Nov. 7, 1967 H. W. HARRISON 3,350,900

SHOCK CUSHIONING ROTARY DRIVING WELL TOOL

Filed Oct. 21, 1965

3 Sheets-Sheet 1

Fig. 1

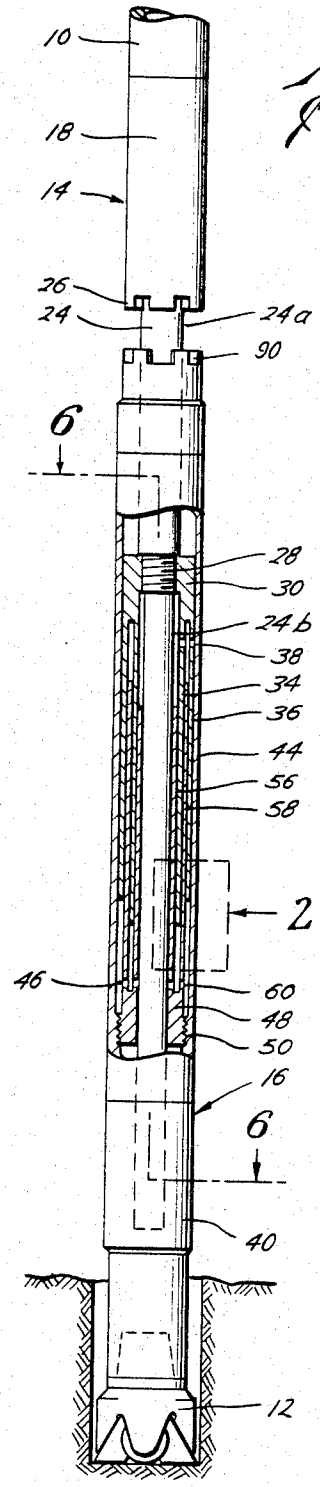
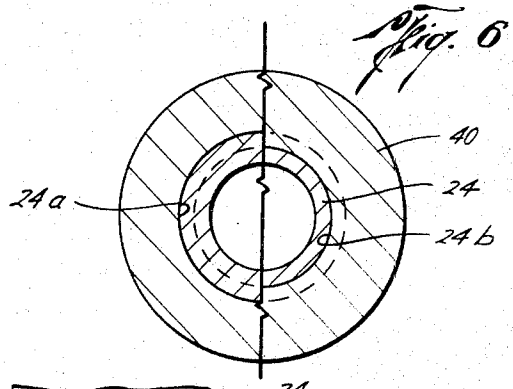


Fig. 6



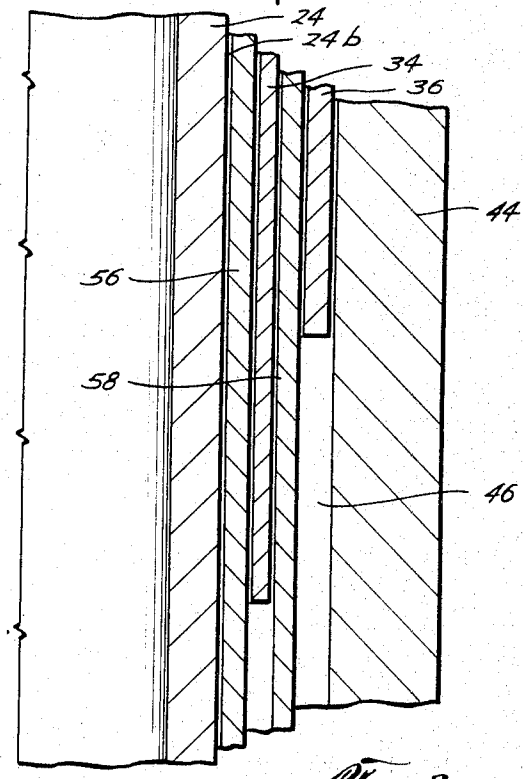


Fig. 2

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Fig. 3A

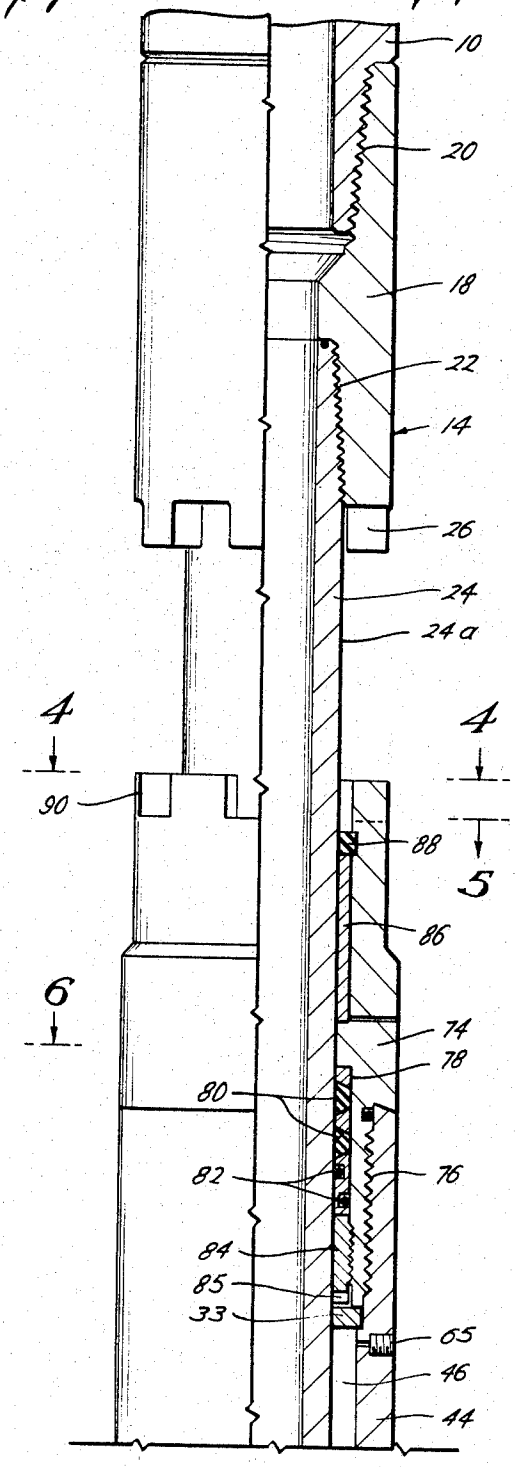
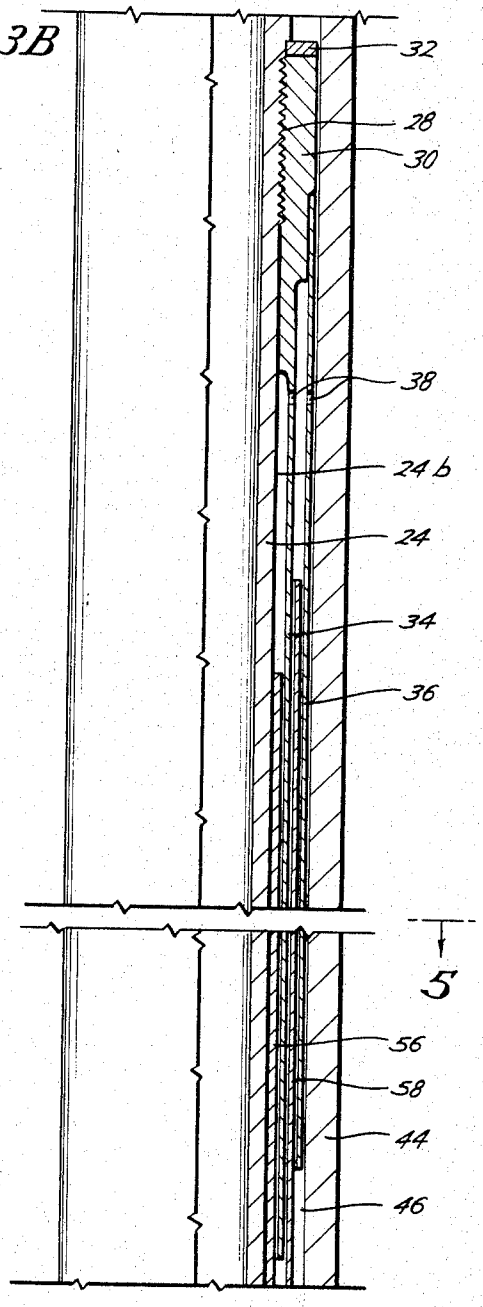


Fig. 3B



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Fig. 3C

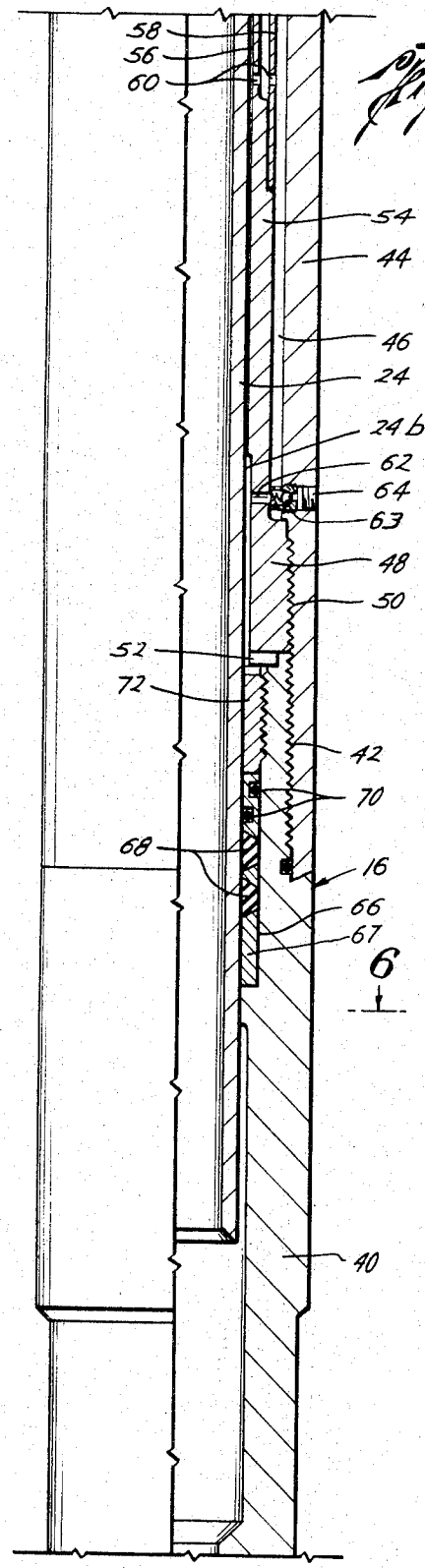


Fig. 4

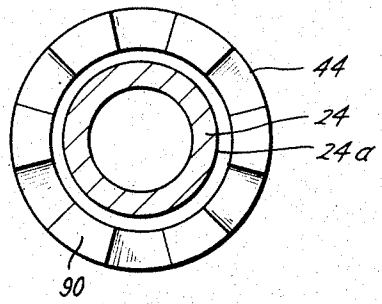
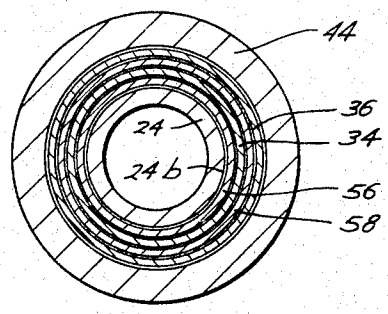


Fig. 5



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3,350,900

SHOCK CUSHIONING ROTARY DRIVING WELL TOOL

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Filed Oct. 21, 1965, Ser. No. 499,138
7 Claims. (Cl. 64—23)

ABSTRACT OF THE DISCLOSURE

The invention embodiment disclosed is a combined rotary clutch and longitudinal shock absorber for use in a drilling string used in rotary drilling in the earth. It has two relatively reciprocable mutually telescoping members with connections respectively for drill stem sections above and below. These interengaged relatively reciprocable members form between them a closed chamber whose volume changes as the members interengage to a greater or lesser degree and there are one or more pairs of closely nested cylinders within the chamber with the cylinders of each pair of the relatively reciprocable members, respectively. Torque is transmitted from one member to the other by a compressible liquid which fills said chamber and acts as a shock absorber for longitudinal shock between said members.

This invention relates to a shock cushioning rotary driving well tool adapted to be incorporated into a rotary driving string extending into a well for the purpose of absorbing or cushioning shocks which the string may encounter in one direction from such tool and prevent them from being transmitted with their full impact to the string in the opposite direction from the tool.

This invention is particularly applicable to a so-called rotary drilling string comprised of a plurality of lengths of drill pipe extending into a well usually having a drill collar or drill collars extending from the lower end of the lowermost section of drill pipe, and having a rotary drill bit on the lower end thereof. Such a drill string is used in drilling wells by the rotary drilling method which involves applying a rotating force to the upper end of the drill string to transmit rotary movement therethrough to the drilling bit on the lower end thereof while such drilling bit is in contact with the earth at the bottom of the bore hole constituting the well. Such drill bit has cutting elements thereon which are usually of a rolling type intended to roll on the bottom of the well and perform a cutting action on the formation as the rolling takes place. In most cases the drill string will be mostly held in tension to prevent it from buckling and corkscrewing in the upper portion of the well, with the drill collars which are heavy tubular elements located in the drill string just above the drill bit, providing sufficient weight to force the drill bit against the bottom of the well as it is being rotated. Regulation of the tension on the drill string from the earth's surface will regulate the proportion of the weight of the drill collars which is allowed to bear on the drill bit to provide the drilling pressure.

In such an arrangement, in certain types of formations, the drill bit will be caused to encounter portions of the bottom of the hole as it is rotated, which portions are very hard, and such encounter produces a shock which is transmitted to the drill collars above the bit. These drill collars being of great inertia, prevent the bit from travelling upwardly under such shock with the result that

the bit or other parts of the drill string may be damaged by the shock as the bit is prevented from yielding under the impact with respect to the other parts of the drill string. Furthermore, in supplying the torque and rotary movement to such bit, if the bit encounters a sudden resistance to movement it will have a shock imparted to it, and because of the inertia of the drill collar or drill collars above the bit will be forced to continue rotation and not allowed to yield somewhat in a rotary direction under the impact, which again tends to cause excessive damage to the bit or other parts.

In some drilling, drill collars as such, are not used, but even in such cases, the inertia of the drill pipe acts in much the same way and with the same result as the inertia of the drill collars.

It is an object of this invention to provide a tool which is capable of insertion in a drill string at an appropriate location or locations above the drill bit, through which the downward force necessary to supply the drilling pressure may be transmitted and the rotary torque necessary to rotate the bit may likewise be transmitted, but which tool will provide a cushioning of any longitudinal shock applied either to the bit or to the drill string above the tool so that it will not be transmitted with its full impact between the bit and the drill string and hence will eliminate or be less likely to cause damage to the bit or other parts of the drill string.

Another object is to provide such a tool in which the transmission of torque from the drill collars or pipe thereabove to the bit therebelow will be adequate for the drilling operation but in which a sudden resistance to turning which may be encountered by the bit and thereby produce a shock will be cushioned by the tool against transmission with full impact to the drill collars or pipe thereabove.

Another object of this invention is to provide a tool which will cushion both rotary and longitudinal impacts to which a bit may be subjected, permitting the bit to yield under such impacts and thereby avoid damage to the bit without necessity for a drill collar or drill collars or drill pipe above the bit to yield by an equal amount or at the same rate.

Another object of this invention is to provide a tool of the general character described which will not be required to be of such excessive over-all length as to interfere with its ease of handling nor permit excessive longitudinal extension and contraction in operation.

Another object of this invention is to provide such a tool in which the over-all lateral dimension or extent of the tool may be not greater than that of the conventional drill collar.

Other objects and advantages of this invention will become apparent from the following description taken in connection with the accompanying drawings in which is set forth by way of illustration and example one embodiment of this invention.

In the drawings:

FIG. 1 is a side elevation with parts broken away and shown in longitudinal cross section illustrating a tool constructed in accordance with this invention disposed between the lower end of a drill collar and a bit of a drill string, the parts being shown in normal drilling relation to one another.

FIG. 2 is a fragmentary cross section on an enlarged scale of that portion of FIG. 1 with the rectangle indicated by the numeral 2.

FIGS. 3A, 3B and 3C constitute successive fractional views half in section and half in side elevation of successive portions of the tool shown in FIG. 1 from top

to bottom thereof, illustrating the parts more in detail than in FIG. 1.

FIG. 4 is a transverse cross section taken along the line 4—4 of FIG. 3A.

FIG. 5 is a transverse cross section taken along the line 5—5 of FIG. 3B.

FIG. 6 is a transverse cross section taken along the line 6—6 of FIGS. 1, 3A and 3C, the left-hand portion of this figure being taken at the location of the line indicated by the numeral 6 in FIG. 3A and the right-hand portion thereof being taken at the location of the line indicated by the numeral 6 in FIG. 3C.

In the illustration in the drawing the objects of this invention have been achieved by the provision of two telescoping members making up the tool with an expansible and contractible chamber between them adapted to expand and contract when the two parts of the tool are caused to telescope with one another to a greater or lesser extent, the chamber being filled with a compressible liquid adapted to take up longitudinal shock as the tool is caused to change its longitudinal length under such shock. Provision for cushioning a rotary shock is made by providing within the chamber so filled with liquid closely spaced relatively rotatable surfaces which are preferably cylindrical but which may be of other forms of surfaces of revolution coaxial with the tool, such as a plurality of discs. These would be arranged with adjacent surfaces secured respectively to the two relatively telescoped members of the tool, so that with the liquid within the chamber they provide a fluid rotary drive between the two members of the tool. Variations in the torque which the tool will transmit are provided through longitudinal contraction or expansion of the tool, causing increase or decrease in pressure of the liquid within this fluid drive and, in the case of cylindrical surfaces, simultaneously causing increase or decrease of the areas of the closely spaced relatively rotatable surfaces.

In FIG. 1 a tool embodying this invention is shown incorporated in a drill string between the lower end of the lowermost drill collar **10** and the drill bit **12**. The tool is shown as comprised basically of an upper and inner member **14** secured to the drill collar **10** and a lower and outer member **16** secured to the upper end of the bit **12**, these two members being telescopically engaged so as to be both longitudinally and rotatably movable relative to one another. In normal usage the upper member **14** is the driving member and the lower member **16** the driven member. Obviously either may be the inner member and the other the outer member.

Both members in this example are made up of a number of composite parts. The upper member includes a fitting **18** having an upper internal thread **20** to receive the threaded lower end of the drill collar and an internally threaded lower end **22** to receive the upper end of the mandrel **24** that actually forms the inner portion of the two telescoping members. The upper portion **24***a* of the mandrel **24** is formed of larger diameter than the lower portion **24***b* thereof. The lower end of the fitting **18** exteriorly of the mandrel **24** has downwardly extending clutch teeth or dogs **26** providing the driving part of an emergency driving clutch.

At the location at which the exterior of the mandrel **24** changes from its larger diameter **24***a* to its smaller diameter **24***b* this mandrel is provided with external threads **28** to receive a sleeve supporting collar **30** in threaded engagement therewith. This collar may have a stop ring **32** held in place thereby adapted for engagement with another stop ring **33** held in the outer member, for the purpose of limiting the expanding movement of the tool.

Depending from the collar **30** and fixedly secured thereto so as to be disposed concentrically with the mandrel **24** and with each other are a pair of sleeves **34** and **36** spaced from each other and from the mandrel **24**. These sleeves have suitably located radial openings or passages **38** therethrough so as to permit free flow of liquid between the interior and exterior of each such sleeve at a location adjacent their attachment to the collar **30**. These sleeves may be integral with the collar as shown in the case of the sleeve **34** or rigidly attached thereto by suitable means as shown in the case of the sleeve **36**. As many sleeves as deemed expedient from the standpoint of design may be employed, each concentric with the others and spaced therefrom as in the case of the sleeves indicated.

The lower or driven member **16** likewise has a lower fitting **40** internally threaded at its lower end to engage and be secured to the bit **12** and at its upper end externally threaded at **42** to receive the outer housing or barrel **44**. Between this outer housing or barrel **44** and the mandrel **24** there is provided by a spacing of these members an annular space forming a chamber **46** and in this chamber the sleeves **34** and **36** are located, the outer sleeve **36** being disposed very closely with respect to but slightly spaced from the inner surface of the housing or barrel **44**.

Similarly to the sleeve supporting collar **30**, there is a sleeve supporting annular member **48** threadedly engaged at **50** with the interior of the barrel **44**, keys or splines **52** being provided on its lower end for engagement by a wrench or the like to tighten it into place in the barrel **44**. Extending upwardly from this collar **48** is an extension **54** from the upper end of which project a pair of sleeves **56** and **58** rigidly carried on the extension **54** and similar to the sleeves **34** and **36** except that they are sized to interfit between the sleeve **34** and the mandrel **24** and between the two sleeves **34** and **36**, respectively, such fit being a relatively close fit but providing a slight space in each case. As in the case of the sleeves **34** and **36**, each of the sleeves **56** and **58** have radical openings therethrough adjacent their securement to the extension **54** as shown at **60**, so as to provide free flow between the interior and exterior of the respective sleeves. Adjacent the juncture between the extension **54** and the collar **48** there is also a radial opening **62** to provide free flow between the interior and exterior of the extension **54**.

In order to close the lower end of the chamber **46** and provide a bearing for relative longitudinal and rotary movement of the mandrel **24** of the driving member relative to the driven member, the fitting **40** is provided with a counterbore **66** in which is carried a bearing sleeve **67** providing a sliding and rotating bearing support for the mandrel **24**, and suitable seal rings **68** and **70** secured in place by a gland nut **72** threaded into the upper end of the counterbore **66**. Similarly, the upper end of the barrel **44** has threadedly mounted thereon a fitting **74** by means of threads **76** and this fitting has a counterbore **78** therein to receive suitable seal rings **80** and **82** held in place by a gland nut **84** which is provided with keys **85** or the like to receive a wrench for tightening it into place into the fitting **74**. Thus a seal is provided around the upper and larger exterior portion **24***a* of the mandrel **24**. A bearing for this upper portion of the mandrel is provided by a second counterbore from the upper end of the fitting **74** into which a bearing sleeve **86** is press fitted and a wiping rod seal **88** prevents abrasive material from entering said sleeve **86**. This fitting **74** on its upper end is provided with upwardly extending dogs or keys **90** adapted to receive the downwardly extending keys or dogs **26** on the member **18** so that when the inner and outer members are fully collapsed to their shortest length, dogs **26** and **90** will engage each other with a positive clutch engagement and provide for an emergency driving of the driven member by the driving member.

Because of the larger diameter of the mandrel at **24***a* where it passes through the seals **80** and **82** as compared with its diameter at **24***b* where it passes through the seals **68** and **70**, downward movement of the mandrel longitudinally with respect to the other member of the tool will decrease the total volume available within the chamber **46** between the two members. In order to cushion such

downward movement of the mandrel, or, conversely, the corresponding upward movement of the outer driven member by an upward shock delivered to the drill bit, this invention contemplates the filling of the chamber **46** with a compressible liquid. This liquid should be such as will increase in pressure very rapidly as its volume is decreased so as to minimize the necessary travel of the members of the tool relative to one another in a longitudinal direction to enable the tool to transmit through such liquid as great a downward force as is contemplated will be necessary for drilling purposes as well as absorbing shocks. The longitudinally extending movement of the members relative to one another is limited by mutual engagement of the stops provided by the ring **33** in the lower end of the fitting **74** and the ring **32** on the upper end of the sleeve supporting collar **30**. Downward or collapsing movement of the tool is limited by the lower end of the fitting **18** coming into engagement with the upper end of the fitting **74**. Liquid may be loaded into the chamber **46** through suitable openings in the barrel **44** and after loading these openings closed by means of plugs **64** and **65**, respectively, so as to hermetically seal the chamber. Preferably in loading the chamber the liquid therein will be placed under an initial pressure or load such as will hold the members of the tool in fully distended and rigid position until a force in excess of that determined by such preloading is applied to the members of the tool tending to collapse it. The stops above mentioned should be so positioned relative to the compressibility of the liquid and the preloading thereof that when the mandrel is fully inserted into the barrel with the dogs **26** engaging the dogs **90** to limit such insertion, the liquid will exert a maximum pressure within the working limits of the strength of the barrel and other parts providing the chamber **46**. Normally the preloading may be somewhat less than $\frac{1}{10}$ of such maximum liquid pressure. While the principal reliance for cushioning of shocks in a longitudinal direction is placed upon the compressibility of the liquid in the chamber **46**, collapsing of the tool by longitudinal forces thereon will, of course, cause the sleeves **34** and **36** to interfit more deeply between the sleeves **56** and **58**, resulting in some flow of the liquid through relatively narrow spaces between the sleeves, during which the viscosity of the liquid will cause it to exert some resistance to rapid flow through such spaces and hence to supply some additional cushioning effect against shocks in a longitudinal direction. The differential of cross sectional areas between the parts **24***a* and **24***b* of the mandrel **24** should be such that under somewhat less than the maximum pressure to be exerted on the liquid in the chamber **46**, such liquid will offer a resistance to further collapsing movement of the mandrel into the barrel equal to the maximum downward force anticipated as desirable to be transmitted through this tool from the drill collar **10** to the bit for drilling purposes.

Not only the exterior surface of the mandrel exposed within the chamber **46** and the interior surface of the barrel exposed within said chamber, but also both the exterior and interior surfaces of each of the sleeves **34**, **36**, **56** and **58** are substantially cylindrical. These are so sized that the surface of each sleeve which lies closely adjacent to the member other than that on which it is mounted will cooperate with said member so that the surface of the sleeve adjacent said member and the surface of the member adjacent the sleeve will present radially inward and radially outward facing cylindrical surfaces facing one another in closely spaced relation to one another. Furthermore, each sleeve will have one of its surfaces effectively providing a cylindrical surface on the member on which it is mounted facing and closely spaced with respect to a cylindrical surface on an adjacent sleeve carried by the other member with one of said cylindrical surfaces facing inwardly and the other outwardly and both exposed within the chamber. Preferably, the spacings between the adjacent surfaces carried by the respective members and between the surface of a sleeve carried by one of the members and the adjacent surface of the other member will all be substantially equal and the amount of this spacing will be determined by the character of such opposed cylindrical surfaces on the respective members and sleeves, the viscosity of the liquid filling the chamber **46**, and the rotary force or torque required to be transmitted from the driving member to the driven member by rotation of the drill bit or other tool. These cylindrical surfaces may have surface roughness such as might be provided by bombarding them with shots or pellets or by the rough marks left by machine tools in order that the surfaces would offer more resistance to the flow of liquid over the same and thereby more effectively transmit rotational forces between the members through the liquid. Such roughness to be most effective should be within the root mean square range of 100 to 1,000.

The greater the degree of collapsing movement of the tool as when greater weight is placed thereon in conducting the drilling operation, the further the sleeves will move into nesting relation with one another and the larger will be the areas of the sleeves opposed to one another with thin layers of the compressible and viscous liquid therebetween. Thus the greater the weight placed on the tool, the greater the torque transmittable by the tool from the driving member to the driven member for a given amount of slippage between these members.

Furthermore, the liquid is preferably of a character which will become more viscous at high pressures, and will offer greater resistance to shear at high pressures, so that by collapsing the tool to a greater degree and thereby increasing the pressure on such liquid, greater torque may be transmitted between the members of the tool.

The closely spaced inwardly and outwardly facing cylindrical surfaces carried by the respective members of the tool within the body of compressible liquid therein thus not only provide the fluid clutch between these members, but provide far greater surface area and hence far greater torque capacity for transmitting torque between the members than would a single inner and outer cylindrical surface closely spaced and carried by the respective members.

Due to the characteristics of a fluid clutch there is some slippage between driving and driven members, which varies with the torque being transmitted. Consequently, in the event of a shock such as caused by engagement of the bit with some unusually hard or solid obstacle tending momentarily to sop it from rotating, the shock of such action will be cushioned by momentarily greater slippage in the fluid clutch instead of having the inertia of the drill collars and entire drill string above the bit emphasize the impact of the bit against such object and possibly damage the bit or other parts.

A suitable liquid for filling the chamber **46** would be one having as uniform as possible performance under shear, little or no tendency toward breakdown of viscosity at high shear rates, having very little variation in viscosity under wide ranges of temperature, and having great resistance to heat and cold as represented by very low vapor pressures and very little or no tendency toward flashing at high temperatures such as normally encountered in drilling wells and induced by internal friction in use in a tool of this character.

One type of liquid which has been found to have the desirable characteristics above mentioned is provided by the dimethyl polysiloxane group of liquids. These are available commercially, being marketed by the Dow-Corning Corporation of Midland, Mich., through its Dow-Corning Engineering Products Division of Dow-Corning Silicone Fluids 210 and 210H. Fluids in this classification having viscosities of 100 centistokes and higher are compressed to approximately 30,000 pounds per square inch when compressed by an amount of 11% to 11½% of original volume and these factors can be adjusted somewhat by different blends of such liquids.

Such a liquid having a viscosity at 75° F. of approximately 12,500 centistokes will have a viscosity at a temperature as high as 400° F. still somewhat above 1,000 centistokes. Furthermore, the viscosity curve of such a liquid for widely varying shear rates is very flat, the fluids being essentially Newtonian in behavior at absolute viscosities of 1,000 centistokes or lower and a shear rates below 10,000 reciprocal seconds.

From the foregoing it will be seen that this invention is one well adapted to attain all of the ends and objects hereinabove set forth, together with other advantages which are obvious and which are inherent to the apparatus.

It will be understood that certain features and subcombinations are of utility and may be employed without reference to other features and subcombinations. This is contemplated by and is within the scope of the claims.

As many possible embodiments may be made of the invention without departing from the scope thereof, it is to be understood that all matter herein set forth or shown in the accompanying drawings is to be interpreted as illustrative and not in a limiting sense.

The invention having been described what is claimed is:

1. A shock cushioning rotary driving well tool comprising telescopically engaged relatively axially movable and relatively rotatable tubular driving and driven members having an annular space between them and a plurality of sealing means, each sealing means being on one of said members and rotatably and slidably sealingly engaging the other, and said sealing means closing the opposite ends of said annular space to form a closed chamber of volume variable upon relative axial movement of said members, said respective members having opposed closely spaced surfaces both exposed and facing each other within said chamber, and a liquid filling said chamber including the space between said surfaces, the viscosity of said liquid and the spacing between said surfaces being so related that said liquid will provide a fluid coupling between said members whereby rotation of one of said members will impart a torque to the other through said fluid coupling and relative axial movement of said members will vary the pressure in said liquid and the torque capacity of said fluid coupling.

2. A tool as set forth in claim 1 in which said liquid is one having substantially the temperature-viscosity and shear-viscosity characteristics of dimethyl polysiloxane.

3. A shock cushioning rotary driving well tool comprising telescopically engaged relatively axially movable and relatively rotatable tubular driving and driven members having an annular space between them and a plurality of sealing means, each sealing means being on one of said members and rotatably and slidably sealingly engaging the other, and said sealing means closing the opposite ends of said annular space to form a closed chamber of volume variable upon relative axial movement of said members, one of said members having a radially inwardly facing cylindrical surface and the other a radially outwardly facing cylindrical surface telescoped with and facing said first surface in spaced relation thereto and both exposed within said chamber, and a resiliently compressible liquid filling said chamber including the space between said surfaces, the viscosity of said liquid and the spacing between said surfaces being related in such a manner that said liquid will provide a fluid coupling between said members whereby rotation of one of said members will impart a torque to the other through said fluid coupling and its resilient compressibility will provide axial shock absorption between said members.

4. A shock cushioning rotary driving well tool comprising telescopically engaged relatively rotatable tubular driving and driven members having an annular space between them and a plurality of sealing means, each sealing means being on one of said members and rotatably and slidably sealingly engaging the other, and said sealing means closing the opposite ends of said annular space to form a closed chamber, one of said members having a radially inwardly facing cylindrical surface and the other a radially outwardly facing cylindrical surface telescoped with and facing said first surface in spaced relation thereto and both exposed within said chamber, and a liquid filling said chamber including the space between said surfaces, the viscosity of said liquid and the spacing between said surfaces being so related that said liquid will provide a fluid coupling between said members whereby rotation of one of said members will impart a torque to the other through said fluid coupling, the members being longitudinally movable relative to each other, the liquid being compressible, and there being stops limiting the relative longitudinal movement of said members, the members and stop positions being so proportioned that within the relative longitudinal movement permitted by said stops the volume of said chamber will change from a maximum at one extreme relative position of said members to a lesser volume at the other extreme relative position of said members, said volumes and the initial pressure and compressibility of said liquid and strength of the materials being so related that the compression of said liquid from the larger to the smaller volume will not raise its pressure to a pressure greater than the safe working pressure for the chamber.

5. A shock cushioning rotary driving well tool comprising telescopically engaged relatively rotatable tubular driving and driven members having an annular space between them and a plurality of sealing means, each sealing means being on one of said members and rotatably and slidably sealingly engaging the other, and said sealing means closing the opposite ends of said annular space to form a closed chamber, one of said members having a radially inwardly facing cylindrical surface and the other a radially outwardly facing cylindrical surface telescoped with and facing said first surface in spaced relation thereto and both exposed within said chamber, and a liquid filling said chamber including the space between said surfaces, the viscosity of said liquid and the spacing between said surfaces being so related that said liquid will provide a fluid coupling between said members whereby rotation of one of said members will impart a torque to the other through said fluid coupling, said members being longitudinally movable relative to each other, said liquid having a viscosity in shear varying with the pressure to which it is subjected and said members and sealing means being so proportioned and relatively positioned that relative longitudinal movement of said members changes the volume of said chamber, whereby the pressure on said fluid may be varied by longitudinal forces applied to said members tending to move them longitudinally relative to one another.

6. A shock cushioning rotary driving well tool comprising telescopically engaged relatively rotatable tubular driving and driven members having an annular space between them and a plurality of sealing means, each sealing means being on one of said members and rotatably and slidably sealingly engaging the other, and said sealing means closing the opposite ends of said annular space to form a closed chamber, one of said members having a radially inwardly facing cylindrical surface and the other a radially outwardly facing cylindrical surface telescoped with and facing said first surface in spaced relation thereto and both exposed within said chamber, and a liquid filling said chamber including the space between said surfaces, the viscosity of said liquid and the spacing between said surfaces being related in such a manner that said liquid will provide a fluid coupling between said members whereby rotation of one of said members will impart a torque to the other through said fluid coupling, said cylindrical surfaces on said respective members including a plurality of nested concentric cylindrical sleeves within said chamber, alternate ones of said sleeves being attached at one end to one of said members and the

other alternate ones at the end opposite said one end to the other of said members, and each of said sleeves having cylindrical surfaces opposed to cylindrical surfaces on the adjacent sleeves and spaced therefrom with a spacing related in said manner to the viscosity of said liquid.

7. A tool as set forth in claim 6 in which said members are longitudinally movable relative to each other whereby the aggregate areas of the cylindrical surfaces on the respective members which are opposed to each other within said chamber will increase as said members move longitudinally relative to one another in one direction and will decrease as said members move longitudinally relative to one another in the opposite direction.

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