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LATERAL SONIC VIBRATION FOR AIDING CASING DRIVE

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2 Sheets-Sheet 1

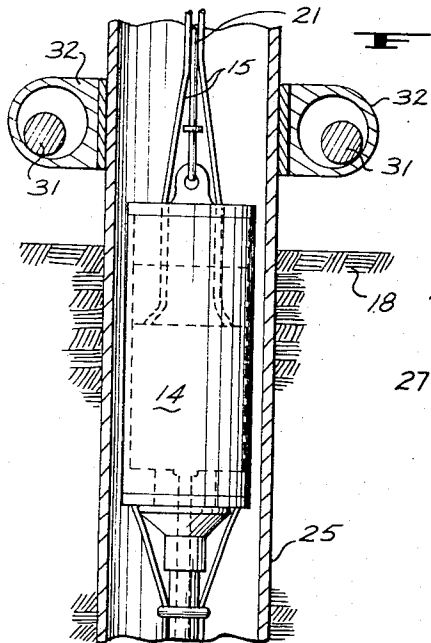


FIG. 1

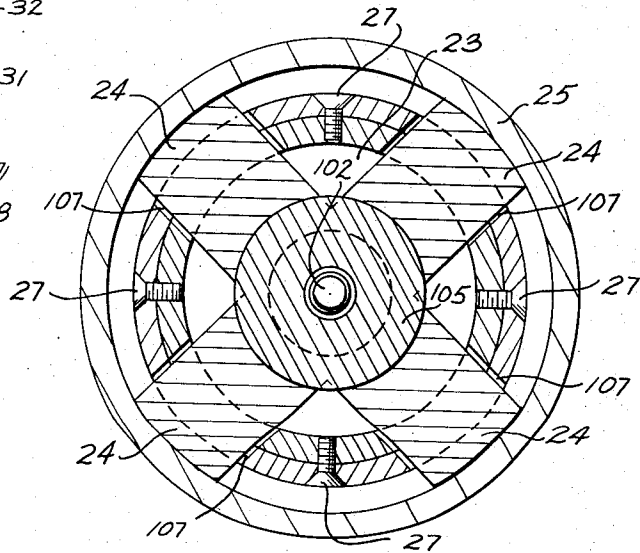


FIG. 4

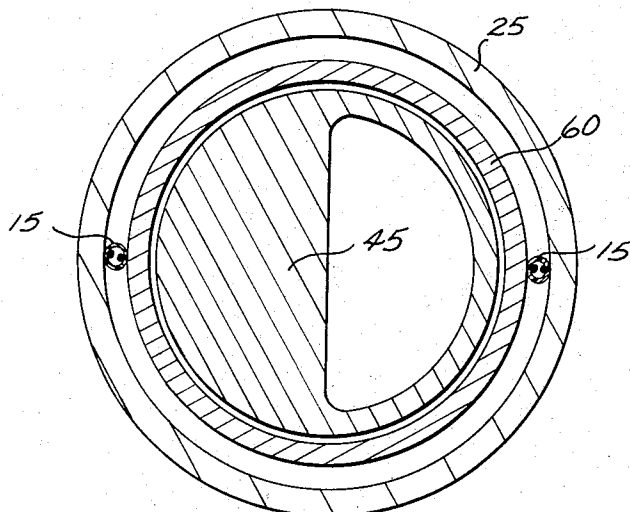
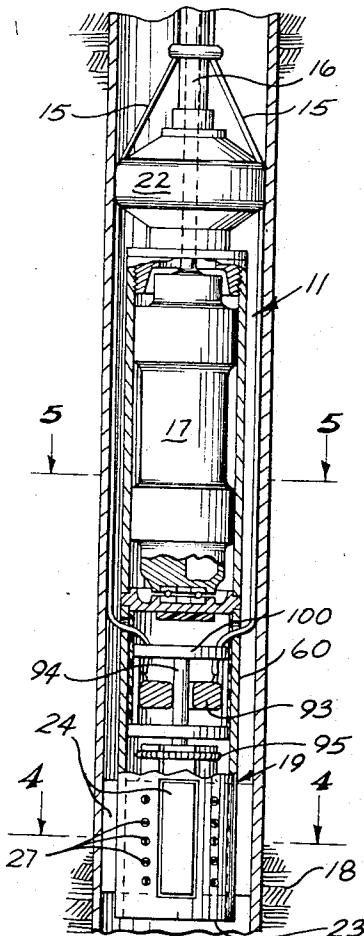


FIG. 5

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2 Sheets-Sheet 2

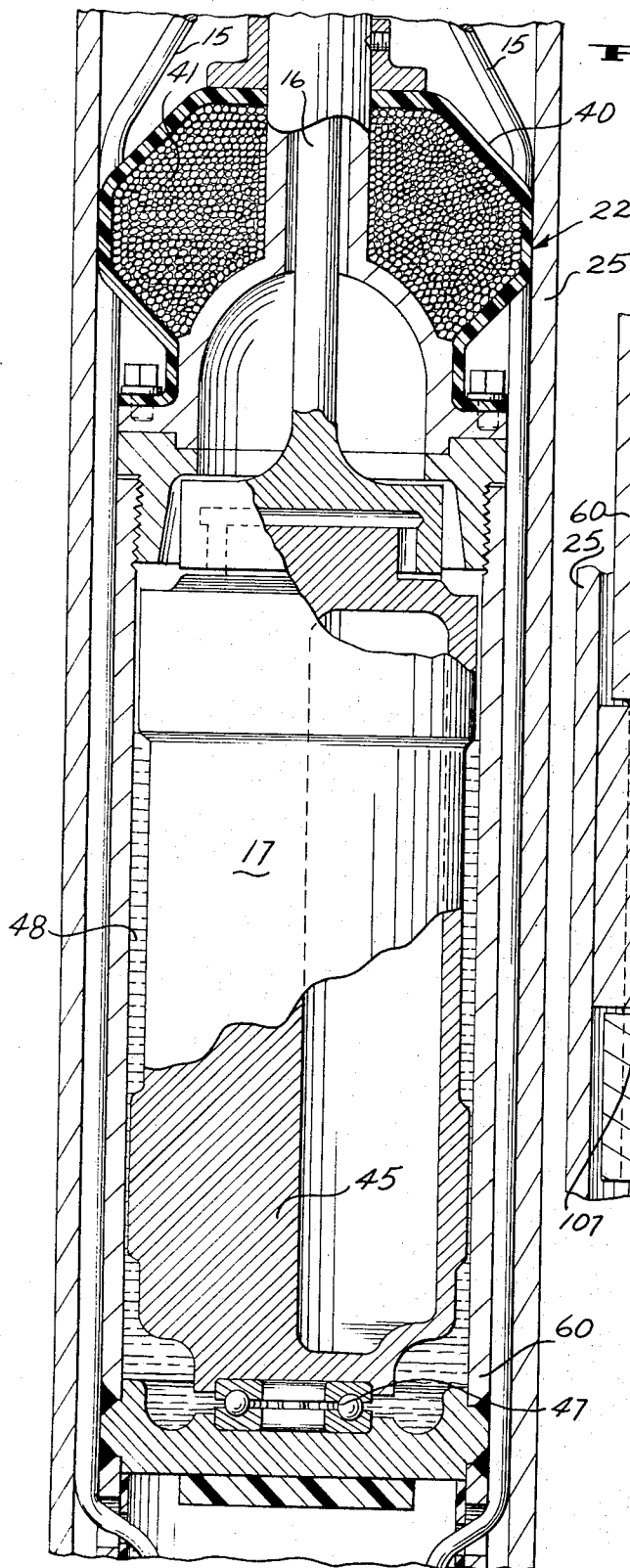


FIG. 2

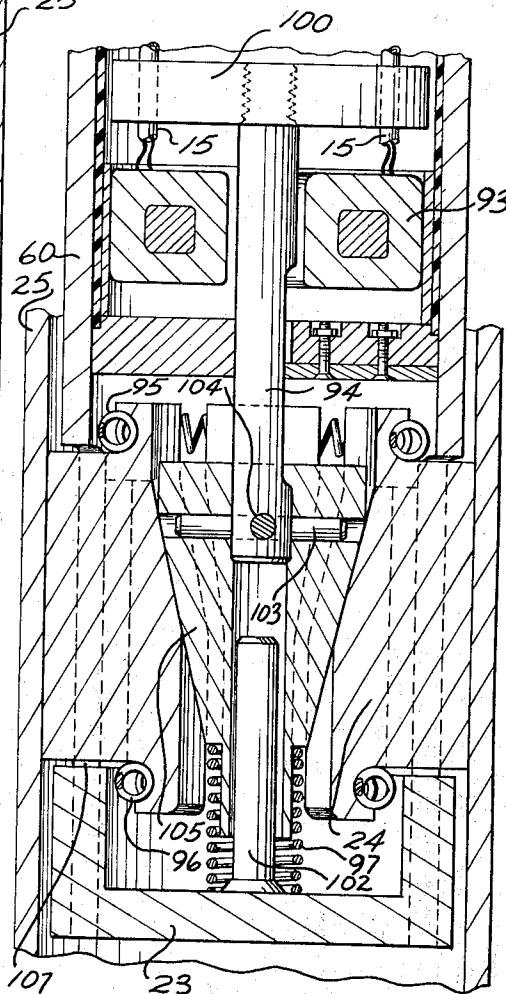


FIG. 3

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## LATERAL SONIC VIBRATION FOR AIDING CASING DRIVE

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9 Claims. (Cl. 175-55)

This invention relates to the utilization of lateral sonic vibration for aiding the driving of a casing or pile member and more particularly to a method and apparatus wherein lateral sonic vibration is employed to facilitate the longitudinal sonic driving of such a member.

Members such as casings or piles can be efficiently driven through earthen formations by utilizing sonic energy which is applied to such members to cause longitudinal resonant vibration thereof. The use of this type of technique is described, for example, in my Patent No. 2,975,846, issued Mar. 21, 1961, and entitled, Acoustic Method and Apparatus for Driving Piles. In situations where high frictional engagement between the driven member and the earthen formation being penetrated occurs, such as, for example, when driving at great depth and/or through hard formations, difficulty is often experienced in driving such member at the speed and efficiency to be desired. This difficulty is often due to the settling back of earth along the casing wall. Thus, the earth tends to grip the casing wall adding friction to the longitudinal vibrational driving system and thereby lowering the efficiency thereof.

The method and apparatus of this invention provide means for minimizing such frictional effects as they appear by utilizing lateral vibrational energy to cause the earthen material to move back away from the casing wall, thus freeing such wall and lowering the effective friction and raising the "Q" of the longitudinally vibrating system. This end result is implemented by utilizing a mechanical oscillator which is rotatably driven to generate lateral vibrations in conjunction with means for selectively coupling the vibrational output of such oscillator to the member being driven at a frictional problem point therealong. Means are provided for lowering the oscillator member and its associated assembly within the casing being driven and for removably clamping such assembly to the casing in the region where the frictional problem exists. In this manner, frictional problems encountered by the longitudinal vibration system can be expeditiously overcome, and such system kept operating at optimum efficiency at all times.

It is therefore an object of this invention to provide means for alleviating frictional problems encountered in sonic driving.

It is a further object of this invention to provide means for applying lateral sonic vibrational energy to a driven member to free such member from a surrounding earthen formation, which lateral vibration is combined with longitudinal vibration in aid of the latter.

It is another object of this invention to provide means for optimizing the effective Q of a sonic driving system.

It is still another object of this invention to provide means for selectively applying lateral sonic energy at a frictional trouble spot along a member being driven through an earthen formation by longitudinal vibrational energy, to free such member from the surrounding earthen formation.

Other objects of this invention will become apparent from the following description taken in connection with the accompanying drawings, of which

FIG. 1 is an elevation view illustrating a preferred embodiment of the device of the invention,

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FIG. 2 is an elevation view partially in cross-section illustrating the lateral oscillator assembly of the preferred embodiment of the device of the invention,

FIG. 3 is an elevational cross-sectional view of a preferred embodiment of the clamping mechanism utilized in the preferred embodiment of the device of the invention,

FIG. 4 is a cross-sectional view taken along the plane indicated by 4-4 in FIG. 1, and

FIG. 5 is a cross-sectional view as taken along the plane indicated by 5-5 in FIG. 1.

It has been most helpful in analyzing the operation of the device of the invention to analogize the acoustically vibrating circuit involved to an equivalent electrical circuit. This sort of analogy is well known to those skilled in the art and is described, for example, in Chapter 2 of Sonics by Hueter and Bolt, published in 1955 by John Wiley and Sons. In making such an analogy, force,  $F$ , is equated with electrical voltage,  $E$ ; velocity of vibration,  $u$ , is equated with electrical current,  $i$ ; mechanical compliance,  $C_m$ , is equated with electrical capacitance,  $C_e$ ; mass,  $M$ , is equated with electrical inductance,  $L$ ; mechanical resistance (friction),  $R_m$ , is equated with electrical resistance,  $R$ ; and mechanical impedance,  $Z_m$ , is equated with electrical impedance,  $Z_e$ . Thus, it can be shown that if a member is elastically vibrated by means of an acoustical sinusoidal force  $F_0 \sin \omega t$  ( $\omega$  being equal to  $2\pi$  times the frequency of vibration), that

$$Z_m = R_m + j\left(\omega M - \frac{1}{\omega C_m}\right) = \frac{F_0 \sin \omega t}{u} \quad (1)$$

Where  $\omega M$  is equal to  $1/\omega C_m$ , a resonant condition exists, and the effective mechanical impedance,  $Z_m$ , is equal to the mechanical resistance,  $R_m$ , the reactive impedance components  $\omega M$  and  $1/\omega C_m$  cancelling each other out. Under such a resonant condition, velocity of vibration,  $u$ , is at a maximum, power factor is unity, and energy is most efficiently delivered to a load to which the resonant system may be coupled.

Just as in electrical circuitry, maximum acoustical energy can be transferred where a good impedance match exists, i.e., where the two elements between which the energy transfer occurs have like impedances.

It is particularly important to note the significance of the attainment of high acoustical Q in the member being driven to increase the efficiency of the vibration thereof and to provide a maximum amount of energy for the driving operation. As for an equivalent electrical circuit, the Q of an acoustically vibrating circuit is defined as the sharpness of resonance thereof and is indicative of the ratio of the energy stored in each vibration cycle to the energy used in each such cycle. Q is mathematically equated to the ratio between  $\omega M$  and  $\omega R_m$ . Thus, the effective Q of the vibrating circuit can be maximized to make for highly efficient, high amplitude vibration by minimizing the effective friction in the circuit and/or maximizing the effectiveness mass in such circuit. This factor has particular significance in the device and method of this invention in that lateral vibrational energy is used to effectively raise the Q of the longitudinal vibrational drive system by lowering the frictional resistance thereof. Thus, an effective remedy is provided in situations where tight sticking conditions which tend to lower the Q and efficiency of the driving system are encountered.

In considering the significance of the parameters described in connection with Equation 1, it should be kept in mind that the total effective resistance, mass, and compliance in the acoustically vibrating circuit are represented in the equation and that these parameters may be distributed throughout the system rather than being lumped in any one component or portion thereof.

Referring now to FIG. 1, a preferred embodiment of the device of the invention is illustrated. Casing member 25 is driven longitudinally into earthen formation 18 by means of the vibrational energy supplied by orbiting mass oscillator 32. Oscillator 32 comprises a pair of oppositely rotating rotor members 31, which are phased so that the lateral vibrational components generated thereby cancel each other out, while vibrational components along the longitudinal axis of casing 25 are additive. The rotor members 31 of orbiting mass oscillator 32 may be pneumatically driven and of the type described in my copending application Ser. No. 454,335 filed May 10, 1965. The housing of oscillator 32 is clamped to the wall of casing 25 by suitable means, such that the vibrational energy generated thereby is tightly coupled to the casing near the top end thereof. The vibrational output of oscillator 32 is preferably in the sonic frequency range and at a frequency such as to cause resonant longitudinal vibration of casing 25, so as to set up standing waves therealong.

The high amplitude longitudinal resonant vibration set up in casing 25 causes the driving end of the casing to efficiently penetrate through earthen formation 18. In certain instances, however, especially where driving at great depths, frictional engagement of the casing with the surrounding earthen formation, either at the penetrating end or at some point thereabove, may occur which impairs the efficiency of the driving operation. Such frictional engagement, as already noted, lowers the effective Q of the resonantly vibrating system and thus lessens the amount of vibrational force available at the driving end of the casing. Whenever such a frictional problem is encountered, lateral oscillator assembly 11 is lowered within casing 25 on cable 21 and clamped to the casing for operation at the trouble spot by means of clamping mechanism 19, as shown in FIG. 1. When the frictional problem has been overcome, lateral oscillator assembly 11 may be completely withdrawn from casing 25 or clamping mechanism 19 merely disengaged from the casing, while such oscillator assembly is kept in readiness within the casing for a subsequent utilization.

Lateral oscillator assembly 11 includes an electric motor 14 which is energized by power received on power lines 15. Motor 14 rotatably drives shaft 16 which in turn rotatably drives orbiting mass oscillator 17. Orbiting mass oscillator 17, the details of which are explained in detail further on in the specification in connection with FIGS. 2 and 5, has a rotor with an eccentrically weighted mass which when rotated generates a lateral vibratory force. This force has a gyratory force pattern which can be resolved into a pair of quadrature related lateral force vectors. The vibrational output of oscillator 17 is coupled to housing 60. Housing 60 in turn is clamped to casing 25 by means of clamping mechanism 19, the operation of which is described in detail in connection with FIGS. 3 and 4 further on in this specification.

Electrical power is supplied on power lines 15 to clamping mechanism 19 when clamping action is desired. Clamping mechanism 19 operates electromagnetically and thus the clamping and releasing of lateral oscillating assembly 11 to and from casing 25 respectively can be controlled by means of power control circuits (not shown) at the surface. Yieldable centering member 22 maintains lateral oscillator assembly 11 centered while it is being lowered without causing undue friction against the walls of casing 25.

In operation, the lateral vibrational energy output of oscillator 17 is superimposed on the longitudinal standing wave generated by oscillator 32, resulting in a complex vibratory sonic pattern having significant lateral as well as longitudinal components. Such complex motion is capable of effectively causing the complex irregular earthen grains to be moved back into a compacted position away from the casing wall to make space for the casing. Thus, it has been found that the earthen grains, due to their irregular shapes and sizes, are readily worked into a com-

packed condition by the complex and variable vector of motion generated, the compacting forces being applied through a variety of angles and directions.

Orbiting mass oscillator 32 is adapted to resonantly drive casing 25 so as to set up standing waves therein. This type of oscillator tends to automatically adjust its rotation frequency to maintain resonance with changes in the impedance of the resonantly vibrating system. For optimum efficiency, oscillator 17 is preferably made to rotate at a frequency which will set up resonant lateral vibration of casing 25, although it has been found that reasonably good results can be obtained without such lateral resonance. In some instances it is desirable to operate the lateral vibration oscillator at substantially the same frequency as that of the longitudinal oscillator.

Referring now to FIGS. 2 and 5, a preferred embodiment of the lateral oscillator assembly of the device of the invention is illustrated. The oscillator assembly is kept centered by means of yieldable centering device 22, which comprises a flexible neoprene boot 40 in which a plurality of small pellets 41 are contained. Thus, boot 40 is forced outwardly against the wall of casing 25 but at the same time is yieldable so as to permit the oscillator assembly to readily slide down the casing.

Oscillator 17 includes a rotor 45 having an eccentric mass which is rotatably mounted in housing 60. Rotor 45 is rotatably supported by means of ball bearings 47 and a fluid bearing provided by means of lubricating fluid 48, contained within housing 60. Rotor 45 is rotatably driven by shaft 16.

Referring now to FIGS. 1, 3 and 4, the preferred embodiment of a clamping mechanism 19 which may be utilized to couple the lateral oscillator output to casing 25 is shown. In FIGS. 1, 3 and 4, the clamping mechanism is shown with its magnetic drive coils 93 energized so as to effect clamping attachment to casing 25. Armature member 100 is threadably attached to rod 94.

Fixedly mounted within housing 60 are magnetic coils 93 which when energized operate to draw armature 100 downward. Connected to shaft 94 by means of cross-arms 103 and 104 is conically shaped actuator member 105. Actuator member 105 has a hollow central portion which slidably fits over post 102. Post 102 is fixedly attached to end cap 23. End cap 23 has a dovetail fit with housing 60 and is attached thereto by means of screws 27 (see FIG. 1).

Four symmetrically positioned pad members 24 are held in position against actuator member 105 by means of circular coil springs 95 and 96. The outer walls of pad member 24 fit through corresponding apertures 107 formed in the walls of housing 60. Electrical power is supplied to magnetic coils 93 through wire leads 15.

When electrical coils 93 are de-energized, actuator 105 is driven upwardly by spring 97 and carries shaft 94 and armature 100 up along with it. With actuator 105 in its upward position, clamping pads 24 are drawn inwardly against the armature surfaces by springs 95 and 96 such that the outer walls of pads 24 are retracted away from the inner walls of casing 25, thus leaving oscillator assembly 11 free to slide up and down within casing 25. With the energization of coils 93, as indicated in FIGS. 1, 3 and 4, armature 100 is drawn downwardly, causing actuator 105 to force the outer walls of pads 24 into tight clamping engagement with casing 25.

Thus, lateral vibrational energy can be superimposed on the longitudinal resonant vibration system at any point along the casing where sticking is encountered to alleviate such condition. In this manner the effective Q of the longitudinal vibration system can be optimized throughout the driving operation to enhance the efficiency of such operation.

While the method and device of this invention have been described and illustrated in detail, it is to be clearly understood that this is intended by way of illustration and example only and is not to be taken by way of

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limitation, the spirit and scope of this invention being limited only by the terms of the following claims:

I claim:

1. A method for sonically driving a member into an earthen formation comprising the steps of  
applying sonic energy to said member longitudinally near one end thereof at a frequency such as to cause longitudinal resonant vibration of said member, thereby causing the other end thereof to drive into said formation, and

applying sonic energy to said member laterally to cause lateral vibration thereof at any point therealong where sticking of said member with the earthen formation is encountered,

such that said lateral vibration is superimposed on said longitudinal vibration to lower the friction in the longitudinal vibration system thereby raising the Q thereof.

2. The method as recited in claim 1 wherein said member is elongated and hollow, and whereby sonic energy to cause lateral vibration thereof is applied by lowering a lateral oscillator assembly within said member and selectively attaching said oscillator unit to said member so as to act at a friction point along said member.

3. The method as recited in claim 2 wherein said oscillator unit is selectively attached to said member by clamping said assembly to said member with an electromagnetically actuated clamping mechanism.

4. The method as recited in claim 1 wherein the sonic energy applied laterally to said member is at a frequency such as to cause lateral resonant vibration thereof.

5. The method as recited in claim 2 wherein said member is tubular and said oscillator assembly is lowered down within said tubular member on a cable to any friction point therealong.

6. In combination, a first mechanical vibrational oscillator assembly for longitudinally vibrating a hollow elongated member to drive said member into an earthen formation, said first oscillator assembly being tightly clamped to the wall of said member, and a second mechanical vi-

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brational oscillator assembly for laterally vibrating said member to alleviate sticking thereof, said second oscillator assembly comprising

a housing,

an eccentrically weighted rotor member mounted in said housing for rotation about an axis substantially parallel to the longitudinal axis of said member, cable means for lowering said housing within said member to any desired point therealong, and clamping means mounted in said housing for removably clamping said housing to said member at any point therealong,

whereby the lateral vibrational output of said second oscillator assembly is superimposed on the longitudinal output of said first oscillator assembly to lower the effective resistance of the longitudinal vibration system thereby raising the effective Q thereof.

7. The combination as recited in claim 6 wherein said first mechanical oscillator assembly has a vibrational output at a frequency such as to cause longitudinal resonant vibration of said member.

8. The combination as recited in claim 6 and additionally including yieldable means mounted on said housing for centering said housing within said member.

9. The combination as recited in claim 7 wherein said second oscillator assembly has a vibrational output at a frequency such as to cause lateral resonant vibration of said member.

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