April 1, 1958 J. J. UDRY 2,828,944

EARTH BORING APPARATUS

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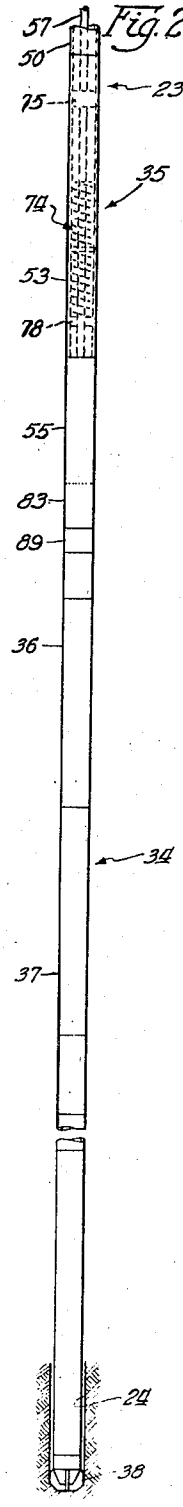


Fig. 2

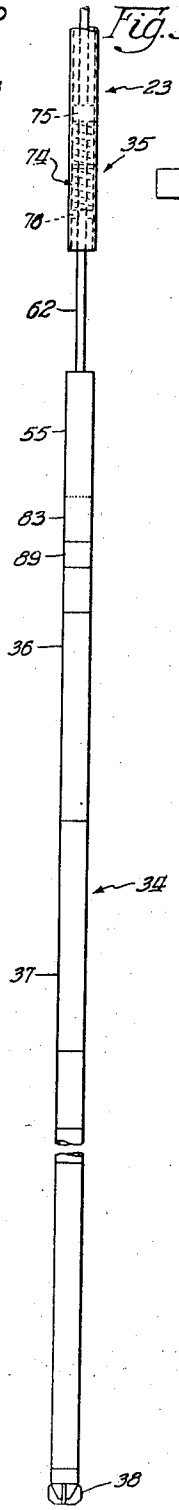


Fig. 3

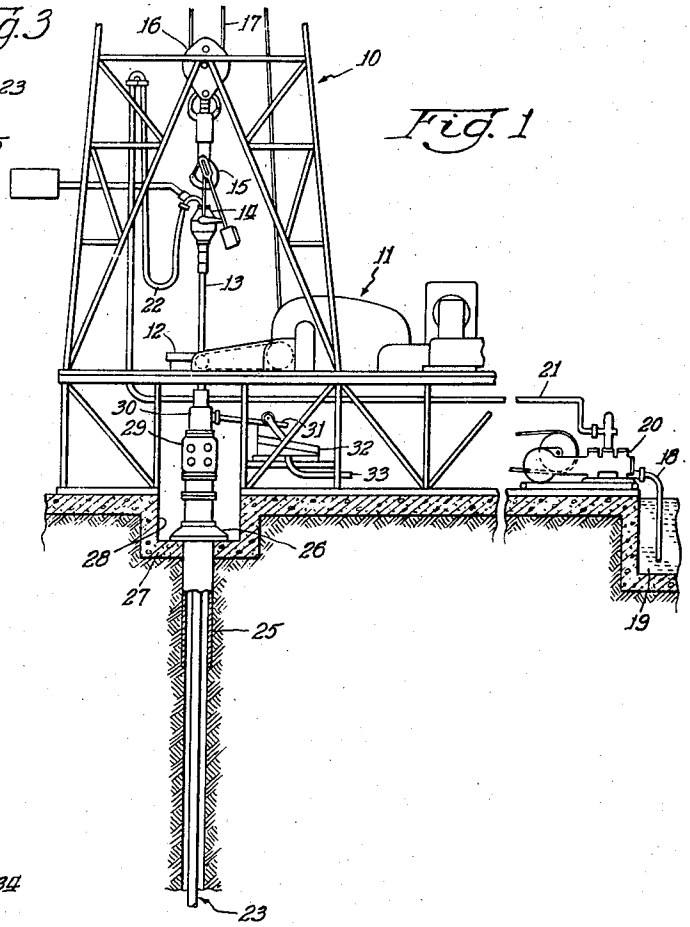


Fig. 1

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EARTH BORING APPARATUS

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Fig. 4A

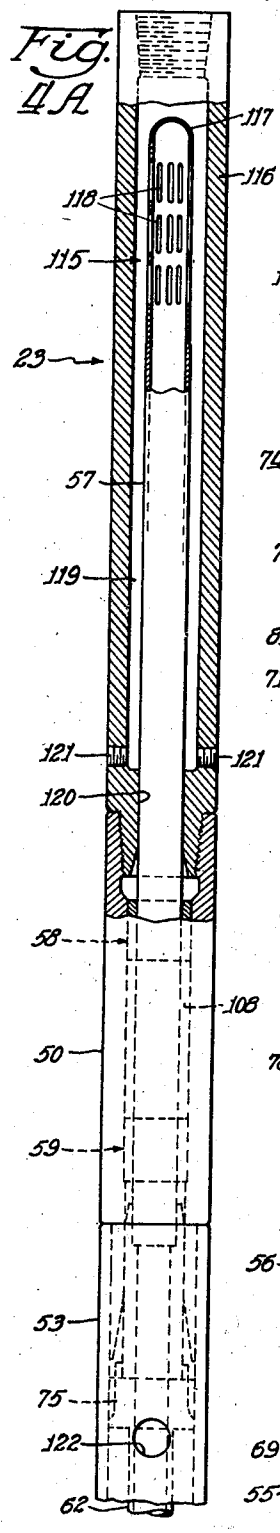


Fig. 5B

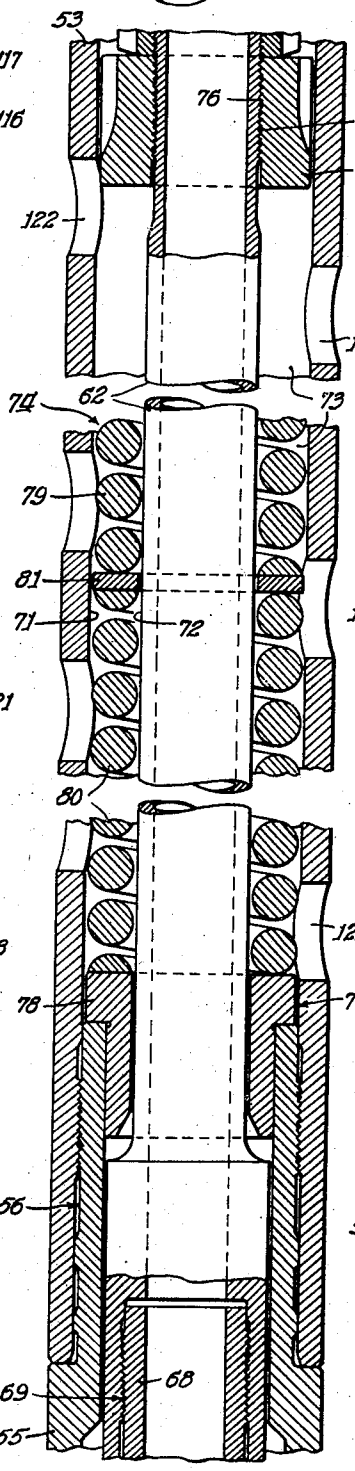
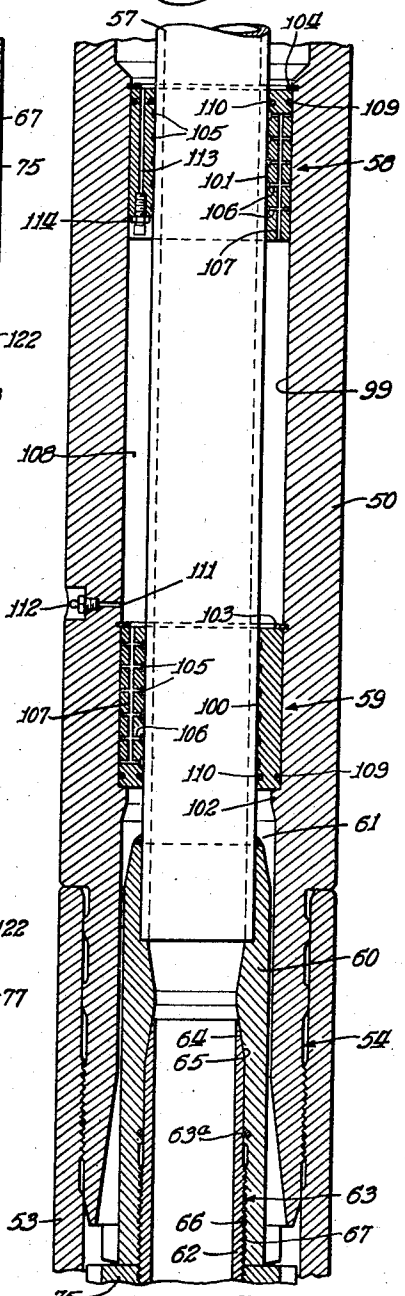


Fig. 5A



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EARTH BORING APPARATUS

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Fig. 4B

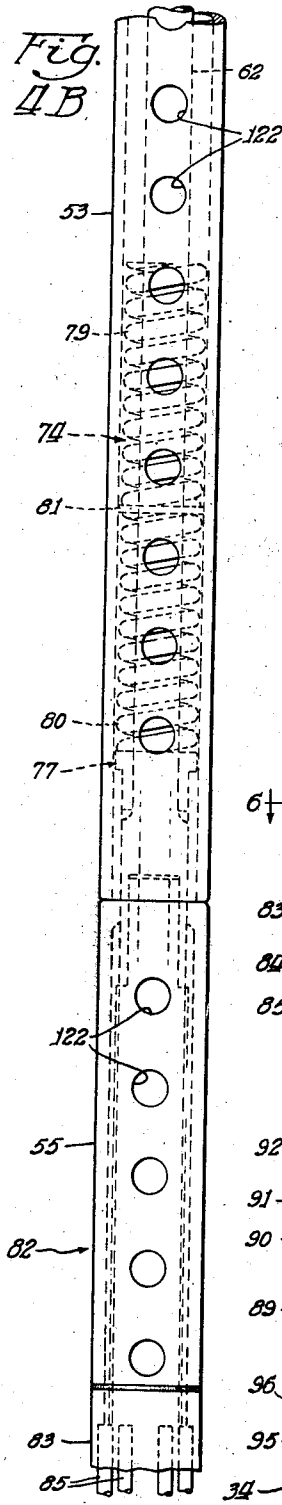


Fig. 5C

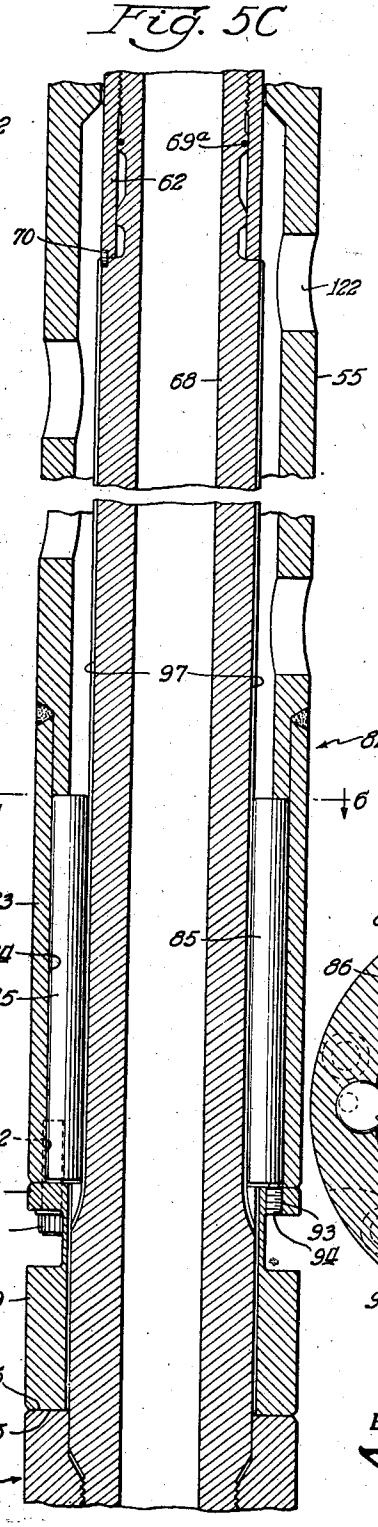


Fig. 4C

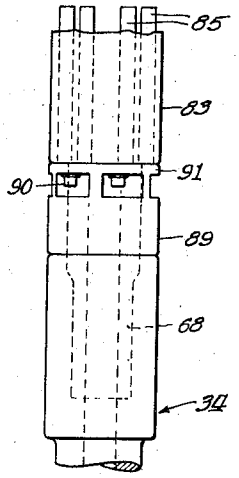
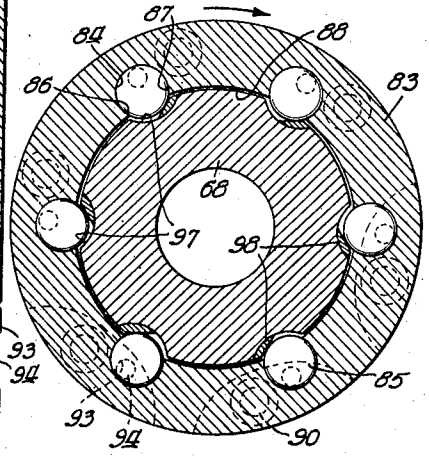


Fig. 6



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EARTH BORING APPARATUS

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Fig. 7

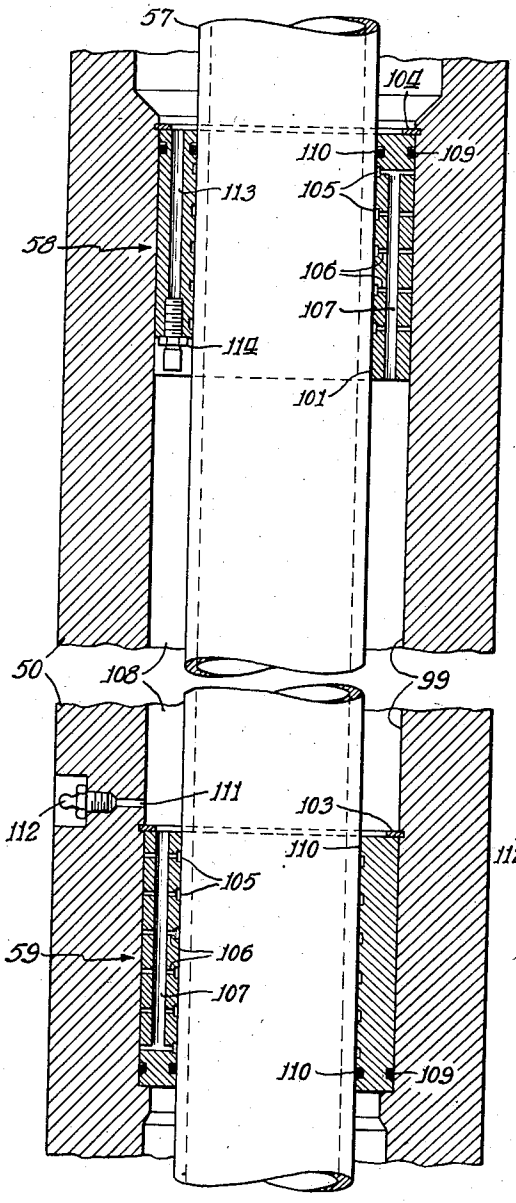
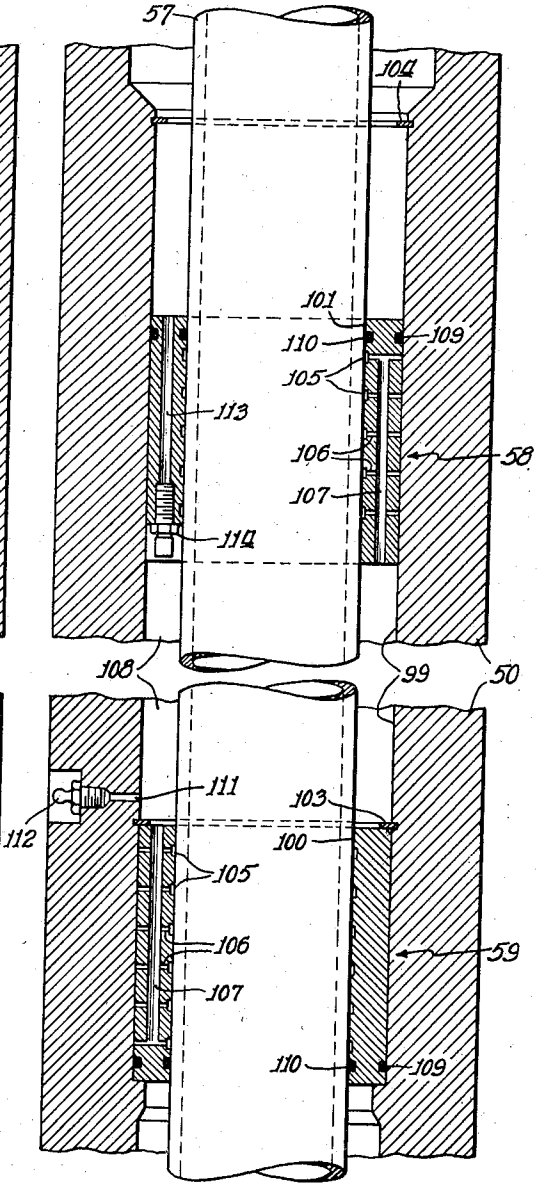


Fig. 8



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United States Patent Office 2,828,944
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2,828,944

EARTH BORING APPARATUS

John J. Udry, Van Nuys, Calif., assignor to Borg-Warner Corporation, Chicago, Ill., a corporation of Illinois

Application March 18, 1954, Serial No. 417,157

7 Claims. (Cl. 255—4)

The present invention relates in general to earth bore drilling apparatus and more particularly to an earth boring drill of the type employing a vertically reciprocating drill rod and bit which vibrates at a frequency substantially equal to the resonant vibration frequency of the rod and bit.

More particularly, the present invention is intended to provide an auxiliary device adapted to be utilized in conjunction with earth bore drilling apparatus of the general type disclosed in the patent to A. G. Bodine 2,554,005.

In earth boring apparatus of the type disclosed in the aforementioned Bodine patent, suitable vibration generating mechanism is utilized for generating sonic vibrations in the drill rod and bit in order to provide the necessary force to execute the drilling operation. In such drilling devices, the vibrating bit is maintained substantially in engagement with the bottom of the well hole and the earth formation immediately adjacent to the bit is shattered either due to vibrations imparted thereto by the bit itself or due to the percussive action of the bit on the formation. In a drill of this type the bit reciprocates or vibrates vertically at very nearly the resonant vibration frequency of the massive drill rod and bit and the amplitude of the vibrations of the vibrating bit is of the order of three-sixteenths to approximately one-half inch.

As is customary in oil well drilling operations, a suitable mud fluid is pumped into the well hole, downwardly through the drill string and drill rod, with the mud fluid emerging from the bottom of the drill rod being forced out of the well hole upwardly around the drill rod and drill string and inside of the well hole. As the mud fluid rises in the well hole in this manner it takes with it the formation fragments or chips of the formation which have been broken up by the bit.

In order to efficiently utilize the energy which supplies the force for vibrating the drill rod and bit, it is necessary that the drill rod and bit be acoustically isolated from the supporting drill string and derrick. Otherwise, the energy supplied to the drill rod and bit for vibrating the same is dissipated in the form of acoustic vibrations or waves which travel to the surface through the drill string and derrick. As a practical matter, when the vibrating drill rod and bit are not substantially acoustically isolated from the supporting drill string, the vibrations travel up the drill string and proceed to set the derrick in vibration at frequencies and amplitudes sufficiently high to shake loose any partially loosened parts thereof. As is apparent, if a bolt or other article is shaken loose from the top of the derrick and falls downwardly, there is a definite hazard to the persons operating the drilling rig.

The principal object of the present invention is therefore to provide a device for acoustically isolating an acoustically vibrating drill rod and bit from the supporting drill string and derrick.

A further object of the present invention is to provide an acoustic isolator adapted for disposition between an

acoustically vibrating drill rod and bit and the supporting drill string whereby the bit may be held against the earth formation at the bottom of the well hole by a substantially constant force under all practical operating conditions.

A further object of the present invention is to provide a lost motion connection between a sonically vibrating drill rod and bit and the supporting drill string therefor, to thereby enable the operator of the drilling rig to more easily control the drilling operation by making it possible for the drill rod and bit to travel continuously downwardly as the earth formation is shattered at the bottom of the well hole without the operator having to continuously lower the supporting drill string. In this connection, the lost motion connection between the drill string and drill rod affords relative sliding movement of the order of twenty inches to two feet so that it is necessary for the drilling rig operator to lower the supporting drill string only when the bit has penetrated the earth formation by approximately this amount. Of course, due to the type of formation being drilled, the speed of penetration of the bit will vary and, accordingly, the frequency with which the operator must incrementally lower the drill string will vary.

A further object of the present invention is to provide a lost motion connection between a drill rod and the supporting drill string which is effective to acoustically isolate the drill rod from the drill string at all times.

A further object of the present invention is to provide an acoustic isolator between a drill rod and its supporting drill string comprising a keyed connection between the drill rod and drill string for causing them to rotate in unison and permitting them to have relative sliding movement and including a resilient coupling means between the drill rod and drill string for isolating the drill string from vibrations in the drill rod.

Another object of the present invention is to provide an acoustic isolator between a drill string and a vibratory drill rod wherein one of the members is telescopically received within the other and each of the members is provided with an abutment affording lost motion therebetween for acoustically isolating the members when the drill rod rests entirely on the earth formation at the bottom of the well hole, and there being a compression spring means disposed between the abutments on the members for effecting a resilient connection between the abutments when the drill rod has penetrated the earth sufficiently deep to take up all of the free lost motion.

Briefly, the present invention contemplates providing a pin member at the upper end of the drill rod adapted to be telescopically received within a generally elongated cylindrical portion formed at the bottom end of the drill string. Suitable abutments are formed on each of the members which provide a lost motion connection between the drill rod and drill string and which lost motion connection is effective to acoustically isolate the drill rod from the drill string. Compression spring means are disposed between said abutments and have sufficient strength to support the entire mass of the drill rod when it is hanging free without having the convolutions of the compression spring means engage each other. As a result, the drill rod is acoustically isolated from the drill string even when substantially the entire mass of the drill rod is supported by the drill string. The acoustic isolator provided by the present invention is particularly desirable in that it is simple and may be composed of rugged parts, the compression spring means being substantially the only part thereof which is subjected to great forces for any extended period of time.

A further detailed object of the present invention is to provide a lubricated pilot bearing suitable for use in an acoustic isolator of the type disclosed herein for maintaining concentric alignment between the telescopically

arranged elements of the isolator and for also continuously properly lubricating the relatively reciprocable elements of the acoustic isolator.

A still further object of the present invention is to provide a pilot bearing comprising a pair of longitudinally spaced sleeve bushings disposed in sealing relationship between a pair of relatively reciprocable sleeve shafts wherein the space between the bushings is filled with a lubricant and one of the bushings is adapted to have an external fluid pressure applied to an outside end thereof for thereby tending to compress the bushings toward each other for placing the lubricant between the bushings under pressure substantially equal to the external fluid pressure.

Another object of the present invention is to provide a pilot bearing suitable for use between the supporting sub of an oil well drill string and the upper sub of an acoustically vibratory drill rod, which pilot bearing comprises a pair of longitudinally spaced bushings which define a lubricant chamber wherein at least one of the bushings is adapted to have the mud fluid, which is used for driving the drill and removing the formation fragments from the bore hole, act on one end of the bushing for placing the lubricant in the chamber between the bushings under pressure substantially equal to the pressure of the mud fluid.

The present application is concerned chiefly with the features of the disclosed pilot bearing and lubricator and it is these features to which the claims herein have been directed. The general features of the acoustic isolator and the constructional details of the improved kelly and of the device for removing coarse abrasive particles from the mud fluid have been disclosed and described in detail herein in order to provide a better and more thorough understanding of the present invention. However, each of these features has been made the special subject of other copending patent applications filed of even date herewith. The general features of the acoustic isolator are disclosed fully and claimed in the copending application of H. V. D. Stewart, Ser. No. 417,117, filed March 18, 1954, now abandoned. The improved kelly or torque transfer unit is fully disclosed and claimed in the copending application of H. V. D. Stewart, Ser. No. 417,118, filed March 18, 1954. The device for removing coarse and abrasive particles from the mud fluid is disclosed fully and claimed in the copending application of J. P. Selberg and J. J. Udry, Ser. No. 417,092, filed March 18, 1954, now Patent No. 2,800,301.

The foregoing and numerous other objects and advantages of the present invention will become apparent from the following detailed description when read in conjunction with the accompanying drawings, wherein:

Fig. 1 is a view showing a typical installation of an oil well drilling apparatus showing the surface equipment and the drill string extending down into the well hole, with the drill rod and bit not being shown in this figure;

Fig. 2 is a view showing the drill rod and bit of the type disclosed in the aforementioned Bodine patent disposed in a well hole with the bit resting on the bottom of the well hole;

Fig. 3 is a view similar to Fig. 2 but shows the drill rod and bit suspended by the drill string with the bit hanging free in the well hole, the entire mass of the drill rod being supported by the drill string;

Figs. 4A, 4B and 4C, when assembled with Fig. 4A above and Fig. 4C below Fig. 4B, disclose on a somewhat enlarged scale, the acoustic isolator comprising the subject matter of the present invention;

Figs. 5A, 5B and 5C, each disclose fragmentary sectional views of portions of the acoustic isolator, Fig. 5A disclosing the pilot bearing and lubricator for the pilot bearing at the upper end of the isolator; Fig. 5B disclosing the lost motion connection between the drill string and drill rod with the compression spring means disposed between abutments respectively formed on the drill string and drill rod and Fig. 5C disclosing the slidable driving connection between the drill string and drill rod near the bottom of the isolator;

Fig. 6 discloses a sectional view of the slidable driving connection between the drill string and drill rod and is taken substantially along the line 6—6 in Fig. 5C and looking in the direction of the arrows; and

Figs. 7 and 8 comprise enlarged detail views of the pilot bearing and lubricator for the pilot bearing; Fig. 7 comprising a view similar to that shown in Fig. 5A and Fig. 8 showing the lubricator cavity compressed due to escape of lubricant therefrom.

Referring now to the drawings wherein like reference numerals have been used in the different views in order to identify identical parts and with particular reference to Fig. 1, the equipment disposed on the surface of the earth above the well hole will first be described. This equipment is conventional and includes derrick **10**, draw works **11**, driving rotary table **12**, kelly **13** extending through table **12**, swivel **14** coupled to the upper end of the fluid passage through kelly **13** and hook **15** supporting the bail of swivel **14**. The hook **15** is suspended by means of a traveling block **16** and cable **17** extending from the top of the derrick **10** and the cable **17** is wound on the usual hoisting drum of the draw works **11**. Mud fluid, such as is conventionally employed in rotary oil well drilling operations, is pumped through a supply line **18** from a supply tank or sump **19** and is delivered under pressure by a pump **20** through a pipe **21** and hose **22** to the gooseneck of swivel **14**, and from this point the mud fluid flows down through the kelly **13** and through a drill pipe string **23** coupled to the lower end of the kelly **13**.

The kelly **13** and the drill string **23** extend into a bore hole **24** which extends downwardly into the earth. The bore hole **24** is lined for a suitable distance down from the ground surface by surface casing **25** which is supported by a landing flange **26** resting on a concrete footing **27** in the bottom of a pit **28**. A blow-out preventer **29** is mounted at the head of the casing **25** and a riser **30** above the blow-out preventer **29** is provided with a mud flow line **31**. The mud flow line or delivery pipe **31** is shown as discharging to a conventional vibratory mud screen **32**, and the mud is returned from the latter back to the sump **19** by means of a pipe line **33**.

The drill pipe string **23** coupled at the lower end of the kelly **13** comprises a conventional drill pipe string and it will be understood that this drill string is made up of a number of usual drill pipe lengths coupled together by the usual tool joints (not shown).

The drill string **23** suspends a drill rod **34** in the well hole **24**, the drill rod **34** being coupled to the drill string **23** by means of an acoustic isolator, indicated generally by reference numeral **35**. Fastened to the drill rod **34**, at the upper end thereof is a turbine **36** and a vibration generator assembly or oscillator **37**, both of which are of the type disclosed in the aforementioned patent to Bodine 2,554,005. It is not essential for a thorough understanding of the present invention to describe the turbine **36** and vibration generator assembly **37** in detail herein as the details of operation and construction of the turbine and vibrator are set forth in full in the aforementioned Bodine patent. It will suffice to state herein that the turbine **36** and vibrator **37** are capable of vibrating the drill rod **34** and a bit **38** secured at the lower end of the drill rod at a frequency approximately equal to the resonant vibration frequency of the drill rod and bit.

The drill rod **34**, in addition to the turbine **36** and vibrator assembly **37** includes a massive elongated elastic longitudinally vibratory rod which is of substantial mass and length. This drill rod **34** may be made up of a plurality of steel drill collars, which are connected together preferably by means of tool joints of the pre-stressed type, such as is disclosed in the copending application of Udry et al., Ser. No. 394,432, filed November 25, 1953. It is contemplated that the lowermost drill collar of the drill rod **34** will be provided with an acoustic or sonic

decoupler cell such as is disclosed in the copending application of Currie et al. Ser. No. 360,706, filed June 10, 1953, now Patent No. 2,771,270. No further description of the decoupler cell will be given herein as the complete details thereof are set forth in said Currie et al. application. Immediately beneath the decoupler cell, the bit 38 is disposed and it is not considered necessary for a thorough understanding of the present invention to describe in detail the construction of the bit 38.

Referring now to Figs. 4A, 4B, 4C, 5A, 5B and 5C in particular, the constructional details of the acoustic isolator and of the pilot bearing and lubricator therefor comprising the subject matter of the present invention will now be described.

The drill string 23 has a lowermost drill collar 50 which is coupled to an upper isolator sub 53 by means of a pre-stressed joint 54 of the type disclosed in the aforementioned Udry et al. application Ser. No. 394,432. The upper isolator sub 53 is coupled to a lower isolator sub 55 by means of a similar pre-stressed joint 56.

The upper end of the drill rod 34 comprises a hollow pilot sub 57 which has a substantially cylindrical outer periphery adapted to slide within a pair of lubricated bushings 58 and 59 in order to pilot the drill rod 34 within the lower end of the drill string 23. The hollow pilot sub 57 is rigidly coupled to a short adapter sub 60, these two subs being retained rigidly secured together by any desired means, such as welding indicated at 61. The short adapter sub 60 is coupled to a main internal isolator sub 62 by means of a joint indicated generally by reference numeral 63. The joint 63 includes mating tapered surfaces 64 and 65 respectively formed on the adapter sub 60 and on the isolator sub 62 and also includes mating threaded portions 66 and 67 respectively formed on the inner periphery of the lower end of the adapter 60 and on the outer periphery of the isolator sub 62. An O-ring 63*a* is disposed within a suitable peripheral groove formed in the interior surface of the adapter sub 60 and is effective to provide a seal between the adapter sub 60 and the internal isolator sub 62.

The joint 63 may also be pre-stressed by relatively turning the mating threaded portions 66 and 67 until the portions of the adapter sub 60 and isolator sub 62 between the threaded regions and tapered regions thereof are respectively pre-stressed in tension and compression. This is effective to insure that the joint 63 will remain tight while the drill rod 34 is vibrated by the vibration generator assembly 37.

The hollow isolator sub 62 is coupled to a hollow torque transfer sub 68 by means of a pre-stressed joint 69 of the type disclosed in the copending Udry et al. application Ser. No. 394,432. The pre-stressed joint 69 is pinned by means of a pin on slug 70 in order to insure against this joint loosening as a result of vibrations induced in the drill rod 34 by means of the turbine 36 and vibration generator assembly 37. An O-ring 69*a* disposed in a suitable groove formed in exterior periphery of torque transfer sub 68 provides a seal between the isolator sub 62 and the torque transfer sub 68.

It will be noted that the upper isolator sub 53 is quite thin for a considerable longitudinal distance and telescopically disposed within the upper isolator sub 53 is the thin internal isolator sub 62 of the drill rod 34. The radially spaced inner surface 71 of the sub 53 and outer surface 72 of the sub 62 provide an annular cavity 73 for receiving compression spring means, indicated generally by reference numeral 74, therebetween.

The longitudinal extent of the annular cavity 73 is defined by a pair of abutment stops comprising an upper abutment stop 75 having internal threads 76 adapted to be threaded onto the externally threaded portion 67 of the internal isolator sub 62 and a lower abutment stop 77 on the sub 55. The abutment stop 75 serves as a lock nut when it is screwed onto the threads 67 until it tightly abuts the lower end of the adapter sub 60. The lower end of the annular cavity 73 is defined by the abutment stop 77 which is received within the upper end of the lower isolator sub 55. The abutment stop 77 has a flange 78 adapted to seat upon the upper end of the lower isolator sub 55.

The compression spring means 74 disposed within the annular cavity 73 comprises a pair of compression springs 79 and 80 having a stiff separating washer 81 disposed therebetween.

When the drill is disposed in the bore hole 24 and the bit 38 is disposed against the earth formation at the bottom of the hole, the relative positions of the drill rod 34 and drill string 23 are as shown in Fig. 2 of the drawings. In other words, so long as the drill bit 38 rests upon the formation at the bottom of the bore hole 24, there is considerable space in the annular cavity 73 above the compression spring means 74 and below the abutment stop 75. When the drill rod 34 hangs suspended in the bore hole 24, with the bit 38 held above the formation at the bottom of the bore hole, the entire mass of the drill rod 34 is suspended by the compression spring means 74. This latter condition is disclosed in Fig. 3 of the drawings. The compression spring means 74 are sufficiently strong to support the entire mass of the drill rod 34, for so long as it hangs free, without causing the compression springs 79 and 80 to compress to the point where the successive convolutions thereof rest upon each other. It is therefore apparent that under all conditions of operation the drill rod 34 is never rigidly coupled to the drill string 23 and thus it may be said that the drill string 23 is acoustically isolated from the vibratory massive drill rod 34.

In the operation of an earth boring drill of the general type disclosed herein, it has been found desirable to rotate the drilling bit as the boring operation progresses. This is due to the fact that when the bit 38 is not rotated as it is vibrated it tends to become locked in the formation at the bottom of the bore hole 24. The acoustic isolator 35 therefore includes means for transferring torque from the supporting rotary drill string 23 to the massive elongated drill rod 34. This torque transfer unit will now be described.

The torque transfer unit for coupling the drill string 23 for rotation in unison with the drill rod 34 is indicated generally by reference numeral 82. The torque transfer unit 82 comprises a sleeve 83 secured rigidly to the lower isolator sub 55 by any convenient means, such as welding for example, and provided with a plurality of semicylindrical openings 84 for snugly receiving an equal number of longitudinally extending pins 85. The converging sides 86 and 87 of each of the openings 84 serve to hold each of the pins 85 in the openings 84. The openings 84 are so located in the sleeve 83 that the pins 85 each project inwardly beyond the inner periphery 88 of the sleeve 83.

A short abutment sub 89 is rigidly secured to the sleeve 83 by means of a plurality of screws 90 which extend through suitable openings in flanges 91 formed on the upper end of the abutment sub 89 and which extend into suitable threaded openings 92 formed in the sleeve 83. The flanges 91 on the upper end of the abutment sub 89 are also provided with a plurality of threaded apertures 93 for receiving suitable short set screws or locking screws 94 which may be turned until they reach the ends of the pins 85 for thereby holding the pins 85 in longitudinally fixed relation in the sleeve openings 84. The lower end of the abutment sub 89 comprises an annular flat surface 95 adapted to abut an upper flat surface 96 formed on the upper end of the uppermost drill collar of the drill rod 34. The annular abutment sub 89 is adapted to rest upon the surface 96 of the drill rod 34 only when the entire mass of the drill string 23 is resting upon the formation at the bottom of the earth bore 24.

The torque transfer unit 82 also includes the hollow

torque transfer sub **68** which is provided with a plurality of longitudinally extending grooves **97**. A groove **97** is provided for each corresponding pin **85**, with each of the grooves **97** comprising a semi-cylindrical cavity formed in the torque transfer sub **68** and formed with a slightly greater radius of curvature than the radius of curvature of the torque transfer pins **85**. In the operation of the present drilling apparatus the sleeve **83** is adapted to rotate in a clockwise direction, as indicated in Fig. 6, and the pins **85** serve as keys, when seated within the openings **97**, for transferring torque from the sleeve **83** to the hollow torque transfer sub **68**. In order to minimize wear on the sides of the grooves **97**, each of the grooves **97** in the hollow torque transfer sub **68** is provided with a hard metal insert **98** made of some substantially wear-resistant material. Therefore, as the sleeve **83** turns in a clockwise direction, the pins **85** strike the wear-resistant inserts **98** and thus wear on the sides of the grooves **97** is held to a minimum.

Because of the fact that the grooves **97** are slightly larger than the pins **85**, there is some freedom between the pins **85** and the defining walls of the grooves **97**. This space provided by the freedom between the sides of the grooves and the pins **85** affords suitable passages for the passage of mud fluid between the grooves and pins, which mud fluid serves to cool these parts of the torque transfer unit which would otherwise heat up considerably due to friction between the pins **85** and inserts **98**. The friction between the pins **85** and inserts **98** is considerable inasmuch as the drill rod **34** and hollow torque transfer sub **88** are vibrating at substantially the resonant vibration frequency of the drill rod **34** simultaneously with rotation of the torque transfer unit **82**. Thus it is apparent that the friction between the pins **85** and the inserts **98** is of such a magnitude as to make it desirable to convey away the heat, generated by the friction, as rapidly as possible. It has been found that by providing the enlarged grooves **97**, the mud fluid, which serves to provide the force or power for actuating the drill rod **34** and bit **38** as well as to provide the force for removing the chips of the formation which are broken away at the bottom of the earth bore by means of the bit **38**, is also effective to cool the torque transfer unit.

Even though there is sufficient play of the pins **85** in the grooves **97** for mud fluid to pass through the grooves **97** in order to cool the torque transfer unit, the torque transfer unit **82** is effective in maintaining the drill rod **34** and drill string substantially concentric with respect to each other at the lower end of the acoustic isolator **35**. Due to the rather extreme forces which act upon the drill rod **34**, it is essential that the uppermost end of the drill rod **34** also be maintained in concentric alignment within the lower end of the drill string **23**. The means for maintaining the upper end of the drill rod **34** in concentric alignment with the drill string **23** will now be described.

The two bushings **58** and **59** comprise pilot bearings disposed between the inner periphery of the drill collar **50** and the outer periphery of the hollow pilot sub **57**. Both bushings **58** and **59** are designed so as to fit rather snugly within the inner surface **99** of the drill collar **50**, but there is freedom for the isolator sub **57** to slide longitudinally or reciprocate within the inner peripheries **100** and **101** of the bushings **59** and **58** respectively.

The bushing **59** is held fixed with respect to the drill collar **50** by means of an inwardly projecting shoulder **102** formed on the inner periphery of the drill collar **50** and by means of an abutment or stop washer **103** disposed in a suitable groove formed on the inner periphery of the drill collar **50**. Upward movement of the bushing **58** with respect to the drill collar **50** is limited by an abutment or stop washer **104** mounted in a suitable groove in the inner periphery of the drill collar **50**. However, the bushing **58** is free to move downwardly with respect to the drill collar **50**. Each of the bushings **58** and **59** are provided with internal peripheral grooves **105**. Radial openings **106** formed in each of the bushings **58** and **59** communicate with the peripheral grooves **105** and a plurality of longitudinal passages **107** establish communication from an annular cavity **108**, comprising the space between each of the bushings, to the internal peripheral grooves **105** formed in each of the bushings **58** and **59**.

Each of the bushings **58** and **59** is respectively provided with a pair of O-rings **109** and **110**, the O-rings **109** being provided for sealing the bushings **58** and **59** with respect to the drill collar **50** and the O-rings **110** being effective to provide a seal between the inner peripheries of the bushings **58** and **59** and the outer periphery of the hollow pilot sub **57**. The drill collar **50** is provided with a radially extending opening **111** for facilitating filling the cavity **108** with a suitable heavy lubricant or grease. A valve **112** provided at the outer end of the radial opening **111** is adapted to open when lubricant is to be forced into the cavity **108** and to automatically close so as to prevent the escape of lubricant from the cavity **108** through the opening **111**. The bushing **58** is provided with a longitudinally extending passageway **113** having a check valve **114** provided at the inner end thereof, which check valve is adapted to open in the direction of fluid escape from the cavity **108**.

When the cavity **108** is being filled with fluid lubricant or grease it is forced under pressure into the cavity through the valve **112**. Fig. 8 shows the cavity **108** when partially filled with lubricant. Air from within the cavity **108** is free to escape through the passageway **113** and through the check valve **114**. Since it is contemplated that the fluid lubricant admitted into the cavity **108** through the valve **112** will be rather heavy, such as a grease, for example, it will be readily apparent that the cavity becomes filled due to the escape of the fluid lubricant through the passageway **113**. Due to the fact that the escape passageway **113** is small and since the bushing **58** fits quite snugly within the inner periphery **99** of the drill collar **50** and due to the further fact that the fluid lubricant admitted into the cavity **108** is heavy, the bushing **58** will tend to remain in the position shown in Figs. 5A and 7 and the cavity **108** will remain filled. When the acoustic isolator **35** is lowered into the earth bore hole **24** and mud fluid is pumped downwardly through the drill string **23** and drill rod **34**, the pressure of the mud fluid is exerted on the upper end of the bushing **58** and on the check valve **114**. The mud fluid pressure thus closes the check valve **114** and the bushing **58** tends to be compressed toward the bushing **59** so as to place the fluid lubricant within the cavity **108** under pressure substantially equal to the pressure of the mud fluid. Subsequently, as the pressure of the mud fluid varies, it will exert a corresponding variable pressure on the upper end of the bushing **58** so that the pressure of the fluid lubricant within the cavity **108** at all times remains substantially equal to the pressure of the mud fluid acting on the bushing **58**.

The fluid lubricant in the cavity **108** communicates with the internal bushing surfaces **101** and **100**, in order to maintain the outer surface of the pilot sub **57** lubricated, through the passageways **107** and **106** leading to the internal peripheral grooves **105**. The O-ring seals **109** and **110** substantially seal the cavity **108** and since the pressure of the mud fluid outside of the cavity on the end of the bushings **58** and **59** is substantially the same as the pressure of the fluid lubricant, there is little tendency for there to be any escape of the fluid lubricant through or around the O-ring seals **109** and **110**.

Figs. 7 and 8 show the relative positions of the upper sleeve bushing **58** when the cavity is enlarged to its full volume and when the cavity is decreased in size due to compression of the bushing **58** toward the bushing **59**. During the operation of the drill there will be some

lubricant leakage out of the lubricant cavity **108**, but since the bushing **58** is capable of moving downwardly (see Fig. 8) under the pressure of mud fluid acting against the outside end thereof, the lubricant pressure within the cavity **108** remains substantially equal to the mud pressure acting on the bushing **58**.

In order to insure against having large fragments of abrasive material reaching the mud turbine **36**, means are provided in the acoustic isolator **35** for removing such large fragments from the stream of mud fluid and this means will now be described. At the upper end of the hollow pilot sub **57** a cap **115** is provided. The cap **115** is secured to the end of the pilot sub **57** by any well known or desired means, such as welding for example, and the cap is adapted to be disposed in substantial concentric relation within the lowermost sub **116** of the drill string **23**. The cap **115** is provided with a semi-spherical leading end **117** for deflecting the mud fluid outwardly toward the inner periphery of the sub **116**. The cap **115** is also provided with a plurality of elongated slots extending longitudinally with respect to the cap **115**, the elongated slots in the cap **115** having been designated by reference numeral **113**. The hollow pilot sub **57** is disposed in substantial concentric relation within the lower end of the drill string sub **116** and an annular cavity **119** exists between the sub **116** and pilot sub **57**. This annular cavity **119** extends from the lower end of the cap **115** downwardly to very near the end of the sub **116** where the inner periphery of the sub **116** is necked in, as indicated at **120**. There is sufficient freedom between the necked-in portion **120** of the sub **116** and the outer periphery of the pilot sub **57** so that the mud fluid entering the cavity **119** may communicate with the upper end of the bushing **58**. It will thus be seen that full mud pressure is applied to the upper end of the bushing **58** so as to cause this bushing to act like a piston against the lubricant disposed in the lubricant cavity **108**.

Mud fluid passing downwardly through the drill string **23**, for the purpose of driving the turbine **36** and carrying away chips of the formation broken away from the bottom of the bore **24** by the action of the bit **38**, passes downwardly through the lowermost drill collar **116** of the drill string **23** and upon reaching the cap **115** is deflected by means of the semi-spherical leading end **117** of the cap **115** toward the shell of the sub **116**. In order for the mud fluid to proceed downwardly through the drill rod **34** it must pass through the openings **118** in the cap **115**. It will thus be seen that the direction of flow of the mud fluid, as it is deflected by the semi-spherical end **117** of the cap **115** and thereafter passes into the pilot sub **57** through the slots **118**, is changed considerably. Since the mud fluid is largely made of fine mud particles retained in suspension in the fluid, the mud fluid flows readily through this meandering path. The heavy or coarse abrasive particles do not so readily adjust themselves to the changes in direction of mud fluid flow and therefore when the heavy or coarse fragments are deflected outwardly by the cap **117** they tend to settle between the cap **115** and the sub **116** into the cavity **119**. Therefore, the coarse or heavy fragments which would abrade the blades of the turbine **36** are prevented from ever reaching the turbine since they settle into the cavity **119** and remain therein.

In order to facilitate removing the mud fluid and the settled coarse fragments from the cavity **119**, a pair of plugs **121**, which may be removed, are provided. The mud fluid may then be washed out through the holes provided when the plugs **121** are removed.

In order to permit and insure the free longitudinal vibratory and reciprocatory movement of the drill rod **34**, the isolator subs **53** and **55** are each provided with a plurality of radial openings **122**. During downward movements of the drill rod **34** the volume of the annular cavity **73** increases and by permitting the mud fluid from outside of the isolator sub **53** to enter the cavity **73** there is no tendency for there to be a vacuum created within the cavity **73** as the drill rod **34** moves downwardly. Likewise, when the drill rod **34** moves upwardly relative to the two isolator subs **53** and **55**, the volume of the cavity **73** decreases and the radially extending openings **122** permit mud fluid within the cavity **73** to escape to the outside of the drill string through the openings **122**. There is thus no tendency for there to be any hydraulic lock created between the drill rod **34** and the drill string. The openings **122** in the lower isolator sub **55** also facilitate the passage of mud fluid into and out of the space between the lower isolator sub **55** and the hollow torque transfer sub **68**. It will be recalled that it is desirable that some mud fluid pass between the pins **85** and the peripheries of the grooves **97** in the torque transfer unit **82** in order to provide cooling of the pins **85** and metal inserts **98**. The mud fluid, as stated previously, may pass downwardly through the grooves **97** and thereafter may escape to the outside of the drill rod by passing between the inner periphery of the abutment sub **89** and the outer periphery of the torque transfer sub **68** and thence outwardly between the abutment surfaces **96** and **95**.

In the operation of the drilling apparatus of the type disclosed herein, the drill string **23** and suspended drill rod **34** are gradually lowered into the earth bore **24** until the bit **38** strikes the bottom of the bore **24**. While the drill string **23** and drill rod **34** are being lowered into the earth bore **24**, the relative positions of the drill string **23** and drill rod **34** are as disclosed in Fig. 3, with the entire mass of the drill rod **34** being supported by the compression spring means **74**. The drilling rig operator will permit the drill string **23** to descend until the bit **38** strikes the formation at the bottom of the bore hole **24** and will permit the drill string **23** to descend thereafter until the abutment surfaces **94** and **96** are almost in engagement. At this time there will be some twenty to twenty-four inches existing between the top of the upper compression spring **79** and the bottom of the abutment stop **75**.

The actual drilling operation is then commenced. Mud fluid is pumped by the pump **20** downwardly through the drill string **23** in order to drive the turbine **36**. The turbine **36** actuates the oscillator **37** and the drill rod **34** is thus set into longitudinal vibration. The vibration of the drill rod **34** is at substantially the resonant vibration frequency thereof. The bit then commences to break up the formation at the bottom of the bore hole **24** and the drill rod **34** descends, the abutment stop **75** moving downwardly at this time toward compression spring **79**. The drilling rig operator will permit the drill rod **34** to descend relative to the drill string **23** for a distance of the order of approximately one and one-half feet. Throughout this entire penetration of the bit **38** into the formation, the vibrating drill rod **34** is acoustically isolated from the suporting drill string **23** since the abutment stop **75** at no time even engages the spring **79** due to the fact that the entire mass of the drill rod **34** is resting on the bottom of the formation in the bore hole **24**.

The drilling rig operator will then permit the drill string **23** to descend approximately one and one-half feet until the stops **95** and **96** are just free of one another. The entire procedure is then repeated. It will therefore be apparent that the work of the drilling rig operator is greatly facilitated as a result of the fact that he does not have to maintain a continuous watch on the descent of the drill string **23**. In other words, the drilling rig operator may permit the drill string **23** to descend about one and one-half feet every half minute to one and one-half minutes depending upon the rate of penetration of the drill into the earth.

If the drilling bit **38** penetrates the formation very rapidly, so that the relative positions of the drilling rod **34** and drill string **23** are like that disclosed in Fig. 3, the entire mass of the drilling rod **34** will be supported by the drill string **23** through the medium of the compres-

sion spring means 74. Assuming that the mud fluid continues to be pumped downwardly through the drill string so that the turbine 36 is continually operated, the massive drill rod 34 will continue to vibrate. The compression spring means 74 between the abutment stops 75 and 77 is effective to isolate the drill string 23 from the drill rod 34, even though the entire mass of the drill rod 34 is supported by the compression spring means 74. As a result, vibrations in the drill rod 34 are not transmitted to the drilling string 23 and derrick 10 even when the mass of the drill rod 34 is entirely carried by the drill string 23.

It is therefore apparent that the present invention provides an efficient acoustic isolator between the telescopically arranged outer supporting drill string sleeve shaft and inner vibratory drill rod sleeve shaft of an earth bore drilling apparatus and by also providing the elongated cavity 73 affording lost motion between the stops 75 and 77 the work of the drilling rig operator is facilitated inasmuch as he does not have to maintain such a diligent watch on the penetration rate of the drill bit 38. By providing the unique kelly or torque transfer apparatus 82, rotation of the drill string 23 is readily transmitted to the drill rod and wear of the different parts is held to a minimum. The unique piloting means for the telescoping drill string and drill rod sleeve shafts comprising the sleeve bushings 58 and 59 is very important since it is essential that the drill rod be maintained in concentric alignment with the drill string. Further, the means for lubricating the bearing surfaces of the pilot bearing is considered to be unique.

The cap 115 for deflecting the mud fluid to thereby facilitate settling of the coarse abrasive fragments in the mud fluid into the cavity 119 is also an important and desirable feature of the present invention.

The location of the torque transfer unit 82 below the acoustic isolating compression spring means 74 is considered to be very beneficial. By locating the torque transfer unit at a point below the isolating springs, it is therefore possible to utilize a pilot sub of small diameter and cross section and to utilize isolator subs of small cross section since they do not transfer torque loads. The pilot sub and all of the sections extending therefrom up to the cap 115 are subjected, in the main, only to tension loads and in designing these portions of the drill it is not necessary to consider torsion fatigue. Since the pilot sub need be of only a small diameter the problem of finding space for locating the isolator compression springs 74 is obviously simplified.

Another advantage of the present acoustic isolator arises from the fact that the isolating compression spring means is disposed between the torque transfer unit and the pilot bearing. It is thus possible to provide the greatest possible length between the pilot bearing and the torque transfer unit and this increases the stability of the internal isolator sub 62.

Another advantage afforded by the present acoustic isolator results from the fact that the outer isolator housing is composed of an upper and a lower isolator sub so that it is not necessary to handle a long heavy sub when the apparatus is being transported. Further, by providing the internal isolator sub 62 separate from the internal hollow torque transfer sub 68, ease of handling is also facilitated and further, it is only necessary that the pilot sub be made of the highest quality steel having good bearing qualities. The use of the coil type compression springs renders the isolating unit practically fool-proof and maintenance is reduced to a minimum. Due to the fact that the compression spring means 74 are actually in operation only a very small percentage of the time that the drilling is actually taking place, the life of the isolating springs 74 is greatly increased.

From the foregoing description of the present invention it will be apparent that it provides an acoustic isolator adapted for use in an earth bore drilling apparatus having a longitudinally vibratory drill rod, which acoustic isolator is simple and effective and requires a minimum of effort in order to maintain the same in proper working order. It is contemplated that numerous changes and modifications may be made in the present invention without departing from the spirit or scope thereof.

What is claimed is:

1. A pilot bearing adapted for use between a pair of telescoping sections of the drill string of an earth bore drilling apparatus wherein one of the sections vibrates longitudinally relative to the other and the drill string is adapted to have mud fluid forced downwardly therethrough and upwardly between the drill string and the inner periphery of the earth bore in order to carry away chips of the earth formation at the bottom of the bore and cut away by the drilling apparatus, said pilot bearing comprising a pair of longitudinally spaced bushings reciprocable relative to each other and disposed between said telescoping sections, said bushings surrounding the inner telescoping section and being in sealing engagement with the outer periphery of said inner telescoping section and in sealing engagement with the inner periphery of the outer telescoping section and said bushings being adapted to be movable relative to said telescoping sections while still maintaining the sealing relationship therewith whereby said bushings isolate the space between said bushings and said telescoping sections from the area above and below the respective bushing to form a lubricant chamber between said telescoping sections, lubricant disposed within said chamber, each of said bushings having one end exposed to and in communication with the mud fluid and thereby being adapted to have the mud fluid act against the respective exposed ends thereof for compressing the bushings against the lubricant disposed in said chamber for maintaining the pressure of the lubricant at substantially the same value as the pressure of the mud fluid, and a pressure relief valve for said chamber for permitting escape of lubricant therefrom in the event that the pressure of the lubricant in the chamber exceeds the pressure of the mud fluid by more than a predetermined amount.

2. A pilot bearing adapted for use between a pair of telescoping sections of the drill string of an earth bore drilling apparatus wherein one of the sections vibrates longitudinally relative to the other and the drill string is adapted to have mud fluid forced downwardly therethrough and upwardly between the drill string and the inner periphery of the earth bore in order to carry away chips of the earth formation at the bottom of the bore and cut away by the drilling apparatus, said pilot bearing comprising a pair of longitudinally spaced bushings disposed between said telescoping sections, said bushings surrounding the inner telescoping section and being in sealing engagement with the outer periphery of said inner telescoping section and in sealing engagement with the inner periphery of the outer telescoping section and said bushings being adapted to be movable relative to said telescoping sections while still maintaining the sealing relationship therewith whereby said bushings isolate the space between said bushings and said telescoping sections from the area above and below the respective bushings to form a lubricant chamber between said telescoping sections, lubricant disposed within said chamber, each of said bushings having one end exposed to and in communication with the mud fluid and thereby being adapted to have the mud fluid act against the respective exposed ends thereof for compressing the bushings against the lubricant disposed in said chamber for maintaining the pressure of the lubricant at substantially the same value as the pressure of the mud fluid, and a pressure relief valve for said chamber and adapted to have the mud fluid act thereagainst for closing the valve whereby the valve opens readily to permit the escape of air and bubbles when the chamber is being filled with lubricant

and the mud fluid acts to hold the valve closed to prevent the escape of lubricant from the chamber except when the lubricant pressure exceeds the mud fluid pressure by a predetermined amount.

3. A pilot bearing adapted for use between a pair of telescoping sections of the drill string of an earth bore drilling apparatus wherein one of the sections vibrates longitudinally relative to the other and the drill string is adapted to have mud fluid forced downwardly therethrough and upwardly between the drill string and the inner periphery of the earth bore in order to carry away chips of the earth formation at the bottom of the bore and cut away by the drilling apparatus, said pilot bearing comprising a pair of vertically spaced sleeve bushings disposed between said telescoping sections, said bushings surrounding the inner telescoping section and being in sealing engagement with the outer periphery of said inner telescoping section and in sealing engagement with the inner periphery of the outer telescoping section whereby said bushings isolate the space between said bushings and said telescoping sections from the area above and below the respective bushings to form a lubricant chamber between said telescoping sections, the lower of said sleeve bushings being fixed with respect to one of said telescoping sections, the upper of said sleeve bushings being reciprocable with respect to said telescoping sections while still maintaining the sealing relationship therewith and said one section having stop means for limiting displacement of the upper sleeve bushing from said lower sleeve bushing, the mud fluid being in communication with and acting against the upper end of said upper sleeve bushing whereby the upper sleeve bushing acts as a piston for pressurizing the lubricant within said chamber at a value substantially equal to the pressure of the mud fluid for thereby minimizing leakage of the lubricant from said chamber, and a pressure relief valve disposed in one of said sleeve bushings for relieving the lubricant pressure in said chamber and adapted to have the mud fluid act thereagainst for closing the valve at all times except when the lubricant pressure exceeds the mud fluid pressure by more than a predetermined amount.

4. A pilot bearing for maintaining the concentric alignment of a longitudinally reciprocable shaft disposed within a sleeve shaft, said bearing comprising a pair of spaced relatively movable sleeve bushings disposed concentrically between said shafts, said sleeve bushings surrounding said reciprocable shaft and having inner and outer bearing surfaces engageable with the respective shafts, whereby said sleeve bushings isolate the space between said bushings and said shafts from the area above and below the respective sleeve bushing, each of said sleeve bushings having spaced peripheral grooves disposed adjacent to said longitudinally reciprocable shaft, the space between said shafts and said bushings defining a lubricant chamber adapted to receive a quantity of lubricant under pressure, and each of said sleeve bushings including means defining lubricant passages communicating with said peripheral grooves for conveying lubricant from said chamber to said peripheral grooves for lubricating the bearing surfaces of said sleeve bushings.

5. A pilot bearing for maintaining the concentric alignment of a longitudinally reciprocable shaft disposed within a sleeve shaft, said bearing comprising a pair of spaced relatively movable sleeve bushings disposed concentrically between said shafts, said sleeve bushings surrounding said reciprocable shaft and having inner and outer bearing surfaces engageable with the respective shafts whereby said sleeve bushings isolate the space between said bushings and said shafts from the area above and below the respective sleeve bushing, each of said sleeve bushings having spaced peripheral grooves disposed adjacent to said longitudinally reciprocable shaft, the space between said shafts and said bushings defining a lubricant chamber adapted to receive a quantity of lubricant under pressure, said sleeve bushings being adapted to have an external fluid pressure applied to the ends thereof for relatively moving said sleeve bushings toward each other for maintaining the pressure of said lubricant substantially equal to said external fluid pressure, and each of said sleeve bushings including means defining lubricant passages communicating with said peripheral grooves for conveying lubricant from said chamber to said peripheral grooves for lubricating the bearing surfaces of said sleeve bushings.

6. A pilot bearing adapted for use between a pair of telescoping shafts of a drill string of an earth bore drilling apparatus wherein one of the shafts is disposed within and vibrates longitudinally relative to the other and the drill string is adapted to have mud fluid forced downwardly therethrough and upwardly between the drill string and the inner periphery of the earth bore in order to carry away chips of the earth formation at the bottom of the bore and cut away by the drilling apparatus, said bearing comprising a pair of spaced relatively movable sleeve bushings disposed concentrically between said shafts, said sleeve bushings surrounding said inner telescoping shaft and having inner and outer bearing surfaces engageable with the respective shafts whereby said sleeve bushings isolate the space between said bushings and said shafts from the area above and below the respective sleeve bushing, each of said sleeve bushings having spaced peripheral grooves disposed adjacent to said longitudinally reciprocable shaft, the space between said shafts and said bushings defining a lubricant chamber adapted to receive a quantity of lubricant under pressure, and each of said sleeve bushings including means defining lubricant passages communicating with said peripheral grooves for conveying lubricant from said chamber to said peripheral grooves for lubricating the bearing surfaces of said sleeve bushings.

7. A pilot bearing adapted for use between a pair of telescoping shafts of a drill string of an earth bore drilling apparatus wherein one of the shafts is disposed within and vibrates longitudinally relative to the other and the drill string is adapted to have mud fluid forced downwardly therethrough and upwardly between the drill string and the inner periphery of the earth bore in order to carry away chips of the earth formation at the bottom of the bore and cut away by the drilling apparatus, said bearing comprising a pair of spaced relatively movable sleeve bushings disposed concentrically between said shafts, said sleeve bushings surrounding said inner telescoping shaft and having inner and outer bearing surfaces engageable with the respective shafts whereby said sleeve bushings isolate the space between said bushings and said shafts from the area above and below the respective sleeve bushing, each of said sleeve bushings having spaced peripheral grooves disposed adjacent to said longitudinally reciprocable shaft, the space between said shafts and said bushings defining a lubricant chamber adapted to receive a quantity of lubricant under pressure, said sleeve bushings being adapted to be disposed between said shafts so that the mud fluid pressure is applied to the ends thereof for moving said sleeve bushings toward each other for maintaining the pressure of said lubricant substantially equal to said mud fluid pressure, and each of said sleeve bushings including means defining lubricant passages communicating with said peripheral grooves for lubricating the bearing surfaces of said sleeve bushings.

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