175-40 CROSS REFERENCE SEARCH ROOM

Dec. 14, 1965 J. A. VARNEY 3,223,183

WELL DRILLING APPARATUS

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Fig. 1

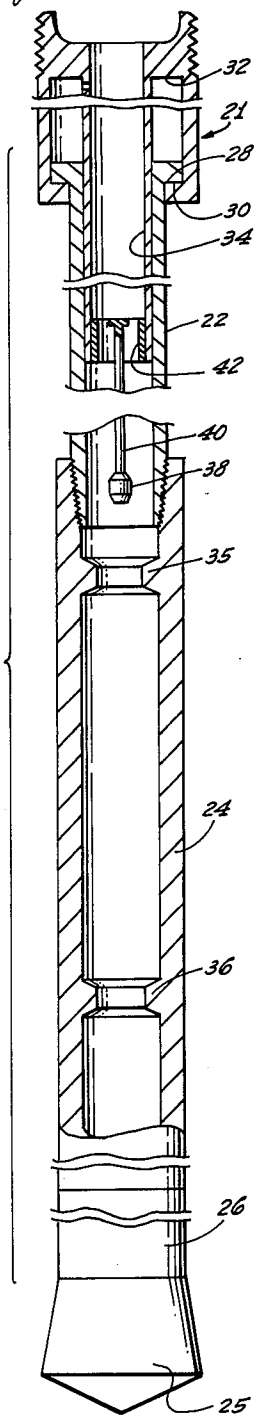

Fig. 2

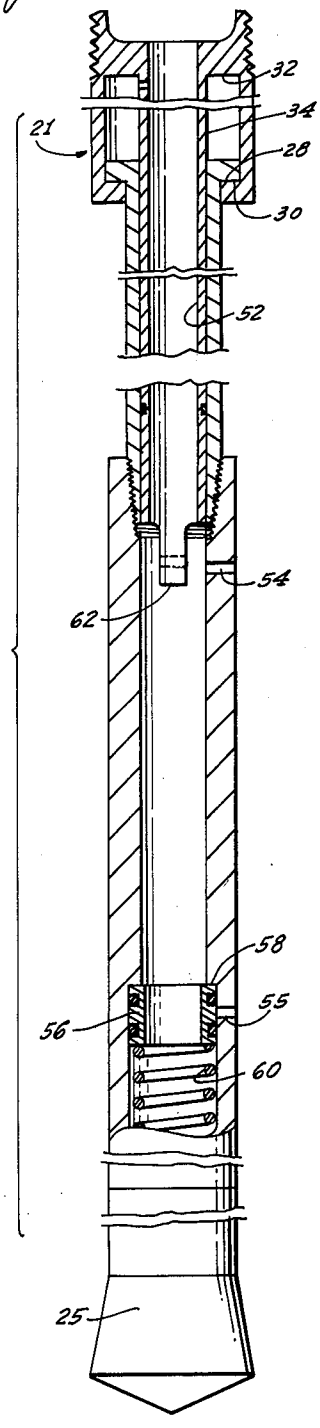

Fig. 1a

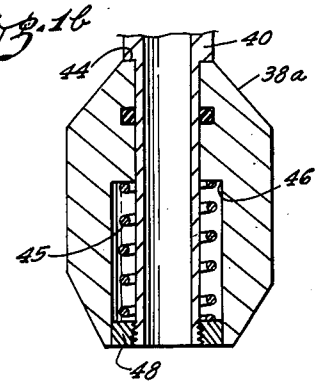

Fig. 3

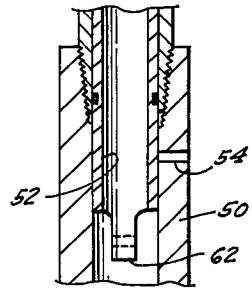

Fig. 4

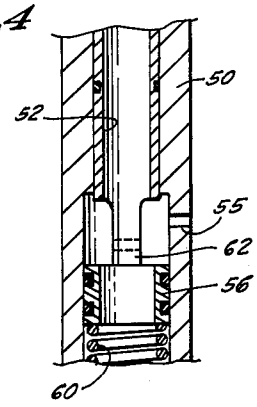

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Fig. 8

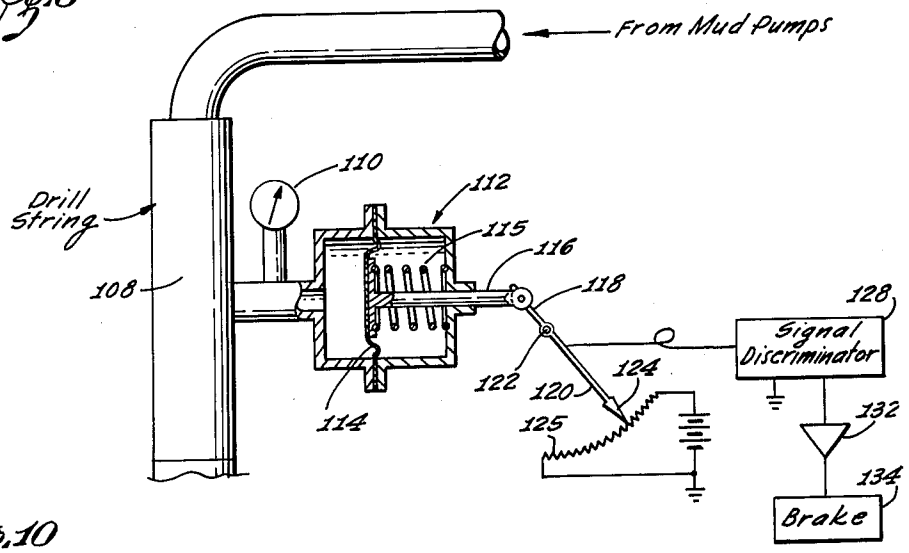

Fig. 10

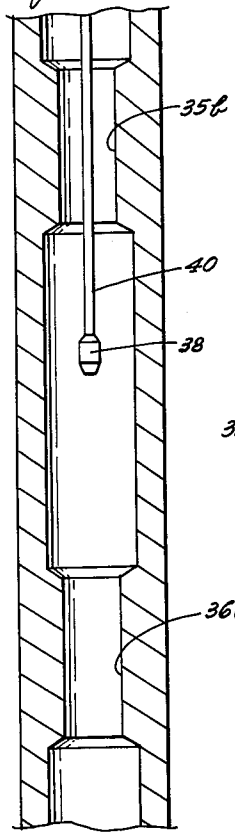

Fig. 9

Fig. 10a

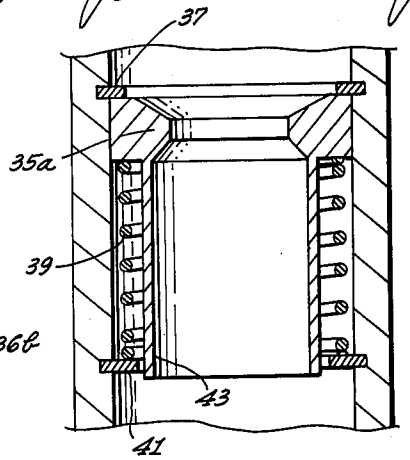

Fig. 11

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Fig. 5

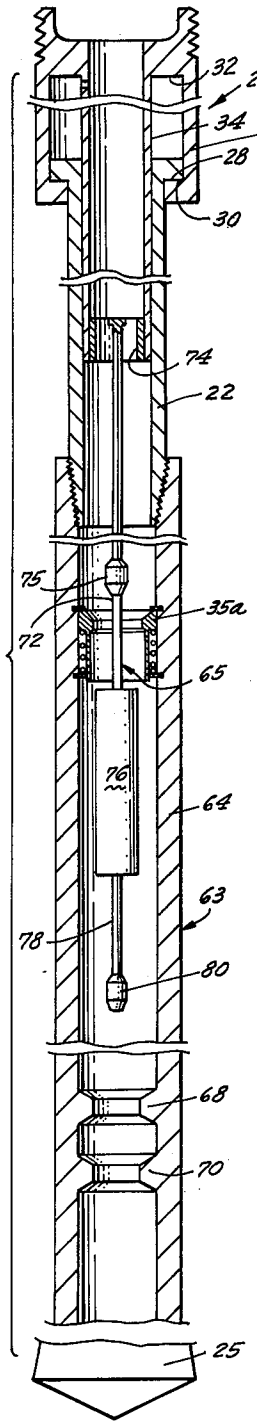

Fig. 6

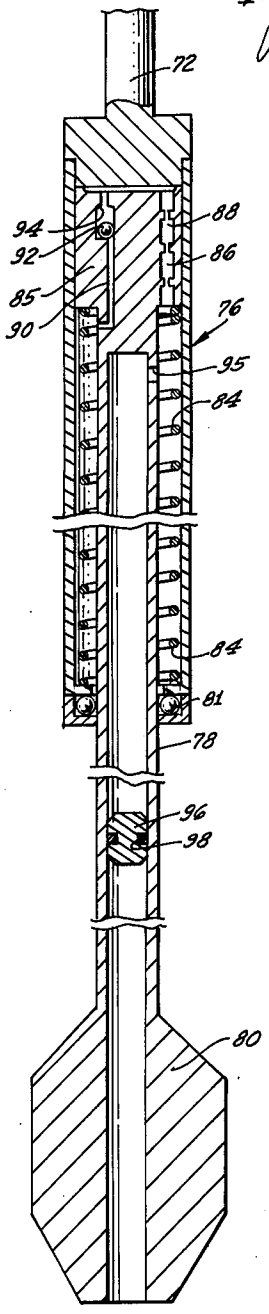

Fig. 7

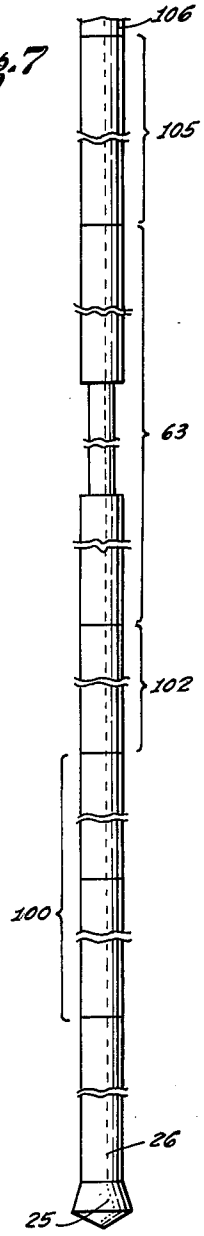

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Fig. 12

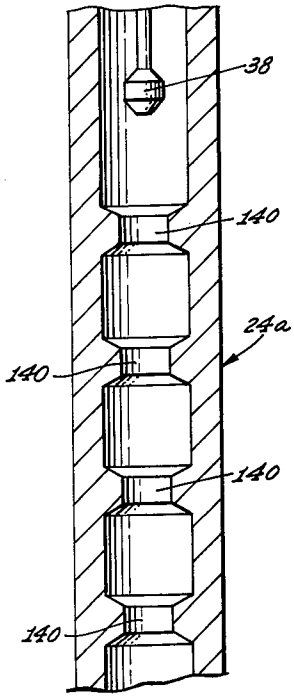


Fig. 13

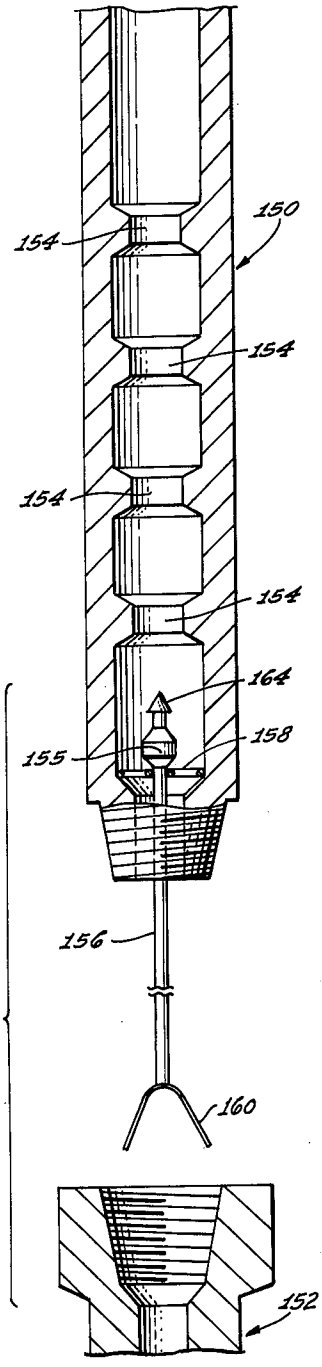


Fig. 14

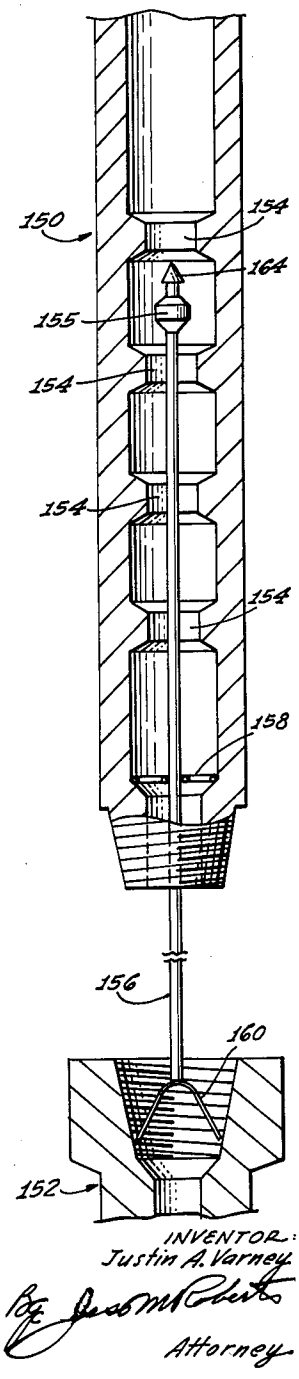
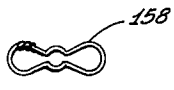


Fig. 15



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3,223,183

WELL DRILLING APPARATUS

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21 Claims. (Cl. 175—27)

This invention relates to apparatus for drilling deep boreholes in the earth and, more particularly, relates to a rotary drilling apparatus in which a drill bit at the lower end of a drill string is rotated for cutting or crushing action with circulating drilling fluid cooling the bit and lifting the cuttings out of the borehole. For the purpose of the present disclosure, the invention is described as embodied in such an apparatus in which the drill bit is rotated by the drill string, but the invention may also be applied to an apparatus in which the drill bit is rotated by a suitable motor on the lower end of the drill string.

In conventional rotary drilling practice, the weight imposed on the drill bit is judged by means of a weight indicator on the draw works and regulated at the top of the well by brake means associated with the hoist drum, the driller slacking off the brake to pay out hoist cable, lower the drill string, and thereby increase the imposed weight on the bit. Holding back the drill string during drilling will reduce such weight as a result of progressive deepening of the hole. Carrying too much weight on the drill bit for a formation of a given character may not only cause excessive wear on, and possible damage to, the drill bit but also tends to result in a crooked borehole which in turn tends to cause increased bending stresses in the drill string. Metal fatigue failure of the drill pipe or tool joints may result. Friction between the drill string and the wall of the borehole may be increased to the point of causing the drilling string to wear severely and even twist off. On the other hand, imposing too little weight on the drill bit results in low rates of penetration. Modern roller type bits depend largely on over stressing and consequent crushing of the formation. Adequate weight must, therefore, be carried by the bit if it is to function efficiently and as intended.

The optimum weight on the bit for any given conditions may be anywhere between half a ton and thirty tons but is usually in the range of five to twenty-five tons. In a deep borehole, however, the total weight of the drill string may exceed 100 tons and consequently the drill string must be kept under tension for the major distance down the well to keep from overloading the bit.

Under favorable conditions where the borehole is only moderately deep the weight imposed on the bit may be calculated by simply referring to the weight indicator at the top of the well. Unfortunately, however, such favorable conditions seldom prevail and the weight indicator is often grossly misleading in a very deep well and especially so if the borehole is crooked or slanted to cause a substantial portion of the weight of the drill string to be borne by frictional engagement of the drill string with the wall of the borehole. It is known that under such circumstances the driller may not even be able to tell whether the bit is on the bottom of the borehole, let alone what the applied weight on the bit is if indeed it is on bottom.

To meet this situation various prior art arrangements have been devised in which a pair of adjacent sections of a drill string are connected by a telescoping joint to permit the two sections to extend and contract. When the two sections are only partially extended the weight of the drill string below the telescoping joint and only that weight is imposed on the bit and a desired magnitude of weight may be imposed on the bit for a long drilling period by simply providing that weight in the drill string below

the telescoping joint. Suitable signal means must be provided, however, to indicate when the two telescoping sections are partially collapsed.

The downward stream of drilling fluid may be used for signaling since pressure changes deep in the well travel rapidly to the surface. Suggestions have been advanced heretofore in the prior art for generating such signals by restricting the stream of drilling fluid in response to the telescoping action in the drill string and thereby creating a pressure rise for detection at the top of the well. Such suggestions have not been fruitful for a number of reasons.

One reason, in some instances, is that the signaling pressure rise is too gradual for accurate detection, especially when the bit progresses at a slow rate. Another reason found in prior art systems is that the signaling pressure rise is unduly prolonged and consequently reduces the efficiency of the system for circulating the drilling fluid. A further reason is encountered when the signals are associated with only one limit of the range of relative movement between the two telescoping sections and it becomes difficult for the driller to guess when he reaches the other limit. When the driller receives a signal that the telescoping sections are nearly fully extended he may inadvertently lower the drill string beyond the point at which the two sections are fully contracted and thus impose on the bit much if not all of the weight of the whole drill string.

The present invention meets this situation by providing a signal system with the capability of indicating approach to both of the two opposite limits of the range of extention and contraction of the two telescoping sections. In the simplest practice of the invention, the two signals are similar and are distinguished from each other simply by relating them to the lowering and raising of the drill string. In the preferred practice of the invention, however, different signals are used to identify the two limits.

An important feature of the invention is that signals of unmistakable character are provided and prolonged pressure rises are avoided by employing signals characterized by abrupt and substantial pressure rises. In some instances the signals are in the form of relatively short pressure pulses of relatively great amplitude created by an axial choke head which is carried by one section and which passes through a choke ring carried by the other section. The invention teaches that the choke head may be yieldingly mounted to be moved abruptly through the choke ring by the dynamic pressure of the drilling fluid and thus produce a distinctly sharp pressure pulse. In other instances, the choke head merely enters the choke ring without passing through the choke ring and thus produces a signal in the form of an abrupt and substantial pressure rise.

The invention further teaches that the choke head may be adapted to pass through a series of choke rings where a multiple pulse signal is desired. In this regard a feature of the invention is the provision for the choke head to move through the series of choke rings at a selected predetermined rate to result in an unmistakable signal in the form of a predetermined number of pulses at predetermined time intervals.

In the preferred practice of the invention, a plurality of signaling telescoping joints is provided in the drill string to make it possible for the driller to vary the weight on the bit under close control. Guided by the signal pulses, the driller lowers the drill stem until the first telescoping action occurs to place the minimum weight on the bit. The weight may then be increased as desired by continuing to lower the drill string until a similar telescoping action is signaled at a selected higher telescoping joint.

A further feature of the preferred practice of the invention is the concept of using the two limit signals created by a telescoping joint to lower the drill string automatically in a manner to maintain a selected magnitude of weight on the bit. The brake is relaxed automatically to lower the drill string in response to a signal indicating that a selected telescoping joint is fully extended and subsequently the brake is tightened in response to the second signal indicating that the joint is nearly collapsed. The automatic control responds to the telescoping action of whichever telescoping joint the driller elects.

The features and advantages of the invention may be understood from the following detailed description and the accompanying drawings.

In the drawings, which are to be regarded as merely illustrative:

FIG. 1 is a somewhat schematic broken sectional view illustrating a first embodiment of the invention in which the two signals are created by the passing of a choke head through two spaced choke rings;

FIG. 1*a* is an enlarged sectional view of a yieldingly retractable choke ring;

FIG. 1*b* is an enlarged sectional view of a yieldingly retractable choke head;

FIG. 2 is a view similar to FIG. 1 showing a second embodiment of the invention in which the signals are produced by valve-controlled bypass means;

FIG. 3 is a fragmentary sectional view showing how the apparatus shown in FIG. 2 produces a signal at one limit of the range of extension and contraction;

FIG. 4 is a fragmentary sectional view showing how the second signal at the other limit is produced by the apparatus shown in FIG. 2;

FIG. 5 is a longitudinal sectional view similar to FIG. 1 illustrating another embodiment of the invention which provides a signal in the form of a series of successive pressure pulses to indicate a given state in the extension and contraction of a telescoping joint;

FIG. 6 is a somewhat diagrammatic broken sectional view of the means in FIG. 5 for mounting the choke head for travel at a controlled rate through a series of signaling choke rings;

FIG. 7 is a diagrammatic broken sectional view showing how a series of telescoping joints may be provided in a drill string whereby the driller may vary the weight imposed on the bit in a closely controlled manner;

FIG. 8 is a diagrammatic view illustrating a system for automatically controlling the weight imposed on a bit;

FIG. 9 is a diagram indicating the character of a sharp pressure pulse;

FIG. 10 is a fragmentary sectional view of another signaling bumper sub assembly;

FIG. 11 is a diagram indicating the character of a prolonged pressure signal;

FIG. 12 is a simplified sectional view of an arrangement for indicating by pressure signals successive stages in the relative movement between telescoping parts of a drill string;

FIG. 13 is a simplified sectional view of a signaling feeler arrangement to indicate the distance from an object of the lower end of a suspended tube;

FIG. 14 is a similar view showing the feeler partially retracted; and

FIG. 15 is a plan view of a wire spider employed in FIGS. 13 and 14.

The invention employs what may be termed a signaling bumper sub assembly which may be of the general construction of a renewable spline type bumper sub manufactured by Baash-Ross Division of Joy Manufacturing Company. In the embodiment of the invention shown in FIG. 1 a telescoping joint in a drill string is provided by a signaling bumper sub assembly which includes a bumper sub body **21** and a mandrel **22** telescopically connected to the body, the body and mandrel constituting two

adjacent telescoping sections of the drill string. The bumper sub body **21** is connected to the drill string in the usual manner and, in the construction shown, the mandrel **22** is fixedly connected to a signal-generating section **24** which may be regarded as a part of the mandrel. The signal-generating section **24** is connected to the usual drill bit **25** by means of at least one drill collar **26** which provides the major portion of the weight of the drill string below the telescoping joint of the bumper sub.

The upper end of the mandrel **22** is provided with an outer circumferential shoulder **28** which engages a cooperating inner circumferential shoulder **30** of the bumper sub body **21** to limit the downward longitudinal extension of the mandrel relative to the body. At this limit position the two telescoping sections are fully extended. The upper end of the mandrel **22** is free to slide telescopically in the bumper sub body **21** to a second upper limit position (not shown) at which the upper end of the mandrel abuts an inner circumferential shoulder **32** of the bumper sub body. At this second limit position the two telescoping sections are fully contracted and the whole weight of the drill string may be imposed on the bit **25**.

In a well known manner, the bumper sub body **21** is provided with what is termed a wash pipe **34** which telescopes into the mandrel **22** throughout the range of extension and contraction of the mandrel to provide a suitable channel for the drilling fluid between the two telescoping sections. The range of extension and contraction of the mandrel relative to the bumper sub body is preferably relatively extensive, for example at least 5 feet.

The structure in FIG. 1 added by the present invention comprises the previously mentioned signal-generating section **24** and what may be termed a choke head or enlargement **38** mounted on a downwardly extending rod **40**, the rod being connected to the lower end of the wash pipe **34** by an apertured fitting or spider **42**. Upper and lower choke rings **35** and **36** respectively formed in the signal-generating section **24** move with the lower section or mandrel **22** but the choke head **38** moves with the upper section or bumper sub body **21**.

When a drill string equipped with the signaling bumper sub assembly shown in FIG. 1 is lowered initially into a borehole the signaling bumper sub assembly is fully extended as indicated in FIG. 1 with the circumferential shoulder **28** of the mandrel resting on the inner circumferential shoulder **30** of the bumper sub body to support all of the components of the drill string below the telescoping joint. At this time the choke head **38** is above the uppermost choke ring **35** as indicated.

When the drill string touches the bottom of the borehole and the lowering of the drill string continues, the signal-generating section **24** becomes stationary and the bumper sub body **21** continues to descend to move the choke head **38** downward through the signal-generating section **24**. The choke head **38** passes through the upper choke ring **35** to restrict the downwardly flowing stream of drilling fluid with the consequence that the back pressure of the drilling fluid rises and then falls thus creating a pressure pulse which travels as a wave to the top of the well. The pressure wave may be detected at the top of the well by means of a pressure gauge in communication with the interior of the drill string. As the two telescoping sections continue to collapse the choke head **38** approaches and passes through the second choke ring **36** to produce a second pressure rise or pulse in the drilling fluid that may be detected at the top of the well.

The driller notes the first signal and may confirm the fact that the drill string has bottomed by simply noting the reduction of the weight registered by the weight indicator. When the second signal occurs as the choke head **38** passes through the lower choke ring **36** the driller applies the brake associated with the hoist drum to terminate the lowering of the drill string and then carries on the drilling operation.

Before he carries on the drilling operation he may take the precaution of backing up the drill string until a pressure signal indicates that the choke head **38** has moved upward through the lower choke ring **36** to be sure that the drilling operation is started with the signaling bumper sub partly contracted with no possibility of imposing the weight of the whole drill string on the drill bit. In any event the drilling operation is continued until the increment permitted by the signaling bumper sub is used up as indicated by a pressure signal generated by the relative upward movement of the choke head **38** through the upper choke ring **35**. The driller then repeats the operation of lowering the drill string until the choke head **38** passes through the lower choke ring **36**.

It may be readily appreciated that the character of a pressure signal depends on the velocity of the relative movement between the choke head and the choke ring and also depends on whether or not the choke head passes completely through and beyond the choke ring. Thus if the choke head enters the choke ring relatively slowly the pressure rise is somewhat gradual, whereas a steep abrupt pressure rise is created by a rapid entrance. If the choke head lingers in the choke ring the pressure rise is sustained. If the choke head moves rapidly into and completely through the choke ring it creates a steep sloped sharp pressure pulse of high amplitude of the character of the pressure pulse shown in FIG. 9 and such a signal is so distinctive and easily recognized as to preclude doubt or error. It is to be understood that in various practices of the invention the various types of signals may be produced depending on the velocity and extent of the relative movement between the choke head and the choke ring.

FIG. 1*a* shows how a choke ring **35***a* may be made yieldingly retractable. For this purpose the choke ring is slidingly mounted and normally abuts a snap-type stop ring **37**. A coil spring **39** nesting on a lower snap-type stop ring **41** urges the choke ring upward and is protected by a cylindrical skirt **43** of the choke ring.

FIG. 1*b* shows how a choke head **38***a* may be mounted on the rod **40** in a yielding manner. In FIG. 1*b* the lower end of the rod **40** is reduced in diameter to form a circumferential shoulder **44** against which the choke head **38***a* is normally yieldingly maintained by a concealed coil spring **45**. The interior of the choke head **38***a* is cut away to form an annular space for the coil spring and the coil spring is mounted in this space under compression between the upper end surface **46** of the recess and a nut **48** on the lower end of the rod.

Preferably the structure in FIG. 1 is modified by substituting the yieldingly mounted choke ring **35***a* of FIG. 1*a* for the upper fixed choke ring **35** and by substituting the yieldingly mounted choke head **38***a* of FIG. 1*b* for the fixedly mounted choke head **38**. With the range of yielding retraction of the choke ring **35***a* substantially greater than the range of yielding contraction of the choke head **38***a*, the pressure signals will be produced in the following manner.

As the choke head **38***a* moves downward and approaches the upper choke ring **35***a*, the rise in pressure on the upstream sides of the choke head and choke ring created by restricting the downward stream of drilling fluid causes both the choke head and the choke ring to retract downward and after the choke head retracts to its limit the choke ring continues to retract downward to its limit. The character of the resulting pressure signal depends on the rate of relative movement between the two telescoped sections of the signaling bumper sub assembly, i.e., the rate at which the drill string is lowered after it hits bottom. Usually the signal is somewhat anomalous in that the rise in pressure is prolonged even when the relative movement is rapid between the two telescoped sections of the signaling bumper sub assembly.

When the downwardly carried yielding choke head **38***a* reaches the lower fixed choke ring **36**, however, the rise in pressure of the restricted stream of drilling fluid causes the choke head to accelerate through the choke ring with a snap action against the resistance of the concealed spring **45** with a consequent substantially instantaneous rise and fall of pressure to create a signal in the form of a steep sharp pressure pulse that travels to the top of the well.

If the yieding choke head **38***a* moves upward from a point below the lower fixed choke ring **36**, it retracts under fluid pressure as it enters the fixed choke ring and prolongs the pressure rise accordingly but the pressure rise is terminated abruptly when the concealed spring **45** is able to snap the choke head upwards back to its normal limit position.

If the yielding choke head **38***a* in its upward movement approaches the yielding choke ring **35***a* from below, the rise in pressure by restriction of the downward stream of drilling fluid causes downward retraction of both the yielding choke head and the yielding choke ring but since the choke ring has a longer range of yielding retraction it snaps past the retracted choke head and then the retracted choke head snaps upward to its normal limit position. As a result the created signal is of the character of an unmistakable steep sharp pressure pulse.

An important advantage of this arrangement is that when the yielding choke head **38***a* is below the upper yielding choke ring **35***a* and above the lower fixed choke ring **36**, relative travel of the choke head in either direction eventually produces a distinctive steep sharp pressure pulse. Thus with the two telescoped sections of the signaling bumper sub assembly extended to an intermediate extent, i.e., substantially half way contracted, distinctive sharp signals will indicate approach of the two telescoped sections to their opposite limits of full contraction and full extension. Guided by the two limit signals the driller can lower the drill string either intermittently or continuously at an appropriately retarded rate to keep the weight on the drill bit constant, the constant weight being the weight of the portion of the drill string that is below the telescoping joint.

The structure of the second embodiment of the invention shown in FIGS. 2, 3 and 4 is largely identical to the structure of the first embodiment as indicated by the use of corresponding numerals to indicate corresponding parts. The second embodiment differs from the first in the substitution of a signal-generating section **50** for the signal-generating section **24** and the substitution of a tubular extension **52** of the wash pipe **34** instead of the choke head **38** on the rod **40**.

The signaling bumper sub **50** has a normally open upper bypass port **54** and a normally closed lower bypass port **55**, the lower bypass port being normally closed by a sleeve valve **56** that is normally held in abutment against a shoulder **58** by a suitable coil spring **60**.

When the signaling bumper sub assembly is fully extended, as shown in FIG. 2, a fraction of the drilling fluid is bypassed through the upper port **54**. When the tubular extension **52** initially moves downward in the initial contraction of the two telescoping sections of the drill string, the tubular extension functions as a sleeve valve and closes the upper bypass port **54** as shown in FIG. 3. The closing of the upper bypass port **54** causes a corresponding rise in the pressure of the drilling fluid which rise may be readily detected at the top of the well.

As the signaling bumper sub assembly continues to contract the tubular extension **52** continues to move downward until eventually a downwardly extending finger **62** of the tubular extension encounters the upper end of the sleeve valve **56** and depresses the sleeve valve in opposition to the spring **60**. The downward displacement of the sleeve valve **56** opens the lower bypass port **55** to cause a pressure drop in the drilling fluid that may be readily detected at the top of the well.

It is to be understood that normally both of the bypass ports **54** and **55** are closed with all of the drilling fluid delivered to the bit. It is contemplated that the bypass

ports will be open only briefly to produce signals by dropping the pressure of the down flowing drilling fluid.

In the operation of the second embodiment of the invention, the drilling of an increment of the borehole is continued until the normal pressure is terminated by the uncovering of the upper bypass port 54 by the tubular extension 52 which produces a signal by dropping the pressure of the drilling fluid. The driller lowers the drilling string with the result that the upper bypass port 54 is covered to restore the pressure and the driller continues to lower the drilling string until the pressure is again dropped by opening of the lower bypass port 55. The driller then backs up the drill string to close the lower bypass port 55, thereby restoring normal drilling pressure. With normal pressure plateau reestablished, drilling is resumed until the pressure is again dropped by the tubular extension 52 uncovering the upper bypass port 54. Then the drill string is lowered by an appropriate increment for continued drilling.

The third embodiment of the invention comprising a signaling bumper sub assembly, generally designated 63, shown in FIGS. 5 and 6, is also largely similar in construction to the first embodiment as indicated by the use of corresponding numerals to indicate corresponding parts. The third embodiment differs from the first embodiment in the substitution of a signal-generating section 64 for the signal-generating section 24 and the substitution of a choke head assembly, generally designated 65, for the rod 40 and choke head 38 of the first embodiment.

The signal-generating section 64 has an upper yieldingly retractable choke ring 35*a* of the previously described construction shown in FIG. 1*a* and a pair of closely spaced lower fixed choke rings 68 and 70. The choke head assembly 65 for cooperating with the choke rings 35*a*, 68 and 70 is supported by a rod 72 that is suspended from the lower end of the wash pipe 34 by an apertured fitting or spider 74. An upper choke head 75 is fixedly mounted on the rod 72 at an upper level. At a lower level, the rod 72 carries a cylindrical casing 76 and a plunger 78 carrying a lower choke head 80 extends downward from the lower end of the casing. For sealing purposes, a suitable O-ring 81 carried by the cylindrical casing 76 slidingly embraces the plunger 78.

As shown in FIG. 6, a long coil spring 84 inside the casing 76 exerts upward pressure on a piston 85 on the upper end of the plunger 78 to hold the plunger in its normal upwardly retracted position. The piston is provided with a dashpot passage 86 having a series of orifices 88 and the piston is further provided with a fluid passage 90 in parallel with the dashpot passage. Flow through the fluid passage 90 is controlled by a check valve comprising a ball 92 and an upper valve seat 94, the check valve serving to prevent downward flow through the fluid passage while freely permitting upward flow.

The interior of the casing 76 is filled with hydraulic fluid such as a suitable oil. The plunger 78 is tubular and is provided with a port 95 in communication with the interior of the casing 76. The tubular plunger contains a floating piston 96 that is embraced by a suitable O-ring 98, the purpose of the floating piston being to equalize the pressure of the instrument oil in the casing 76 with the drilling fluid in the drill string and to accommodate thermal expansion and contraction of the instrument.

When the signaling bumper sub assembly 63 is at its fully extended position shown in FIG. 5, the upper choke head 75 is spaced above the upper choke ring 66 and the casing 76 and the lower choke head 80 are positioned substantially above the two lower choke rings 68 and 70. When the drill string touches bottom and the lowering of the drill string continues, the upper choke head 75 approaches the upper choke ring 35*a* and the choke ring retracts with consequent prolongation of the pressure signal. As the signaling bumper sub assembly continues to contract the lower choke head 80 approaches the lower pair of fixed choke rings 68 and 70.

When the choke head 80 enters the choke ring 68 and thereby raises the pressure of the drill fluid stream by restricting the stream, the dynamic pressure of the accelerated drill stream against the upper end of the choke head 80 causes the choke head to pull the plunger 78 downward in opposition to the coil spring 84. When the plunger 78 is forced downward in this manner the ball valve 92 in the piston 85 closes against the seat 94 to confine the fluid flow through the piston to the dashpot passage 86. The dashpot passage with its orifices 88 retards the downward movement of the plunger 78 and the choke head 80 to a predetermined rate which spaces apart in predetermined manner the two signals produced by the passage of the choke head 80 through the two choke rings 68 and 70. The apparatus is preferably adjusted to cause the creation of two unmistakable sharp pressure pulses by the passage of the pressure head 80 through the two closely spaced choke rings 68 and 70.

When the signalling bumper head assembly 63 is subsequently extended by the drilling operation the choke head 80 is withdrawn upward through the two choke rings 68 and 70 to produce two somewhat prolonged signal pulses and then the spring 84 retracts the plunger 78 to its normal position. As the signaling bumper sub assembly continues to extend, the upper choke head 75 eventually passes upward through the upper yielding choke ring 35*a* to produce a single sharp signal pulse that indicates the approach of the two telescoping sections to their fully extended positions.

The advantage of the arrangement shown in FIG. 5 is in the character of signals that are produced once the signaling bumper sub assembly is partially extended to place both choke heads 75 and 80 in the range between the upper yielding choke ring 35*a* and the lower pair of fixed choke rings 68 and 70. Thereafter, a single unmistakable sharp pressure pulse signals approach of the assembly to full extension and an unmistakable pair of closely spaced sharp pressure pulses signals approach of the assembly to full contraction. The two kinds of signals for the two limits give the driller unmistakable guidance for governing the lowering of the drill string.

FIG. 7 shows in a simplified manner how a series of signaling bumper sub assemblies may be incorporated into a drill string to make it possible for the driller to vary the weight on the drill bit by increments at will without pulling the drill string from the well bore. The drill bit 25 is mounted on the lower end of the usual drill collar 26 and the drill collar 26 is connected to the lower end of a signaling bumper sub assembly 100 which is the signaling bumper sub assembly shown in FIG. 1 but modified as shown in FIGS. 1*a* and 1*b*. Immediately above the signaling bumper sub assembly is a second drill collar 102 which is connected to the lower end of a second signaling bumper sub assembly 63 which is the signaling bumper sub assembly shown in FIG. 5. Immediately above the signaling bumper sub assembly 63 is a third drill collar 105 which is connected to the lower end of a third signaling bumper sub 106. The third bumper sub 106 is of the same construction as the signaling bumper sub shown in FIG. 5, but differs in having three lower choke rings instead of two.

When the drill string shown in FIG. 7 is lowered into the well bore and before the drill bit touches bottom, the entire drill string is in tension with the total weight carried at the top of the well. When the drill bit touches bottom and then the upper end of the drill string is lowered further by a few inches, the weight of the drill string below the first signaling bumper sub assembly 100 comes to rest on the bottom of the borehole and the first signaling bumper sub assembly 100 partially collapses. Thus a minor portion of the total weight of the drill string is imposed on the drill bit with the major portion carried at the top of the well.

The second signaling bumper sub assembly 63 does not collapse because it carries the weight of the second drill

collar **102** as well as the weight of the upper of the two relatively movable parts of the first signaling bumper sub assembly **100**. The third signaling bumper sub assembly **106** does not collapse because it carries the weight of the third drill collar **105** plus the weight of the second signaling bumper sub assembly **63** plus the weight of the second drill collar **102** plus the weight of the upper of the two relatively movable parts **100** of the first signaling bumper sub assembly **100**.

When the upper end of the drill string is lowered until the first signaling bumper sub assembly **100** is completely collapsed and the upper end of the drill string is then lowered an additional few inches, the second signaling bumper sub assembly **63** partially collapses to increase the weight on the drill bit. At this time all of the weight below the upper of the two relatively movable parts of the second signaling bumper sub assembly **63** is on the drill bit and all of the weight above the lower of the two relatively movable parts of the second signaling bumper sub assembly is suspended from the top of the well.

Further lowering of the drill string to the point of partial collapse of the third signaling bumper sub assembly **106** increases the weight on the drill bit to include all of the parts below the third signaling bumper sub assembly, including the two signaling bumper sub assemblies **63** and **100** as well as the three drill collars **105**, **102** and **25**.

The value of the embodiment of the invention shown in FIG. 7 is, first, in the range of adjustment of the weight imposed on the drill bit and, second, in positive indication of the amount of imposed weight. The weights imposed by contraction of the different signaling bumper sub assemblies may be distinguished because approach to full contraction of the lower assembly **100** produces a single sharp pressure pulse, approach to full contraction of the intermediate assembly **63** produces a pair of sharp pressure pulses, and approach to full contraction of the upper assembly **106** produces a series of three closely spaced sharp pressure pulses.

FIG. 8 shows an automatic control system connected to the upper end of a drill string **108**. A pressure gauge **110** and a pressure transducer, generally designated **112**, are connected to the upper end of the drill string **108** in pressure communication with the drilling fluid that is pumped into the drill string.

The pressure transducer **112** has a diaphragm **114** which is exposed to the pressure of the drilling fluid and is backed by a heavy coil spring **115**. The diaphragm is connected to a slidable rod **116** which in turn is connected to the short arm **118** of a lever **120** that is mounted on a pivot **122**. The lever **120** is operatively connected to a potentiometer and for this purpose carries a brush or movable contact **124** which is adapted to traverse a potentiometer resistor **125** that is connected across a battery **126**. The brush or movable contact **124** is connected to a signal discriminator or sensor **128** of a type well known in the art. When the movable contact **124** is reciprocated by a pressure pulse in the stream of drilling fluid the potentiometer converts the pulse into a voltage pulse at the input of the signal discriminator **128**.

The drill string **108** is equipped with a signaling bumper sub assembly that is identical with the construction shown in FIG. 1 except that both of the two choke rings are increased in axial dimension. For example, the fixed upper choke ring may be of the extended length of the upper choke ring **35***b* in FIG. 10 and the fixed lower choke ring may be of the extended length of the lower choke ring **36***b* in FIG. 10.

It is apparent that with the choke head **38** at the intermediate position shown in FIG. 10, relative upward movement of the choke head into the upper choke ring **35***b* will produce a pressure signal of the character shown in FIG. 11, the rise in pressure being prolonged as long as the choke head is within the choke ring. In like manner, relative downward movement of the choke head into the lower choke ring **36***b* will produce a prolonged pressure rise of the character shown in FIG. 11.

When such a pressure rise occurs, the potentiometer in FIG. 8 sends a corresponding rising voltage signal to the signal discriminator **128** and the signal discriminator sends a command to a power transformer **132** which responds by actuating the brake **134**. The power transformer functions in the manner of a well known type of pushbutton switch which on successive actuations alternately opens and closes a circuit. Thus one command signal from the signal discriminator causes the power transformer to relax the hoist brake **134** for lowering the drill string and the next signal tightens the hoist brake to terminate the lowering movement of the drill string. In this manner the control system shown in FIG. 8 automatically keeps the signaling bumper sub assembly partially collapsed for constant imposition on the drill bit of the weight of the portion of the drill string below the telescoping joint in the bumper sub assembly. Thus the leading shoulder **135** of the pressure signal shown in FIG. 11 is produced by the entrance of the choke head into a choke ring and the trailing shoulder **136** is produced by the subsequent reversal of the relative movement of the choke head and the consequent withdrawal of the choke head from the choke ring.

It is apparent that in the automatic system illustrated by FIGS. 8 and 10, that the choke head **38** and the two choke rings **35***b* and **36***b* constitute two cooperative means on two sections respectively of the drill string to vary the flow of the fluid as the two sections approach both full contraction and full extension thereby to create pressure changes in the fluid to serve as two signals indicative of the two limits respectively of the range of movement of the two sections.

The principles of the invention may be incorporated in an arrangement to indicate the degree to which the telescoping parts of a drill string are collapsed. FIG. 12 for example, shows a structure which is identical with structure shown in FIG. 1 with a series of equally spaced choke rings **141–144** substituted for the two widely spaced choke rings of FIG. 1. The range of collapse of the signal-generating section **24***a* relative to the corresponding bumper sub body (not shown) is divided into equal parts and the choke rings **141—144** are spaced accordingly. By simply counting the pressure signals that are created by progressive extension or progressive contraction of the signaling bumper sub assembly the operator may be continually informed of the various stages of collapse of the assembly.

The principles of the invention may be applied to many other situations where a fluid stream is available for signaling purposes and it is desirable to measure a short distance. For example, FIGS. 13 and 14 show a string of tubing **150** being lowered from a barge (not shown) into the ocean to make a screw-thread connection with the upper open end of casing **152** near the ocean floor. The problem is to ascertain when the lowering tubing **150** approaches the casing **152** and then to lower the tubing gradually and carefully until the tubing actually touches the casing and can be rotated into threaded engagement with the casing.

The lowest section of the string of tubing **150** is provided with a series of equally spaced choke rings **154** for cooperation with a choke head **155** on a feeler rod **156**. The feeler rod slidingly extends through a spider **158** that serves as a stop to engage the choke head **155** as shown in FIG. 13 and thus suspend the feeler rod when the string of tubing **150** is initially lowered. The spider **158** may be a piece of stiff ⅛ inch wire of the configuration shown in FIG. 15.

The lower end of the feeler rod **156** is provided with a spring wire fork **160** to keep the feeler rod from entering the casing **152**. The upper end of the feeler rod **156** is formed with a fishing spear **164**.

When the tubing string **150** is being initially lowered with the feeler rod **156** fully extended as shown in FIG. 13, water is continuously pumped downward through the tubing string to serve as a signaling medium. Consequently, any retraction of the feeler rod **156** causes the choke head **155** to pass through one or more of the choke rings **154** and the extent to which the feeler rod is contracted may be ascertained by counting the resulting pressure signals that are created in the stream of water.

With the lowering tubing string **150** aligned with the casing **152** the forked lower end of the feeler rod **156** eventually makes contact with the casing **152** and then continued lowering of the tubing string **150** causes the choke head **155** to move relatively upward through the successive choke rings **154**. The first pressure signal warns the operator to lower the tubing string **150** cautiously from that point and by counting the pressure signals the operator can ascertain just when the screw thread **165** on the lower end of the tubing string is about to make contact with the screw thread **166** of the casing **152**.

After the tubing string **150** is joined to the casing **152** a fishing tool may be lowered through the tubing string to engage the spear **164** for withdrawing the feeler rod **156** to the surface. The spring wire fork **160** readily contracts to pass through the choke rings **154**. The wire spider **158** may be withdrawn with the feeler rod or may drop harmlessly into the well.

My description in specific detail of the selected embodiments of the invention will suggest various changes, substitutions and other departures from my disclosure within the spirit and scope of the appended claims.

I claim:

1. In a drill string having a drill bit at its lower end and forminng a passage for the pumping of fluid therethrough to the bit to facilitate the drilling of a borehole, the combination of:

a pair of sections of the drill string interconnected by a telescoping joint for extension and contraction whereby the pair of sections may be collapsed to apply substantially all of the weight of the drill string on the bit or may be extended through a given range to limit the applied weight to the weight of the drill string below the telescoping joint while drilling proceeds through the range;

ring means at one point on one of the two sections restricting the fluid passage locally; and

a body carried by the other of the two sections to pass completely through the ring means in response to relative movement between the two sections thereby to choke the stream of the fluid temporarily to produce a pulse of pressure in the fluid, said ring means and body being located on the two sections to cooperate as on end of said range is approached.

2. In a drill string having a drill bit at its lower end and forming a passage for the pumping of fluid therethrough to the bit to facilitate the drilling of a borehole, the combination of:

a pair of sections of the drill string interconnected by a telescoping joint for extension and contraction whereby the pair of sections may be collapsed to apply the full weight of the drill string on the bit or may be extended through a given range to limit the applied weight to the weight below the telescoping joint while drilling proceeds through the range;

an annular restriction member in the fluid passage in one of the two telescoping sections;

a choke member carried by the other of the two sections to move into said restriction member in response to relative movement between the two sections to choke the stream of the fluid to produce a pressure signal in the fluid stream,

at least one of said two members being movably mounted for longitudinal movement in the direction of fluid flow in response to rise in the pressure of the stream of fluid and retraction in the opposite direction, said one member being biased to seek its retracted position in opposition to the normal pressure of the fluid stream whereby said one member is normally retracted, but as it approaches the other member, and thus partially restricts the fluid stream, it is accelerated towards the other member by the consequent pressure rise of the fluid stream thereby to cause a relatively sudden pressure rise.

3. In a drill string having a drill bit at its lower end and forming a passage for the pumping of fluid therethrough to the bit to facilitate the drilling of a borehole, the combination of:

a pair of sections of the drill string interconnected by a telescoping joint for extension and contraction whereby the pair of sections may be collapsed to apply the full weight of the drill string on the bit or may be extended through a given range to limit the applied weight to the weight below the telescoping joint while drilling proceeds through the range;

an annular restriction member in the fluid passage in one of the two telescoping sections;

a choke member carried by the other of the two sections to move into said restriction member in response to relative movement between the two sections to choke the stream of the fluid to produce a pressure signal in the fluid stream,

said choke member being mounted with freedom to move through a longitudinal range relative to the section on which it is mounted;

yielding means exerting force counter to the direction of fluid flow and normally overcoming the pressure of the fluid stream to hold the choke member at a retracted position,

said force being insufficient to overcome a rise in pressure of the fluid stream caused by restriction of the stream by the choke member in cooperation with the restriction member whereby relative approach of the choke member to close proximity to the restriction member causes acceleration of the choke member into the restriction member with a consequent steep rise in the fluid pressure.

4. A combination as set forth in claim **3** in which said longitudinal range exceeds the axial dimension of the restriction member whereby the choke member is accelerated clear through the restriction member with the consequent creation of a relatively short high amplitude pressure pulse in the fluid stream.

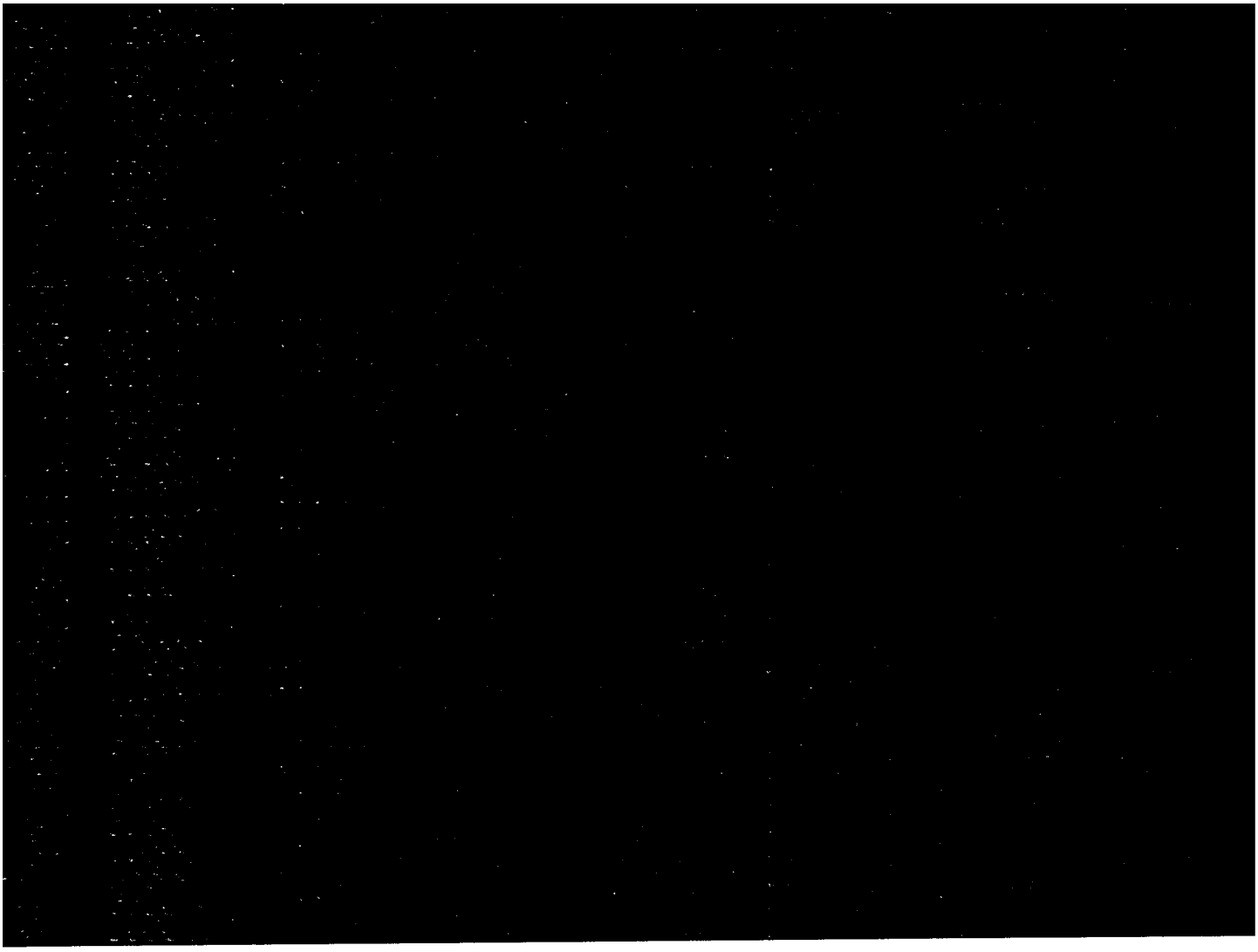
5. A combination as set forth in claim **3** in which said longitudinal range is less than the axial dimension of the restriction member whereby the choke member is accelerated into but not through the restriction member with consequent creation of a relatively sudden rise of the pressure in the fluid stream to a relatively high sustained level.

6. In a drill string having a drill bit at its lower end and forming a passage for the pumping of fluid therethrough to the bit to facilitate the drilling of a borehole, the combination of:

a pair of sections of the drill string interconnected by a telescoping joint for extension and contraction whereby the pair of sections may be collapsed to apply the full weight of the drill string on the bit or may be extended through a given range to limit the applied weight to the weight below the telescoping joint while drilling proceeds through the range;

an annular restriction member in the fluid passage in one of the two telescoping sections;

a choke member carried by the other of the two sections to move into said restriction member in response to relative movement between the two sections to choke the stream of the fluid to produce a pressure signal in the fluid stream,



said restriction member being mounted with freedom to move through a longitudinal range relative to the section on which it is mounted;

yielding means exerting force counter to the direction of fluid flow and normally overcoming the pressure of the fluid stream to hold the restriction member at a retracted position,

said force being insufficient to overcome a rise in the pressure of the stream caused by restriction of the stream whereby relative approach of the restriction member to close proximity to the choke member causes acceleration of the restriction member.

7. In a drill string having a drill bit at its lower end and forming a passage for the pumping of fluid therethrough to the bit to facilitate the drilling of a borehole, the combination of:

a pair of sections of the drill string interconnected by a telescoping joint for extension and contraction whereby the pair of sections may be collapsed to apply the full weight of the drill string on the bit or may be extended through a given range to limit the applied weight to the weight below the telescoping joint while drilling proceeds through the range;

an annular restriction member in the fluid passage in one of the two telescoping sections;

a choke member carried by the other of the two sections to move into said restriction member in response to relative movement betwen the two sections to choke the stream of fluid to produce a pressure signal in the fluid stream,

said choke member being mounted with freedom to move through a longitudinal range relative to the section on which it is mounted;

lapsed to apply the full weight of the drill string on the bit or may be extended through a given range to limit the applied weight to the weight below the telescoping joint while drilling proceeds through the range;

a pair of first means spaced apart on one of the two sections at positions corresponding to the two ends of the range; and

a second means carried by the other of the two sections to cooperate with said two spaced means to create pressure signals in the fluid stream as the two ends of the range are approached.

10. In a drill string having a drill bit at its lower end and forming a passage for the pumping of a fluid stream therethrough to the bit to facilitate the drilling of a borehole, the combination of:

a pair of sections of the drill string interconnected by a telescoping joint for extension and contraction whereby the pair of sections may be collapsed to apply the full weight of the drill string on the bit or may be extended through a given range to limit the applied weight to the weight below the telescoping joint while drilling proceeds through the range;

a plurality of first means spaced apart on one of the two sections longitudinally thereof;

a second means on the other of the two sections to cooperate wtih said plurality of first means to create pressure signals, said plurality of first means being close together to cooperate in producing a signal characterized by a plurality of successive pressure rises,

said second means being mounted with freedom to move through a longitudinal range exceeding the overall longitudinal dimension of the plurality of

means responsive to the other of said two signals to cease the lowering of the drill string to cause said pair to extend subsequently as the borehole is progressively deepened by the drilling operation, whereby the drill string may be lowered to cause a selected pair of sections to collapse and the two responsive means may then be effective to keep the selected pair contracted thereby to maintain a corresponding weight on the drill.

14. In a drill string having a drill bit at its lower end and forming a passage for the pumping of fluid therethrough to the bit to facilitate the drilling of a borehole, the combination of:

a pair of sections of the drill string interconnected by a telescoping joint for extension and contraction whereby the pair of sections may be collapsed to apply the full weight of the drill string on the bit or may be extended through a given range to limit the applied weight to the weight below the telescoping joint while drilling proceeds though the range;

means including a valve means on one of the two sections operative to bypass a portion of the fluid through the wall of the section to produce a signal by lowering the pressure of the fluid in the passage; and

means carried by the other section to operate said valve means in response to the relative movement of the two sections.

15. In a drill string having a drill bit at its lower end and forming a passage for the pumping of fluid therethrough to the bit to facilitate the drilling of a borehole, the combination of:

a pair of sections of the drill string interconnected by a telescoping joint for extension and contraction whereby the pair of sections may be collapsed to apply the full weight of the drill string on the bit or may be extended through a given range to limit the applied weight to the weight below the telescoping joint while drilling proceeds though the range;

two cooperative means on the two sections, respectively, of the pair to vary the flow of fluid as the pair of sections approach full contraction and full extension thereby to create pressure changes in the fluid to serve as two signals indicative of the two limits respectively of the range;

means responsive to one of said two signals to initiate lowering of the drill string to contract the pair of sections; and

means responsive to the other of said two signals to cease the lowering of the drill string to cause said pair to extend as the borehole is progressively deepened by the drilling operation.

16. In a drill string having a drill bit at its lower end and forming a passage for the pumping of fluid therethrough to the bit to facilitate the drilling of a borehole, the combination of:

a plurality of pairs of sections of the drill string in which the two sections of each pair are interconnected by telescoping joints for contraction and extension of the pair whereby the pairs may be contracted successively beginning with the lowermost pair by bottoming the drill string in the borehole and then continuing to lower the drill string, the weight on the bit being determined by the number of contracted pairs of sections; and

means to vary the pressure of the fluid in the drill string in response to contraction of each of the pairs to send signals to the top of the drill string to indicate the contraction of the pairs, said means comprising cooperating parts of the two sections respectively of each pair of sections exposed to the fluid in the drill string to variably restrict the stream of fluid in response to longitudinal movement of the two sections relative to each other.

17. A combination as set forth in claim 16 in which the means to vary the fluid pressure creates a different signal for each pair of sections to identify the individual pairs.

18. In a drill string forming a passage for the pumping of fluid through the drill string, the combination of:

a pair of sections of the drill string interconnected by a telescoping joint for extension and retraction through a given range of relative movement;

a plurality of first means on one of the two sections spaced apart longitudinally of the sections in accord with a plurality of subdivisions of said range;

and a second means carried by the other of the two sections to traverse the plurality of first means in said range of relative movement and to cooperate with the plurality of first means for choking action to create corresponding pressure signals in the fluid stream indicative of the different stages of relative movement between the two sections.

19. In a drill string having a drill bit at its lower end and forming a passage for the pumping of fluid therethrough to the bit to facilitate the drilling of a borehole, the combination of:

a series of pairs of drill string sections in the drill string with the sections of each pair interconnected by a telescoping joint whereby with the drill string bottomed in the borehole, the upper end of the drill string may be lowered to cause longitudinal contraction of the drill string by collapse of the pairs of sections in sequence with consequent progressive increase in the weight imposed on the drill bit;

two cooperative means on the two sections of the lowermost pair of sections responsive to collapse of the lowermost pair to signal initiation of the longitudinal contraction of the drill string;

and two cooperative means on the two sections of the uppermost pair of sections responsive to collapse of the uppermost pair of sections to signal approach to full contraction of the drill string.

20. In a structure forming a passage confining a fluid stream, the combination of:

two sections of the structure telescoped together for longitudinal movement relative to each other;

a restriction in the passage carried by one of the two sections;

a choke head carried by the other section and normally spaced from the restriction longitudinally of the passage;

means to sense a condition;

means responsive to said sensing means to cause longitudinal movement between the two sections thereby to cause relative movement of the restriction and the choke head towards each other to create a signaling pressure rise in the stream by progressively restricting the stream with progressive increase in the local velocity of the stream;

and means to accelerate the relative movement between the choke head and the restriction in response to the rise in velocity thereby to increase the rate of pressure rise.

21. In a drill string having a drill bit at its lower end and forming a passage for the pumping of a fluid stream therethrough to the bit to facilitate the drilling of a borehole, the combination of:

a pair of sections of the drill string interconnected by a telescoping joint for extension and contraction whereby the pair of sections may be collapsed to apply the full weight of the drill string on the bit or may be extended through a given range to limit the applied weight to the weight below the telescoping joint while drilling proceeds through the range;

a first means comprising at least one choke ring on one of the two sections;

a second means comprising a different number of closely spaced choke rings on said one of the two sections, said first and second means being spaced apart longi-

tudinally of said one section at positions corresponding to the two ends of the range; and

a choke body carried by the other of the two sections to enter the choke rings to create pressure rises in the fluid stream to indicate the two limits of the range and to distinguish between the two limits of the range.

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