottom hole pressure P_{ANN} which is measured using the pressure sensor and transmitted for example using upwards telemetry. The bottom hole pressure P_{ANN} and other well parameters, e.g., a net-flow value corresponding to a difference of the flow of fluid pumped into and the flow coming out of the well, may be used to compute the target pressure P_{TARGET}. One example for a method used to compute the target pressure P_{TARGET} is known from the international application published under WO02/06634A1.

[0034] Two situations may be distinguished. The term *e* used in the following represents a determined threshold that is used to avoid control oscillations. The threshold may be pre-set in the logic circuit.

[0035] When

$$P_{ANN} < P_{TARGET} - \varepsilon$$

the logic circuit sends a signal to the actuator to increase the choke aperture, thereby reducing the pressure drop ΔP.

[0036] When

$$P_{ANN} > P_{TARGET} + \varepsilon$$

the logic circuit sends a signal to the actuator to decrease the choke aperture, thus increasing the pressure drop.

[0037] This principle is schematically illustrated is Fig. 4. P_{ANN} *is* measured using the appropriate pressure sensor of the bottom hole instrument assembly of the drill string and its value is subtracted from the target value P_{TARGET}, the result being compared to ε in box 401. Depending on the result obtained in box 401, an actuator control signal is output in box 402 to the actuator of the variable aperture to increase or decrease the variable aperture and influence the pressure drop at the variable choke 403.

[0038] The method for controlling the variable chokeaperture described herein is given by way of example. A person skilled in the art could easily adapt or modify the method by introducing different or more sophisticated methods known from prior art for controlling the variable choke aperture and the resulting pressure differential.

[0039] The present invention allows to maintain an underbalance pressure condition in an efficient way. More particularly the invention overcomes the problems of over corrections and oscillations encountered in prior art. This is achieved by suppression of significant time lag between measurement of the bottom hole pressure and regulation of the parameters leading to a desired value of the bottom hole pressure.

[0040] Having described preferred embodiments of the invention with reference to the accompanying drawings, it is to be understood that the invention is not limited to these precise embodiments and that various changes and modifications could be effected therein by a person skilled in the art without departing from the spirit or scope of the invention as defined in the appended claims.

Claims

1. A method for underbalance drilling in a reservoir comprising operating a variable aperture (203) of a downhole choke (202) located at a downhole extremity of a drill string (102), to control a pressure differential (ΔP) between a drilling fluid (103) pumped down the drill string from surface and flowing into the variable aperture of the choke, and the drilling fluid flowing out of the variable aperture, in order to achieve a negative differential pressure between a reservoir pressure (P_R) and a bottom hole pressure (P_{ANN}) at the downhole extremity of the drill string.

2. A method according to claim 1, further comprising

   - measuring the bottom hole pressure (304),
   - adjusting automatically (302, 300) the variable aperture in order to keep the bottom hole pressure in a determined range.

3. A method according to claim 2, in which values in the determined range are smaller than the reservoir pressure.

4. A method according to anyone of claims 2 or 3, in which the measuring of the bottom hole pressure is performed using a bottom hole instrument assembly (201) located at the downhole extremity of the drill string.

5. A method according to anyone of claims 1 to 4, further comprising

   - measuring a momentary bottom hole pressure,
   - computing a target pressure (P_{TARGET}) de-

pending at least on the measured momentary bottom hole pressure,
- adjusting automatically the variable aperture in order to keep the bottom hole pressure in a predetermined range around the target pressure value.

6. A method according to claim 5, further comprising

- increasing the variable aperture in case the bottom hole pressure is smaller than the target pressure value, thereby increasing the bottom hole pressure,
- decreasing the variable aperture in case the bottom hole pressure is greater than the target pressure value, thereby decreasing the bottom hole pressure.

7. A system for performing underbalance drilling in a reservoir using a drill string (102) into which drilling fluid (103) is pumped from the surface using a drilling fluid pump (104), the system comprising at a downhole extremity of the drill string

- a choke (202) having a variable aperture (203) through which the drilling fluid flows.

8. A system for performing underbalance drilling according to claim 7, further comprising

- an actuator (300) for varying the variable aperture,
- a controller (302) that computes and sends a control signal to the actuator depending on a value of a bottom hole pressure in order to adjust the bottom hole pressure.

9. A system for performing underbalance drilling according to anyone of claims 8, further comprising

- a pressure sensor to measure the bottom hole pressure and output a value of the bottom hole pressure to the controller.

10. A system for performing underbalance drilling according to claim 9, further comprising

- storage means for storing a value of a target pressure, the controller using the target pressure to compute the control signal in order to adjust the bottom hole pressure in a determined range around the target pressure.

11. A choke device (202) for use in a drilling string, the choke device having a variable aperture (203) through which drilling fluid pumped into the drill string may flow.

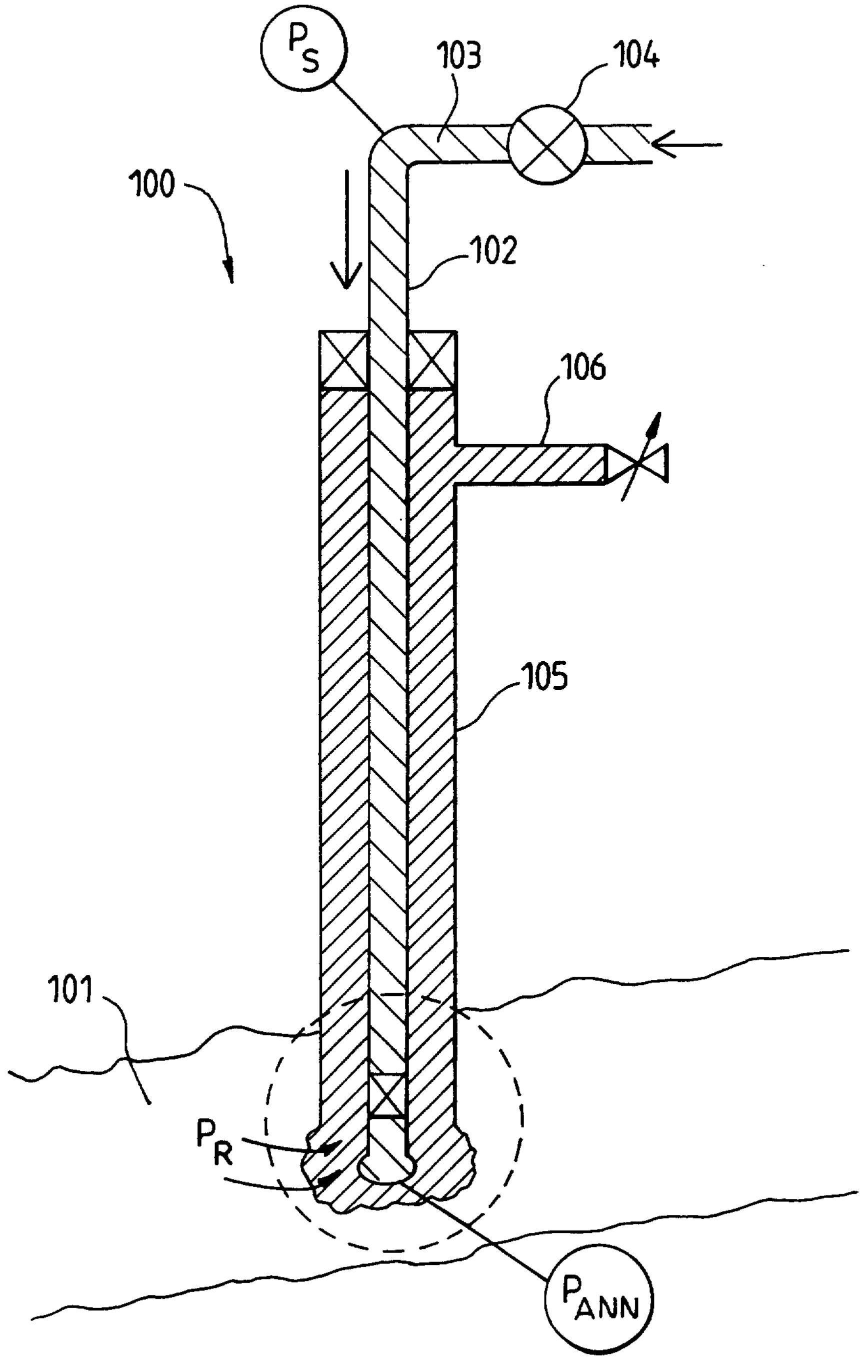


FIG.1

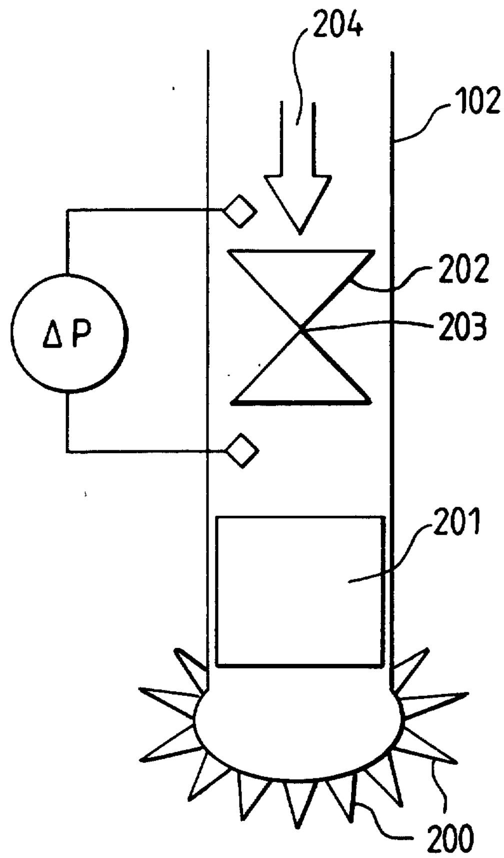
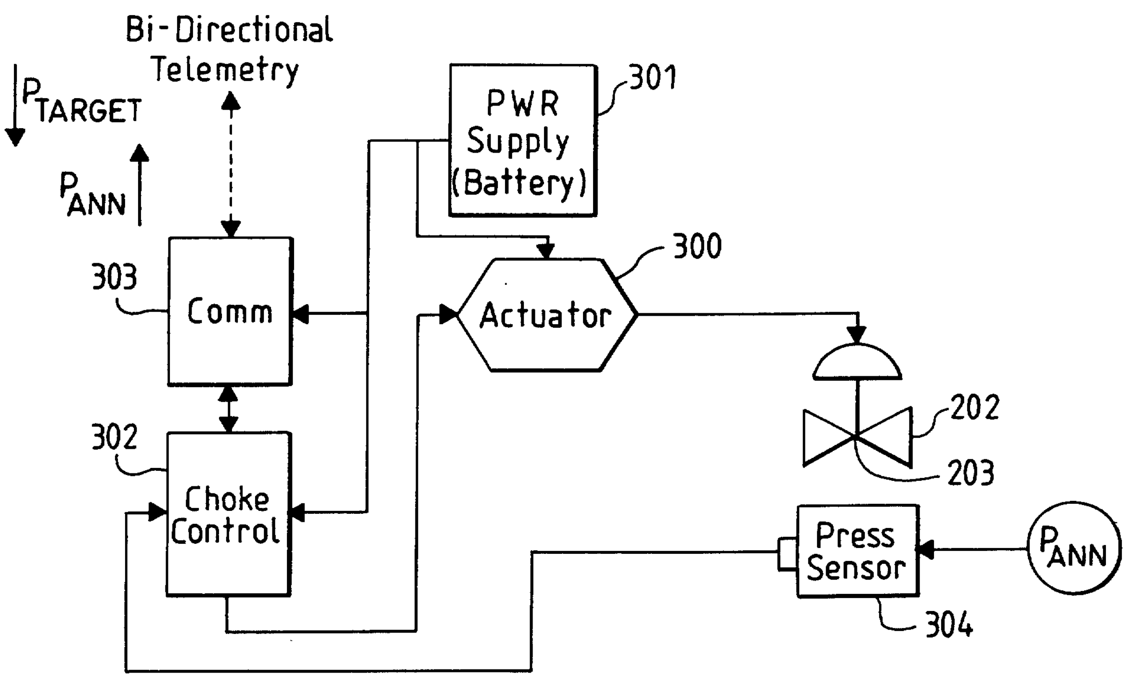


FIG. 2



Bi-Directional Telemetry
P_{TARGET}
P_{ANN}
PWR Supply (Battery)
301
300
303
Comm
Actuator
302
Choke Control
202
203
Press Sensor
P_{ANN}
304

FIG.3

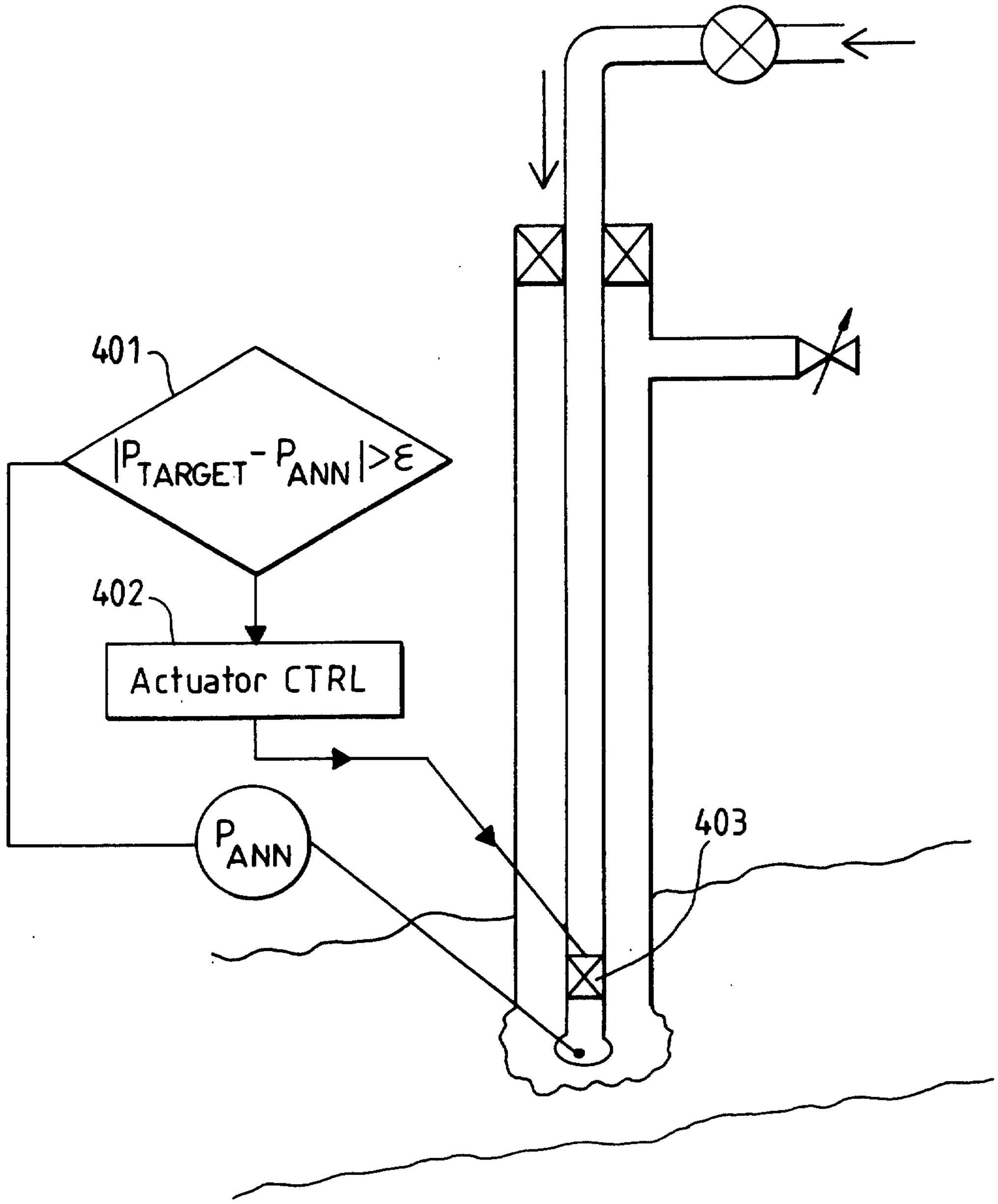


FIG. 4

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EUROPEAN SEARCH REPORT

Application Number
EP 02 29 1569

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	29 October 2002	Schouten, A

CATEGORY OF CITED DOCUMENTS

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