Sept. 20, 1960 A. G. BODINE ET AL 2,953,351

MASS VIBRATION ABSORBER FOR SONIC OIL WELL DRILL

Filed Aug. 26, 1957 4 Sheets-Sheet 1

FIG. 1

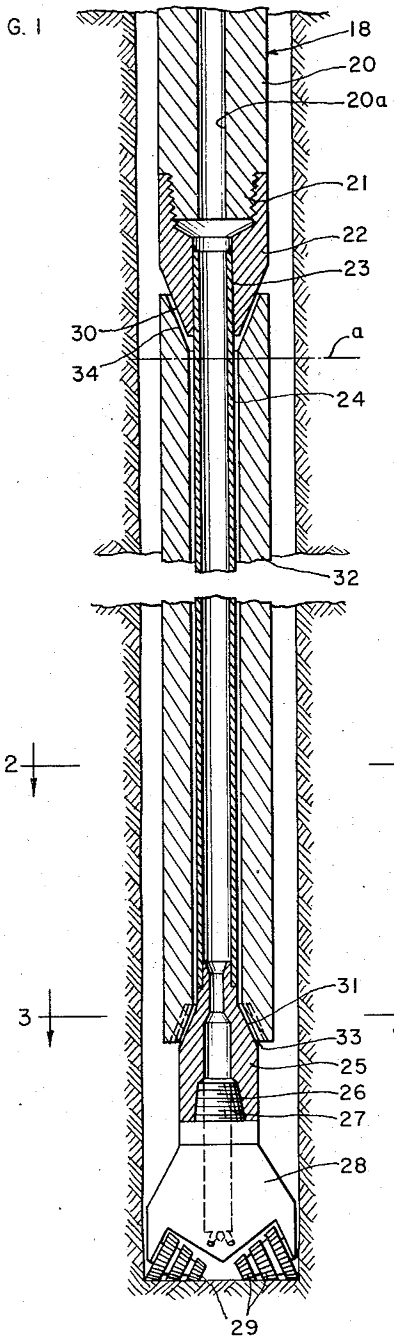


FIG. 2

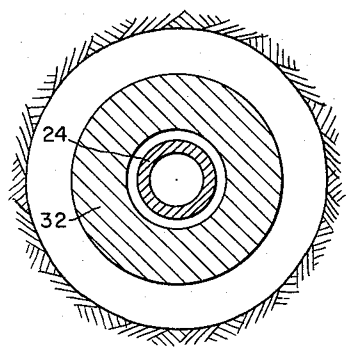
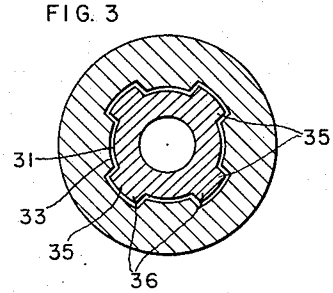


FIG. 3



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MASS VIBRATION ABSORBER FOR SONIC OIL WELL DRILL

Filed Aug. 26, 1957 4 Sheets-Sheet 2

FIG. 4

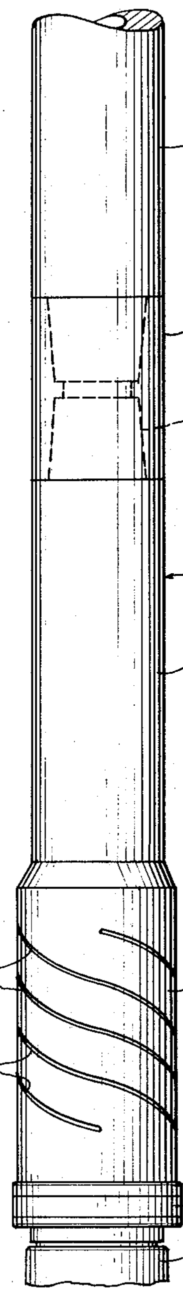
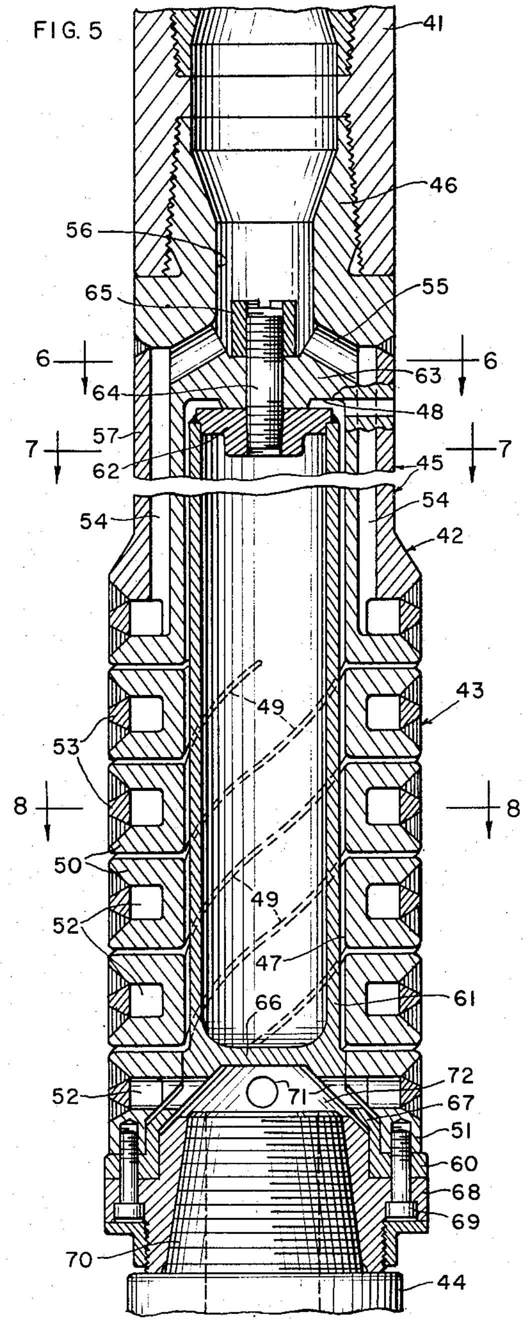


FIG. 5



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MASS VIBRATION ABSORBER FOR SONIC OIL WELL DRILL

Filed Aug. 26, 1957 4 Sheets-Sheet 3

FIG. 6

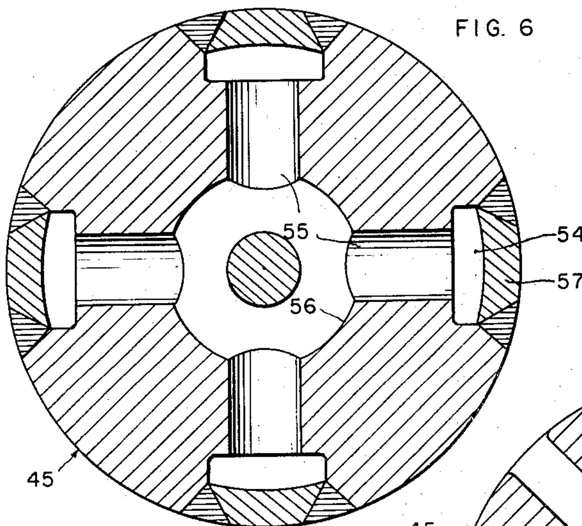


FIG. 7

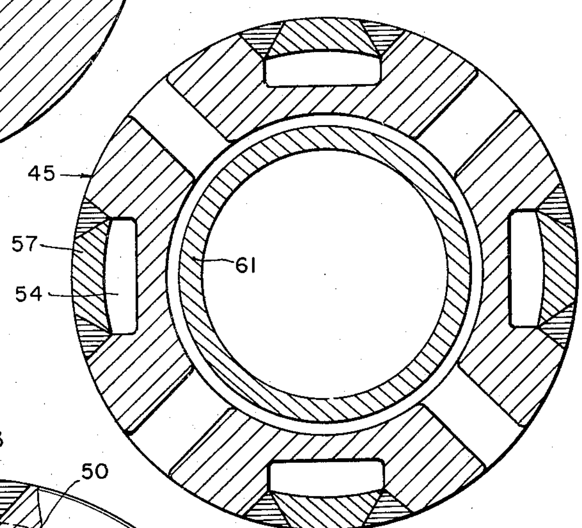
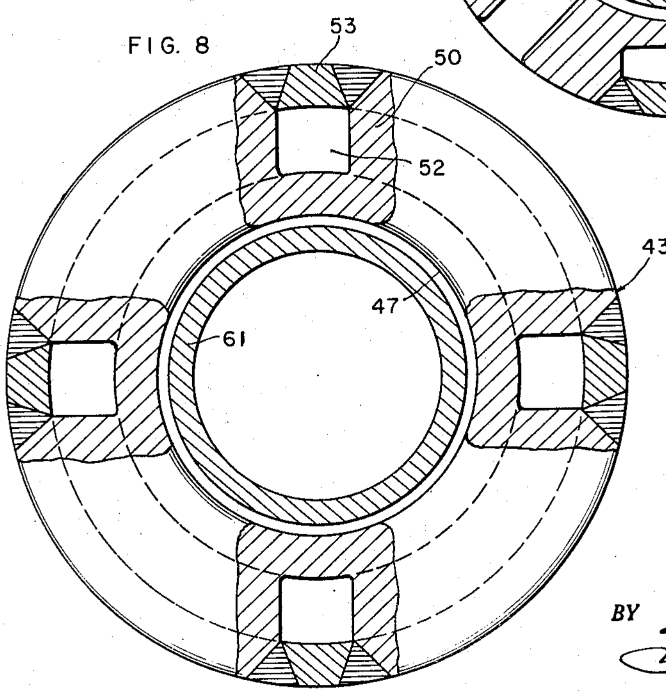


FIG. 8



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MASS VIBRATION ABSORBER FOR SONIC OIL WELL DRILL

Filed Aug. 26, 1957 4 Sheets-Sheet 4

FIG. 9

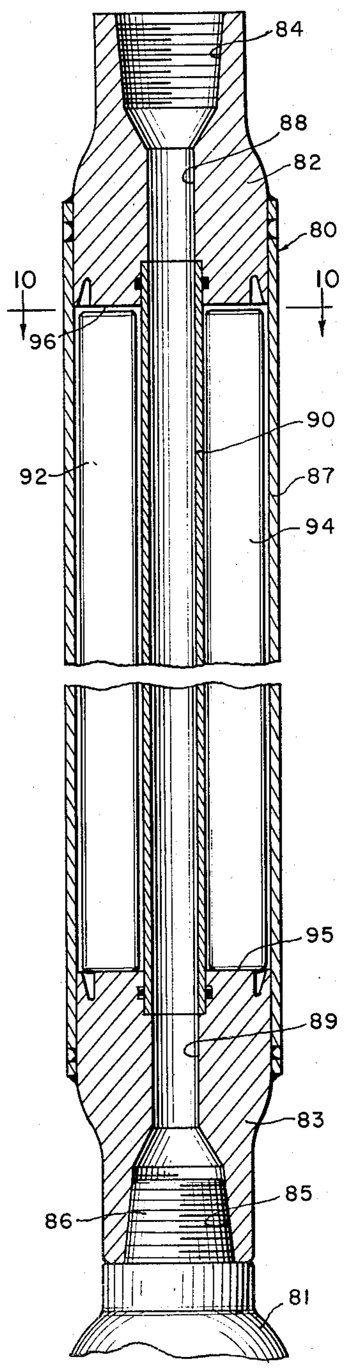


FIG. 10

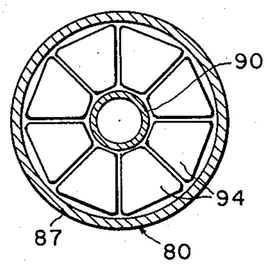
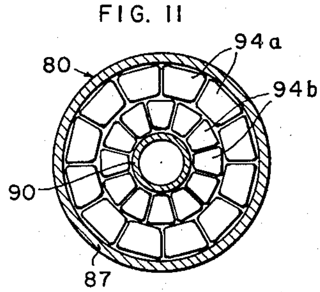


FIG. 11



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United States Patent Office

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MASS VIBRATION ABSORBER FOR SONIC OIL WELL DRILL

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Filed Aug. 26, 1957, Ser. No. 680,292

9 Claims. (Cl. 255—4.4)

This invention relates generally to deep well drilling, and more particularly to means for improving the drilling action of conventional rotary drag bits or roller cutter rock bits, especially for relatively irregular formations.

In the operation of the conventional rotary bit such as those of the toothed roller type, designed for and operating on relatively irregular formations, an undesirable relatively low frequency vibratory action is often encountered. Ideally, in this type of drilling, successive teeth of the cutters should cut their way into the formation without elevation of the bit body and any part of the drill string above. However, in practice, the bit rises and falls, due possibly to roughness of the hole bottom, slant of the formation, or other factors. The kelly may be observed to rise and fall, with a relatively slow but regular periodicity. Obviously, during each rise, the cutters are not making proper progress through the formation. It may be mentioned that the periodicity observed under the conditions here described is not that of the contact frequency of individual cutter teeth with the rock, but is one of a lower order. Thus a number of cutter teeth may engage the rock during the cycle; but whenever the bit is not fully down, the cutter teeth do not make the full cuts into the formation of which they are capable. The full explanation of the reason for this condition remains somewhat obscure, but the condition is one often observed in drilling relatively uneven or irregular rock formations.

A broad object of the invention is to provide means for suppressing the described tendency for vertical oscillation of the bit in rotary drilling.

The present invention introduces the broad concept of a mass impedance element discontinuously coupled to the drill column near the vibratory bit. The bit, as stated above, is under certain conditions prone to a type of undesirable vibration, and is hence a vibration generator. The concept of the invention is to couple to this generator, for part of the time duration of each vibration cycle, a mass impedance element, so as to periodically, i.e., one or more times each cycle, impose a mass loading on the generator, or bit. The mass element is thus repeatedly in and out of vibration transmission "circuit," so as to present a discontinuous impedance, much like a rectifier if placed in an electronic oscillator circuit. The original vibratory motion of the bit may be regarded as substantially sinusoidal in character. Sudden imposition of mass loading at a selected point or points in the cycle destroys this substantially sinusoidal wave motion, clipping the wave peaks at low amplitude, and converting the wave into a nonlinear form containing a large number of high frequency harmonics. The "Q" factor of the original wave is almost completely destroyed. In consequence, vibration of the bit and drill stem is greatly reduced, or virtually eliminated. The drill settles down to smoother, nonvibratory cutting, with greater drilling rate, and lessened bit damage.

One illustrative form of the invention comprises a massive sleeve surrounding the drill stem between the

collars and bit, and provided at its lower end with an impact shoulder adapted for engagement with an impact seat formed on the upper portion of the body of the bit, or on a member close to and tightly joined to the bit. The sleeve may ride normally on this impact seat. If the bit should begin to vibrate at material amplitude, the sleeve shoulder and the bit seat separate; and on each succeeding upstroke of the bit, the impact bit seat strikes the sleeve shoulder. This usually happens as the sleeve is falling, so that there is considerable out-of-phase relative motion. Thus, the bit is suddenly mass loaded. In other terms, a mass impedance is suddenly connected to the vibration generator comprised of the bit. On the downstroke of the bit, the impact surfaces separate, owing to the fact that the bit descends more rapidly than the sleeve. This tendency for the bit to descend quickly with an acceleration of more than one G is a result, in most forms of the invention, of a downward bias force owing to a compressive elastic stress developed in the members connecting the bit to the drill string above. A downward bias is also exerted by the mud pressure inside the bit, ahead of where the mud issues from the bit nozzle. This action very rapidly damps out the large amplitude vibrations.

In another embodiment, the upper end of the sleeve also has an impact shoulder, which is adapted for engagement with a downwardly facing impact seat on the drill stem. These elements come into engagement during the downstroke. Thus mass loading is imposed at a point in the cycle during the upstroke, and at another point in the cycle during the downstroke. Moreover, the sleeve is moving up when engaged by the descending drill stem, so that energy delivered from the drill stem to the sleeve on the upstroke is now returned to the drill stem to retard it on the downstroke. Similarly, energy delivered to the sleeve on the downstroke of the drill stem is returned to the drill stem at time of impact on the upstroke to retard the upstroke. By virtue of this energy conservation, a lighter sleeve may be employed.

A still further feature of one form of the invention is to utilize a plurality of mass elements designed to frictionally slide or work on one another during vibration conditions, with the effect of introducing a frictional resistance that consumes vibration energy (converts it to heat).

The invention will be better understood by now referring to the following detailed description of several illustrative embodiments thereof, reference being had to the accompanying drawings, in which:

Fig. 1 is a longitudinal sectional view of one embodiment of the invention;

Fig. 2 is a transverse section taken on line 2—2 of Fig. 1;

Fig. 3 is a transverse section taken on line 3—3 of Fig. 1;

Fig. 4 is an elevational view of another embodiment of the invention, the bit being broken away;

Fig. 5 is an enlarged longitudinal sectional view of the embodiment of Fig. 4;

Fig. 6 is a transverse section on line 6—6 of Fig. 5;

Fig. 7 is a transverse section on line 7—7 of Fig. 5;

Fig. 8 is a transverse section on line 8—8 of Fig. 5;

Fig. 9 is a view partly in elevation and partly in longitudinal section of another embodiment of the invention;

Fig. 10 is a transverse section on line 10—10 of Fig. 9; and

Fig. 11 is a view similar to Fig. 10, but showing a modification.

Referring first to that embodiment of our invention shown on Figs. 1 to 3, numeral **18** designates generally the lower end portion of a rotary drill shaft, the lower end portion of a conventional string of drill collars being shown at 20, and the upper end of these collars will be understood to be coupled to the drill pipe string above in the usual manner. Collars have the usual circulation bore 20*a*. Screwed onto the coupling pin 21 at the lower end of lowermost collar 20 is a sub 22 formed with a central bore 23, in which is welded the upper end portion of a tube 24 of reduced diameter, the lower end of which is welded to a lower sub 25 having at the bottom a threaded box 26 adapted to receive the pin 27 on the upper end of conventional toothed roller cone bit 28, the latter having, for example, a conventional toothed conical roller cutters 29, of which there may be two, three, or four, as in conventional bits. Upper sub 22 has a downwardly converging conical impact surface 30 leading inwardly to tube 24, and lower sub 25 has an upwardly converging conical impact or seating surface 31 leading inwardly toward the tube 24, as shown.

Surrounding the tube 24 between the subs 22 and 25 is a relatively massive sleeve 32, having at its lower end a conical impact shoulder 33 opposed and parallel to the aforementioned surface 31 on lower sub 25, and having at its upper end a conical impact shoulder 34 opposed and parallel to the aforementioned conical surface 30 on upper sub 22. The surface 33 will be understood to seat normally on the seating surface 31 on sub 25, and by relative upward movement of sleeve 32, the shoulder 34 at the upper end of the sleeve may engage or impact against the seat 30 on upper sub 22. In the position illustrated in Fig. 1, the sleeve 32 is in an intermediate position of operation, with its shoulder 33 spaced by a short clearance distance from seat 31, and with its upper shoulder 34 also spaced by a short clearance distance from upper seat 30.

Preferably, in order to key the sleeve 32 against relative rotation with respect to the balance of the drill stem, and in this manner provide mass impact loading for any torsional vibrations, the conical seat 31 on the lower sub is provided with a plurality of ribs 35 (see Fig. 3), received loosely in slots 36 formed in shoulder 33. Similar ribs and slots may be used at the upper end of the sleeve 32 if desired, although such are omitted from the present drawings.

The specific embodiment shown in Figs. 1 to 3 has coacting engagement or impact surfaces 31 and 33 at the lower end of the sleeve 32, and additional coacting engagement or impact surfaces 30 and 34 at the upper end of the sleeve. In a simpler form of the invention, the engagement surfaces 30 and 34 may be omitted, in which case the sleeve may be terminated, for instance, at the level indicated in dot-dash lines at *a*.

The operation of the embodiment of Figs. 1 to 3 will first be described on the assumption that the engagement shoulders 30 and 34 are not employed, the upper end of the sleeve 32 terminating, for example, at the level *a*. In the operation of the drill, a condition at the hole bottom may be encountered which will cause the bit 28 to be set into vibration. Prior to such vibratory action, the sleeve 32 will be understood to have been riding on the bit body with its seating shoulder 33 in engagement with the seat 31. As the bit suddenly starts to vibrate, the sleeve is thrown upwardly, or separates, from the seat 31. Thereafter, on each upstroke of the bit, the seat 31 impacts against the shoulder 33 on the sleeve, whereby the bit is suddenly loaded by the mass of the sleeve. On the ensuing downstroke of the bit, the impact surfaces 31 and 33 separate, owing to the fact that the bit descends more rapidly than the sleeve. Such relative retardation of the sleeve relative to the bit may be owing to the enveloping upwardly flowing drilling fluid, or to a downward acceleration of the bit owing to the internal pressure of the conventional drilling mud fluid, or to elastic vibration of the tube 24 or to all these factors in combination. On the next upstroke of the bit, the surface 31 again impacts against the sleeve surface 33, and so on. This repeated coupling of the mass element 32 with the bit 28 rapidly damps out the vibrations. It will be understood that if the mass element were fixed to the bit, it would be set into vibration along with the bit, and no very great damping effect would be accomplished. It is the fact that the mass element is discontinuously coupled with the vibratory bit that suppresses the vibration. As earlier described in the introductory portion of the specification, the bit tends normally to vibrate with a substantially sinusoidal wave action. The sudden imposition of mass loading on the bit as the bit travels upwardly clips the wave peaks at low amplitude, and converts the wave of vibration into a nonlinear form containing a large number of high frequency harmonics. The "Q" of the vibratory system is virtually destroyed. Vibration of the bit and drill stem is thereby materially reduced, or virtually eliminated. The drill cutters settle down to smooth, nonvibratory cutting action, with materially increased penetration rate.

In the operation of that form of the invention described immediately above, the mass element 32 engages the drill stem once during each cycle of the vibration, and disengages therefrom at a later point in the cycle.

The operation of the drill of Figs. 1 to 3 will next be described with the assumption that the impacting surfaces 30 and 34 are employed. In this case, action on the upstroke is substantially as before. On the downstroke of the bit and drill stem, however, impact surface 30 engages the upper impact shoulder 34 of sleeve 32. Thus, mass loading is not only imposed on the drill stem at a point in the cycle during the upstroke, but at a subsequent point in the cycle during the downstroke. Owing to engagement of the lower end of the sleeve by the impact surface 31 during the upstroke of the bit and drill stem, the sleeve is thrown upwardly somewhat, and is still moving upwardly when the drill bit and stem have reversed direction and start downwardly. Accordingly, the descending drill stem strikes the still ascending sleeve, so that energy delivered from the drill stem to the sleeve on the upstroke is now returned to the drill stem to retard it on the downstroke. Similarly, energy delivered to the sleeve on the downstroke of the drill stem is returned to the drill stem at time of impact on the upstroke to retard the upstroke. By virtue of this energy conservation, a lighter sleeve may be employed.

Figs. 4 to 8 show another illustrative embodiment using a helical form of mass impedance element, the several turns of which are made both heavy and flexible so as to interengage with each other to impose discontinuous mass loading on the bit when vibratory conditions occur.

The lower end portion of the usual string of drill collars is indicated at 40, and coupled thereto, as by coupling 41, is the upper end of a long tubular member 42, having a helically slotted section 43, and to the lower end of which is coupled the bit, fragmentarily indicated at 44. The bit may be of any conventional or suitable toothed roller cutter type, or any other, as before.

The member 42 is milled from a solid cylindrical bar of steel. It comprises an upper cylindrical stem 45, of the same diameter as the drill collars above, formed at the top with threaded coupling pin 46 for connection with the box of coupling 41. Below stem 45 is the helically slotted section 43, of enlarged outside diameter, and a bore 47 extends upwardly through this helically slotted portion and up in stem 45 to a blind end 48. The section 43 is formed, in the present case, by means of four spiral slots 49, forming quadruple pitch coil member comprised of four relatively heavy but flexible, close spaced spiral bars 50 connecting the stem 45 with a base annulus 51. These bars so formed are massive and have a large amount of lateral surface for active engagement when the bars deflect laterally. Moreover, the slots are narrow.

The four spiral bars 50 are hollow, forming mud fluid passageways 52. This formation may be provided by first grooving the bars **50**, and then welding spiral filler strips **53** into place, as shown.

The upper ends of the several passageways communicate with the lower ends of passageways **54**, and the upper ends of the latter communicate via passageways **55** with a bore **56** extending downwardly through coupling pin **46**. It will be understood that the bore **56** is thus in communication with the circulation mud fluid passageway extending downwardly through the drill stem and collars above. The passageways **54** are formed in this instance by vertically grooving the sides of stem **45**, and then welding filler strips **57** in place, as illustrated.

Engaging the lower end of annulus **51** is a mounting flange **60** of a long connecting mandrel **61** that extends upwardly, with clearance, through the bore of the coils and the stem **45**. Welded to the top of mandrel **61** is a head **62**, which engages a transverse wall **63** extending across stem **45**, and head **62** and wall **63** are interconnected, as by means of stud **64** and jamb nut **65**. The lower end of mandrel **61** is closed by a wall **66**, and is joined to flange **60** by a generally conical wall member **67**. This wall member **67** will be seen to be received snugly within the aforementioned base annulus **51**. A bit coupling member **68** has a shoulder engaging the flange **60**, and screws **69** secure the coupling member **68**, flange **60**, and annulus **51** in assembly. The coupling member **68** is formed with a tapered and threaded socket to receive the coupling pin **70** at the top of the bit.

Bores **71** through wall **67** and extending into annulus **51** will be seen to communicate with the fluid passageways **52** through the several bars of the coil members, so that the circulation passages downwardly through the spiral bars **50** are thus continued to the space **72** above the upper end of the coupling pin **70** at the upper end of the bit, to be thence continued downwardly through the usual circulation passage in the bit, as indicated.

In the operation of the embodiment of Figs. 4 to 8, vibration of the bit results in relative movement of the turns of the flexible coil elements **50** with respect to each other, causing them to interengage. It will be seen that the drill stem is continued downwardly from the lower end of the collars through the coupling **41** to the upper end portion of stem **45**, and thence via walls **63** and **62**, to and through the fairly heavy walled mandrel **61** to the bit. The coil elements **50** are, by comparison, relatively flexible in their lateral vibration, and capable of a substantial degree of independent vibration. Upon inception of bit vibration, vibrations are transmitted to both ends of the several coil elements **50**, to the lower end through the coupling means connected to the base annulus **51** of the coils, and to the upper end through the mandrel **61**, and back down the long stem **45**. It will be seen that both ends of these coils are fastened basically to the same element. In addition, owing to the irregular engagement action of the several cutters on the hole bottom, the vibration occurs in various modes and with various lateral and torsional as well as longitudinal components. Moreover, owing to these irregularities, and different lengths of vibration transmission paths from the cutters to the coil elements, these elements vibrate in diverse phase relations in various longitudinal, lateral and torsional modes. Owing to these irregularities, the several heavy coil elements interengage, impact, or "rattle" against one another under conditions of substantial bit vibration. In addition, the fluid within the coils is caused to impact against the sides of the coil passages because of the lateral orientation thereof. These impacts result in irregular, intermittent mass loading of the bit, with vibration deterrent effects similar, in general, to those described in connection with the first described embodiment.

It is important to recognize that the inductive mass must be heavy. As the bit rolls along the bottom of the hole it generates vibrations in the drill stem above. These vibrations have an approximate frequency. If the highest component of this frequency number is divided into the number representing the speed of sound in the material of which the drill stem is composed, a quotient will be determined which can, for the purpose of this discussion, be called "wavelength." (This does not imply that a discrete wave pattern is generated in the drill stem.)

The equivalent length of the vibration portion at the bottom of the drill stem itself is something of the order of one eighth of this quotient. Our inductive mass is advantageously of this order of magnitude in weight for those situations where the bit gives out something like a characteristic frequency. We have found in most instances our loose inductive mass should be at least 420 pounds.

With reference now to Figs. 9 and 10, a further embodiment of the invention is shown, comprising a mass and resistance dampener unit **80** adapted to be intercoupled between the lower end of the drill collars, not shown, and the bit, fragmentarily indicated at **81**. The device **80** comprises upper and lower coupling heads **82** and **83**, respectively, the former formed with a threaded box **84** to receive the coupling pin at the lower end of the collars, and the latter formed with threaded box **85** to receive the threaded coupling pin **86** of the bit. Heads **82** and **83** are interconnected by a tubular housing **87**, which may be welded thereto, as indicated. Heads **82** and **83** have circulation passages **88** and **89**, and a central tube **90** fitted into heads **82** and **83** around passages **88** and **89** conveys the circulation mud fluid between passages **88** and **89**.

In the annular space inside housing **87** and around tube **90** are positioned a plurality of vertically disposed mass elements in the form of steel bars **94**, which may be of trapezoidal cross section, so as to nest together nicely, as shown in Fig. 10. The bars **94** are dimensioned to fit loosely with one another and with the tube **90** and housing wall **87**, as clearly illustrated. The lower ends of the bars normally engage and stand on an impact seat **95** formed at the top of lower head **83**, while the upper ends of the bars are adapted for engagement with the downwardly facing impact surface **96** on the lower end of upper head **82**. The bars **94** are of such lengths as to provide clearance between their upper ends and the upper impact surface **96** when resting on the lower impact surface **95**; and in the operation of the device, upon inception of bit vibration, the bars **92** move between the surfaces **95** and **96**, impacting first against one and then the other, as well as sliding frictionally against the surface of wall **87** and tube **90**, and to some extent on one another.

The operation of the embodiment of Figs. 9 to 11 is similar in general to Figs. 1 to 3, and will not require repetition. In addition, however, the movement that occurs between the plurality of bars **94** relative to one another, and to the wall **87** and tube **90**, results in a material extent of frictional sliding resistance, with corresponding energy consumption. This energy consumption is a material additional deterrent to bit vibration, over and above the mass loading factor. In this case, therefore, a plurality of mass elements act to provide intermittent or discontinuous mass loading on the bit, and act also to provide a means of consuming bit vibration energy owing to frictional resistance between the mass elements sliding on one another and on the wall surfaces of their housing.

Fig. 11 is a view similar to Fig. 10, but showing a modification wherein the bars are made with smaller cross sectional area, so as to permit increase in their number, and resulting increase in surface contact area between the bars, with the effect of increasing the frictional resistance factor. Thus, an outer ring of trapezoidal bar elements **94*a*** surrounds an inner ring of trapezoidal bar elements **94*b***. It will further be understood that the bars may be further subdivided, or other configurations employed to increase the frictional resistance factor. Moreover, these elements may be subdivided longitudinally so as to comprise a greater number of individual bodies.

Various illustrative forms of the invention have now been illustrated and described. It will be understood, of course, that the examples given are for illustrative purposes only, and that various changes in design, structure, and arrangement may be made without departing from the spirit and scope of the invention as defined by the appended claims.

We claim:

1. In a rotary system for drilling a well bore, the combination of: a rotary drill shaft, a bit on the end of said shaft, which bit tends to develop undesirable vibrations when drilling, and which is subject to a bias force in addition to the weight of the bit tending to urge the bit toward the hole bottom, a bit vibration dampener comprising a mass element freely movable relative to a lower portion of said shaft in a direction longitudinally thereof, and in out-of-phase relation to bit vibration motion, an impact seat on said shaft normally supporting said mass element and adapted to alternately separate from and impact thereagainst upon occurrence of bit vibration, and guiding means on said shaft laterally confining said mass element from contact with the wall of said well bore during drilling.

2. The subject matter of claim 1, wherein said mass element comprises a sleeve surrounding the drill shaft, of diameter sufficiently smaller than the well bore to avoid contact therewith during drilling, and said impact seat comprises an upwardly facing shoulder on said shaft engageable with the lower end of said sleeve.

3. The subject matter of claim 2, including also a downwardly facing shoulder on said drill shaft above said sleeve and engageable with the upper end thereof, the distance between said shoulders exceeding the length of said sleeve by an amount such that said shoulders alternately impact against said sleeve in response to bit vibration.

4. In a rotary system for drilling a well bore, the combination of: a rotary drill shaft, a bit on said shaft, which bit tends to develop undesirable vibrations when drilling, and which is subject to a bias force in addition to the weight of the bit tending to urge the bit toward the hole bottom, an inertia means carried by said shaft for relative movement thereon, and being arranged to move in out-of-phase relation to bit vibration motion, to intermittently deliver impacts against, and thereby intermittently mass load, the drill shaft and bit in response to vibration of the bit and shaft whereby to quell such vibration, and guiding means on said shaft laterally confining said inertia mass from contact with the wall of said wall bore during drilling.

5. The subject matter of claim 4, wherein said inertia means is arranged for free longitudinal movement on said shaft between impact shoulders on said shaft spaced apart by a distance such that said inertia means impacts alternately thereagainst in response to vibration of the bit and shaft incident to drilling.

6. The subject matter of claim 4, wherein said inertia means comprises a plurality of mass elements adapted to frictionally work against one another in response to said vibration of the bit and shaft.

7. The subject matter of claim 6, wherein said inertia means comprises a plurality of vertical bars nested together.

8. The subject matter of claim 7, wherein said guiding means comprises a jacket on said shaft surrounding said vertical bars.

9. The subject matter of claim 1, wherein said drill shaft includes a drill collar, and a stem section extending downwardly from the lower end of said collar, and wherein said bit is attached on the lower end of said stem section, with said impact seat located on said stem section immediately above said bit, and wherein said mass element is located below said collar.

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UNITED STATES PATENT OFFICE
CERTIFICATION OF CORRECTION

Patent No. 2,953,351 September 20, 1960

Albert G. Bodine et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

In the drawings, Sheets 1, 2, 3, and 4, and in the heading to the printed specification, lines 2 and 3, title of invention for "MASS VIBRATION ABSORBER FOR SONIC OIL WELL DRILL" read -- MASS VIBRATION ABSORBER FOR OIL WELL DRILL --.

Signed and sealed this 25th day of April 1961.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

DAVID L. LADD
Commissioner of Patents