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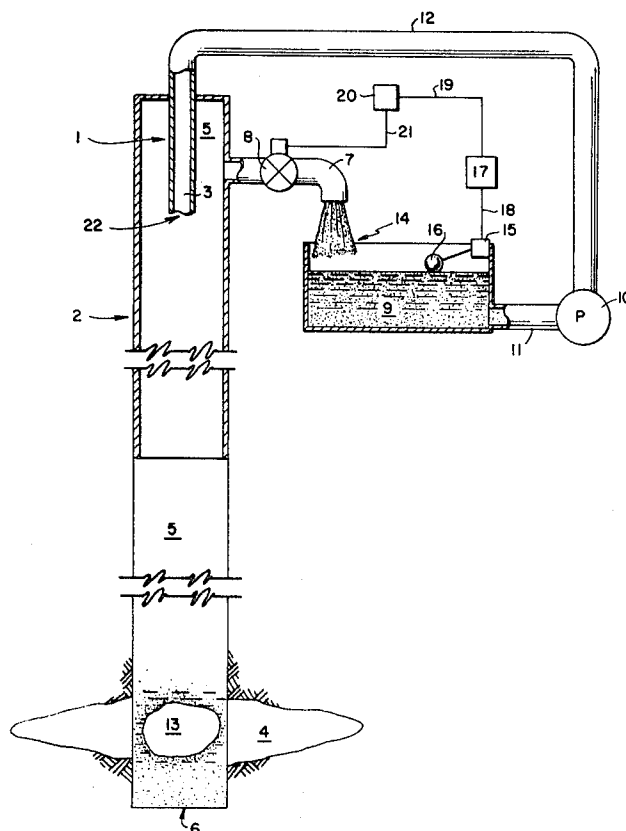
[54] **METHOD AND APPARATUS FOR CONTROLLING A WELL**
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175/38, 175/218
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[50] Field of Search 175/24, 25,
38, 40, 48, 65, 218; 166/75; 73/151, 155, 308,
311-313

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UNITED STATES PATENTS

2,627,178	2/1953	Hayward et al.	73/155
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ABSTRACT: A method and apparatus for controlling a well to prevent a blowout and an accompanying loss of the drilling mud which utilizes the change in volume of the drilling mud in the mud pits. This change in volume is converted to a corresponding pressure change necessary to compensate for the volume change in the relationship of the gas and drilling mud in the well bore to make such compensation as is necessary to maintain the pressure constant at the bottom of the well bore.



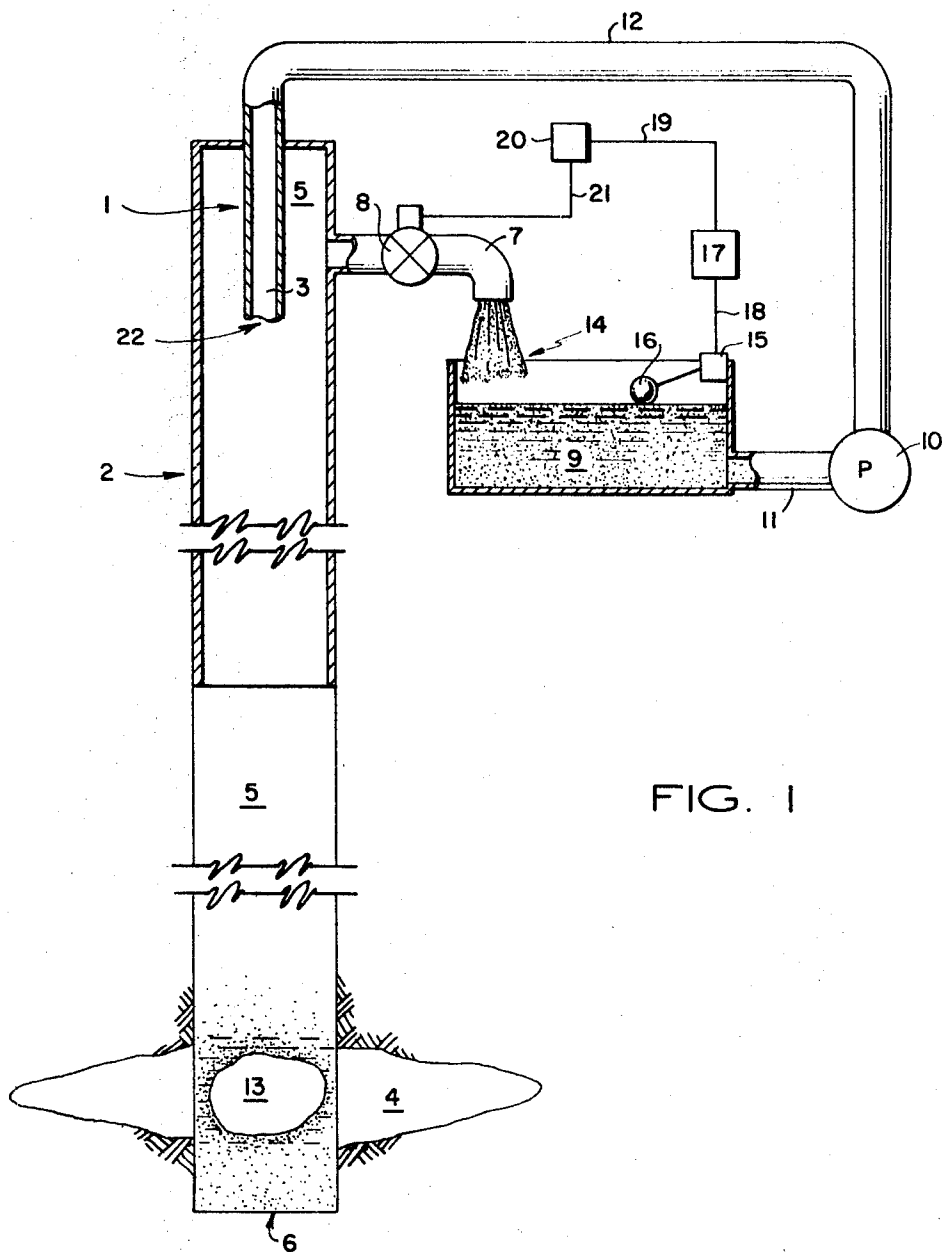


FIG. 1

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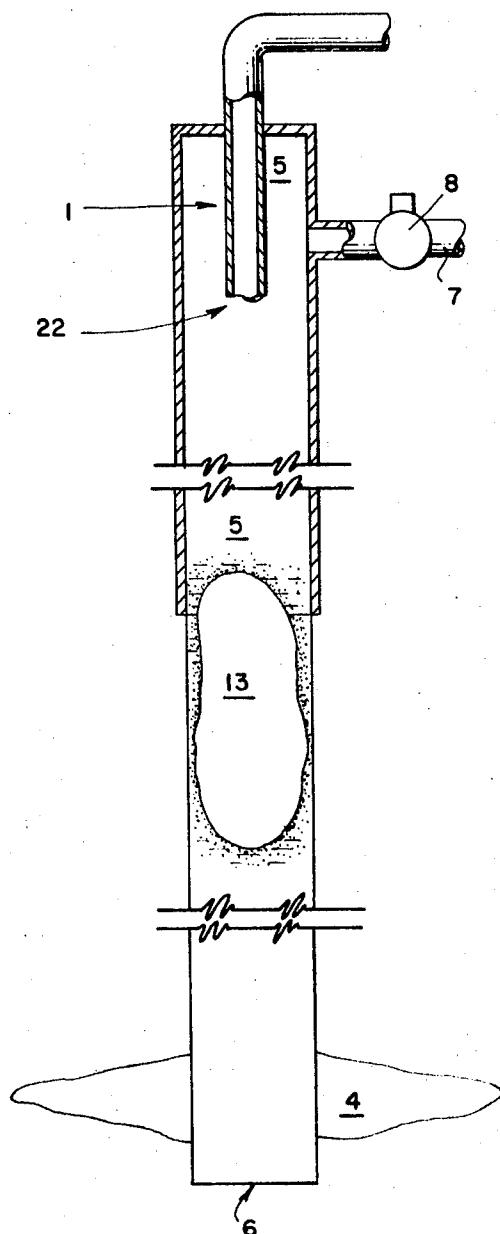


FIG. 2

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METHOD AND APPARATUS FOR CONTROLLING A WELL

BACKGROUND OF THE INVENTION

In drilling a well, high-pressure gas from the underground reservoir pierced by the well bore sometimes enters the well bore. The entry of the gas is controlled by the pressure exerted by the drilling mud and/or extra pressure exerted at the surface by closing in the top of the well bore. The intrusion of gas is manifested by the forcing of an equivalent amount of drilling mud out of the well bore into the mud pits. The removal of mud from the well bore decreases the pressure opposite the underground reservoir and allows more gas to enter the well bore.

A blowout can then occur when the gas blows most of the mud out of the hole and the gas itself appears at the surface. Fire and accompanying loss of life and property can result from the uncontrolled blowing of gas at the surface. On the other hand, if too much pressure is exerted upon the well bore while controlling the gas, fracturing of the protective casing in the well bore or of the earth can occur and the gas will then escape in an uncontrolled manner into the earth. This may manifest itself by blowing in an uncontrolled manner around the drilling rig where it has worked its way to the surface. Also, the gas may repressure other reservoirs within the earth. In either case, there is an economic loss from the loss of potential fuel.

Heretofore three types of blowout-control procedures have been used.

1. Historically an attempt has been made to control subsurface pressures by holding the volume of mud in the pits constant. This approach has not been satisfactory because, due to the nature of the gas laws and the length of the column of intruding fluid of the gas or oil, this method impressed such great pressures upon the well bore that the casing or the earth was fractured causing uncontrolled loss of the reservoir material to the earth. This also causes the hazards listed above.
2. A method has been attempted whereby the calculation of the expansion of gas by means of the general gas law was attempted. The result of this calculation was a theoretical surface pressure that should be maintained as the intruding fluid was pumped to the surface. This was unsatisfactory because the intruding fluid was not totally understood and the theoretical calculations were not sufficiently accurate.
3. Another approach involves using not the pressure on the annulus of the well, but the drill pipe pressure to maintain a constant bottom hole pressure. This method is simple and accurate. However, this method is usable only when the drill pipe is at the bottom of the hole.

The method and apparatus of this invention employ a technique that is simple and accurate and that is usable when there is no drill pipe in the well bore or the drill pipe does not extend to the bottom of the well bore. Thus, it provides a method and apparatus for killing a well and preventing a blowout when the constant drill pipe pressure method of subparagraph 3 above is unusable.

SUMMARY OF THE INVENTION

It has now been discovered that potential blowouts and accompanying lost mud circulation problems can be controlled by measuring only a single parameter related to the operation of the well and by making only a single calculation in determining the change in pressure required to be impressed on the well bore to compensate for the volume change of drilling mud in the well bore displaced by the intruding material. This maintains the pressure at the bottom of the well bore substantially at the desired value.

According to this invention there is provided a method which comprises measuring the change of volume in the mud in the mud pits during the potential blowout and relating this measured-volume change to the pressure change in the well

bore. It is then possible to increase or decrease the pressure in the well bore according to this relationship of volume on the surface versus pressure in the well bore. In this way, the pressure at the bottom of the well bore can be maintained at substantially the desired operating pressure.

This invention also relates to apparatus which employs a combination of means for measuring mud volume change in the mud pits, means for receiving and converting this measured volume change to a pressure change, and means for changing the pressure in the well bore in amounts substantially equal to the determined pressure change to maintain the pressure at about the bottom of the well bore substantially at the desired normal operating pressure.

Other aspects, objects, and advantages of the invention will be apparent to those skilled in the art from the disclosure and the appended claims.

DETAILED DESCRIPTION OF THE INVENTION

In the drawings, FIGS. 1 and 2 show schematic drawings of a well bore and its associated apparatus. For reasons due to the operation of the drilling procedure, the drill pipe is not at the bottom of the hole.

More specifically FIG. 1 shows a well bore 1 lined with casing 2, and containing a drill pipe 3 which does not extend to the bottom 6 of well bore 1. Casing 2 does not extend to the bottom of the hole so that the open well bore is in communication with the underground reservoir formation 4. The annulus 5 of the open hole and around the partial length of drill pipe 3 contains drilling mud from bottom 6 of well bore 1 upwards and through the return line 7, choke 8, and into one or more mud pits 9.

Mud is removed from the mud pits by pump 10 and pumped through pipes 11 and 12 into the interior of the drill pipe 3. The mud then passes down to bottom 22 of drill pipe 3 and upwardly in annulus 5 to the return line 7. Thus, there is no controlled circulation below bottom 22 of drill pipe 3. Gas from formation 4 can enter annulus 5 and thereby collect in the well bore. A gas bubble 13 is shown in FIG. 1. Gas bubble 13, however, could, for example, be water, oil, or any combination of the three.

The introduction of gas bubble 13 into annulus 5 causes a corresponding volumetric displacement of drill mud into pit 9. This causes an increase in the volume (and therefore liquid level 14) of the mud pit 9.

This initial displacement of mud can be quite small in terms of the volume of mud present since the pressure at the bottom of the well bore is very high and gas bubble 13 will initially be quite compressed. However, as the bubble rises towards the surface of the well, as it will do since it is lighter than the drilling mud, it increases in volume because the pressure on the bubble decreases as the bubble progresses towards the surface of the earth. This is shown in FIG. 2. Thus, as gas bubble 13 progresses upwardly in annulus 5, it will expand, if allowed to do so, and displace larger and larger volumes of mud into mud pit 9.

The increase of volume of mud in pit 9 is sensed by a conventional mud pit volume totalizer mechanism 15. For example, a pneumatic mechanism such as that disclosed in U.S. Pat. No. 3,086,397 can be employed. This mechanism uses a float 16 that rides on the mud surface 14. This can also be done by replacing the pneumatic totalizing circuitry with electric totalizing circuits.

The volume change measured by mechanism 15 is transmitted to a conventional and commercially available pneumatic multiplier or electric multiplier 17 by means of line 18 wherein the volume change is converted to equivalent pressure needed to compensate for the loss of mud in the well bore caused by bubble 13.

The pressure change determined by device 17 then can be transmitted by way of line 19 to the choke controller 20 which adjusts through line 21 the opening in choke 8 to the proper pressure.

The method of this invention therefore comprises measuring the change of volume of mud in the mud pit, converting the volume change thus measured to a pressure change needed to compensate in the well bore for the mud displaced by the expanding gas according to the formula:

$$\left(\frac{\text{Volume change measured}}{\text{Annular volume between tubing and casing per unit length of the well bore}} \right) \times \left(\frac{\text{Mud weight expressed as pressure per unit area exerted by the mud per unit length of the well bore}}{\text{Mud weight expressed as pressure per unit area exerted by the mud per unit length of the well bore}} \right)$$

and changing the pressure in the well bore in amounts substantially equal to the pressure change thus determined thereby compensating for the volume change and maintaining the pressure in the well bore substantially at the normal operating value.

In the above formula the volume change can, as a nonlimiting example, be measured in barrels (U.S.), the annular volume being the volume of annulus 5 measured in barrels (U.S.) per foot of length of the well bore, and the mud weight being expressed in pounds per square inch per foot of length of the well bore.

The formula would then be:

$$\Delta P = (\Delta V) (0.052 \text{ WtM} / AV)$$

where:

ΔP = Change in pressure on the bottom of the well bore, p.s.i.

ΔV = Change in volume in the mud pits, barrels (U.S.).

WtM = Mud weight, pounds/gallon.

0.052 = Conversion factor to change mud weight pounds/gallon to mud weight, p.s.i./ft. of length of well bore.

AV = Effective volume of the hole, barrels (U.S.)/ft. of length of well bore.

This formula then shows that the change in pressure at the bottom of the hole (ΔP) is dependent upon the change in volume of the surface pits, since in the drilled hole the volume and mud weight may be regarded as a constant.

The result of this formula (ΔP) can then be used to either manually correct the surface pressure by means of a hand operated choke control or may be used to automatically control choke by means of raising or lowering the surface pressure at the choke according to the value ΔP . The manual control is obvious to one skilled in the art. The automatic control is commonly used in industry where a change of pressure is sensed from some source and the change of pressure is used to change a control or throttle in the valve.

Thus, by way of further example, a drilling mud weighing 10 pounds/gallon in the apparatus in FIG. 1, when displaced in part by the intrusion of gas bubble 13 into annulus 5, will be indicated by an increase in the volume of mud in the mud pit 9, and will be detected by mechanism 15 and transmitted to device 17. Device 17 will perform the appropriate mathematical processes as described in the above formula and either display the result for manual correction or transmit the result to throttling valve 8 to automatically exert the proper change in pressure upon the well bore.

Reasonable variations and modifications are possible within the scope of this disclosure without departing from the spirit and scope of this invention.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A method for controlling a well to prevent a blowout or lost circulation wherein said well contains a drill pipe and casing with an annulus therebetween and said well contains mud,

and there is a mud pit communicating with the annulus, comprising

measuring any change of volume of mud in the mud pit from the volume of mud present under normal drilling conditions,

converting the volume change measured to a pressure change needed to compensate for the volume change according to the formula:

$$\left(\frac{\text{Volume change measured}}{\text{Annular volume between the drill pipe and casing per unit length of the well bore}} \right) \times \left(\frac{\text{Mud weight expressed as pressure per unit area exerted by the mud per unit length of the well bore}}{\text{Mud weight expressed as pressure per unit area exerted by the mud per unit length of the well bore}} \right)$$

and,

changing the pressure in the well bore an amount substantially equal to the pressure change determined thereby compensating for said volume change and maintaining the pressure in the well bore substantially at the normal operating value.

2. The method according to claim 1 wherein said volume change is measured in U.S. barrels, said annular volume is measured in U.S. barrels per foot of length of the well bore, and said mud weight is expressed as pounds per square inch per foot of length of the well bore, the pressure change obtained in pounds per square inch, and the pressure in the well bore increased the amount of said pressure change if said volume change was an increase or the pressure in the well bore decreased the amount of said pressure change if said volume change was a decrease.

3. The method according to claim 2 wherein said mud weight is converted to pounds per square inch per foot of length of the well bore by the formula: (mud weight in pounds per U.S. gallon) $\times$ (0.052).

4. A method according to claim 1 wherein said volume change is displayed and said change of the surface pressures is made as dictated by said display.

5. A method according to claim 1 wherein said surface pressure change is made automatically.

6. Apparatus for controlling a well to prevent a blowout or lost circulation wherein said well contains a drill pipe and casing with an annulus therebetween and said well contains mud, and there is a mud pit communicating with the annulus, comprising in combination, means for measuring mud volume change in the mud pit, means for receiving and converting said measured volume change to a pressure change needed to compensate for the volume change according to the formula:

$$\left(\frac{\text{Volume change measured}}{\text{Annular volume between the drill pipe and casing per unit length of the well bore}} \right) \times \left(\frac{\text{Mud weight expressed as pressure per unit area exerted by the mud per unit length of the well bore}}{\text{Mud weight expressed as pressure per unit area exerted by the mud per unit length of the well bore}} \right)$$

and means for changing the pressure in the well bore an amount substantially equal to said pressure change to maintain the pressure in the well bore substantially at the normal operating value.

7. The apparatus according to claim 6 wherein said volume change measuring means is a pneumatic means which employs a float means that floats on the surface of the mud in said mud pit, said receiving and converting means is a multiplier means, and said means for changing the pressure in the well bore is a choke which controls the output of mud from the well bore.