May 14, 1968 E. M. GALLE 3,382,936

SHOCK ABSORBING AND STATIC LOAD SUPPORTING DRILL STRING APPARATUS

Filed March 28, 1966 5 Sheets-Sheet 1

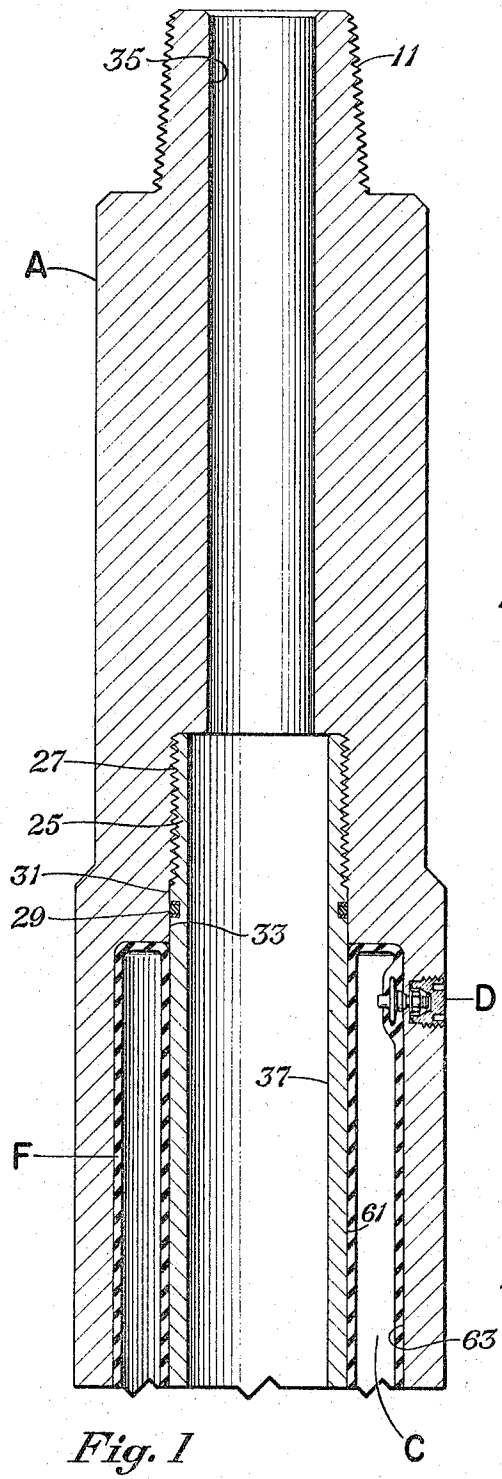


Fig. 1

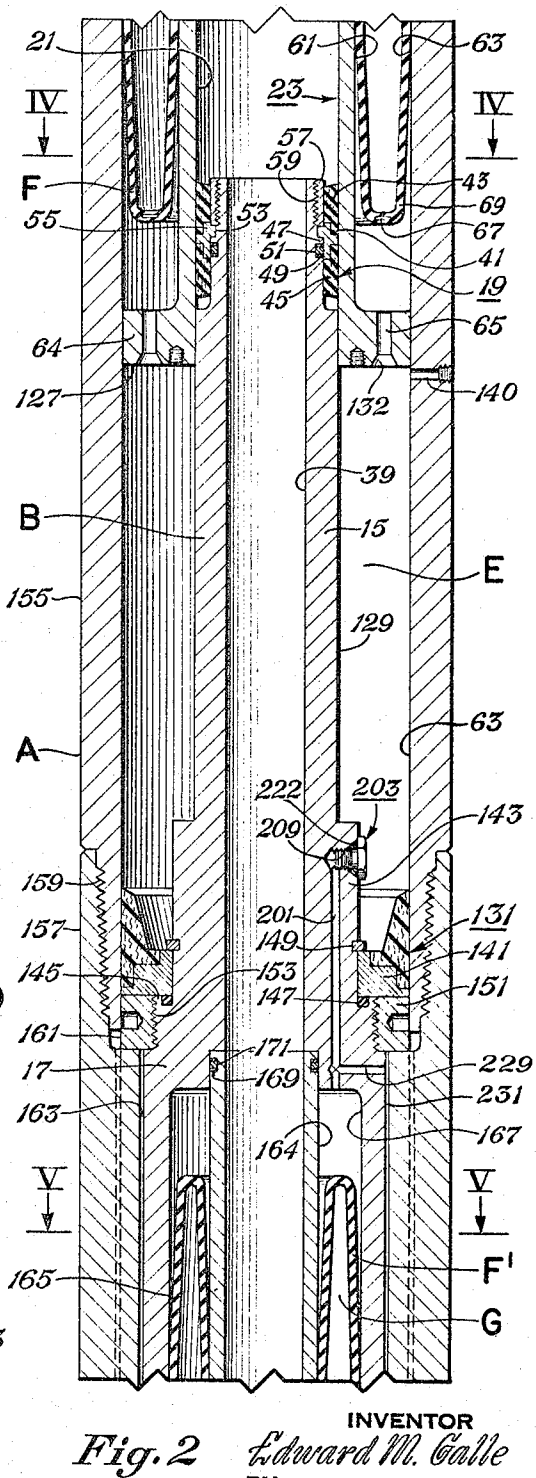


Fig. 2

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May 14, 1968 E. M. GALLE 3,382,936

SHOCK ABSORBING AND STATIC LOAD SUPPORTING DRILL STRING APPARATUS

Filed March 28, 1966 5 Sheets-Sheet 2

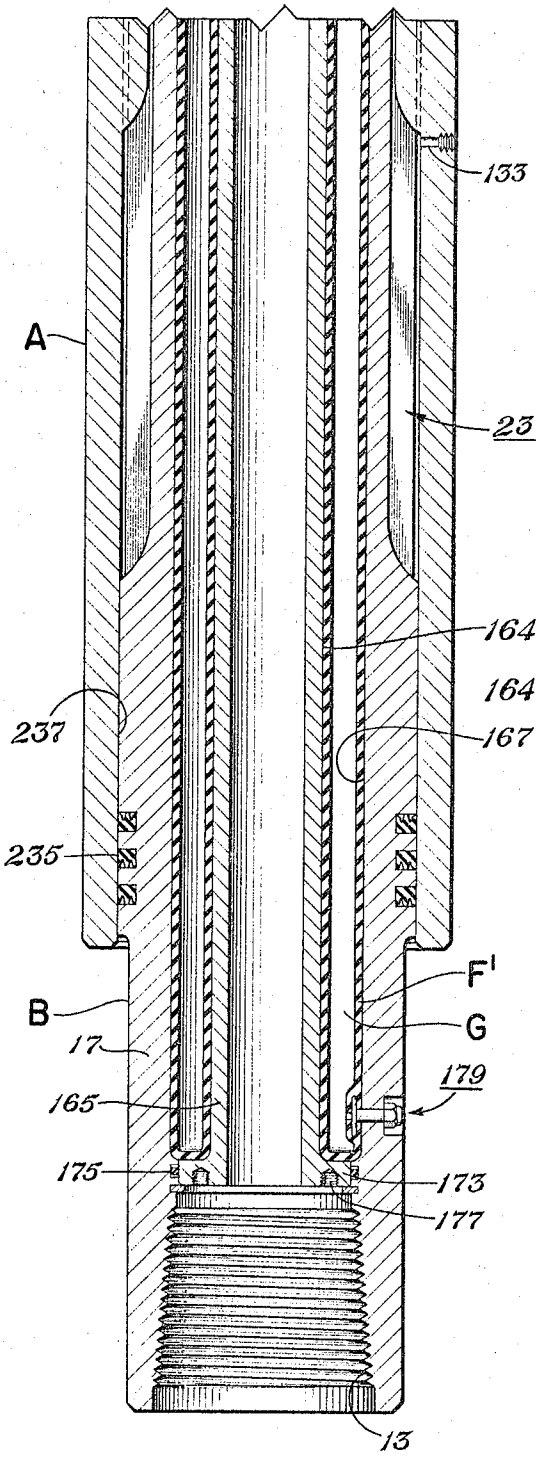


Fig. 3

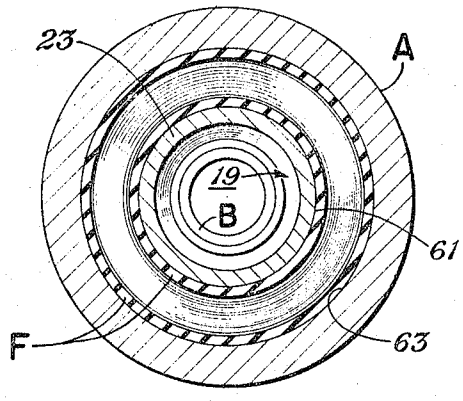


Fig. 4

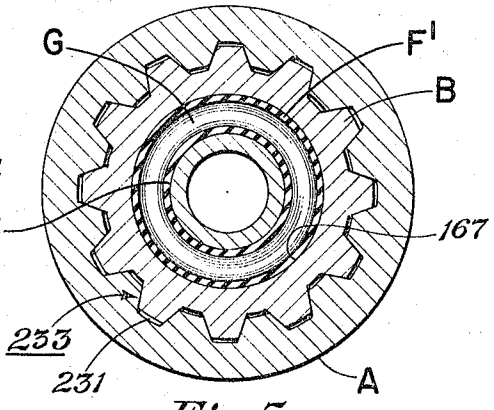


Fig. 5

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SHOCK ABSORBING AND STATIC LOAD SUPPORTING DRILL STRING APPARATUS

Filed March 28, 1966 5 Sheets-Sheet 3

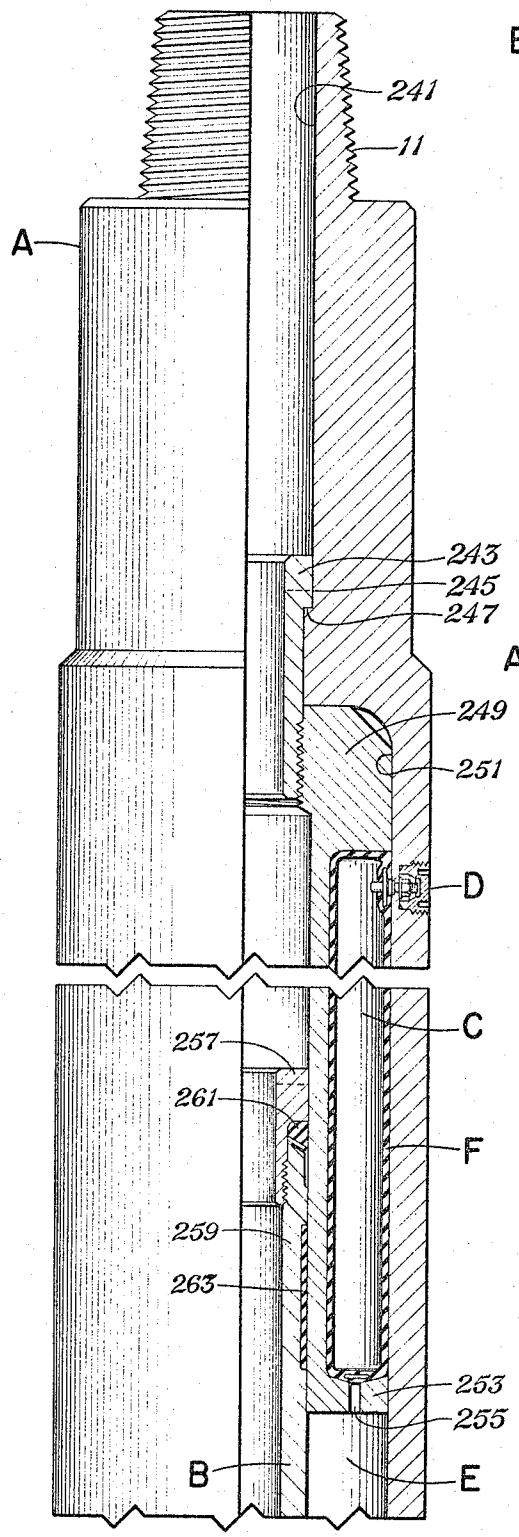


Fig. 6

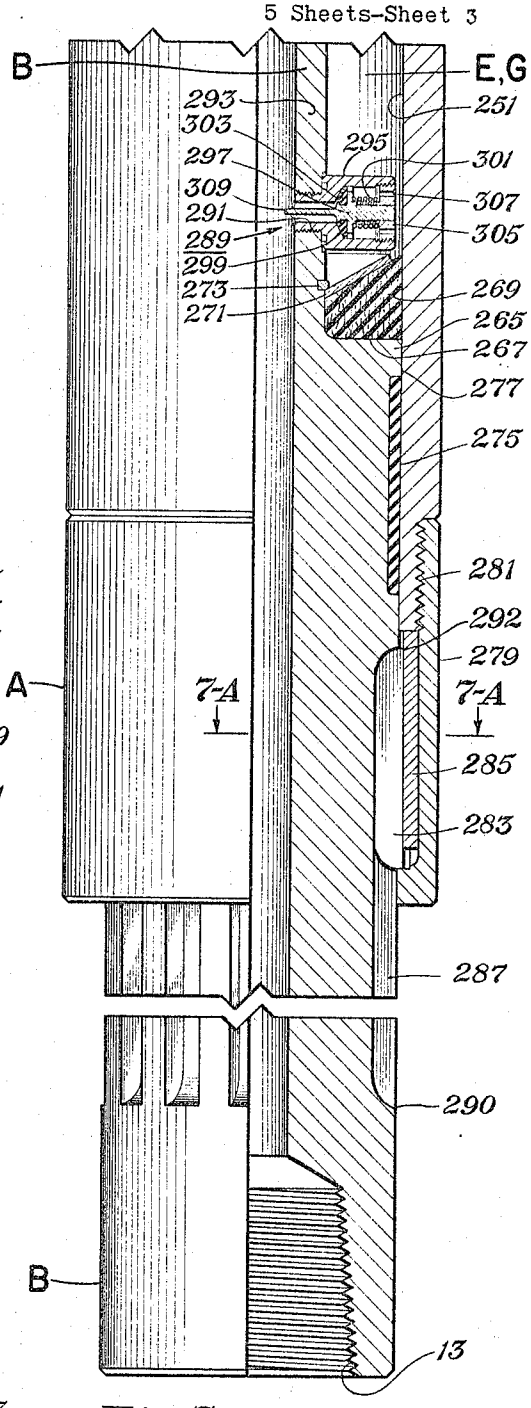


Fig. 7

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SHOCK ABSORBING AND STATIC LOAD SUPPORTING DRILL STRING APPARATUS

Filed March 28, 1966 5 Sheets-Sheet 4

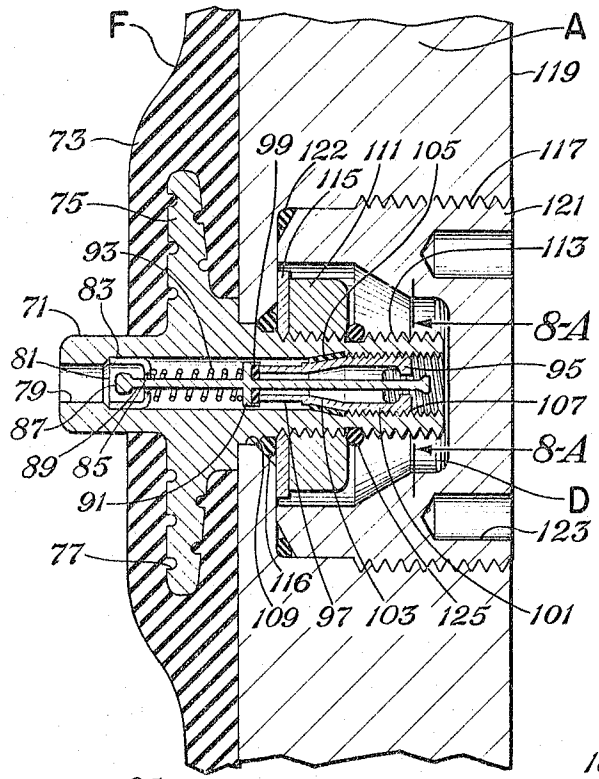


Fig. 8

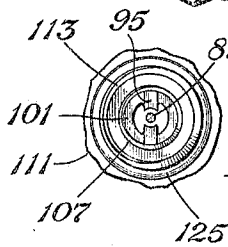


Fig. 8-A

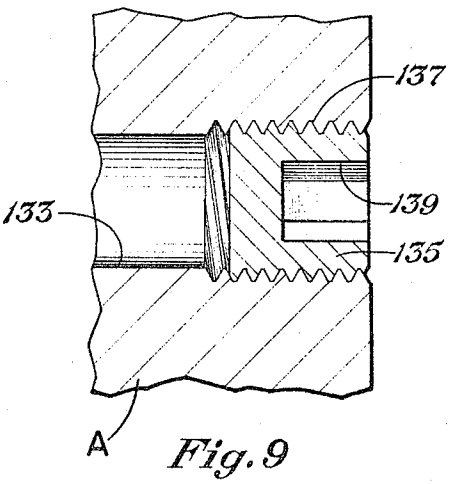


Fig. 9

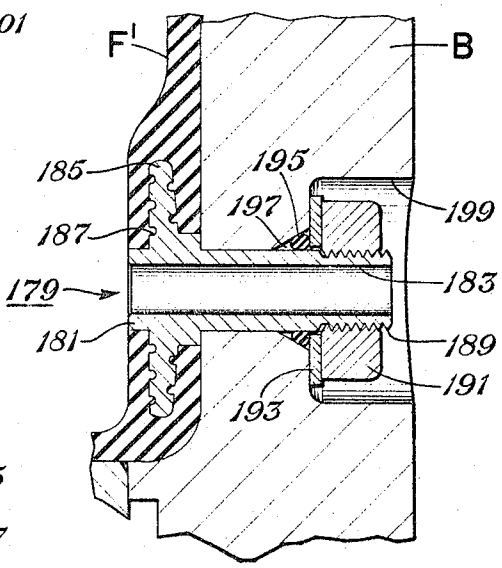


Fig. 11

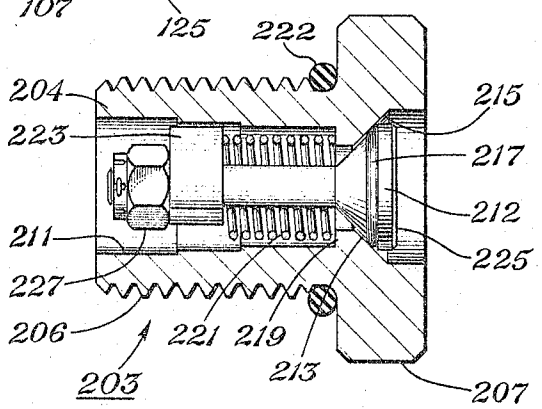


Fig. 10

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SHOCK ABSORBING AND STATIC LOAD SUPPORTING DRILL STRING APPARATUS

Filed March 28, 1966 5 Sheets-Sheet 5

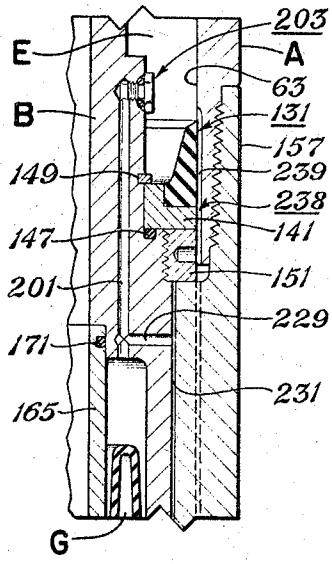


Fig. 5-A

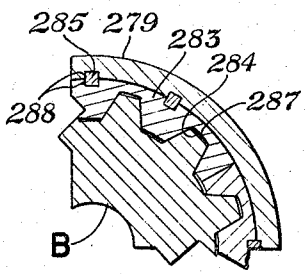


Fig. 7-A

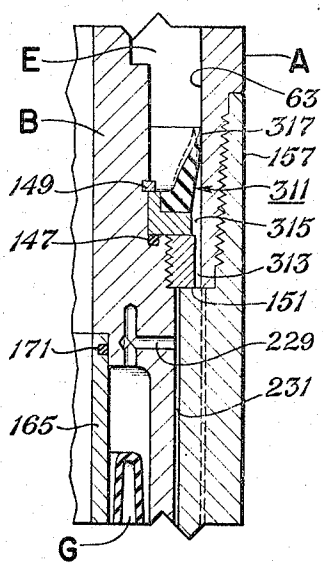


Fig. 12

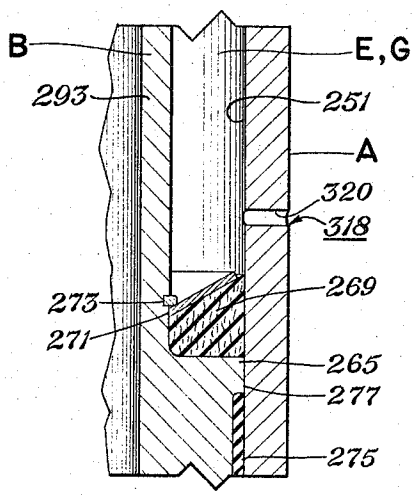


Fig. 13

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3,382,936

SHOCK ABSORBING AND STATIC LOAD SUPPORTING DRILL STRING APPARATUS

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Filed Mar. 28, 1966, Ser. No. 537,920
16 Claims. (Cl. 175—321)

My invention relates in general to rotary well drilling and in particular to apparatus for insertion into a drill string, for absorbing shock loading and for supporting the static loading existing in the drill string at the point of insertion of the apparatus therein.

Elastic vibrations are generated by the action of the drill bit on the bore hole bottom, and are transmitted through the drill string, with frequently detrimental results on many components of the drilling equipment.

Previously, apparatus has been developed for insertion into the drill string at a location immediately above the drill bit for the purpose of reducing elastic vibrations. One such unit, which succeeds in reducing elastic vibrations in the drill string, is now commercially available. It has disadvantages, however, which derive from its manner of construction, but principally from the fact that it utilizes the deformation of a solid elastic material, such as a synthetic rubber, to dampen or absorb elastic vibrations. While such devices perform satisfactorily in some circumstances, they have relatively high and invariable spring constants with disadvantageous results. That is, the spring constant of the apparatus is established upon manufacture and can only be satisfactorily changed by redesign of the apparatus, such as for example by replacing the elastic material with another material having different properties. Even so, the range of spring constants which can be effectively utilized with such devices is comparatively small.

Ideally, the spring constant of a drill string shock absorber should be relatively low and variable to enable satisfactory use of the device under a variety of drilling conditions. A shock absorbing apparatus using a gas would enable attainment of a low spring constant, a large static load carrying range, and the ability to more conveniently vary the spring constant, as well as other advantages. It is accordingly the general object of my invention to provide shock absorbing and static load supporting drill string apparatus that utilizes fluids in a manner to effectively obtain the above and other advantages.

One of the problems encountered when attempting to provide shock absorbing and static load supporting drill string apparatus that utilize gaseous fluids is the difficulty in sealing the fluids inside the apparatus. Gaseous fluids have a low viscosity which makes them difficult to effectively seal. Thus, another object of my invention is to provide shock absorbing and static load supporting drill string apparatus which will enable effective sealing of gaseous fluids in the apparatus.

In accomplishing the immediately preceding object, I developed a sealing system which utilizes liquid fluids to help solve the problem of sealing gases. Since there always exists the possibility of leakage of fluids (even liquids) past seals, I was faced with the problem of keeping the apparatus operative and effective in the event a quantity of liquid leaked past the seals. It is, therefore, another object of my invention to provide means for automatically replenishing the liquid which leaks past the seals of shock absorbing and static load supporting apparatus.

Also, it is advantageous to keep the pressure drop across seals as low as possible, and it is, therefore, another object of my invention to provide apparatus which will effect this result.

It also became apparent to me that to use gaseous fluids in a shock absorbing and static load supporting drill string apparatus, it would be necessary for the gaseous fluids to

be subjected to extremely high pressures to enable the apparatus to support the large loads normally imposed on drill bits and the drill strings. There are disadvantages and dangers which arise when using high pressure gases at the surface of earth drilling operations and thus it is another object of my invention to provide apparatus that automatically compresses the gas from a relatively low and safe value at the surface of the ground to a high working value as the apparatus is lowered in the well bore. It is another object of my invention to provide means for decompressing the gas when the apparatus is raised to the surface of the well. This is accomplished in a manner such that there are no detrimental results, such as loss of stroke of the apparatus. If the total available stroke of the apparatus were significantly decreased by compression of the fluids, it would be necessary to make the apparatus longer to compensate for the loss of stroke. As a result, manufacturing costs would increase and the problem of handling the apparatus might become complex.

The above and other objects are effected by my invention as will be apparent from the following description taken in accordance with the accompanying drawings, forming a part of this application, in which:

FIGS. 1, 2 and 3 are fragmentary side elevational views in longitudinal section which show a preferred embodiment of my shock absorbing and static load supporting drill string apparatus;

FIGS. 4 and 5 are cross sectional views as seen looking respectively along the lines IV—IV and V—V of FIG. 2;

FIG. 5–A is a fragmentary cross sectional view of a pressure relief means to relieve pressure inside the apparatus in certain circumstances;

FIGS. 6 and 7 are side elevational views, partially in section, which illustrate an alternate embodiment of my shock absorbing and static load supporting drill string apparatus;

FIG. 7–A is a fragmentary cross sectional view as seen looking along the lines 7–A of FIG. 7;

FIG. 8 is an enlarged fragmentary and longitudinal section view of valve means used to introduce a gaseous fluid into the apparatus, such valve means being shown also in FIGS. 1 and 6;

FIG. 8–A is a cross sectional view as seen looking along the lines 8–A of FIG. 8;

FIG. 9 is a cross sectional view of a seal plug used to prevent fluid flow into or from a part shown in FIG. 2;

FIG. 10 is a side elevational view, partially in section, of a fluid flow diode in the form of a check valve, which is also illustrated in FIG. 2;

FIG. 11 is a view in longitudinal section of fluid flow conduit means, which is also shown in FIG. 3;

FIG. 12 is a fragmentary cross sectional view of a modified form of apparatus; and

FIG. 13 is a fragmentary side elevation view in section illustrating an alternate embodiment.

A broad description

The various forms that my apparatus may take have a number of common and salient features. FIGS. 1, 2 and 3 are views of one form of apparatus, and FIGS. 6 and 7 are views of apparatus in another form. Each form has a tubular body A which carries a reciprocable piston member B which is adapted to rotate with body A when the drill string is rotated. The tubular body A in this instance has a gas cavity C formed therein and valve means D which communicates with the gas cavity to enable the introduction of gas into the cavity and pressurization thereof from an external source. The introduction of gas into the cavity and pressurization thereof may be effected at the surface of the well being drilled.

It is my purpose in providing the gas cavity for the piston member B to be supported by the pressurized gas.

But since gaseous fluids are relatively difficult to seal due to their low viscosity, I have provided a pressure transmitting liquid chamber E which communicates with the gas cavity and with the ambient drilling fluid (meaning the drilling fluid flowing upwardly around the exterior of the apparatus or that flowing downwardly through the apparatus). This feature of my invention provides a number of advantages, but of immediate and particular interest is the fact that liquid in chamber E may be sealed much easier than gases due to the relatively high viscosities of liquids when contrasted with gases.

To further facilitate sealing of the fluids, I use a movable and fluid responsive separation element F that prevents intermingling of the gas in gas cavity C with the liquid in pressure transmitting liquid chamber E, for if the gas and liquid become intermingled the gas will eventually contact the seals to once again create a sealing problem.

The pressure of the drilling fluid in the vicinity of the apparatus may be transmitted to the liquid in the pressure transmitting liquid chamber E and thus to the gas in gas cavity C. And, therefore, as the apparatus is lowered through the drilling fluid in the well bore, the increasing hydrostatic pressure continually compresses the gas without causing movement of the piston member B relative to tubular body A. This feature of my invention enables the provision of a much shorter apparatus than would be possible if the continuing gas compression resulted in shortening the stroke of the piston member.

Additional features and advantages of my invention will become apparent in the following detailed descriptions. Such features as automatic replenishment of liquids that leak past the seals will be explained, for example, as well as a system for balancing pressures inside the various regions of the apparatus to decrease pressure drop across the seals to minimize leakage. Also explained are means to enable automatic decompression of the gas when the apparatus is substantially fully extended, as when raising the apparatus from the well bore.

Description of the apparatus of FIGS. 1 through 5

Referring initially to FIG. 1, the numeral **11** designates a threaded pin connection, a common way to adapt the apparatus for attachment in a drill string. A threaded box connection **13** (see FIG. 3) is shown in the lower portion of the apparatus to receive a drill bit or other drill string member. As shown in FIGS. 2 and 3, tubular body A receives a reciprocable piston member B, which has a relatively small diameter upper region **15** and an enlarged lower region **17**. Upper region **15** has seal means **19** thereon to engage the cylindrical surface **21** of a sleeve **23** that is secured internally in the tubular body. The upper threaded end portion **25** of the sleeve **23** (see FIG. 1) is received by a mating threaded cylindrical portion **27** formed in an upper, internal region of tubular body A. Seal rings **29** are provided on the outer cylindrical surface **31** of the sleeve **23** to engage a mating interior cylindrical surface **33** formed inside body A to prevent the flow of fluid past the above described threads.

Cylindrical surface **35** formed inside the upper region of body A; cylindrical surface **37** formed inside sleeve **23**; and cylindrical surface **39** formed inside the piston member B together constitute an axial passage through which drilling fluid may flow toward the drill bit and the bottom of the bore hole.

A satisfactory form of previously mentioned seal means **19** is illustrated in FIG. 2. This particular seal means has an annular metal ring **41** with upper and lower resilient portions **43**, **45** bonded thereto. Annular ring **41** has a cylindrical surface **47** which engages a seal ring **49** positioned within a groove **51** formed on an exterior cylindrical surface of an upper portion of the piston member B. An annular, inwardly protruding shoulder **53** is formed on annular ring **41** and is received by a mating groove **55**, one portion of which is machined in the cylindrical surface **47** of the piston member and another portion of which is formed by one end of a cap **57** which is secured to the upper extremity of piston member B by suitable means such as threads **59**. Hence, the seal means **19** confines the downward flow of drilling fluid to the axial passage extending through the apparatus. The seal means **19** has been found to be a satisfactory reciprocable bidirectional seal and is of the type commonly used on mud pump piston.

There is an annular gap between the exterior cylindrical surface **61** of the sleeve **23** and the interior cylindrical surface **63** of tubular body A. This annular gap serves as the gas cavity C, and to complete the enclosure of this space, a radially extending flange **64** is formed on the lower region of the sleeve **23**. One or more apertures **65** are formed axially through flange **64** to connect gas cavity C with the pressure transmitting liquid chamber E.

To prevent the gas of gas cavity C (which will be introduced to the gas cavity in a subsequently described manner) from intermingling with the liquid in the pressure transmitting liquid chamber E, I provide the movable fluid responsive separation element F, which in this instance is a pliable, sealed and fluid impervious bag made preferably of a synthetic rubber. Valve means D is bonded to the bag to permit the introduction of gas therein and to enable pressurization of the gas to a selected degree. Thus, the valve means D enables the pressure in gas cavity C to be selectively varied. As shown in FIG. 2, the lower extremity of the pliable bag is narrower than the upper extremity so that liquid may easily flow therearound and collapse the bag when the liquid pressure exceeds the gas pressure.

The pliable bag forms an annular enclosure that fills the gap between the exterior cylindrical surface **61** of sleeve **23** and the interior cylindrical surface **63** of tubular body A, as may be seen in the cross sectional view designated FIG. 4. One or more metal plates **67** are bonded inside the pliable material of the bag to fortify its lowermost radially extending region **69** thereof (see FIG. 2) to prevent the extrusion of the pliable material through the aperture **65**.

The constructional details of a preferred valve means D used to introduce gas under pressure into the above-described pliable gas bag is shown in FIGS. 8 and 8–A. A valve body **71** is bonded to a portion of the pliable material (here rubber) **73** and a radially extending protrusion **75** extends from the body to provide a larger area for bonding. A plurality of annular grooves **77** are provided in the protrusion **75** to increase the effectiveness of the bond. An aperture **79** extends axially through valve body **71** and includes a beveled shoulder **81** that receives an anchor **83** having an aperture **85** therein. The anchor receives and confines an enlarged portion **87** of a valve stem **89** which has a radially extending portion **91** formed in its approximate midsection. A compression spring **93**, or rather one of its end portions, forcefully engages the anchor **83** and the radially extending portion **91** of the valve stem to urge the valve stem axially outward with respect to the longitudinal axis of tubular body A.

The valve stem extends through a valve core **95**, which has an inner portion **97** and an outer portion **101** joined thereto by a conical midsection **103** that engages a conical seal **105** and urges it against a mating conical region of valve body **71**. The components of the valve means cooperate to prevent the flow of gas outwardly through the valve means. The gas pressure inside gas cavity C and the action of the compression spring **93** urge the seal **99** into sealing engagement with the extremity of inner portion **97** of valve core **95**.

As is shown in FIG. 8–A, the outer region of the valve core **95** is shaped to receive a hand tool (not shown) which will permit the rotation of the valve core. The valve core is secured to valve body **71** by suitable means such as threads **107**, and thus rotation of the valve core en-

ables its removal or attachment to the valve body. The valve body itself is retained in an aperture **109** formed through the tubular body A by a nut **111** secured to threads **113** formed on the valve body **71**. A washer **115** is provided to present a radial surface that engages an O-ring **116** as shown in FIG. 8 for preventing fluid flow past valve body **95**. A cylindrical threaded counterbore **117** is formed in the exterior wall **119** of tubular body A to receive a plug **121** which covers and protects the otherwise exposed portions of the valve means, but which enables easy access thereto when it is necessary to introduce or exhaust gas from gas cavity C. An O-ring **122** prevents the flow of fluid between plug **121** and counterbore **117**. Tool grip indentations **123** are provided to make removal of the plug easier.

To introduce gas into gas cavity C, the plug **121** is removed and an adapter (not shown) is inserted over the threads **113** of the outer exposed region of the valve body **71**. An O-ring **125** is normally provided around the exterior of the exposed portion of the valve body **71** to be urged against the nut **111** to insure that gas does not leak from the adapter to the atmosphere but travels through the valve body. The high pressure of the gas coming from the adapter and mechanical depression of the valve stem **89** causes gas cavity C to be filled with gas. It is advantageous to use an inert gas such as argon or nitrogen so that there are no chemical reactions with any of the components of the valve means D or with the separation element F and to lessen the danger of downhole fires or explosions. To withdraw gas from the gas cavity C it is only necessary to mechanically depress the valve stem **89**.

The valve means D described above is an advantageous apparatus to use in combination with my shock absorbing and static load supporting apparatus and is similar to the conventional automobile tire valve. There are, however, a number of valve means which may be used to introduce gas into the gas cavity C and thus my invention is not limited to use with any particular form of valve means.

The uppermost surface of the pressure transmitting liquid chamber E of FIGS. 1 through 5 is defined by the radially extending lower surface **127** (see FIG. 2) of the flange **64** that protrudes radially outward from the sleeve **23**. The sidewalls of this chamber are defined by a cylindrical surface **129** formed on an upper portion of the piston member B and the previously mentioned interior cylindrical surface **63** of the tubular body A. The lower extremity of the chamber is defined by a seal means **131**. If the pressure transmitting liquid chamber E is filled with liquid, upward movements of piston member B will transmit fluid through the apertures **65** of flange **64** to the gas cavity C. The separation element F will prevent the intermingling of the gas and the liquid and simplify the problem of sealing the fluid inside the pressure transmitting liquid chamber E.

Satisfactory apertures **65** used in actual practice were ⅜ inch diameter holes and thirty of them were drilled through flange **64**. The beveled entrance **132** had an included angle of 60 degrees and a maximum diameter of ⅝ inch. The liquid used in pressure transmitting chamber E was an extreme pressure gear lubricant having a viscosity of 2500–3500 Saybolt Universal Viscosity Seconds at one hundred degrees F.

To introduce lubricant into the apparatus an aperture **133** is formed through the tubular body A and a pressure plug **135** (best seen in FIG. 9) is threaded as indicated by the numeral **137** to be received in a mating threaded portion of aperture **133**. An indentation **139** is formed in the pressure plug so that it may satisfactorily receive a tool such as an Allen head wrench to permit convenient insertion or removal of the pressure plug. A plugged vent hole **140** (like the arrangement in FIG. 9) is provided in an upper region of pressure transmitting chamber E so that air inside the apparatus may be expelled upon introduction of the lubricant. It is helpful to expand the lower flexible bag F with about fifty pounds of gas pressure so that less air will be trapped inside the apparatus upon introducing the lubricant into the apparatus.

As may be seen in FIG. 2, the seal means **131** has a metal core **141** which encircles a cylindrical portion **143** on piston member B, and a shoulder **145** is also formed on the piston member to limit the downward axial movement of metal core **141**. An O-ring groove on shoulder **145** receives an O-ring **147** to prevent the flow of fluid past shoulder **145**.

To prevent upward movement of the seal means **131** along cylindrical surface **143**, a snap ring **149** is provided within a suitable groove formed in the cylindrical surface. Moreover, a retainer ring **15** is secured to a threaded cylindrical portion **153** formed on piston member B. To assemble the seal means **131** on the piston member B a lower portion **157** of tubular body A is first assembled with the piston member B by inserting piston member B downward into the lower portion **157**. The retainer ring **151** is then screwed into the position shown in FIG. 2, and then the metal core **141** of the seal is slipped over the cylindrical surface **143** of the piston member, after first inserting O-ring **147** into groove **145**, and lowered to a position to enable snap ring **149** to be properly positioned. Upper and lower portions **155**, **157** (see FIG. 2) are secured to each other by means of the threads **159**. Since the outer surface **161** of the retainer ring **151** extends radially outward further than does the inner surface **163** of the lower portion **157** of the body member, the piston member has limited downward axial movement.

The apparatus described thus far would enable effective absorption of shock loading and would support static loads, but it would have significant disadvantages. One disadvantage would be that loss of stroke would occur as the apparatus was lowered into the well bore due to compression of the gas in gas cavity C caused by the increasing hydrostatic pressure in the well bore unless the initial gas pressure were equal to the hydrostatic pressure at the operating depth of the apparatus. Thus, only a small amount of lubricant leakage past seal means **131** could occur before the apparatus became inoperative. Even if seal means **131** does not leak, when operating the apparatus in extremely deep holes the stroke could be completely lost before reaching operating depth. While it is possible to supply gas at the surface of the well at a pressure sufficient to prevent said loss of stroke, it could be dangerous and certainly inconvenient to work with extremely high pressure gases at the surface of the well.

I, therefore, have provided means which will automatically compress the gas without loss of stroke while the apparatus is being lowered into the well bore, thus dispensing with the necessity for working with high pressure gases at the surface of the well. A much lower initial gas pressure is introduced into gas cavity C, with resulting convenience and safety. In the apparatus of FIGS. 1 through 5, a fluid reservoir G is formed in the lower region of piston member B. This reservoir is defined by the exterior cylindrical surface **164** of a hollow core **165** inside the piston member B and an interior cylindrical surface **167** also formed in the piston member B. The upper end of the core **165** is received by an annular groove **169** (see FIG. 2) formed at the approximate midsection of piston member B, and a seal **171** is provided at that region to prevent the flow of drilling fluid from the axial passage of the apparatus into the fluid reservoir G. The lowermost surface of the fluid reservoir G is defined, at least partially, by a radially extending shoulder **173** formed on the lower region of the core **165**. A seal **175** is inserted in a suitable groove in piston member B and urged against the exterior of shoulder **173** to prevent the flow of fluid between the fluid reservoir G and the axial passage of the apparatus, and a plurality of threaded apertures **177** are provided

on a downwardly facing portion of the radial shoulder **173** to enable the insertion therein of a tool to facilitate the removal of core **165**.

As may be seen in FIG. 3, fluid flow conduit means **179** are provided on the lower region of piston member B to provide communication between the fluid reservoir G and the ambient drilling fluid. The constructional details of a satisfactory fluid flow conduit means **179** are shown in FIG. 11. First, it should be noticed that a separation element F', which in this instance is a flexible and fluid impervious bag made of material such as synthetic rubber, is inserted into the fluid reservoir G. Its purpose is to separate the pressure transmitting liquid in this reservoir from the drilling fluid.

Referring again to FIG. 11, the fluid flow conduit means **179** has a body portion **181** that is bonded to the rubber of the separation element F'. The body has an aperture **183** extending therethrough to communicate with the exterior of piston member B so that the ambient drilling fluid may enter or leave the drilling fluid reservoir G. To facilitate the above-mentioned bonding, body portion **181** has a radially extending protrusion **185** with a plurality of annular grooves **187** therein. The outermost extremity **189** of the body portion **181** is threaded to receive a nut **191** along with a washer **193**. A suitable seal ring **195** is urged by the washer **193** and the cylindrical surface **197** of body portion **181** against a portion of the aperture formed through piston member B to prevent the leakage of fluid around the exterior of body portion **181**. A counterbore **199** is formed in the piston member B to receive the nut **191** and washer **193** so that none of the fluid flow conduit means **179** extends past the outer diameter of the piston member.

Thus, ambient drilling fluid may enter the fluid reservoir G through the fluid flow conduit means **179** and consequently, the fluid pressure of the ambient drilling fluid in the annulus of the well bore will be transmitted to the fluid inside the fluid reservoir G.

As may be seen in FIG. 2, a fluid passage **201** connects the fluid reservoir G with the pressure transmitting liquid chamber E so that the fluid pressures therein will be equalized and transmitted to the gas cavity C. The fluid in this instance should be permitted to flow only from the drilling fluid reservoir G to the pressure transmitting liquid chamber E and not be reversible. I, therefore, provide a fluid flow diode **203** in the fluid passage **201** to effect this result. The diode in this instance is a check valve, a preferred construction of which may be seen in FIG. 10. The check valve has a body **204** including a cylindrical portion **206** with threads on its exterior and a radially extending flange portion **207** in the form of a nut so that the check valve may be easily removed from the threaded aperture **209** (see FIG. 2) of the piston member B. A fluid flow passage **211** is formed axially through body **204**. A valve element **212** is inserted in the fluid flow passage **211**, said valve having a conical outer portion **213** that engages the conical counterbore **215** formed in body **204**. A seal ring **217** disposed in a suitable groove in conical portion **213** prevents the flow of fluid past the conical surfaces. A shoulder **219** is formed in the body and receives one end portion of a compression spring **221**. The opposite end of the compression spring engages an enlarged piece **223** assembled on the valve element, and thus the seal **217** is urged against the conical surface **215** formed inside the body **204**. Moreover, the fluid pressure inside pressure transmitting liquid chamber E, acting against the face **225** of the valve element **212** urges the seal **217** against conical surface **215** to further seal the fluid. A suitable fastener means such as a nut **227** retains enlarged piece **223**, and the compression spring **221** on valve element **212**. Therefore, when the fluid pressure inside the fluid passage **201** is sufficient to overcome the strength of compression spring **221**, fluid will flow from the drilling fluid reservoir G into the pressure transmitting liquid chamber E. Since the strength of the compression spring **221** is small, any appreciable increase in the pressure of the fluid in drilling fluid reservoir G is transmitted into the fluid inside the pressure transmitting liquid chamber. A seal **222** is placed around cylindrical portion **206** of body **204** to prevent, when assembled in the apparatus, fluid flow around the exterior of the check valve.

Referring again to FIG. 2, notice that a radially extending fluid flow passage **229** is formed in the piston member B to extend to the gap **231** between the piston member and the tubular body A. This passage is just below the seal means **131** and communicates with the previously described fluid passage **201** which extends between the fluid reservoir G and the pressure transmitting liquid chamber E. Thus, any fluid that leaks past the seal means **131** enters the fluid flow passages **229** and **201**, thereby providing a system for automatically storing any fluid that leaks past the seal means **131** in fluid reservoir G. When the apparatus is raised, the piston member, due to its own weight and the weight of the drill string members below it, causes downward movement of the piston member and a reduction of the pressure in the pressure transmitting liquid chamber E below the pressure inside fluid reservoir G. This causes fluid to flow from fluid reservoir G past the fluid flow diode **203** into the pressure transmitting liquid chamber E until piston member B reaches its lowermost position, thus replenishing lubricant that leaked past seal means **131**. This prevents loss of stroke of the piston member due to fluid leakage past the seals.

As is shown in FIG. 5, a splined connection **233** is formed between the lower extremity of the piston member B and the tubular body A so that rotation of the drill string and tubular body A rotates the piston member B, but at the same time permits axial movements of the piston member B relative to the body A. A plurality of seal rings **235** are provided on a lower region of the piston member B to engage a cylindrical surface **237** also formed on the lower portion of tubular body A. These seal rings prevent the flow of fluid from the fluid reservoir G to the exterior of the apparatus past the splined connection **233**.

FIG. 5–A illustrates pressure relief means **238** used to decompress the gas in gas cavity C upon withdrawal of the apparatus from the well bore. The pressure relief means shown in FIG. 5–A includes one or more grooves **239** formed axially along the interior surface **63** of tubular body A. These grooves are in the vicinity of seal means **131** when the piston member B is in its lowermost position and are slightly longer than the axial length of the seal means. Their manner of operation will become apparent in the following operational description.

Operation and advantages of the apparatus of FIGS. 1 through 5

The threaded pin connection **11** shown at the upper extremity of the FIG. 1 apparatus is secured to a drill string member after assembling the piston member B and the other components of the apparatus as previously described. A gaseous fluid is introduced under pressure through valve means D until the desired pressure is reached in gas cavity C. Then, a liquid such as lubricating fluid, which is selected for its compatibility with the components of the apparatus, is inserted into the apparatus, through the aperture **133** (see FIG. 3) to fill chambers E and G. A drill bit may be connected with box connection **13** shown on the lower portion of the apparatus (see FIG. 3) to prepare it for lowering into the well bore.

As the apparatus is lowered in the well bore, the hydrostatic pressure gradually increases in the vicinity of the apparatus. When the hydrostatic pressure becomes greater than the pressure in gas cavity C, drilling fluid enters fluid reservoir G to equalize the pressure of the fluids in the apparatus with the hydrostatic pressure. When the apparatus is compressed axially, diode **203** and seal means **131**, **19** prevent escape of fluids from pressure transmitting

liquid chamber E and gas cavity C, enabling the fluid to support axial loads.

When the drill string is raised through the well bore, the decreasing hydrostatic pressure at the shallower depths decreases the pressure inside fluid reservoir G, with resulting decreases in the pressure inside pressure transmitting liquid chamber E and gas cavity C due to the provision of pressure relief means **238**. The pressure inside pressure transmitting liquid chamber E will always be essentially the same as the hydrostatic pressure surrounding the apparatus. When the apparatus reaches the surface of the well bore, the pressure of the gas in gas cavity C is essentially the same as it was when the apparatus was initially introduced to the well bore. Therefore, the gas pressure returns to a safe level.

In the above operational description, assume that the pressure inside gas cavity C is established at about 1,000 p.s.i. at the surface of the well. As the apparatus is lowered into the well bore, the pressure in the annulus is transmitted to the fluid reservoir G; to the pressure transmitting liquid chamber E; and to the gas cavity C as previously explained. When the fluid pressure inside pressure transmitting liquid chamber E becomes slightly greater than the pressure inside gas cavity C, liquid flows into the gas cavity through apertures **65**. Simultaneously, drilling fluid flows into the fluid reservoir G, thus making the pressure in the gas cavity C equal to the pressure inside pressure transmitting liquid chamber E and also equal to the pressure inside the fluid reservoir G, which is the same as the hydrostatic pressure of the fluid in the well bore in the vicinity of the apparatus.

Liquid will continue to flow through aperture **65** into gas cavity C as the hydrostatic pressure of the fluid in the well bore increases until finally the bottom of the well bore is reached. When the weight of the drill string is applied to the drill bit, the liquid trapped in the pressure transmitting liquid chamber E is forced into the gas cavity C by upward movement of the piston member B. The upward force exerted by the bottom of the hole on the drill bit is counteracted by a force equal to the pressure differential between the pressure in the pressure transmitting liquid chamber E and the pressure of the drilling fluid in the well bore multiplied by the annular effective area of the upwardly facing portion of the piston member B. Suppose, for example, that the pressure of the drilling fluid in the well bore is 4,000 p.s.i. and the pressure in the pressure transmitting liquid chamber E is 5,000 p.s.i. If the effective annular area of the piston member B is approximately 40 square inches, then the apparatus would support about 40,000 pounds of static load.

When the circulation pump (not shown) at the surface of the well is turned on, additional static load carrying capacity is generated due to the pressure differential across the bit acting on the effective upwardly facing area defined by the cylindrical surface or bore **21**. If there is a 1,000 p.s.i. pressure drop across the drill bit and if the area of bore **21** were approximately 12 square inches, then 12,000 pounds of additional load carrying capacity would be generated.

It can be expected that under typical operating conditions the pressure inside pressure transmitting liquid chamber E will be approximately 1,500 p.s.i. greater than the hydrostatic pressure in the vicinity of the apparatus. The pressure drop across the drill bit will be approximately 1,000 p.s.i. and therefore, the pressure differential across the seal **19** at the upper extremity of the piston member B will be about 500 p.s.i., thus minimizing the danger of leakage of liquid past the seal **131** into or from the pressure transmitting liquid chamber E.

Since the pressure in the fluid reservoir G and the pressure of the drilling fluid on the exterior of the apparatus are substantially equal, there is little likelihood of leakage past the seal rings **235** (see FIG. 3) at the lower region of the piston member B. This feature of my apparatus also helps minimize loss of liquid from the apparatus and simplifies the sealing problem.

Seal means **131** (see FIG. 2) is the only seal that separates fluids having a high pressure differential, but any leakage of fluid past this seal from the pressure transmitting liquid chamber E returns to the fluid passages **229** and **201** as previously explained. If at any time the static load is removed from the drill bit, liquid will be urged by the resulting pressure differential past the fluid flow diode **203**, thus returning fluid to the pressure transmitting chamber E. Seal means **131** is in an environment of clean lubricating fluid, a feature which is also advantageous for promoting long seal life.

The apparatus illustrated in FIGS. 1 through 5 has a number of significant advantages, as may be seen from the above description. One of the most salient features of the invention is that the use of the gas in the apparatus results in an extremely low spring constant, which is a distinct advantage with respect to absorbing shocks. The use of the pressure transmitting liquid chamber in combination with a gas cavity greatly simplifies the problem of sealing, since the liquids have a relatively high viscosity. The communication of the liquid in the pressure transmitting liquid chamber E and the gas in the gas cavity C with the pressure of the drilling fluid in the well bore through the drilling fluid reservoir G in the manner previously described enables the continual compression of the gas with increasing depth in a manner such that no loss of stroke of the tool occurs. This enables the provision of a tool that is much shorter than would be possible if the compression of the gas were effected in a manner such that loss of the stroke of the tool occurred. Moreover, the automatic replenishment of the liquid that may leak from the pressure transmitting liquid chamber past its seal means, also prevents loss of stroke and makes the use of this apparatus advantageous. Moreover, the use of the movable separation element F prevents the interminging of the gas and the liquid in the apparatus to further simplify the sealing problem since it is now essential only to provide seals that are effective in the presence of a liquid. The balancing of the pressures inside the apparatus with the pressures of the drilling fluid inside and outside the apparatus decreases the pressure differential across the various seals to further simplify the sealing problem. Finally, my decompression means prevents excessively high pressure from being trapped in the apparatus when the apparatus is withdrawn from the well bore. This enables the apparatus to be used in successive well bores of differing depths without manual decompression of the gas.

The apparatus of FIGS. 6 through 7

A modified form of shock absorbing and static load supporting apparatus is shown in FIGS. 6 and 7. This apparatus has a tubular body A, piston member B, gas cavity C, valve means D, and pressure transmitting liquid chamber E. It may also utilize the separation element F. But it does not have a separate fluid reservoir G as does the apparatus of FIGS. 1 through 5. Rather, its pressure transmitting liquid chamber E also serves as the fluid reservoir G.

Referring initially to FIG. 6, the upper axial bore **241** of tubular body A receives a sleeve **243** that has a shoulder **245** formed on its upper region to engage a mating shoulder **247** which extends radially inward from the axial bore **241**. The lower and outer extremity of sleeve **243** is threaded to receive an adapter **249** that forms, along with the interior cylindrical surface **251** of tubular body A, the gas cavity C. Adapter **249** has a lower outwardly extending radial shoulder **253** that confines a separation element F of the type previously described in connection with FIGS. 1 through 5. One or more apertures **255** connects the gas cavity C with the pressure transmitting liquid chamber E. The piston member B receives a threaded cap **257** on its upper extremity to

define with the body 259 of the piston member an annular groove to receive a suitable seal ring 261. In this particular instance an elongated bearing 263 is disposed in a suitable groove beneath the seal ring 261.

The lower region 265 of the piston member B is enlarged as shown in FIG. 7, and suported on a radially extending surface 267 is a seal ring 269 that is retained by a conical shaped ring 271 and a snap ring 273. The seal ring 269 is urged against the cylindrical surface 251 of the tubular body A. Also, a bearing 275 is disposed in a suitable groove in the outer cylindrical surface 277 of the enlarged portion 265 of the piston member.

A retaining collar 279 is secured by threads 281 to a lower region of the tubular body A. This collar confines a plurality of ring segments 283 that have female splines 284 formed therein. Male splines 287 are formed on the exterior of piston member B. As shown in FIG. 7–A, there are a plurality of ring segments 283 which are rotationally locked with respect to collar 279 by keys 285 positioned in suitable keyways 288 formed in collar 279 and ring segments 283. The male splines 287 on piston member B terminate at regions 290 and 292 (see FIG. 7) and allow piston member B to move axially with respect to removable splines 283 within the limits defined by regions 290, 292. Thus, collar 279, the splines, and the keys 285 cooperate to retain the piston member B in tubular body A, while permitting a predetermined amount of axial movement therein. Rotation of the drill string and thus tubular body A will cause rotation of the piston member B.

The valve means D for introducing gas under pressure into the gas cavity C is identical with the one shown in FIGS. 1, 8 and 8–A.

The fluid flow conduit means 289 is in effect a fluid flow diode (see FIG. 7) and is secured in a threaded aperture 291 in the wall 293 of piston member B. The purpose of the fluid flow conduit means is to introduce drilling under pressure into the pressure transmitting liquid chamber E, which as previously mentioned, also serves the same purpose as the fluid reservoir G of the apparatus of FIG. 1. The fluid flow conduit means 289 has a body 295 that is hollow to receive a valve element 297. The valve element has a seal ring 299 that is urged by a compression spring 301 against an annular lip inside the body. A threaded cap 305 is used to retain the valve element 297 inside body 295 and also to confine the compression spring 301 in its selected position. The cap 305 has a plurality of apertures 307 through which a drilling fluid may flow.

The action of the compression spring and the pressure of the fluid inside the pressure transmitting liquid chamber E urges the seal ring 299 against annular lip 303 to prevent fluid flow through the apparatus. However, should the pressure of the fluid flowing through the axial passage of the apparatus exceed the pressure of the liquid inside the pressure transmitting liquid chamber E to the extent that the valve element 297 opens, then the fluid will flow into the pressure transmitting liquid chamber E. Hence, this apparatus, like the apparatus of FIGS. 1 through 5, will automatically compress the gas in gas cavity C as the apparatus is lowered into a well bore.

Preferably the fluid flow diode 289 should require a pressure differential of slightly less than the pressure drop across the bit before it will open to insure that the apparatus will be operative at low axial loads. The fluid flow diode 289 may communicate with the annulus instead of the axial bore of the apparatus (provided the opening pressure is relatively low), which will also insure operation of the apparatus at low axial loads. Also, the apparatus of FIGS. 6 and 7 may be provided with the decompression means 237 shown in FIG. 5–A when the diode is vented to the annulus.

Thus, this apparatus has many of the advantages of the apparatus of FIGS. 1 through 5 and is somewhat more simple. It does have the disadvantage, however, that the abrasives in the drilling fluid come into contact with the splines previously described. In addition, assuming no leaking across the seals and no automatic decompression means, the pressure in the pressure transmitting chamber E and of the gaseous fluid in the gas cavity C are maintained at bottom hole pressure while the apparatus is being moved to the surface of the well, and could present a problem or danger to drill rig personnel when disassembling the apparatus. For this reason, the valve element 297 of the fluid flow conduit means 289 has a protrusion 309 that extends through the wall 293 of the piston member B and into the axial fluid passage. When the apparatus reaches the surface of the well, an elongated tool is inserted up through the threaded box connection 13 (see FIG. 7), through the axial fluid passage of the apparatus, and is used to depress the protrusion 309 of the valve element to release the fluid pressure inside the pressure transmitting chamber E and the gas cavity C. Since the high pressure discharge of fluid is inside the axial fluid passage of the apparatus, there is no danger to the drill rig personnel.

As can be seen from the above, the drawings illustrate two basic forms of my invention; namely, the type shown in FIGS. 1 through 5 and the type shown in FIGS. 6 and 7. One of the main distinctions in these two forms of the invention is that the apparatus of FIGS. 1 through 5 has three chambers, the middle chamber being used to contain a lubricant, with certain above-described advantageous results. A second form of the invention shown in FIGS. 6 and 7, however, has no middle chamber but utilizes the drilling fluid in a chamber called a pressure transmitting liquid chamber to communicate with the gas cavity. In both forms of the invention, the gas cavity is illustrated as being in the tubular body A. This cavity can just as easily, however, be in the piston member B, and conversely, the fluid reservoir G can be located in the piston member. In other words, the gas cavity C and the fluid reservoir G can all be placed in the piston member, or in the tubular body, or in both these members.

My invention is not limited to the specific forms of the fluid flow diode, the conduit means, or the valve means illustrated in the drawings. FIG. 12 illustrates, for example, a fluid flow diode 311 which replaces the fluid flow diode 203 of FIG. 2 and is in effect a special form of the seal means 131 of FIG. 2. In this modification of the invention the piston member B and the tubular body A may be identical with the ones shown in FIGS. 1, 2 and 3. Here, the retainer ring 151 has a clearance 313 extending therethrough to communicate with the gap 231 between the piston member and the tubular body. The upper end of the clearance 313 communicates with another annular gap 315 which is located immediately below the annular lip 317 of a flexible seal ring. When the pressure inside gap 315 exceeds the pressure inside the pressure transmitting liquid chamber E, the annular lip 317 is flexed inwardly, allowing fluid to flow from fluid reservoir G into the pressure transmitting liquid chamber E. If, however, the pressure inside the pressure transmitting liquid chamber E is higher than the pressure inside fluid reservoir G, the annular lip 317 will be urged outwardly against the interior cylindrical surface 63 of tubular body A. This is a simplifying and advantageous modification, since the seal means 311 functions as a fluid flow diode, eliminating the necessity for a separate diode such as the one designated by the numeral 209 in FIG. 2.

The positions of the various above-described fluid flow diodes can be varied. The diode 289 of FIG. 7 can be vented to the annulus instead of to the axial passage inside the tool. Similarly, the fluid flow conduit means 179 of FIG. 3 may be vented to the axial passage inside the apparatus instead of to the annulus. Also my invention is not limited to the various dimensions and material specifications given throughout the specification, since these were given by way of example and not by way of limitation.

Automatic gas compression may be obtained by the use of a valve means **318** shown in FIG. 13. This valve means is not a fluid flow diode because it does not restrict flow to only one direction. Rather, it consists of an aperture **320** which is formed in the tubular body A and which allows ambient drilling fluid to freely enter the pressure transmitting liquid chamber E as the apparatus is lowered in the well bore. When the bottom of the bore hole is reached and weight applied to the drill bit, piston member B moves upward and eventually seal ring **269** closes the aperture **320**. Since fluid cannot leave the pressure transmitting liquid chamber E, shock absorption and static load carrying capacity is effected by further compression of the gas.

When the drill bit is raised from the bore hole bottom (assuming no leakage past seal **269**) the piston member B will return to its initial position under the influence of the compressed gas and gravity so that seal **269** is lower than aperture **320**. Thus, the gas in gas cavity C is decompressed to the initial value that it had at the surface of the well.

While I have shown my invention in only a few of its forms, it should be apparent to those skilled in the art that it is not limited to the specific forms shown, but is susceptible of various changes and modifications without departing from the spirit thereof.

I claim:

1. In an apparatus for insertion into a drill string and having utility for abrosbing shock loading and for supporting static loading existing in the drill string, said apparatus comprising:

a tubular body having one end portion adapted to be secured to a drill string member;

a piston member having one end portion also adapted to be secured to a drill string member, said piston member being reciprocably carried by said body to define therewith a sealed pressure transmitting liquid chamber and an axial passage through which drilling fluid may flow toward the bore hole bottom;

a sealed gas cavity formed internally in a selected one of said tubular body and said piston member to communicate with said liquid chamber;

a movable separation element separating the gas in said gas cavity and said liquid to prevent the intermingling of gas liquid and to transmit by movement the fluid pressure of the liquid to the gas; and

valve means extending through said tubular body and into said sealed gas cavity whereby the pressure in the gas cavity may be selectively varied.

2. The invention defined by claim **1** wherein said movable separation element is a pliable, sealed and fluid impervious bag disposed in said gas cavity and a valve means communicating with said gas cavity is bonded thereto and extends through said apparatus to enable pressurization thereof from an external source of gas.

3. The invention defined by claim **1** wherein said gas cavity is formed annularly in said tubular body, and liquid filled flow restriction means connects the gas cavity and the liquid chamber to increase shock absorption.

4. The invention defined by claim **3** wherein said movable separation elements is a pliable, sealed and fluid impervious bag disposed in said gas cavity and a valve means communicating with said gas cavity is bonded thereto and extends through said apparatus to enable pressurization thereof from an external source of gas.

5. In an apparatus for insertion into a drill string and having utility for absorbing shock loading and for supporting static loading existing in the drill string, said apparatus comprising:

a tubular body having one end portion adapted to be secured to a drill string member;

a piston member having one end portion also adapted to be secured to drill string member, said piston member being reciprocably carried by said body to define therewith a pressure transmitting liquid chamber and an axial passage through which drilling fluid may flow toward the bore hole bottom;

a gas cavity formed internally in a selected one of said tubular body and said piston member to communicate with said liquid chamber;

valve means carried by said apparatus for communication with the gas cavity to enable pressurization thereof from an external source of gas;

means carried by said apparatus to enable the introduction of liquid into said pressure transmitting liquid chamber; and

a fluid flow diode communicating between said liquid chamber and the ambient drilling fluid to replenish liquid that leaks from said pressure transmitting liquid chamber.

6. The invention defined by claim **5** wherein said fluid flow diode is a check valve through which drilling fluid may enter said liquid chamber.

7. The invention defined by claim **6** wherein a movable separation element separates the gas in the gas cavity and the fluid in said pressure transmitting liquid chamber.

8. The invention defined by claim **6** wherein said gas cavity is formed annularly in said tubular body and liquid filled flow restriction means connects the gas cavity and the liquid chamber to increase shock absorption.

9. The invention defined by claim **7** wherein said movable separation element is a pliable, sealed and fluid impervious bag disposed in said gas cavity and a valve means communicating with said gas cavity is bonded thereto and extends through said apparatus to enable pressurization thereof from an external source of gas.

10. In an apparatus for insertion into a drill string and having utility for absorbing shock loading and for supporting static loading existing in the drill string, said apparatus comprising:

a tubular body adapted to be secured to a drill string member;

a piston member having one end portion also adapted to be secured to a drill string member, said piston member being reciprocably carried by said body to define therewith a sealed pressure transmitting liquid chamber and an axial passage through which drilling fluid may flow toward the bore hole bottom;

a gas cavity formed internally in a selected one of said tubular body and said piston member to communicate with said liquid chamber;

a liquid reservoir formed in a selected one of said tubular body and said piston member and being partially filled with drilling fluid and partially filled with a liquid also contained in said pressure transmitting liquid chamber;

said gas cavity, said pressure transmitting liquid chamber and said reservoir being in communication with each other;

a fluid flow diode interposed between said reservoir and said pressure transmitting liquid chamber to enable fluid flow only from said reservoir into said pressure transmitting liquid chamber; and

fluid flow conduit means for connecting said reservoir with the ambient drilling fluid.

11. The invention defined by claim **10** wherein movable separation elements are positioned within said gas cavity and said liquid reservoir to separate the various fluids therein.

12. The invention defined by claim **10** wherein said gas cavity is formed annularly in said tubular body and liquid filled flow restriction means connects the gas cavity and the liquid chamber to increase shock absorption.

13. The invention defined by claim **11** wherein said movable separation elements are pliable, sealed and fluid impervious bags.

14. In an apparatus for insertion into a drill string and having utility for absorbing shock loading and for supporting static loading existing in the drill string, said apparatus comprising:

a tubular body adapted to be secured in a drill string;

a piston member reciprocably and sealingly carried by said body to define therewith a pressure transmitting liquid chamber and an axial passage through which drilling fluid may flow toward the bore hole bottom;

a gas cavity formed in a selected one of said tubular body and said piston member to communicate with said pressure transmitting liquid chamber; and

a valve means interposed between said pressure transmitting liquid chamber and the ambient drilling fluid to transmit the hydrostatic pressure of the drilling fluid to said pressure transmitting liquid chamber to automatically compress the gas in said gas cavity as the apparatus is lowered through the well bore, and to prevent fluid flow from said pressure transmitting liquid chamber to the ambient drilling fluid when the apparatus is axially compressed.

15. The invention defined by claim **14** wherein said valve means is a fluid flow diode that permits fluid flow only into said pressure transmitting liquid chamber.

16. The invention defined by claim **15** wherein pressure relief means is interposed between said pressure transmitting liquid chamber and the ambient drilling fluid to equalize the pressures therebetween when the drill string members are raised through the well bore.

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