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APPARATUS FOR WELLBORE TELEMETERING

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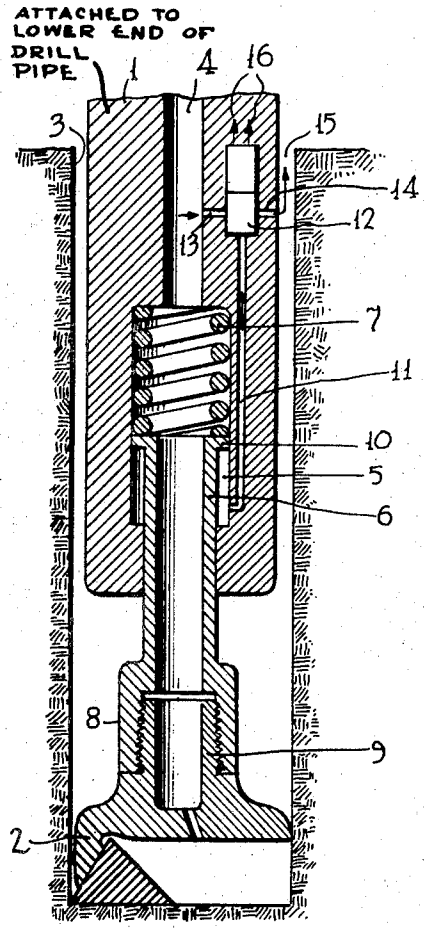


FIG. 1



FIG. 2

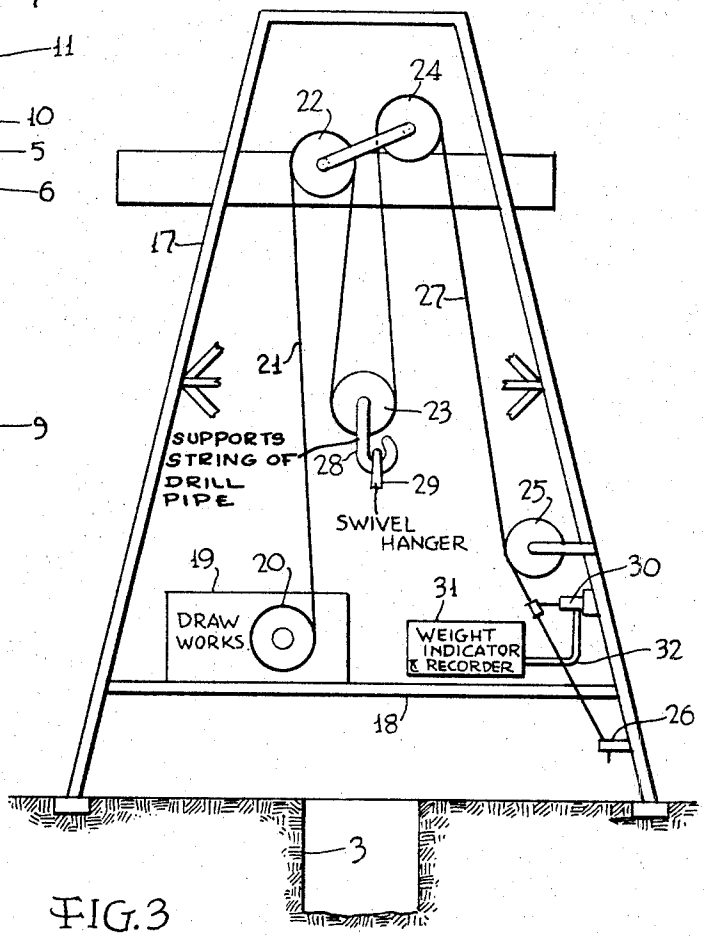


FIG. 3

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APPARATUS FOR WELLBORE TELEMETERING

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ABSTRACT OF THE DISCLOSURE

In rotary drilling apparatus being used for the drilling of boreholes in the earth, downhole measurements are telemetered to the surface by automatically altering or varying the drilling mud flow path to an extent corresponding to and representative of the measurement being made. These alterations effect a change in the weight of the suspended drill string, and this weight change is measured and recorded at the surface.

This invention relates to telemetering and more particularly to a method and apparatus for telemetering information from downhole to the surface, in a borehole being drilled by rotary drilling equipment, either while drilling is taking place, or else while the drill bit is resting on the bottom of the borehole (in either case, without removing the drill string from the hole).

It is often desired to transmit data such as formation pressure, formation resistivity, temperature, etc. to the surface while drilling is taking place. (Numerous methods have been proposed for the logging or gathering of such data, in the first place.) Also, several methods have been proposed for sending such information or data from the bottom of a borehole to the surface, after the information has been gathered. One of the prior methods for telemetering a signal from downhole to the surface is disclosed in the copending Mayes application, Ser. No. 372,004, filed June 2, 1964, now Patent No. 3,302,457, dated Feb. 7, 1967, this method involving the control, at a downhole location, of a restriction in the drilling mud flow path by the variable or variables to be measured, and the sensing at the surface of the resulting pressure changes in the mud line.

The present invention is concerned with the same general problem as is the aforementioned prior application, that is, with the sending or telemetering of information from downhole to the surface, after the information has been obtained or gathered.

An object of this invention is to provide, for use in a borehole, a novel method and apparatus for telemetering information from downhole to the surface.

Another object is to provide an inexpensive yet effective means, associated with rotary drilling equipment in a borehole, for telemetering information from downhole to the surface.

The objects of this invention are accomplished, briefly, in the following manner: Near the bottom of a string of drill pipe suspended within the borehole being drilled, means is provided for varying the effective suspended weight of the drill string in response to a measurement to be telemetered to the surface, and means is provided at the surface for detecting and/or recording variations in the effective weight of the drill string. By way of example, the drilling mud flow path is altered in response to the downhole measurement or data, and this alteration is used to effect a change in the weight of the drill string.

A detailed description of the invention follows, taken in conjunction with the accompanying drawing, wherein:

FIG. 1 is a sectional view, somewhat diagrammatic, of the bottom of a borehole being drilled with the rotary drilling and telemetering apparatus of this invention, showing such apparatus in position therein;

FIG. 2 is a representation of a typical weight record which might be produced in response to a signal telemetered to the surface; and

FIG. 3 is a diagrammatic representation of the surface weight indicating and recording equipment used with the apparatus of FIG. 1.

First referring to FIG. 1, a special drill collar **1** is attached to the lower end of a string of drill pipe (not shown) which rotates a drill bit **2** being used to drill a borehole **3**. Collar **1** has therein the usual longitudinal drilling mud passage **4** which forms a continuation of the mud passage conventionally provided by the bore of the drill pipe above this collar. At its lower end, the collar **1** has therein an enlarged chamber **5** whose upper end communicates with the lower end of passage **4**; within chamber **5** is mounted for sliding movement a tubular sub member **6**. The sub **6** is spring-loaded by means of a compression spring **7** whose lower end bears against the upper end of member **6** and whose upper end bears against the internal shoulder formed by the upper end of chamber **5**.

Member **6** extends downwardly, from a piston-like head **10** provided at its upper end, through the lower end wall of chamber **5**, to a point below the lower end of collar **1**, and at its lower end said member has a box coupling **8** which threadedly engages a pin coupling **9** on the upper end of bit **2**. Advantageously, the outer periphery of the shank portion of member **6** is of square cross-section, as is also the hole (in the lower end wall of chamber **5**) through which said member passes, so that, during ordinary drilling, the rotation of collar **1** causes the rotation of member **6** and, through the latter, of bit **2**, for drilling purposes. The chamber **5** and the bore of member **6** form a continuation of the drilling mud flow drill string and the mud passage **4**, to bit **2**.
path which extends from the surface down through the

The portion of the chamber **5** beneath head **10** is connected, by means of a vertically-extending passage **11** provided in the wall of drill collar **1**, to a solenoid-operated three-way valve **12** located in the wall of collar **1**. Valve **12** is also connected, by means of a short horizontally-extending passage **13** in the drill collar **1**, to the mud passage **4** inside the collar **1**, and, by means of another short horizontally-extending passage **14**, to the outside of the collar **1**, and in particular, to the annulus **15** between the outside of the collar and the wall of the borehole **3**. It will be appreciated that, during normal drilling, drilling fluids are flowing in both the mud passage **4** and in the annulus **15**, these drilling fluids being pumped down the mud passage **4** and back up the annulus **16**; there is a substantial pressure differential (e.g., 1,000 pounds per square inch) between the inside of the drill collar **1** (i.e., mud passage **4**) and the outside thereof (i.e., the annulus **15**).

Valve **12** is a valve which operates in on-off fashion, to either couple the aforementioned pressure differential from passage **4** to the lower portion of chamber **5**, by way of passages **13** and **11**, or to relieve the pressure from below piston **10** by connecting passage **11** to passage **14** and thus to annulus **15**. The solenoid valve **12** is opened and closed, in on-off fashion (to thereby connect passage **11** to passage **13** or to passage **14**, respectively), in some sequence controlled by the characteristic (such as resistivity, self-potential, radioactivity, etc.) being measured at the downhole location. Such operation of the solenoid valve is effected by way of the leads **16**, which connect the solenoid operating the valve **12** to the measuring apparatus. As just mentioned, the measuring apparatus controls valve **12** through leads **16**, and such measuring apparatus is responsive to a downhole characteristic being measured, such as resistivity, self-potential, radioactivity, etc. The valve **12**

can be operated electrically, from the same power supply that operates the downhole logging device or other downhole measuring apparatus. Circuitry necessary to operate the valve **12** would be conventional in most respects, although special design precautions would have to be taken in view of the severe operating environment. Typically, the ratio of closed time to open time of the valve **12** would be controlled by some measured data desired to be telemetered to the surface, thus producing a valve operation which can be represented by a pulse width modulated signal, of the type shown in FIG. 2.

As previously described, when the valve **12** is "on," passage **13** is connected to passage **11**, and the differential in pressure between the inside of the drill collar and the outside thereof is coupled to the lower portion of chamber **5**. Then, this pressure becomes effective on the lower face of movable head **10**, pushing this head upwardly and varying the load on spring **7**. It should be apparent that sub **6** and drill bit **2** are pushed upwardly along with head **10**. If there is 1,000 pounds per square inch differential in pressure between the inside of the drill collar **1** and the outside of the collar, and if the lower face of head **10** has an area of ten square inches, it is possible to vary the load on spring **7** (in the above-described manner, when valve **12** is "on") by 10,000 pounds, in a particular sense.

In drilling, a known amount of weight is let down on the bit **2**. This would tend to compress the spring **7**. Whatever load is supported by spring **7** would be subtracted from the total amount of weight of the drill pipe, as indicated on the weight indicator at the surface. By the operation of the three-way valve **12**, the total amount of weight that is shown on the weight indicator is changed, because the load on spring **7** is then changed. That is to say, when valve **12** is turned "on," the total weight shown on the weight indicator varies in one direction (by an amount of 10,000 pounds, in the example given), and when valve **12** is turned "off," the weight shown on the weight indicator varies in the opposite direction, by an equal amount. Since, as described, the valve **12** is operated against time in accordance with some measured data, the resulting change of total weight represents a signal (having the form illustrated in FIG. 2, for example) being sent from the bottom of the hole, which may be detected at the surface by the weight indicator thereat.

Now refer to FIG. 3, which illustrates somewhat schematically the surface weight indicating and recording equipment used for detecting signals telemetered from downhole by the apparatus of FIG. 1.

A derrick **17** has a drilling platform **18** on which is mounted a draw works schematically represented at **19**. the draw works includes a drum **20** to which one end of a wire cable **21** is secured. The cable or line spools over one sheave **22** of a crown block which is secured at the top of derrick **17**, then through a traveling block **23**, back over another sheave **24** of the crown block and around a grooved wheel **25** secured to a leg of the derrick; the end of the cable opposite to that attached to drum **20** is anchored at **26** to the derrick leg, or it may be anchored to the substructure. The sheaves **22** and **24** are shown displaced laterally only for purposes of clarity; actually, these sheaves are mounted for rotation about axes which are collinear. Also, the number of sheaves illustrated for the crown block and traveling block is merely representative, and there may be more than this number; there is always one more sheave in the crown block than in the traveling block. The portion **27** of the cable which extends from the crown block sheave **24** to the anchor **26** is ordinarily known as the "deadline."

The traveling block **23** carries a hook **28** which, by means of a swivel hanger **29**, supports through a swivel (not shown) a kelly (not shown) which is attached to the upper end of the string of drill pipe. The string of drill pipe, of course, extends downwardly from the top of borehole **3** and carries at its lower end the apparatus illustrated in FIG. 1.

Near the anchored lower end of the "deadline" **27**, there is a transducer 30 (e.g., a hydraulic or a pneumatic or electric transducer) whose movable actuating element is coupled to the deadline, in order to sense the tension therein (due to the weight supported thereby). The transducer **30** supplies an output signal to a weight indicator and recorder **31** by way of a coupling **32**. The transducer **30** at the surface responds to the variations in the total weight supported by the hook **28** and cable, to feed to recorder **31** the signal (such as illustrated in FIG. 2) which is telemetered from downhole.

By means of an appropriate transducer (not shown) coupled to the weight indicator **31**, the weight variation signal received at the surface can be decoded to provide an information signal corresponding to the data which has been measured downhole.

The invention claimed is:

1. Method of telemetering from downhole to the surface, in a borehole being drilled by rotary drilling equipment, which comprises suspending a string of drill pipe within the borehole, varying at a downhole location the effective weight of the suspended string in response to a measurement, telemetering the variation in effective weight, to the surface and detecting at the surface variations in such effective weight.

2. In a borehole being drilled by rotary drilling equipment wherein a fluid is pumped under pressure through a string of drill pipe suspended within the borehole: the method of telemetering from downhole to the surface which comprises producing, at a downhole location, changes in the fluid flow path in response to a downhole measurement, utilizing downhole such produced changes to vary the effective weight of the suspended string of pipe, telemetering such variations in effective weight to the surface, and detecting at the surface variations in such effective weight.

3. Method of telemetering a measurement from downhole to the surface in a borehole being drilled by rotary drilling equipment, which comprises suspending a string of drill pipe within the borehole, resiliently coupling a bit to the lower end of said pipe string, varying a characteristic of the downhole coupling between said bit and said pipe string in response to a measurement, thereby varying the effective weight of the suspended string of pipe, telemetering such variations in effective weight to the surface, and detecting at the surface such variations in effective weight.

4. In a borehole wherein a fluid is pumped under pressure through a string of pipe suspended within the borehole: the method of telemetering from downhole to the surface which comprises resiliently coupling a member to the lower end of said pipe string, producing, at a downhole location, changes in the fluid flow path in response to a measurement to be telemetered to the surface, utilizing downhole such produced changes to vary a characteristic of the downhole coupling between said member and said pipe string, thereby varying the effective weight of the suspended pipe string, telemetering such variations in effective weight to the surface, and detecting at the surface variations in such effective weight.

5. Apparatus for telemetering from downhole to the surface, in a borehole being drilled by rotary drilling equipment, comprising a string of drill pipe suspended within the borehole, means at a downhole location and coupled to such string of pipe for varying the effective weight of the suspended string in response to a measurement to be telemetered to the surface, and means at the surface responsive to said downhole means for detecting variations in such effective weight.

6. In a borehole being drilled by rotary drilling equipment wherein a fluid is pumped under pressure through a string of drill pipe suspended within the borehole: apparatus for telemetering from downhole to the surface, comprising means at a downhole location and coupled to such string of pipe for producing changes in the fluid

flow path in response to a measurement to be telemetered to the surface, downhole means in said pipe string for utilizing such produced changes to vary the effective weight of the suspended string of pipe, and means at the surface responsive to said downhole effective weight varying means for detecting such variatoins in effective weight.

7. Apparatus for telemetering from downhole to the surface, in a borehole, comprising a string of pipe suspended within the borehole, a member forming a part of said pipe string and resiliently coupled to the lower end of said pipe string, downhole means in said pipe string for varying a characteristic of the downhole coupling between said member and said pipe string in response to a measurement to be telemetered to the surface, said downhole means being arranged to vary the effective weight of the suspended pipe string, and means at the surface responsive to such downhole means for detecting variations in such effective weight.

8. In borehole equipment wherein a fluid is pumped under pressure through a string of pipe suspended within the borehole: apparatus for telemetering from downhole to the surface, comprising a member resiliently coupled to the lower end of said pipe string, means attached to said string of pipe at a downhole location for producing changes in the fluid flow path in response to a measurement to be telemetered to the surface, downhole means in said pipe string for utilizing such produced changes to vary a characteristic of the downhole coupling between said bit and said pipe string, thereby varying the effective weight of the suspended pipe string, and means at the surface responsive to said downhole effective weight varying means for detecting variations in such effective weight.

9. Apparatus for telemetering from downhole to the surface, in a borehole, comprising a string of pipe suspended within the borehole, a sub at the lower end of said pipe string, said sub being mounted for vertical sliding movement with respect to said pipe string, resilient means arranged between said sub and said pipe string acting to load said sub with respect to said pipe string, downhole means in said pipe string for varying the loading provided by said resilient means in response to a measurement to be telemetered to the surface, thereby varying the effective weight of the suspended pipe string, and means at the surface responsive to said load varying means for detecting variations in such effective weight.

10. Apparatus as defined in claim 9, including also a bit secured to the lower end of said sub.

11. Apparatus as set forth in claim 9, wherein said resilient means comprises a compression spring one end of which bears against said pipe string and the other end of which bears against said sub.

12. Apparatus in accordance with claim 11, including also a bit secured to the lower end of said sub.

13. In a borehole being drilled by rotary drilling equipment wherein a fluid is pumped under pressure through a string of drill pipe suspended within the borehole: apparatus for telemetering from downhole to the surface, comprising a sub at the lower end of said pipe string, at least a portion of said sub being mounted for vertical sliding movement with respect to said pipe string, resilient means between the moveable portion of said sub and said pipe string acting to load said sub with respect to said pipe string, downhole means in said pipe string, acting in response to a measurement to be telemetered to to the surface, for utilizing a portion of the pressure of said fluid to vary the loading provided by said resilient means, thereby varying the effective weight of the suspended pipe string, and means at the surface responsive to the variations in loading of said resilient means for detecting variations in such effective weight.

14. Apparatus as defined in claim 13, including also a bit secured to the lower end of said sub.

15. Apparatus as set forth in claim 13, wherein said resilient means comprises a compression spring one end of which bears against said pipe string and the other end of which bears against said sub.

16. Apparatus in accordance with claim 15, including also a bit secured to the lower end of said sub.

17. Apparatus for telemetering from downhole to the surface, in a borehole comprising a string of drill pipe suspended within the borehole, said pipe string including an elongated sub coupled to its lower end, said sub having portions mounted for vertical sliding movement with respect to said pipe string, said portions including a head at the upper end of said sub, said head having upper and lower faces; a compression spring one end of which bears against said pipe string and the other end of which bears against the upper face of said head, downhole means in said pipe string responsive to a measurement to be telemetered to the surface for applying a pressure representing such measurement to the lower face of said head, and means at the surface responsive to such applied pressure for detecting variations in the effective weight of the suspended pipe string.

18. Apparatus as defined in claim 17, including also a bit secured to the lower end of said sub.

19. Apparatus in accordance with claim 18, wherein a fluid is pumped under pressure through said pipe string, and wherein the pressure applied to the lower face of the head is derived from changes in the fluid flow path produced by said measurement responsive means.

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