Sept. 8, 1959 A. G. BODINE, JR 2,903,242

SUSPENSION SYSTEM FOR SONIC WELL DRILL OR THE LIKE

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Fig. 1

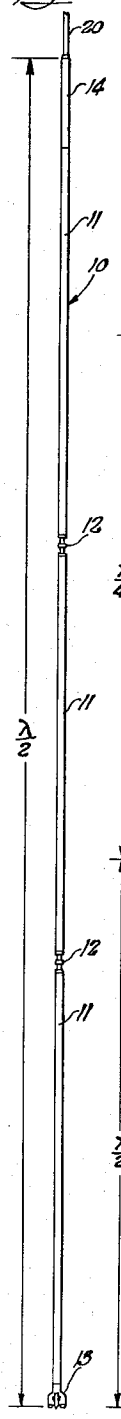


Fig. 2

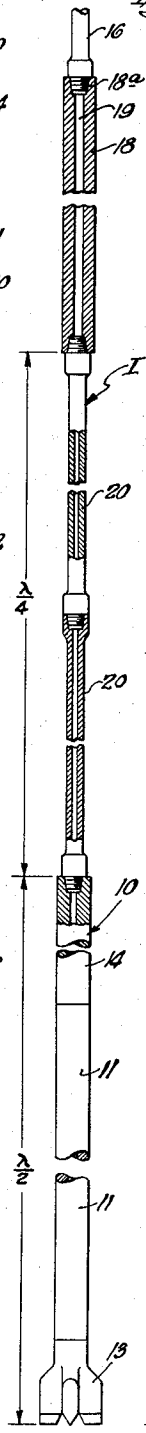


Fig. 3

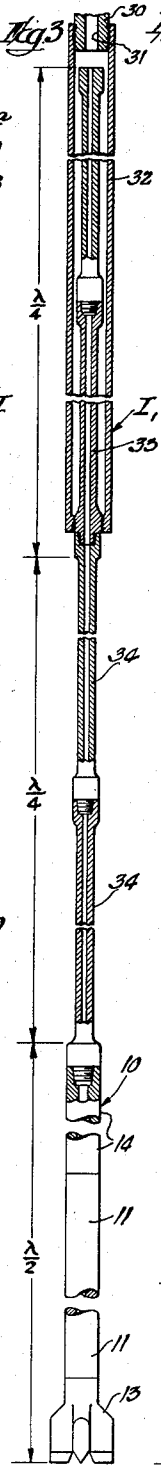


Fig. 4

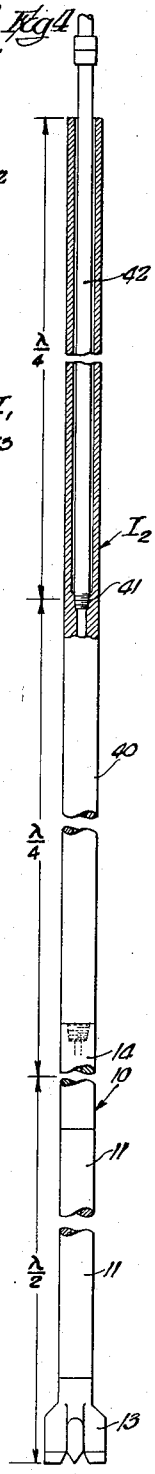


Fig. 5

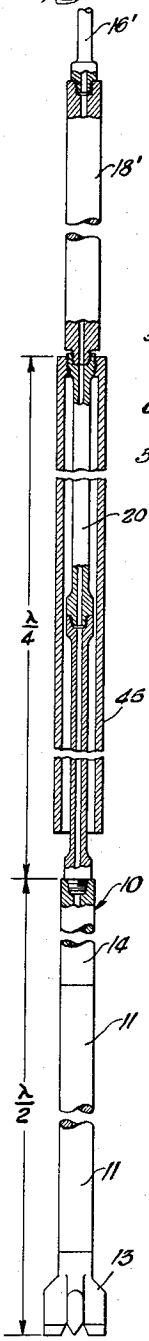


Fig. 6

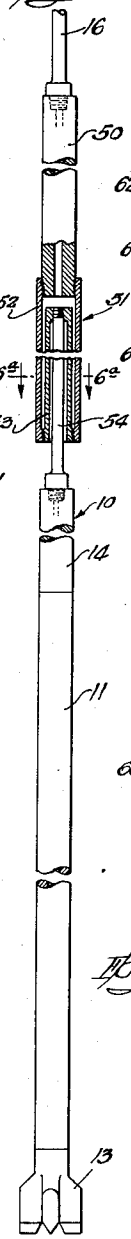


Fig. 7

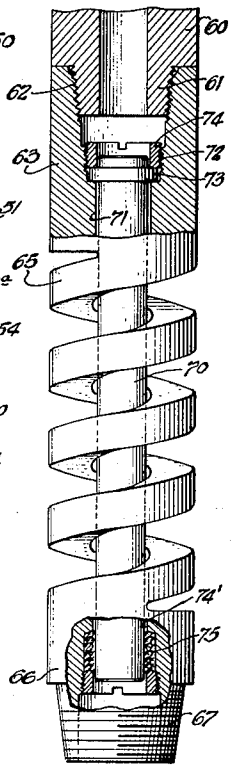
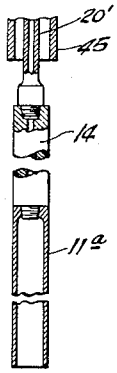


Fig. 5a



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Fig. 10

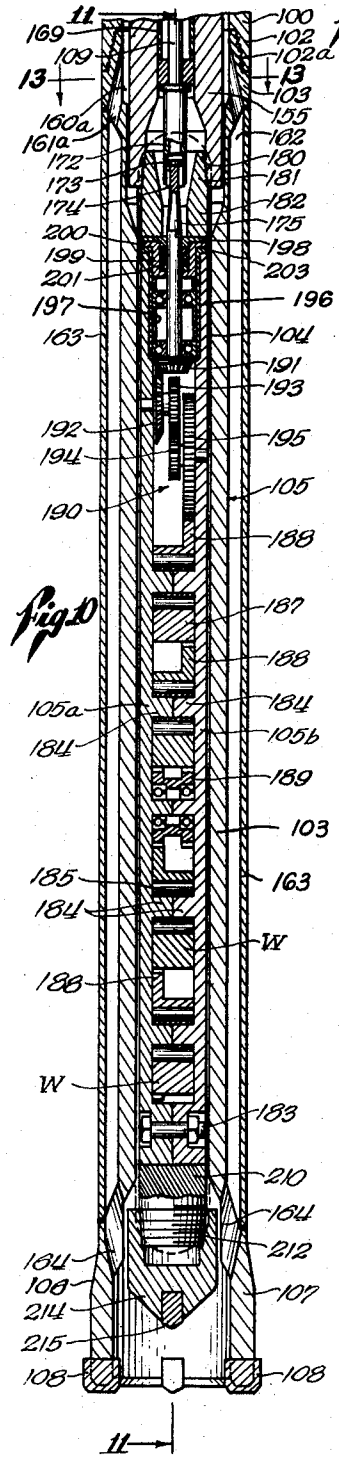


Fig. 9

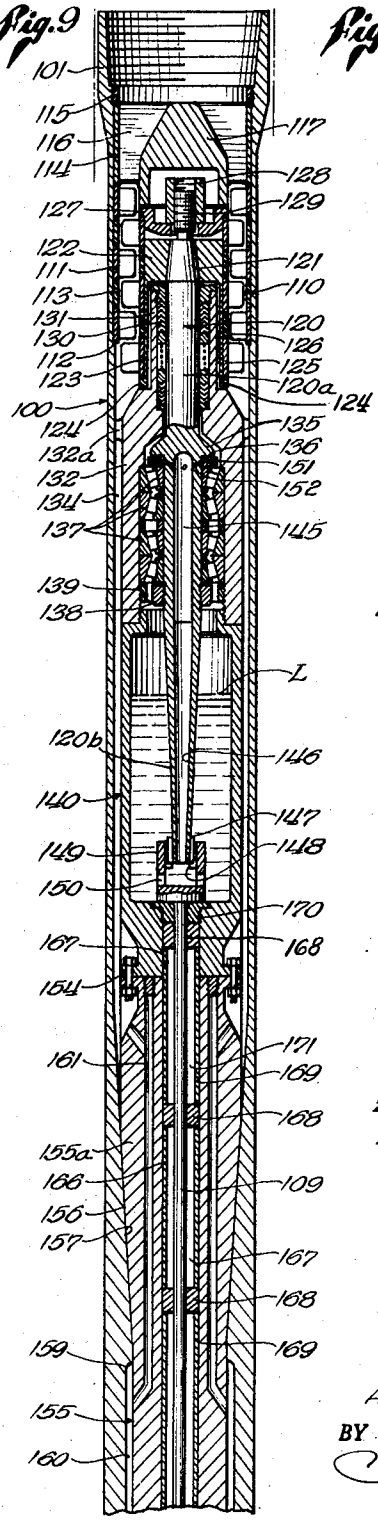
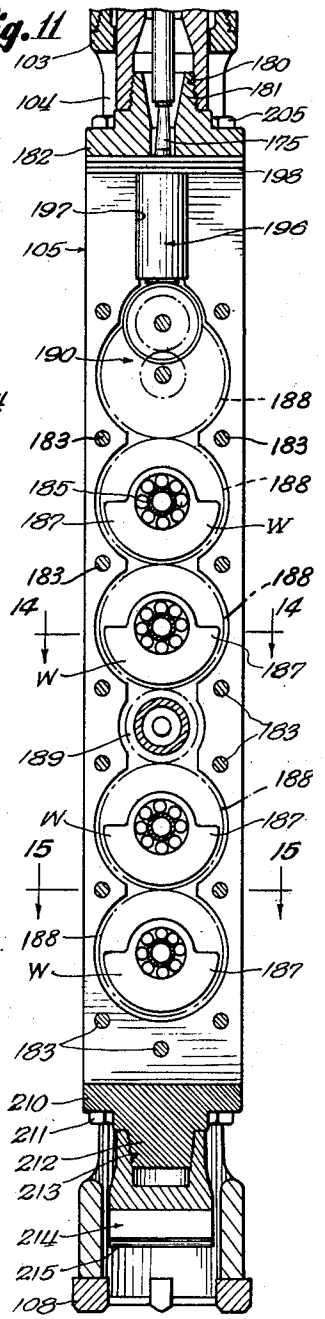


Fig. 11



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SUSPENSION SYSTEM FOR SONIC WELL DRILL OR THE LIKE

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Fig. 8

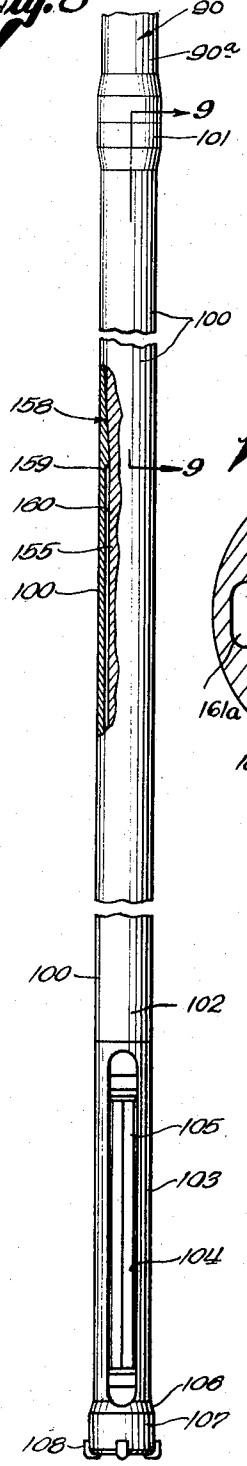


Fig. 12

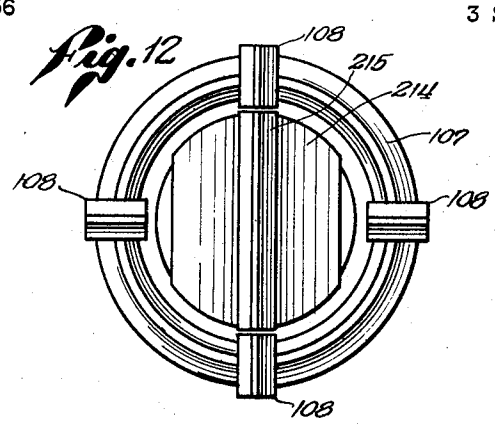


Fig. 13

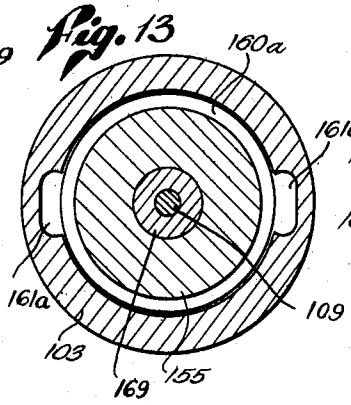


Fig. 14

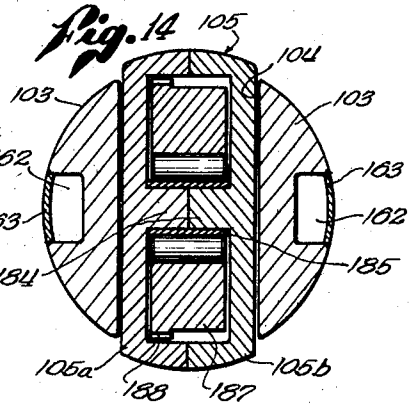
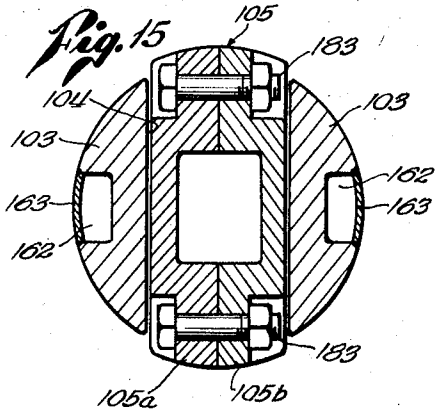


Fig. 15



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United States Patent Office 2,903,242 Patented Sept. 8, 1959

2,903,242

SUSPENSION SYSTEM FOR SONIC WELL DRILL OR THE LIKE

Albert G. Bodine, Jr., Van Nuys, Calif.

Application September 21, 1956, Serial No. 611,131

18 Claims. (Cl. 255—28)

This invention relates to suspension systems for sonic vibratory devices in general, and, in an illustrative application, to a suspension system for a sonic well drill.

The principally known sonic drill of the class here referred to, disclosed and claimed in my patent No. 2,554,005 (sometimes known as a half, or full, wavelength drill, though it can be any multiple of half wavelengths), comprises an elastic column such as a section of heavy steel drill collar suspended from a conventional drill string, the collar being coupled at its lower end to a drill bit, and a longitudinal sonic standing wave being maintained in this collar by a suitable mechanical oscillator coupled thereto. This standing wave is a free-free pattern whereby velocity anti-nodes occur at both ends thereof. The velocity anti-node condition at the lower end is useful in that vibration at this point is required in order to vibrate the bit. The velocity anti-node at the upper end, however, in absence of countermeasures, undesirably sends sonic waves up the drill string. Such leakage of sonic waves up the drill string represents a serious loss of sonic energy, and vibration of the drill string is in any event highly undesirable for obvious reasons.

The sonic drill assembly may comprise an elastic vibratory column made up of from one to several hundred feet of drill collar, in addition to the bit, oscillator, and oscillator drive. It is accordingly very heavy, and the means by which this assembly is suspended from the drill string must be robust, as well as having the necessary compliance so that no restraint against vibration of the sonic drill is imposed thereby. A prime requisite is that this suspension means must be of such nature as will effectively isolate the vibratory drill assembly from the drill string, since, as stated above, transmission of sonic energy up the drill string represents a serious power loss, shakes the derrick, and is generally undesirable. The suspension means must also, of course, be very fatigue resistant. Still further, in a rotary drilling system, the suspension means must be capable of transmitting torque, and it must have provision for conducting a stream of drilling fluid. Moreover, it usually must be of such design that it can accommodate variable loading of the drill collar by either pushing or pulling on the drill string.

A general object of the present invention is the provision of an improved sonic drilling system wherein vibrations are prevented from transmission from the vibratory drilling assembly to and up the supporting drill string.

A further object is the provision of a mode of suspension of a sonic drill from a drill string involving coupling to a velocity node, or stress anti-node, of the vibratory assembly.

A still further object is the provision of a sonic drill wherein the upper end region of the vibratory assembly is the location of a stress anti-node, to which the drill string is directly coupled.

A further object is the provision of a suspension means for a half or full wave type of sonic drill assembly,

to be interposed between the drill assembly and the drill string, characterized by effective isolation of the vibratory drill assembly from the drill string.

A further object is the provision of a suspension means as defined in the preceding object, having such a degree of dynamic compliance that substantially no restraint to vibration is imposed thereby upon the sonic drilling assembly.

A still further object is a suspension system having low damping.

A still further object is the provision of a suspension means which is fatigue proof over long periods of service.

A still further object is the provision of a suspension system for a half or full wave sonic drill, designed also for effective transmittal of torque, for conduction of drilling fluid, and for accommodation of imposition of load by the drill string, or reduction of load by exerting tension in the drill string.

Further objects of the invention are the provision of corresponding improvements in suspension systems for other vibratory systems where corresponding or analogous conditions and problems are encountered and must be met.

Generally stated, the present invention contemplates coupling of the supporting drill string directly to a velocity node (stress anti-node) i.e., a region of high mechanical impedance, of the elastically vibratory system of the sonic drill. The concept of mechanical impedance will be understood to signify, in a mechanical, elastically vibrating system, the ratio of cyclic peak force acting at any given point in the system to displacement velocity at that point in the system. It will be seen that a region of high mechanical impedance is one at which cyclic force amplitude is maximized, but displacement velocity, and therefore also vibration amplitude, is minimized, or reduced substantially to zero. It will be seen that coupling of the drill string directly to a stress anti-node of the sonic drill, in accordance with the invention, is in direct contrast to some prior sonic drilling systems of the half wave type, wherein the upper end portion of the vibratory system is the location of a velocity anti-node, and the drill string has been coupled directly thereto, with consequent maximum vibration transmission into and up the drill string. It may be noted in passing that efforts have been made to introduce vibration insulators between the vibratory upper end portion of a half wave or full wave type sonic drill and the drill string, but that, as experience has demonstrated, such attempts, because of the high power involved, have met with great difficulty. Good drilling rates have been attained, but relatively severe vibration of the drill string has not been prevented when drilling at high power.

Referring now particularly to the half or full wave type of sonic drill, broadly considered, the invention contemplates, as stated above, the coupling of the drill string directly to a velocity node, or in other words, to a stress anti-node, of the vibratory system. It will be recalled that a half or full wave sonic drill has velocity anti-nodes (regions of maximum vibration amplitude) at the upper and lower ends of its elastic vibratory column (from which circumstance such a column is described acoustically as a "free-free" bar or column), and that the first velocity node, or stress anti-node, is spaced a quarter wavelength distance down from the upper end. Accordingly, in one form of the invention, the drill string is attached to the vibratory assembly at such stress anti-node region, located a quarter wavelength distance down from the upper end of the vibratory column.

In one preferred form of the invention, applicable to the half or full wave type of sonic drill, there is provided, in addition to the vibratory elastic column, a vibration

isolator comprising a discrete acoustic "circuit" having a region of high mechanical impedance, whereat it is attached to the drill string, and having also a region of low mechanical impedance, whereat it is coupled to a low impedance region of the elastic column of the sonic drilling assembly. By use of a suspension system having high impedance at its drill string attachment point, there results minimal acoustic coupling to the drill string above; and by the provision of a suspension system having low impedance at its point of connection to a low impedance region of the sonic drill assembly, there is offered minimal blocking impedance to the sonic drill.

Mechanical impedance is, of course, the vector resultant of resistive and reactive components. The resistive component can be made low by providing for low damping. The reactive component at the point of coupling to the drill can be made low by tuning the suspension system to resonance at the frequency of operation of the drill, either fundamental, or harmonic, depending upon which is to be combatted. This may be done by a suitable choice of mass and compliance within the suspension, e.g., in a "lumped constant" system, by such a relationship of mass to elastic compliance that the system is selectively frequency responsive, or resonant at the operating frequency of the drill. It may also be accomplished by use of a "distributed constant" system having such mass, elasticity, and distribution of both mass and elasticity as to provide a resonant standing wave system that is frequency responsive to the operating frequency of the drill. Such a system has both velocity anti-node and pressure anti-node regions, the former a region of low impedance, affording a suitable coupling point for the drill, and the latter a region of high impedance which affords a suitable coupling point for the drill string.

One physical example of the last mentioned type of suspension system, having such acoustic properties, comprises a heavy mass directly coupled to the drill string, and a slender tubing of quarter wavelength for the fundamental resonant operating frequency, or harmonic of interest, of the sonic drill assembly, connecting such mass to the upper end of the sonic drill assembly, as set forth above. As another example, there may be used, in lieu of the heavy mass, another quarter wavelength of compliant tubing, connected to the first quarter wavelength tubing adjacent the coupling point to the drill string. The performance of such devices will be more fully set forth in the ensuing detailed description. A number of additional configurations are within the scope of the invention, and some of these will be described hereinafter.

Another form of the present invention involves a modification in the configuration of the sonic drill which facilitates direct coupling of the drill string to the stress anti-node region of the drill, this form of sonic drill having been first disclosed in my prior application Ser. No. 442,805, filed July 12, 1954, entitled Polyphase Sonic Earth Boring Drill and Process, of which the present application is a continuation-in-part. This configuration results from the "folding" of a half wave sonic drill into a double (or plural) legged elastic bar structure, the midpoint of which is uppermost, with the legs, of quarter wavelength, depending therefrom. The resulting structure may form an inverted U or a depending fork, or two concentric legs joined at the top. The now uppermost midpoint of the structure remains the location of a stress anti-node, or velocity node, after the described "folding." In accordance with the present invention, the drill stem is then directly coupled to this non-vibratory uppermost "midpoint" of the plural leg structure. Analyzed acoustically, I have provided a plurality of coupled acoustic support elements (acoustic elastically vibratory bars) operating with a balanced phase difference and joined at respective high impedance regions to achieve a non-vibratory support point, which is therefore incapable of transmitting vibrational energy into any means coupled thereto; and

I have directly coupled the suspension drill string to this non-vibratory support point.

Referring now to the drawings showing certain selected illustrative embodiments of the invention:

Fig. 1 is an elevational view of a typical half wave sonic drill assembly showing a fragmentary lower end portion of a suspension means in accordance with the invention;

Fig. 2 is a view partly in elevation and partly in section, with longitudinal portions of the sonic drill assembly broken away, showing one illustrative suspension means according to the invention, coupled to a sonic drill of the type represented in Fig. 1;

Figs. 3, 4, 5 and 6 are views similar to Fig. 2, but showing modifications;

Fig. 5*a* shows a modification of a portion of Fig. 5;

Fig. 7 is a view, partly in elevation and partly in section, showing a "lumped constant" type of suspension means for a sonic drill.

Fig. 8 is an elevational view, partly in section, showing another embodiment of the invention;

Fig. 9 is a longitudinal medial section of the embodiment of Fig. 8, extending downwardly to a point just below the head of the fork structure;

Fig. 10 is a longitudinal medial section of the lower end portion of the embodiment of Fig. 8;

Fig. 11 is a section taken on line **11—11** of Fig. 10;

Fig. 12 is a bottom elevational view of the embodiment of Fig. 8;

Fig. 13 is a section taken on line **13—13** of Fig. 10;

Fig. 14 is a section taken on line **14—14** of Fig. 11; and

Fig. 15 is a section taken on line **15—15** of Fig. 11.

Referring first to Fig. 1, numeral **10** designates generally a typical half wave sonic drill assembly, comprising, in this instance, an elastic column rod or bar, made up of three more or less conventional drill collars **11**, connected to one another by conventional drill collar couplings **12**, a bit **13** coupled to the lower-most drill collar **11**, and an oscillator and driver or power means therefor, represented at **14**, coupled to the uppermost drill collar. The unit **14** may comprise a mechanical vibrator in the form of a plurality of rotating eccentric weights, so arranged that while longitudinal components of vibration are additive, lateral components of vibration are cancelled, powered by a turbine which is in turn driven by the usual stream of mud fluid circulated down through the drill string as in conventional rotary drilling practice. Suitable forms of such devices are described in my aforementioned Patent No. 2,554,005.

Referring now also to Fig. 2, a fragmentary lower end portion of the drill string is indicated at **16**, and between this drill string and the sonic drill is intercoupled the suspension system or isolator I of the invention. This isolator includes a massive bar **18**, conventionally coupled, as indicated at **18***a*, to the lower end of the drill string. This bar **18** has circulation bore **19** for drilling fluid. In a typical embodiment, the bar **18** may be of a length of, for example, 40 feet, an outside diameter of eight inches, and may comprise a section of conventional drill collar. The isolator further includes a relatively slender pipe **20**, of a typical length of approximately 70 to 75 feet, and which may comprise two intercoupled sections of conventional drill pipe, coupled at its upper end to the lower end of bar **18**, and at its lower end to oscillator and power unit **14**, all as clearly indicated in Fig. 2. Assuming the sonic drill assembly **10** to vibrate in its fundamental half wavelength standing wave mode, and to have an over-all length of 140 feet, it will be seen that the slender pipe section **20** is of quarter wavelength (or slightly more, in view of the fact that the mass of bar **18** is not infinite) for the fundamental resonant frequency of operation of the drill. It is, in other words, frequency responsive to the drill.

In operation and still assuming the sonic drilling assembly **10** to vibrate in a half-wavelength mode, the slender, elastically compliant pipe section **20** then vibrates at the same frequency in a quarter wavelength mode, its upper

end standing substantially stationary in view of its being anchored to the massive bar **18**, and its lower end vibrating vertically in consonance with the vertical vibration of the upper end portion of the sonic drilling assembly **10**. The intercoupled lower end portion of pipe **20** and upper end portion of drilling assembly **10** will be seen to be at a velocity anti-node of the vibratory system, and the intercoupled upper end portion of pipe **20** and massive bar **18** to be at what is effectively a velocity node, or stress anti-node, of the system. The massive bar **18** will further be seen to be a region of the system characterized by high mechanical impedance, and the point of interconnection between the lower end of pipe **20** and sonic drilling assembly **10** to be a region of low mechanical impedance of the system.

Under the conditions as stated, bar **18** remains firm and steady, and does not transmit material vibratory energy up the drill string **16**. The pipe **20**, however, is a relatively compliant member for the critical frequency, and its lower end portion vibrates naturally in consonance with the vibration of the upper end portion of the sonic drilling assembly, so that the vibration of the latter is unimpeded. It will be observed that by having given the pipe **20** effectively a quarter wavelength for the natural resonant frequency of vibration of the sonic drilling assembly, it has been pre-tuned, in combination with mass **18**, to vibrate resonantly at the fundamental frequency of operation of the sonic drilling assembly. It accordingly participates in the wave action generated in the sonic drilling assembly without presentation of material blocking impedance. It will further be observed that the bar **18** and compliant pipe section **20** are adapted equally for imposing compressional loading on the sonic drilling assembly, or for exerting tension thereon, thus not interfering with controlled application of bias loading on the sonic drill. It will further be evident that the system is one of low damping, and therefore of low energy dissipation.

As described in the immediately preceding passages, the suspension system has been tuned to respond to the fundamental resonant frequency of the sonic drill. However, the sonic drill may have important and sometimes troublesome overtone frequencies, and it will be evident that the suspension system, or "isolator," may alternately be designed to respond critically to these. Such overtone frequencies may be initially induced, or may be stimulated and/or augmented by striking of the bit against the rock. For example, assuming that it is the second harmonic of the sonic drill that is to be combatted, the isolator device, instead of being a one-quarter wavelength device for the fundamental frequency of the sonic drill, is made to be a quarter wavelength device for the second harmonic of the sonic drill. In other words, the length of its elastic column for this case is halved. Also, I may use two of the suspension systems in tandem, one dimensioned for critical response to the fundamental, and the other for critical response to the harmonic.

As mentioned above, the sonic drill may be designed for full wavelength vibration, in which case the elastic column, or drill collar, has a velocity anti-node at each end, and another velocity anti-node at its midpoint. If the operating frequency remains the same as for the half wave case, the length of the drill collar is doubled, and becomes 280 feet. The length dimension for the isolator, however, remains the same, since the length of a quarter wave along the system has not been altered. The same result would follow for a sonic drill having a collar length of one and one-half wavelengths. It might be here mentioned that for increasing the weight on the bit a full wavelength sonic drill is desirable and quite feasible, as is a system of one and one-half wavelengths; and that for these cases, it is advantageous to maintain the frequency by operating at the higher harmonic, so as to be thus able to increase the over-all length of the system without lowering the operating frequency. It is also to be pointed out that when operating a sonic drill at a frequency to give one full wavelength performance, for example, a half wavelength mode, as well as higher harmonics (second harmonic and above) may be set up therein by reason of impacting against the formation. Isolators properly dimensioned for response to any or all such frequencies may obviously be used in the system.

It will be seen that for each example given above, the isolator is dimensioned for quarter wavelength performance at the critical frequency of the component of vibration of the drill that is to be combatted. In terms of impedance, it has a low impedance where connected to the drill, and a high impedance where connected to the drill string. It should further be understood that these impedance characteristics are self-contained characteristics in the isolator, at the critical frequency for which it is dimensioned, and are not contributed to by either the sonic drill or the drill string. The requisite is that the impedance of the isolator where connected to the sonic drill below, i.e., comparable to the low impedance of the sonic drill at the connection point, so as to present minimal blocking impedance to the drill; and that the impedance be high at the point of connection to the drill string, so as to have minimal vibratory motion at that connection point, and therefore minimal acoustic or vibratory coupling to the drill string.

Fig. 3 shows a modified isolator I_1, the same type of sonic drill again being designated by numeral **10**, and comprising a column of drill collars **11** and bit **13**, and oscillator and driver **14**. At the top of the figure is fragmentarily illustrated the lower end portion of a massive bar **30**, formed with circulation bore **31**, and this bar, like bar **18** of Fig. 2, may comprise a section of conventional drill collar of a typical length of 40 feet, it being further understood that the upper end of collar **30** is coupled in conventional manner to the drill string above, not shown in Fig. 3, but understood to be arranged in a manner similar to that shown in Fig. 2.

Screw-threaded onto the lower end of collar **30** is a long suspension sleeve **32**, whose lower end is furnished with an internal screw-threaded coupling to the lower end of a relatively slender upstanding pipe column **33** reaching nearly to the lower end of collar **30**. This pipe column **33** may conveniently comprise two intercoupled lengths of conventional drill pipe, as illustrated, suitable annular working clearance being provided between pipe **33** and sleeve **32**. A slender pipe column **34**, equivalent in length and cross section to the pipe **33**, is coupled to the lower end of pipe **33** below the lower extremity of sleeve **32**, and its lower end is coupled to oscillator and power unit **14** of the sonic drill, as indicated. This pipe **34** may also be composed of two lengths of conventional drill pipe, the lower end of the lower length being adapted for coupling into the larger diameter unit **14**.

Assuming the sonic drill assembly **10** again to vibrate in a half wavelength standing wave mode, i.e., as a free-free bar, and to have an over-all length of 140 feet, pipe sections **33** and **34** each may have a length of approximately 70 feet, and each is accordingly of quarter wavelength for the fundamental resonant frequency of operation of the drill. In other words, pipe sections **33** and **34** taken together comprise a half wave system, being effectively what is known in acoustics as a free-free bar, whereby the whole vibrating system is one full wavelength.

In operation, with sonic drilling assembly **10** vibrating in its half wavelength mode, the elastic suspension column made up of pipe sections **33** and **34** vibrates also, at the same frequency, in a half wavelength mode, its lower end vibrating in consonance with the vertical vibration of the upper end portion of the sonic drilling assembly **10**, its upper end vibrating equally and oppositely thereto, and its center section, where the two pipe sections **33** and **34** are intercoupled to one another, and to the lower end of suspension sleeve **32**, standing substantially stationary. The two pipe sections **33** and **34** thus

are dynamically opposed to one another during this vibratory operation. The intercoupled lower end portion of pipe section **34** and the upper end portion of drilling assembly **10** are then at a velocity anti-node of the overall vibratory system, the upper end portion of pipe **33** is at another velocity anti-node of the system, and the intercoupled lower end portion of pipe **33** and upper end portion of pipe **34** are at a velocity node of the system. Each velocity anti-node will be at a low impedance region of the vibratory system, and the intercoupled end portions of pipes **33** and **34** are at a region of high mechanical impedance of the system. Sleeve **32** is somewhat flexible and elastic, and of substantially quarter wavelength (or slightly longer in view of the fact that the mass **30** is not infinite) for the fundamental resonant frequency of the system. Accordingly, any small remaining vibration in the high impedance region where the pipes **33** and **34** are coupled to one another, sets up a small corresponding quarter wave mode of vibration in the sleeve **32**. The massive collar **30** coupled to the upper end portion of sleeve **32** establishes a very high mechanical impedance at that point of coupling, such that while sleeve **32** may vibrate slightly in a quarter wavelength mode owing to any remaining vibration at the juncture of pipes **33** and **34**, the coupling point between collar **30** and sleeve **32** functions as a highly rigid anchorage, and transmission of any vibratory energy up the collar **30** is reduced to negligible amplitude. The isolator, considered as a unit apart from the remainder of the system, will be seen to have a point of low impedance for the critical vibration frequency where it is to be connected to the sonic drill, i.e., of magnitude comparable to the low order of impedance magnitude at the top end of the drill, and a high impedance region at its mid-point, where the pipe column **33, 34** is hung from the sleeve **32**. The sleeve **32**, in turn, has a relatively low impedance where connected to the column **33, 34**, such that any small vibration at this junction point can be transmitted to the sleeve. The mass **30** at the top, however, is of very high impedance, and holds the upper end of sleeve **32** rigid, such that a small amplitude quarter wave type vibration can occur in the sleeve, but is blocked from upward transmission by the mass **30**. As with the system of Fig. 2, the system of Fig. 3 may also be adapted for critical response to a harmonic component of standing wave vibration present in the overall wave pattern of the sonic drill. To design it for critical response to the first overtone, for example, the length of the pipes **33** and **34** and of the sleeve **32** are simply halved. The discussion given above of the various modes of vibration that can occur in the sonic drill, and the dimensioning of the isolator for critical response thereto, applies here in similar manner.

Fig. 4 shows another embodiment of suspension means or isolator I_2 in accordance with the invention, the sonic drill, of the same type as in the preceding figures, being again designated by numeral **10**, and being made up of components as before, bearing the same reference numerals. Coupled to the upper end of oscillator and driver unit **14** for the sonic drill is the lower end of a long, heavy section, elastic pipe member **40**, whose length, assuming it to be designed for critical response to the fundamental resonant frequency of the sonic drill, and assuming the drill to be driven in its half wave mode, is substantially equal to the length of the sonic drill assembly **10**. This pipe **40** is here shown to be of the same outside diameter as the drill collars **11**. At its midpoint, the pipe **40** has an internally reduced and internally screw-threaded section **41**, into which is coupled the screw-threaded coupling pin on the lower extremity of elongated drill pipe **42**, suitable annular clearance being provided between pipe **42** and the bore of pipe **40**, as illustrated.

In operation, pipe **40** vibrates in a half wave mode, in a manner similar to the intercoupled pipe sections **33** and **34** of the embodiment described immediately above. That is to say, the lower end portion of pipe **40** vibrates in consonance with the upper end portion of the sonic drill, the upper end portion of pipe **40** vibrates in opposition to the lower end portion of said pipe, and the intermediate section of pipe **40** stands substantially stationary. In acoustic terms, the lower and upper end portions of pipe **40** are low impedance, velocity anti-node regions, while the intermediate section of the pipe is a high impedance, velocity node region of the system. The high impedance intermediate section of pipe **40** thus standing substantially stationary, vibrations in the sonic drill assembly and in the upper and lower regions of the pipe **40** are isolated from the drill pipe **42**. The fuller theoretical discussion given in connection with the earlier described embodiments applies here as well.

With further reference to Fig. 4, the "isolator" I_2 shown therein has been properly described in the foregoing as a device interposed between the upper end of the elastic collar column of a half wave sonic drill and the lower end of a drill string. It is also correct, however, to view the interposed "isolator" device as a half-wave length upward extension of the elastic drill collar or column of the sonic drill, thus converting the elastic column of a half-wave sonic drill, for example, to full wavelength, with provision being made for direct coupling of the drilling string to the stress anti-node region at the mid-point of the said half wavelength extension. The device I_2 may, indeed, be readily fabricated from two drill collars, connected by a double-pin sub, to which sub the drill string is coupled by a suitable threaded joint. In short, the embodiment of Fig. 4 may be regarded, broadly, as made up of a free-free vibratory elastic column, with a drill string suspension coupling attached directly to an intermediate high impedance or stress anti-node region of the column. Moreover, the column length may be equal to any number of half wavelengths, including unity.

Fig. 5 shows another embodiment, used again with a sonic drill comprised of drill collars **11**, bit **13**, and oscillator or power unit **14**. The suspension system in this case contains components similar to those of the system of Fig. 2, including drill collar **18'** suspended from drill pipe **16'**, and slender pipe **20'** coupling the lower end of collar **18'** to the upper end of the sonic drill. The lengths of the members may also be as in Fig. 2. That is to say, pipe **20'** is of quarter wavelength for the resonant frequency of interest of the sonic drill. The embodiment of Fig. 5 differs from that of Fig. 2 in that an elastic sleeve **45** surrounds the pipe **20'**, its upper end being firmly joined, as by a suitable screw-threaded coupling, to the upper end of pipe **20'**. The sleeve **45** is of substantially the same length as the pipe **20'**, so that it also is of quarter wavelength for the frequency of interest of the sonic drill.

Considering the operation of the embodiment of Fig. 5 first without the sleeve **45**, it will be recalled from a discussion of Fig. 2 that the upper end portion of the elastic coupling pipe **20'** is at a velocity node of the system, and is a region of relatively high impedance, this condition depending upon the heavy mass afforded by the collar **18'**. The collar **18'** provides a substantial blocking impedance for the vibratory energy otherwise traveling up the system. Considering now the pipe **45**, this added component furnishes a dynamic means for balancing the vibratory standing wave action in the pipe **20'**, and may be used either together with massive collar **18'**, for additional stability and isolation, or as an alternative therefor. Accordingly, considering the system in absence of the heavy mass afforded by the collar **18'**, it is found that the quarter wavelength elastic sleeve **45**, extending downwardly around the quarter wavelength pipe section **20'**, is set into quarter wave standing wave action in 180° phase opposition to the standing wave experienced by the pipe **20'**. Thus, as pipe **20'** elastically contracts, sleeve **45**

elastically elongates, and vice versa. By designing the sleeve 45 to have elasticity and mass distribution equivalent to that of pipe 20', the upper end juncture of the two stands substantially stationary, and becomes a high impedance, velocity nodal region of a "folded" ½ wavelength standing wave system. The performance is analogous to that obtained with the system of Fig. 4, with the exception that the two quarter wavelength portions of the system of Fig. 5 comprised of the pipe 20' and sleeve 45, which are again in phase opposition, lie alongside each other, such that longitudinal forces are again everywhere dynamically balanced. The upper end juncture of pipe 20' with sleeve 45 accordingly stands substantially stationary, and is a point to which the drill pipe above might be directly attached. It is deemed of further advantage, however, to include the heavy drill collar 18' so as to have an additional inertial type of high impedance in the system, which affords additional assurance of substantially total isolation of the vibratory system from the drill stem.

Fig. 6 shows still another embodiment of the system, using again a sonic drill 10 including oscillator or power unit 14, drill collars 11, and bit 13. In this case, as in Fig. 2, the drill pipe 16 is coupled at its lower end to a massive drill collar, here indicated at 50, and a compliant coupling 51 whose effective critical frequency is made responsive to the resonant frequency of interest of the sonic drill.

For compactness, the coupling 51 is formed of three telescoped tubular elements, an outside tube 52 screw-threadedly attached at its upper end to the lower end of collar 50, an immediate tube 53 annularly spaced inside tube 52 and screw-threadedly connected at its lower end to the lower end of pipe 52, and an inside pipe 54, annularly spaced inside immediate pipe 53, and screw-threadedly connected at its upper end to the upper end of pipe 53. The lower end of pipe 54 is coupled to the upper end of the sonic drill, as shown. The total effective length of the three sections 52, 53 and 54, is made equivalent to a single, straight quarter wavelength pipe. Owing to the doubling back or folding of the coupling, however, the total over-all length of the coupling for quarter wave operation analogous to that of Fig. 2 is generally found to be somewhat less than that of a straight pipe. This is a matter depending somewhat upon the masses of the coupling elements and the mechanical design, which cause the system to behave somewhat as one having "lumped" constants, with resulting reduced length for the same resonant frequency. Frequency response, however, is equally important.

The elastic coupling 51 behaves essentially as does the coupling pipe 20 of Fig. 2. However, the inside pipe 54 and outside sleeve 52 are always in tension, or compression, at the same time, whereas the intermediate member 53 is in compression while members 54 and 52 are in tension, and is in tension while members 54 and 52 are in compression. The members thus cooperatively elastically contract, or elongate, as the case may be, to give a "folded" quarter wavelength performance which is the equivalent of that of Fig. 2. Of course, the amplitude of elastic elongation and/or contraction is a maximum at the lower end portion of the inside pipe 54 and progressively diminishes to substantially zero at the point of coupling of the outside pipe 52 with the collar 50.

It will be seen that in the system of Fig. 6, the circulation fluid passes through the bore of collar 50, to be received by pipe 54 and thence conducted to the sonic drill.

Fig. 7 shows a "lumped" constant type of isolator suitable for a free-free sonic drill, and which is analogous in basic respects to that of the standing wave systems of the first described embodiments. In this case, the lower end portion of a drill collar 60 (which may be similar, for example, to the drill collar 18 of Fig. 2, and may be similarly suspended from the more slender drill pipe above) has been formed at its lower end with a threaded pin 61 which is screwed into the threaded box 62 of a tool joint 63 integrally joined with the upper end of heavy helical spring 65. Integral with the lower end of spring 65 is a tool joint 66 having threaded pin 67 adapted to be screwed into a coupling box at the upper end of a sonic drill such as represented in the earlier figures of the drawings. The spring 65 is here shown to be furnished with a fluid pipe 70 whose upper extremity is received in a bore 71 extending up into tool joint 63, an enlarged threaded bore 72 above bore 71 receiving an annular flange 73 on the upper extremity of pipe 70, and a threaded retaining ring 74 being screwed into bore 72 to fix the pipe 70 in assembly with the upper tool joint 63. The lower end portion of pipe 70 is slidably received within a bore 74' extending downwardly into tool joint 66, suitable packing being used at 75, as clearly shown.

This helical spring isolator is designed with such mass and elasticity constants as to have a natural resonant vibration frequency matched to the vibration frequency of interest, fundamental or harmonic, of the sonic drill to which it is coupled. This is determined by the formula

$$f=\frac{1}{2\pi}\sqrt{\frac{k}{m}}$$

in which m is equivalent mass, k is effective spring constant and f is the frequency to be isolated. Such frequency response match having been provided, the spring elongates and contracts in consonance with the vertical vibration of the upper end of the sonic drill, the upper end of the spring, where connected to the massive collar 60, standing substantially stationary. Circulation fluid is conveyed through the spring by the pipe 70, previously described as fixedly mounted within the tool joint 63 at the upper end of the spring, and fitted for relative sliding movement within the lower tool joint 66.

Reference is next directed to Figs. 8 to 15, showing an illustrative plural legged quarter wavelength sonic drill with an uppermost common high impedance stress antinode region, and direct coupling between the drill string and such high impedance region. The illustrative drill shown employs a leg structure comprising a center leg and an outside tubular leg depending from a unitary head. This embodiment utilizes an unbalanced rotor type of vibrator in one leg, in this instance, in the lower portion of the center leg, and this vibrator is driven by a turbine which is located above the head of the structure and which is driven by the circulated mud fluid conventionally used in oil well drilling.

At 100 is designated a relatively long, steel tubular member, whose upper portion furnishes a housing for the turbine, and the remainder of which forms a portion of the head and the outside leg structure. This member 100 is formed at the top with a threaded box 101 for coupling to a conventional drill pipe string, indicated fragmentarily at 90. In most cases, the drill string includes one or more standard drill collars 90a, coupled to the upper end of member 100 at box 101, giving added weight on bottom, and the conventional drill pipe is then coupled to the upper end of these collars. The lower end of the member 100 has a threaded box 102 into which is screwed the coupling pin 102a on the upper end of a cylindrical member 103 forming the lower end portion of the outside leg structure. This member 103 has a central longitudinal slot 104 running nearly from end to end, in which is received, with good clearance, a vibrator housing 105, later described in more particular. The lower end portion of body 103 is tapered outwardly, as at 106, to furnish a tubular lower extremity 107 of somewhat enlarged diameter, and inset in this lower extremity are hardened bit elements as indicated typically at 108.

The vibrator mechanism inside housing 105 is driven through a long vertical transmission shaft 109 from a mud driven turbine 110 housed in the upper end portion of tubular member 100. The bladed turbine stators 111 are supported within the tubular member 100 by means of a shoulder formed at 112, and the stators are separated

by intervening spacers 113. Engaging the upper stator 111 is a sleeve 114, held in place by a retainer 115 screwed into box 101, and provided with radial vanes or ribs 116 supporting a central distributor hub 117 shaped to guide the mud fluid from above downwardly to the turbine blades, as indicated. The turbine shaft 120 has near its upper extremity a tapered section 121 on which is tightly mounted a turbine rotor head 122, the latter having a downwardly extending sleeve portion 123 formed with an outwardly extending flange 124 at its lower end. Mounted on sleeve 123 and supported by the flange 124 are the bladed turbine rotors 125, separated by spacers 126. A cap 127 engages the top rotor and the parts are held in assembly by means of a nut 128 screwed down onto the threaded upper extremity 129 of the turbine shaft. The blades of the stator and rotor of the turbine will be understood to be properly inclined, in accordance with conventional practice in fluid driven turbines.

The section 120*a* of the turbine shaft is furnished with suitable packing, as indicated at 130, carried by a reduced tubular upward extension 131 of a tubular bearing housing 132 annularly spaced inside the tubular exterior member 100 by positioning lugs 132*a* formed on said housing, the extension 131 being received, with clearance, inside the turbine rotor sleeve 123, as indicated. The annular space 134 between the bearing housing 132 and the outside tube 100 forms a channel for the mud fluid discharged from the turbine. Below the section 120*a* the turbine shaft has a flange or collar 135 furnishing a shoulder which engages a washer 136 supported by the inner race ring of the uppermost of a stack of roller bearings 137, the lowermost being retained by a nut 138 threaded on the shaft. The outer race rings of these bearings are received in a bore in the housing 132, and supported therein by a retainer 139.

Threaded into the lower end of bearing housing 132 is the reduced neck of an oil housing 140, of the same diameter as bearing housing 132, the mud fluid channel 134 thus continuing down around the outside of the housing 140. The turbine shaft 120, whose lower end portion 120*b* reaches down into oil housing 140, has a longitudinal bore 145 extending downwardly through its lower end from a point just below collar 135, and this bore is tapered downwardly within the portion 120*b* of the shaft, as indicated at 146. The turbine shaft portion 120*b* is also tapered downwardly, and its lower end is formed as a spur gear 147 meshing with internal gear teeth 148 in a cup-like coupling member 149 tightly mounted on the upper end of transmission shaft 109. Oil ports 150 are provided in the lower portion of cup 149.

Oil is maintained in housing 140 to such a level as indicated at L, and is supplied through ports 150 to the bottom end of the hollow turbine shaft. The aforementioned washer 136 is radially drilled, as at 151, and the turbine shaft is formed with drill holes 152 establishing communication between the interior of the hollow shaft and the drill holes in the washer. When the turbine shaft rotates, oil climbs in the tapered portions of the bore through centrifugal force, and fills the hollow turbine shaft up to the level of the drill holes 152. Oil is forced out through the drill holes 152, and thence out through the drill holes 151 in washer 136 to lubricate the bearings.

The lower end of oil housing 140 is flanged and bolted, as indicated at 154, to corresponding flange formations on the upper end of a long, generally cylindrical steel shank or rod 155, which forms a portion of the head and center leg structure of the fork. The upper end portion 155*a* of this shank or rod 155 has a long downward taper 156 and engages a complementary taper 157 on the inside of tube 100. The parts 155 and 100 are pressed or driven together to produce a tight wedge fit, and thus become structurally integrated to one another in the region of the tapered joint. This region of said members comprises the high impedance head structure 158 of the device. It is the location of a stress anti-node, or velocity node, during operation.

Just below the taper, the internal diameter of bore member 100 is enlarged, as indicated at 159 (Figs. 8 and 9), to provide a "crotch" and an annular mud fluid channel 160 between the members 100 and 155. This channel 160 receives mud fluid from channel 134 via a suitable number of passages 161 extending through the upper end portion 155*a* of the shank 155, as clearly shown in Fig. 9. The channel 160 is continued for a short distance down into member 103, as at 160*a* (Fig. 10), where communication is had via ports 161*a* with two longitudinal mud slots 162 formed in opposite sides of the member 103 (see also Fig. 14). The mud slots 162 are closed on the outside by cover plates 163 welded in position, as indicated, and discharge at their lower ends, via ports 164, into the space inside the lower tubular extremity 107 of member 103, from which final discharge takes place at the bottom of the well hole.

The shank 155 has a central bore 166, extending downwardly from a similar bore 167 through the bottom of oil housing 140 and these bores receive bearing bushings 168 for transmission shaft 109, the bushings being spaced by sleeves 169. A plug 170 screwed into the top of bore 167 holds the bushings and spacers in assembly at the top, and has sufficient clearance with shaft 109 to pass oil from housing 140 down into the space 171 around the shaft.

Press fitted on the lower end of shaft 109 (Fig. 10) is a drive sleeve 172 having internal splines 173 meshing with splines 174 on vibrator drive shaft 175. The lower end of shank 155 is formed with an internally threaded box 180 to receive a threaded pin 181 on a flanged head member 182 at the upper end of the vibrator housing 105.

The vibrator housing is longitudinally split into two halves 105*a* and 105*b*, bolt connected as at 183 (Figs. 10, 11 and 15). The two housing halves are formed with a plurality of mating shaft portions 184, surrounded by bushings 185, and journalled on these bushings are eccentrically weighted vibrator rotors 187. In the illustrated embodiment, there are four such rotors 187, all in vertical alinement, and interconnected by suitable gears. Each rotor is formed with a spur gear 188, and the spur gears of the two upper rotors are in mesh with one another, as are the spur gears of the two lower rotors. The lower gear of the upper pair is interconnected with the upper gear of the lower pair through an idler gear member 189. The gear on the upper rotor is driven from the vibrator drive shaft 175 through a gear set 190.

The weights W of the unbalanced rotors are positioned so that all move vertically in unison, which is accomplished if for instance they are all initially positioned with their weights at the bottom, as in Fig. 11. It will be evident that each eccentrically weighted rotor will exert a thrust at its bearing as it rotates. Only the thrust in the vertical direction is, however, useful. By arranging the rotors in pairs of oppositely rotating members, the vertical components of thrust are additive, while the lateral components are cancelled. Also, by use of the idler 189, the two inside rotors turn in the same direction, and the two outside rotors also turn in the same direction, thus achieving balance against couples.

Vibrator shaft 175 is journalled in suitable bearings contained in a bearing housing 196 received in a bore 197 formed in the upper end of vibrator housing 105, the housing 196 having at the top a flange 198 engaging the top end of housing 105. A packing retainer 199 has a similar flange 200 engaging the flange 198, and this retainer contains a suitable packing 201 around the shaft 175 to prevent oil from above leaking down into the inside of the vibrator housing. A flanged packing retainer 202 is placed between the flange 200 and the aforementioned head number 182 (Fig. 11), the parts being secured in assembly by means of screws 205 passing down through head member 182 and flanges 202, 200 and 198 to engage

in threaded sockets in the two halves of the vibrator housing.

A flanged fitting 210 is secured to the lower end of housing 105, as by screws 211, and has a threaded coupling pin 212 engaging the threaded box 213 of an inside bit member 214, the latter being provided, in this instance with a hardened insert blade 215 extending transversely across the space inside the outside tubular part 107. The bit element 215 is here shown as elevated somewhat above the outside bit elements 108, being designed to disintegrate large fragments of formation initially broken free by action of the outside bit elements 108. It will be evident, however, that the bit element 215 may alternatively be placed on a level with the elements 108, and no limitation to the illustrated arrangement is accordingly to be implied. Also the bit element 215 may be omitted, leaving the outside bit to do the work on the formation, the inside leg then being less damped, and contributing greater fly-wheel effect to the system as a whole. Moreover, the drill can be arranged with a bit only on the inside leg, so that the outside leg functions as a counterbalancing vibrator, with minimum damping.

It will be seen that the drill of Figs. 8–15 forms a structure having a central leg formed by the shank 155 and vibrator, and an outside leg structure comprised of the centrally slotted body 103 and the portion of the outside tubular member 100 below the juncture of the latter with the shank member 155. The region of the member 155 and the member 100 wherein said members are integrated structurally to one another, in this instance by the long taper joint at 156, 157, forms the high impedance, stress anti-nodal head structure 158 of the device. The length of the legs below the head structure, i.e., from the crotch 159 to their lower extremities, has an essential relationship to the frequency at which said legs will vibrate, as mentioned earlier. For an operating frequency of 120 cycles per second, this leg length should be approximately 33 feet.

Operation is as follows: the turbine is driven by mud fluid pumped down the usual drill string, the mud fluid being eventually discharged to the bore hole at the bottom, and forming a fluid column rising to the ground surface around the drill string, in the usual way. The turbine shaft 120 drives the vibrator connected to the lower end of the central leg of the structure through the connections previously described, causing the vibrator to create an alternating force in a vertical direction at a frequency dependent upon the speed at which the turbine is driven by the mud flow. This speed is governed by the rate at which mud fluid is pumped through the drill string at the ground surface. The vertical alternating force developed by the vibrator is exerted on the lower end of the shank 155, which comprises the central leg of the structure. When the turbine is driven at such speed that the vibrator frequency approaches or coincides with the resonant frequency of the device, the shank 155 vibrates in the vertical direction with substantial amplitude. This frequency for resonant operation is given by the ratio

$$\frac{S}{4L}$$

where S is the speed of sound in the material of the structure and L is the length of the legs. Each of the legs is capable of elastic vibration in a longitudinal direction as a "fixed-free" bar of quarter wavelength, or odd multiple thereof, assuming it to be acted upon by an alternating force of resonant frequency. Such resonant elastic vibration is set up in the central leg by direct drive from the vibrator when operated at the resonant frequency. A velocity anti-node then exists at the lower end of the central leg, and a high impedance estress anti-node exists at its upper end, at the head or upper end juncture of the legs. The cyclic stresses so set up in the head or upper end juncture of the legs so react on the upper end of the outside leg structure 100—103 that sympathetic longitudinally elastic vibrations, like those in the central leg to which the vibrator is directly connected, are set up in the outside leg structure, but at 180° phase difference. The result is that both the inside and outside leg structures undergo elastic elongation and contraction, their joined upper end structures standing substantially stationary, and their free lower bit-carrying ends reciprocating, the motions of the two leg structures being similar but at 180° phase difference. Thus the bit element carried by the lower end of the outside leg structure is descending, and vice versa.

As stated earlier, the unitary head structure for the legs is a high impedance region (stress anti-node, or velocity node), and is hence inherently substantially non-vibratory. The drill string, coupled to this high impedance point of the drill, is inherently isolated from the vibration in the drill structure. In this fundamental and generic respect, the quarter wave, fixed-free, drill of Figs. 8–15 is an acoustic analogue of the free-free drill of Fig. 4.

In a more specific aspect, the drill configuration of Figs. 8–15 is analogous also to the isolator configuration of Fig. 5. Viewing the device of Fig. 5 in this aspect, it can be seen that the central leg 20′ and the concentric outside leg 45 comprise a unitary resonant circuit structure having a stationary node at the juncture with element 18′. This unitary structure, viewed together with the oscillator and driver unit 14 for oscillatory drive purposes, and assuming the massive energy-storing vibratory collar 11 to be disconnected or omitted, would have a characteristic resonant mode of operation exhibiting the above mentioned stationary juncture point and also exhibiting out-of-phase, or opposed, vibration of the lower ends of legs 20′ (with unit 14) and leg 45. It then becomes possible, I have found, to add, in place of the eliminated heavy collar 14, a very light and thin walled tubing which becomes a part of and vibrates in the resonant circuit comprising the members 20′, 45 and 14. The elimination of the large mass of collar 11 causes the legs 20′ and 45 to become a major or substantial portion of the resonant acoustic circuit structure, thus "tuning out" the mass of the oscillator and drive unit 14. The substituted light tubing becomes a part of the resonant circuit 20′, 45 and 14, and vibrates as a part of this circuit without wastage of force.

In Fig. 5*a* I have shown a modification of the lower portion of the system of Fig. 5, wherein a thin walled tubing 11*a*, such as referred to above, has been substituted for the massive collar 11. Members 20′ and 45 are made fairly substantial, so as to handle substantial energy flow and storage in the system, and the substituted light tubing 11*a* then need not possess great energy storage capacity. In the illustrative embodiment of Fig. 5*a*, the tubing 11*a* has a plain, flat end at the bottom, providing a thin annular edge in lieu of a drill bit. This configuration, I have found, will drill rapidly through the earth, and functions very well for taking cores at any chosen region. Moreover, by simply giving such thin walled element 11*a* a greater diameter than any other part of the drill, a continuous coring type of drilling operation can be carried out.

A number of illustrative embodiments of the invention have now been described and are illustrated in the drawings. It is to be understood, however, that these are but representative of various forms in which the invention may be embodied in practice, and that various additional specific embodiments are within the scope of the claims appended hereto.

I claim:

1. An isolator adapted for intercoupling between a vibratory drill system having a predetermined vibration frequency and having a vibratory support point characterized by low mechanical impedance, and a supporting means, comprising: an elongated longitudinally elastically compliant member of effectively substantially quarter-wavelength for said predetermined frequency adapted to

be coupled at one end to said vibratory system at said vibratory support point, a massive inertia member joined to the other end of said elongated member, and means for coupling said massive inertia member to said supporting means.

2. An isolator adapted for intercoupling between a vibratory drill system having a predetermined vibration frequency and having a vibratory portion characterized by low mechanical impedance, and a supporting means, comprising: an elongated longitudinally elastically compliant member of substantially half-wavelength for said predetermined frequency adapted to be coupled at one end to said vibratory system at said vibratory portion, and at its midpoint to said supporting means.

3. An isolator adapted for intercoupling between a vibratory drill system having a predetermined vibration frequency and having a vibratory support point characterized by low mechanical impedance, and a supporting means, comprising: an elongated longitudinally elastically compliant member of substantially half-wavelength for said predetermined frequency adapted to be coupled at one end to said vibratory system at said vibratory support point, an elongated longitudinally elastically compliant member of substantially quarter-wavelength for said frequency joined at one end to the midpoint of said half-wavelength compliant member, and a massive inertia member joined to the other end of said elongated quarter-wavelength compliant member, said massive inertia member adapted for coupling to said support member.

4. An isolator adapted for intercoupling between a vibratory drill system having a predetermined vibration frequency and having a vibratory support point characterized by low mechanical impedance, and a supporting means, comprising: a pair of parallel elongated elastically compliant members of quarter-wavelength for said frequency joined to one another at one end to form a unitary vibratory device, the opposite end of one of said elongated members being adapted for coupling to said support point of said vibratory system, and means for coupling said joined ends of said elongated members to said support means.

5. The subject matter of claim 4, including also a massive inertia means coupled to said joined ends of said elongated members, and wherein said massive inertia member is interposed between said members and said support means.

6. An isolator adapted for intercoupling between a vibratory drill system having a predetermined vibration frequency and having a vibratory support point characterized by low mechanical impedance, and a supporting means, comprising: a helical spring adapted for coupling at its lower end to said vibratory system at said support point, and a massive inertia member coupled to the upper end of said helical spring and to said support means.

7. An isolator adapted for intercoupling between a vibratory drill system having a predetermined vibration frequency and having a vibratory support point characterized by low mechanical impedance, and a supporting means, comprising: a massive inertia means coupled to said support means, a vertically elastically compliant coupling means of effectively quarter-wavelength comprised of a series of an odd number of parallel, overlapped vertically extending and elongated elastic members alternately connected, each to the next, at upper and lower ends thereof, said elastically compliant means being coupled at one end of said series of members to the vibratory support point of said vibrating system, and at the other end of said series of members to said massive inertia means.

8. An isolator adapted for intercoupling between a vibratory drill system having a predetermined vibration frequency and having a vibratory support point characterized by low mechanical impedance, and a supporting means, comprising: an elongated longitudinally elastically compliant member of effectively substantially quarter-wavelength for said predetermined frequency intercoupled between said support means and said vibratory system at said vibratory support point, and means coupled to the upper end portion of said elongated longitudinally elastically compliant member for resisting longitudinal vibratory movement of said upper end portion of said member.

9. An isolator adapted for intercoupling between a vibratory drill system having a predetermined vibration frequency and having a vibratory support point characterized by low mechanical impedance, and a supporting means, comprising: a two-terminal device, including a vibratory lower terminal joined to said vibratory support point of said vibratory system, and a non-vibratory upper terminal, a massive inertia member coupled to said upper terminal and to said support means, said device having an elastically compliant portion which is elastically vibratory longitudinally of a direction line extending between said upper and lower terminals, and which has mass and elasticity constants, establishing resonance thereof at said vibration frequency of said vibratory system.

10. In a sonic well drilling system, the combination of: a sonic drill including a massive elastic drill rod with a bit on one end and a mechanical vibrator attached thereto and arranged to exert vibratory forces longitudinally of the rod at a frequency to generate a longitudinal standing wave in the rod, with a velocity antinode at the upper end thereof; a drill string for supporting said sonic drill; and a resonant vibration isolator intercoupled between said drill string and said sonic drill, said isolator embodying a two-terminal device, including a vibratory lower terminal joined to said sonic drill, and a non-vibratory upper terminal, a massive inertia member coupled to said upper terminal and to said drill string, said device having an elastically compliant portion which is elastically vibratory longitudinally of said drill string and sonic drill, and which has mass and elasticity constants establishing resonance thereof at a standing wave frequency generated in said drill rod by said vibrator.

11. A wave transmission isolator adapted for interconnecting between a supporting means and a vibratory drill system having a predetermined vibration frequency and direction and having a vibratory support point, comprising: an elastically resonant vibratory coupling structure including a vibratory portion of low acoustic impedance attached to said support point of said drill system and having its direction of vibration in the direction of vibration of said support point, and including also a non-vibratory portion of high acoustic impedance attached to said supporting means, said elastically vibratory coupling structure having mass and elasticity constants establishing resonance thereof at the vibration frequency of said drill system.

12. The subject matter of claim 11, wherein said portion of high acoustic impedance includes a massive inertia member.

13. The subject matter of claim 11, wherein said coupling structure embodies two balanced oppositely phased elastically vibratory members joined at said non-vibratory portion thereof to provide said high impedance.

14. A wave transmission isolator adapted for interconnecting between a supporting means and a vibratory drill system having a predetermined vibration frequency and direction and having a vibratory support point, comprising: an elastically vibratory resonant coupling structure having coacting stiffness and vibrating mass for giving a resonant vibration pattern at the vibration frequency of said drill, said coupling structure being attached between said supporting means and said support point of said drill, said coupling structure having its vibratory motion in the direction of said drill vibration at said support point, and the resonant vibration pattern of said coupling structure having a high acoustic impedance at its point of attachment to said supporting means and a low acoustic impedance at its point of attachment to said vibratory support point.

15. The subject matter of claim 14, wherein said coupling structure includes a massive inertia member in the region of its point of attachment to said supporting means to provide said high acoustic impedance.

16. The subject matter of claim 14, where said coupling structure embodies two balanced oppositely phased elastically vibratory members joined at said non-vibratory portion thereof to provide said high impedance.

17. In a sonic well drilling system, the combination of a sonic drill including a massive free-free elastic rod with a bit on one end and a mechanical vibrator attached thereto and being arranged to exert vibratory forces longitudinally of the rod at a frequency to generate a longitudinal standing wave in the rod, with a velocity antinode at the upper end thereof and a velocity node region at an intermediate region thereof, a non-vibratory support attachment for said rod, and an isolator for isolating the standing wave vibration of said rod from said non-vibratory support attachment therefor, which isolator is

intercoupled between said rod and said support attachment, said isolator comprising a jacket member connected at its upper end to said support attachment and at its lower end to said velocity node region of said rod, said jacket member surrounding said rod above said velocity node.

18. The apparatus of claim 2 wherein said vibratory portion is a sonically actuated bit characterized by said low mechanical impedance, wherein said vibration frequency is provided by a mechanical vibrator, and wherein said compliant member is a massive cross-section bar of length corresponding to a standing wave pattern establishing said half-wave length.

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