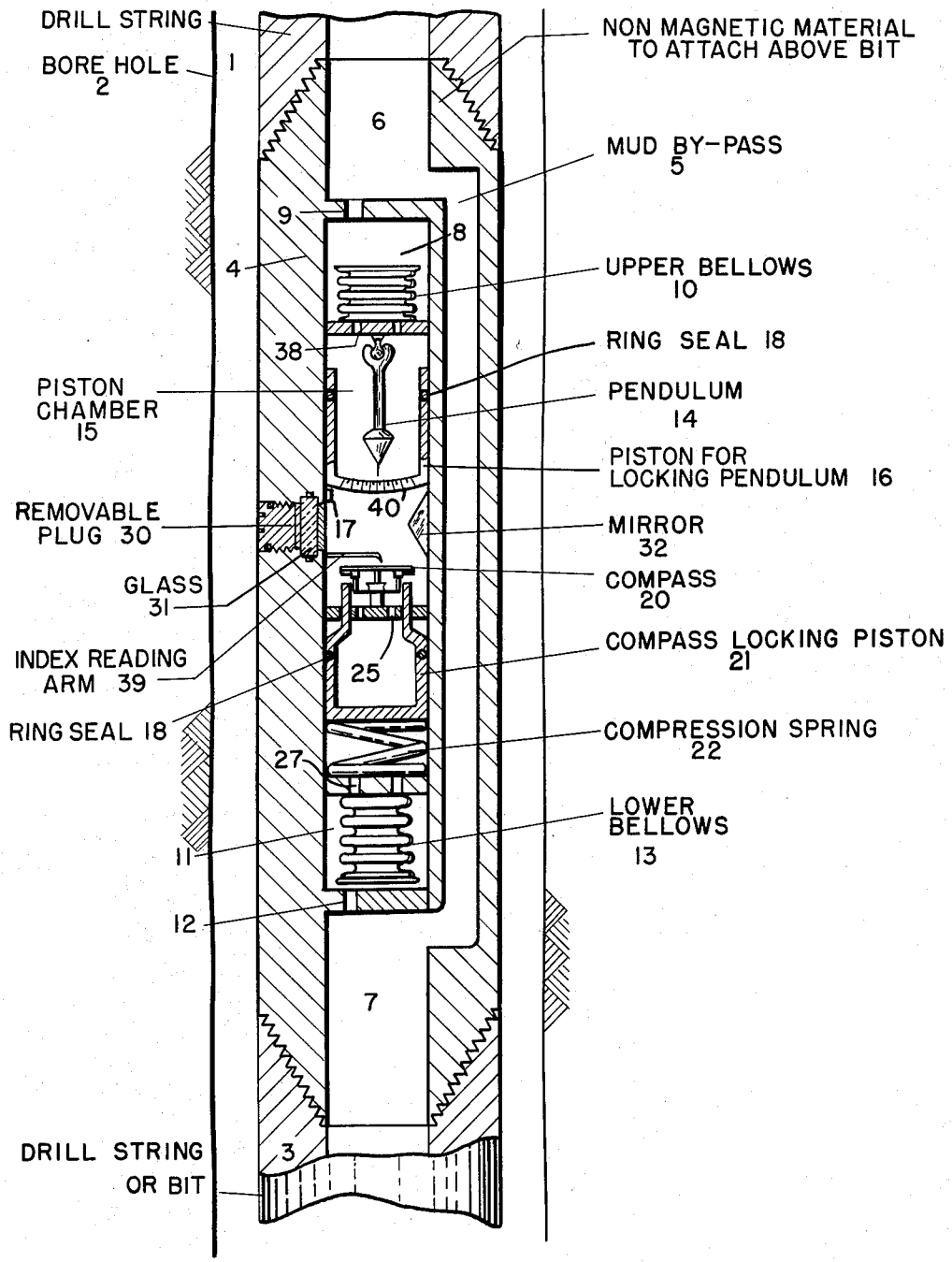
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BOREHOLD INCLINOMETER

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BOREHOLE INCLINOMETER

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The present invention is concerned with the logging of bore holes being drilled for the production of oil. The invention is more particularly concerned with an apparatus which is adapted to be attached to the drill pipe or drill stem while drilling and which will give a complete bore hole inclination plot without the necessity of removing the string and thereafter determining the inclination of the bore hole by special down hole equipment.

It is well known in the art to drill bore holes in the earth's substrata in order to search for and to produce oil. In these operations the bore hole is usually bored by utilizing a drill string having attached to its lower end thereof various types of drill bits. During the drilling operation drilling fluid or mud is passed downwardly within the drill string and upwardly in the area between the bore hole and the drill string in order to remove the drill cuttings. During the drilling operation it is essential that a complete bore hole inclination plot be known in order to determine the actual depth of the bore hole and the extent and direction of deviation from the vertical. Heretofore in the past it has been necessary to remove the drill string section by section and then to pass downwardly in the bore hole special instruments adapted to give the inclination plot of the bore hole. After this has been determined the drill string is assembled section by section and the drilling operation continued.

By the apparatus of the present invention the necessity for lowering a special instrument and withdrawal of that instrument from the bore hole is eliminated. The apparatus is attached to the drill pipe but does not interfere with normal drilling operations. When the drill pipe is withdrawn from the bore hole during the normal course of drilling operations, as for example to change drill bits, the bore hole inclination and orientation can be noted without incurring the loss of time that would be involved in making a trip into and out of the bore hole with a special logging tool.

The apparatus of the present invention may be fully understood by reference to the attached drawing illustrating one embodiment of the same. The apparatus is shown attached to the lower end of a drill string **1** positioned within bore hole **2**. The apparatus of the present invention comprises an elongated casing **4** having a diameter substantially equivalent to the diameter of the drill string or drill collars, and adapted to be attached to the lower end of the drill string and adapted to have attached to its lower end a suitable bit or further sections of drill pipe or drill collars, the upper end of whichever element is used being designated by reference numeral **3**. A drilling mud by-pass **5** communicates between the entrance passage **6** and the exit passage **7** of the inclinometer assembly. An upper bellows chamber **8** full of drilling fluid communicates freely with entrance passage **6** by means of port **9**. This upper bellows chamber **8** contains upper bellows element **10** which is full of liquid, preferably a selected clear oil. A lower bellows chamber **11** is full of drilling fluid and communicates freely with

exit passage **7** by means of port **12**. Lower bellows chamber **11** contains lower bellows **13** which bellows is full of the selected oil. A free-swinging pendulum **14** is positioned within piston chamber **15**. Piston **16** is slidably positioned within piston chamber **15**. The downward movement of piston **16** is restricted by stop **17** while the upper movement is restricted by the lower point of pendulum **14**. A suitable ring seal **18** is used to prevent the flow of oil to within the piston. The piston is suitably graduated, as by means of the scale **40** so as to determine the exact position of the pendulum **14** upon locking. Free communication is provided from within upper bellows **10** to the area within piston chamber **15** by means of ports **38**.

A compass **20** is disposed above an inverted compass locking piston **21**. An index reading arm **39** extends over the face of the compass so as to facilitate an exact determination of the compass position. A compression spring **22** maintains an upward thrust against the head of piston **21**. The area between the head of piston **16** and the base of piston **21** is filled with a clear oil so that the readings of the pendulum and the compass can readily be determined by mirror elements **32**.

In operation the inclination assembly functions as follows. Drilling mud is pumped down the drill string **1** through entrance passage **6**, through mud by-pass **5** and out exit passage **7** into the drill bit or a lower section of drill string. The mud flows through the bit and returns to the surface through the annulus between the drill string and the bore hole. The pressure, and therefore the force that actuates the piston system is provided by the slight resistance to the flow offered by mud by-pass **5**. When normal drilling fluid flow is maintained through the drill string a small pressure drop or ΔP exists between the entrance passage **6** and the exit passage **7**. This pressure differential is sufficient to actuate the bellows of the instrument. The fluid ports **9** and **12** transmit the average fluid pressure drop that occurs through the instrument while serving, because of their restricted size, to damp out erratic fluid pressure surges. Thus when drilling mud is being circulated, a downward thrust is exerted on upper bellows **10** through port **9**. Compression of bellows **10** forces liquid through ports **38** against piston **16**. Downward motion of piston **16** forces the liquid below it through ports **25**, moving piston **21** down against the upward thrust of spring **22**. Note here that the strength of spring **22** may be increased such that under normal circulating rates the pressure drop through mud by-pass **5** is not sufficient to release the compass and pendulum. Therefore, in this modification the assembly will not be free during drilling and not subject to drilling vibrations. When a reading is desired, the circulating rate is increased, causing the pressure drop across the mud by-pass **5** to increase, which in turn causes the compass and pendulum to be freed during the time the mud is circulated at an increased rate. An increased circulating rate for a period of one to three minutes should be sufficient to allow the compass and pendulum to come to equilibrium. Flow is then stopped, causing the compass and pendulum to be locked and the instrument is then removed from the bore hole.

When piston **21** moves downward against the upper thrust of compression spring **22**, the fluid below the head of piston **21** flows into lower bellows **13** through ports **27** and an equilibrium is obtained. However when pumping is stopped for the removal of the drill string the upper thrust of spring **22** pushes piston **21** upwardly and locks compass **20** in place. When piston **21** moves upwardly it pushes the fluid above it against piston **16**, causing the latter to move upwardly and lock pendulum **14** in place. The instrument is then withdrawn to the

surface upon withdrawal of the drill string from the bore hole and the position of compass **21** and pendulum **14** are determined. This is accomplished by removing a removable plug **30** and looking through a glass **31** and taking the readings from mirrors **32**. The head of piston element **16** is transparent so that the position of the point of pendulum **14** on scale **40** is readily determined.

A particular adaptation of the present invention is to select the strength of spring element **22** so that the ΔP across the unit at normal pumping rates is insufficient to force the spring downwardly. Thus the pendulum and the compass will not be released. For example, normal pumping rates in gallons per minute vary in the range of from about 100 to 500 gallons per minute, usually in the range of about 200 to 300 gallons per minute. In accordance with a preferred concept of the present invention spring element **22** exerts sufficient upward thrust against the pressure differential secured during these pumping rates so as to overcome the ΔP keeping the respective pistons in the upward position. Thus the pendulum and compass elements will not be released. A normal drilling operation can be carried out at these rates. However when it has been decided to withdraw the drill string and it is desired to know the inclination of the bore hole the pumping rates will be increased about, for example, from five hundred gallons per minute, say to seven hundred gallons per minute. The increased ΔP resulting from this increase across the assembly will overcome the upward thrust of the spring, piston **16** and piston **21** will be forced downwardly and the pendulum and compass elements will swing free. Their position will be determined by the inclination of the bore hole and the orientation of the assembly. Pumping can then be stopped, the ΔP will drop to zero and the spring elements will exert the upward thrust and force piston **21** and **16** upwardly thus locking the pendulum and the compass in the position assumed while swinging freely.

Having described the invention, it is claimed:

1. Improved bore hole inclinometer assembly adapted for insertion in a string of drill pipe above a drill bit in a bore hole, comprising: an elongated casing member attachable to said drill string and having a top central opening and a bottom central opening communicating with the bore of the drill string, an upper bellows chamber positioned within said casing member, an upper bellows within said upper chamber, a piston chamber positioned below said upper bellows chamber, in fluid communication with the interior of said upper bellows, a lower bellows chamber positioned below said piston chamber, a lower bellows positioned within said lower bellows chamber with the interior of said lower bellows in fluid communication with said piston chamber, a pendulum suspended within said piston chamber, a first piston slidably positioned within said piston chamber adapted to move into contact with and thereby lock said pendulum, a compass mounted within said piston chamber, a second piston slidably positioned within said piston chamber adapted to move into contact with and thereby lock said compass, a spring urging at least one of said pistons into locking position, fluid filling said piston chamber and said bellows, means establishing fluid communication between said upper bellows chamber and said top central opening, means establishing fluid communication between said lower bellows chamber and said bottom central opening, and a channel within said casing connecting said top central opening with said bottom central opening, said channel presenting greater resistance to fluid flow than said top and bottom central openings, whereby fluid circulation through said drill string will exert a pressure differential, communicable to said pistons through said bellows, sufficient to move said pistons out of locking position against the action of said spring.

2. Apparatus as defined by claim 1 including a fluid-sealed inspection port whereby the positions of said compass and of said pendulum can be determined by visual inspection external of said piston chamber.

3. Apparatus as defined by claim 2 including mirror elements positioned within said piston chamber adjacent said pendulum and said compass and visually accessible through said inspection port whereby to facilitate visual inspection of said pendulum and said compass.

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