Feb. 24, 1970 A. G. BODINE 3,496,883

METHOD AND APPARATUS FOR THE REMOVAL AND REPLACEMENT OF RAILROAD TIES AND THE LIKE

Filed Sept. 6, 1966 3 Sheets-Sheet 1

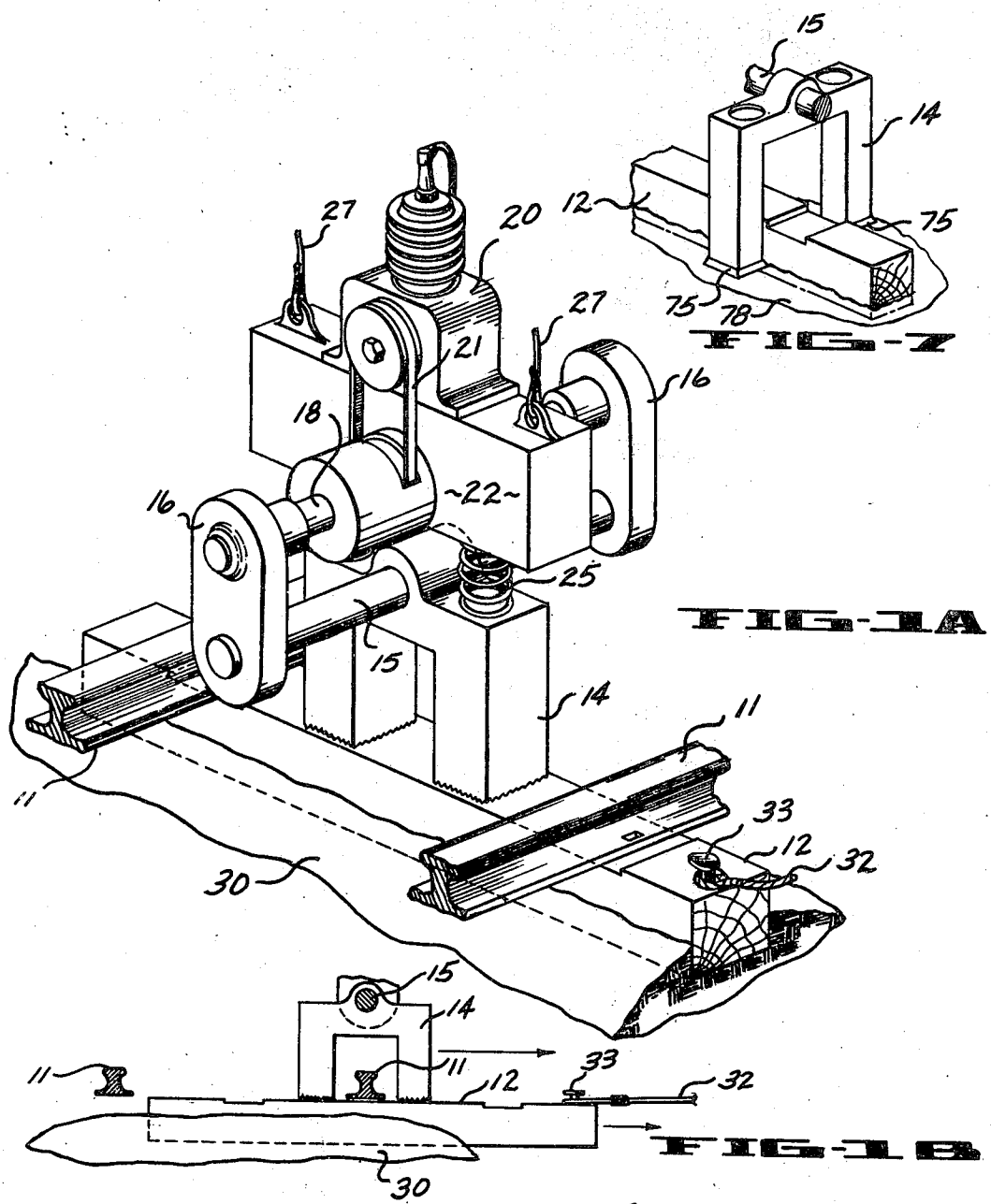


FIG-2

FIG-1A

FIG-1B

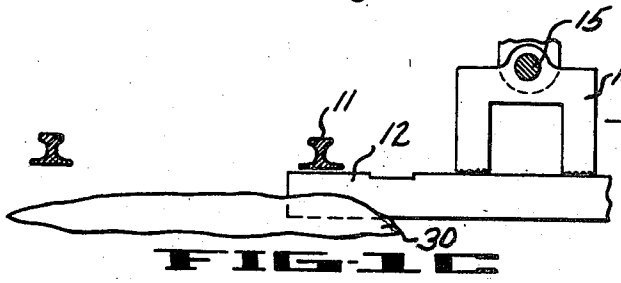


FIG-1C

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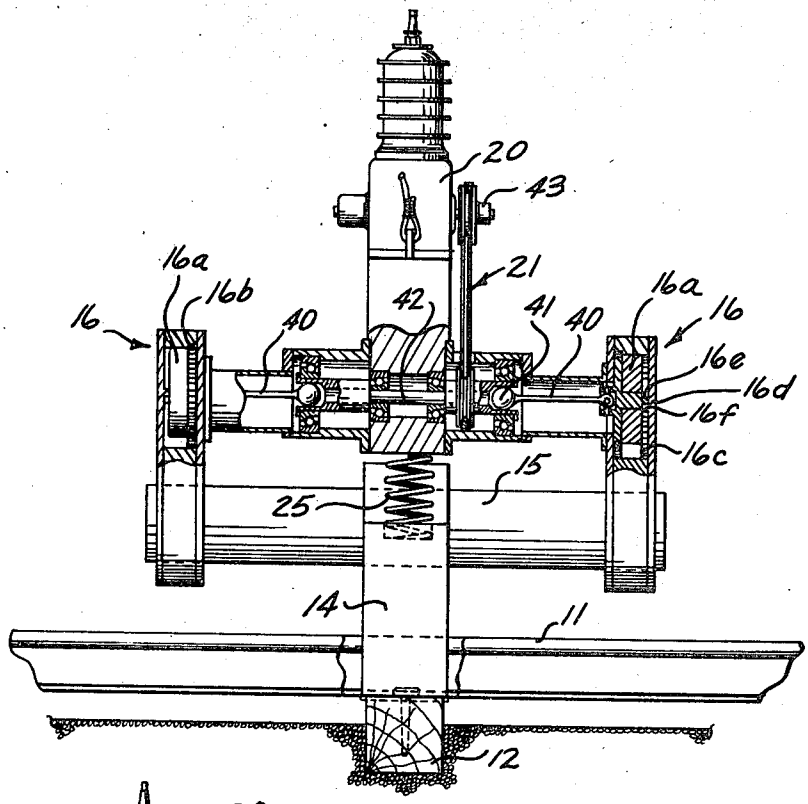


FIG. 2

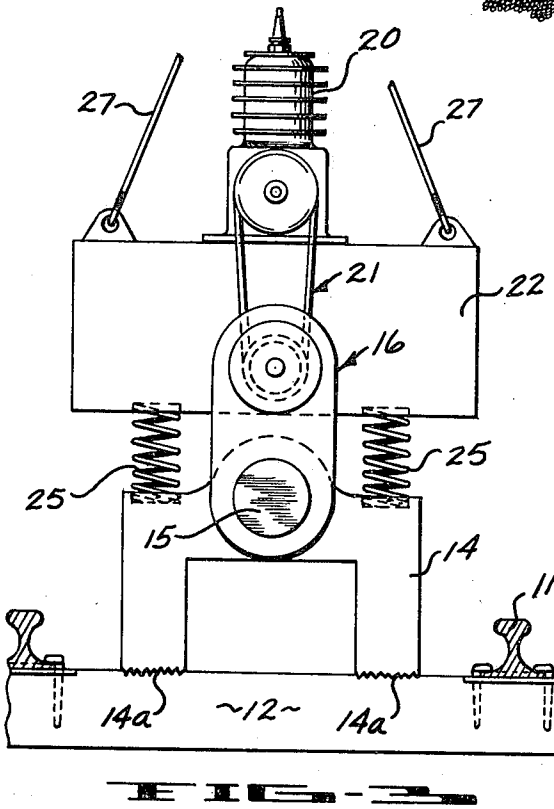


FIG. 3

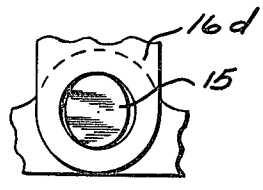


FIG. 4

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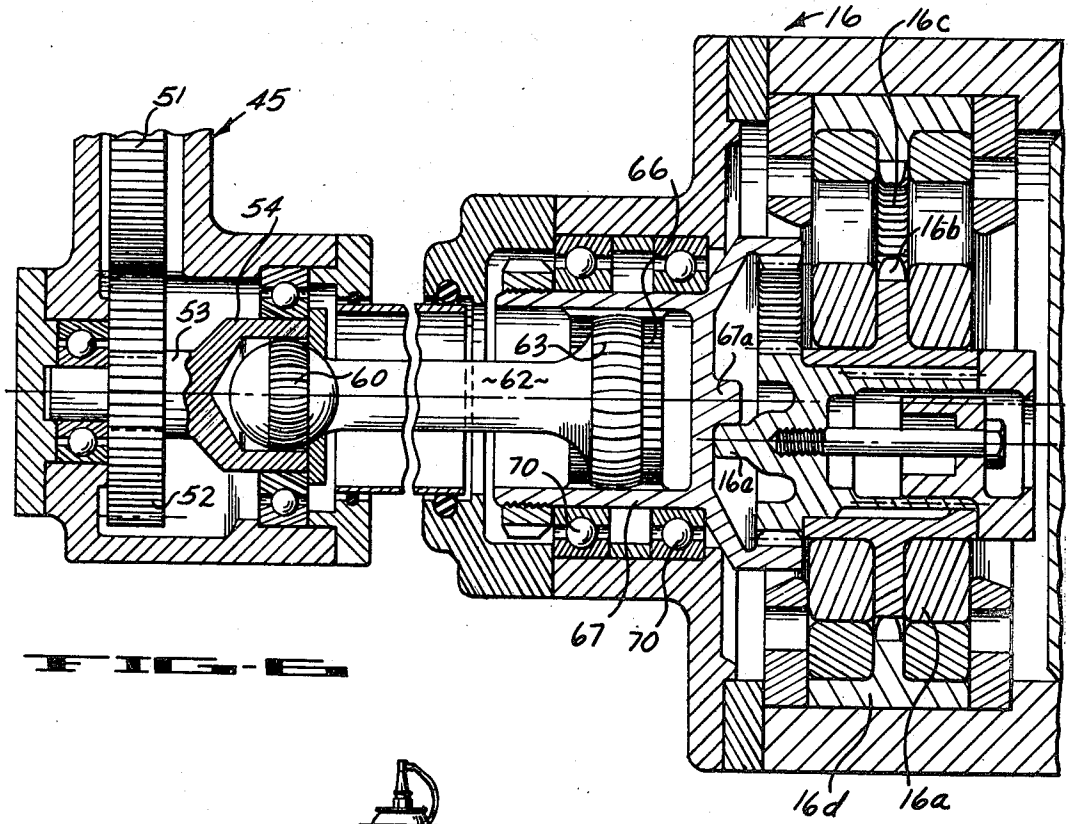


FIG-6

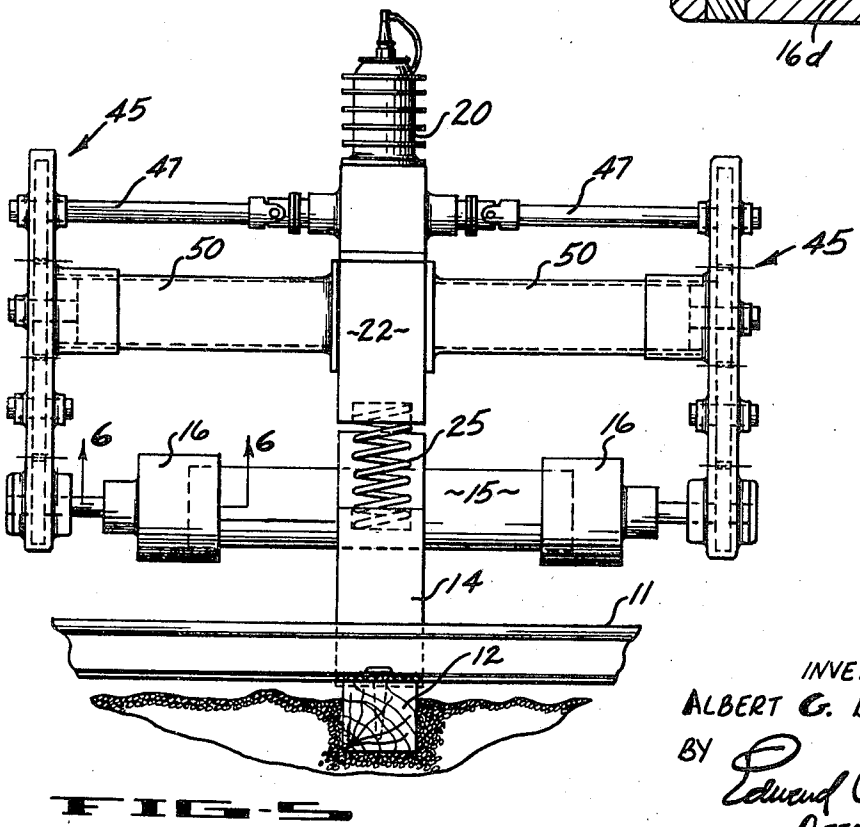


FIG-5

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3,496,883

METHOD AND APPARATUS FOR THE REMOVAL AND REPLACEMENT OF RAILROAD TIES AND THE LIKE

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Int. Cl. E01b 29/10, 27/00
U.S. Cl. 104—9 18 Claims

ABSTRACT OF THE DISCLOSURE

A bar member is supported on a railroad tie to be removed and resonantly vibrated by means of an orbiting mass oscillator which is mounted thereon. While high level sonic energy is in this manner being coupled to the tie to loosen it from the earthen material in which it is embedded, the tie is biased downwardly so that it works away from the rails. The tie is then laterally pulled out from under the rails.

This invention relates to a method and apparatus for the removal and replacement of railroad ties and the like, and more particularly to such a method and apparatus in which sonic energy is utilized to enable the accomplishment of the removal and replacement operations in a highly efficient manner.

Railroad ties need replacement during their service life sometimes at relatively frequent intervals due to deterioration which lessens their ability to properly support the rails. One type of such deterioration is caused by the gradual embedding of the rail and its tie plate into the tie caused by repeated travel of the train over the track. Another problem is presented by the deterioration of the ballast around the tie which requires replacement of not only the ballast but also the tie itself.

A commonly employed technique of the prior art for removing railroad ties utilizes a large guillotine type of cutting axe which chops the tie in two, the top surface of the tie then being split away so that the remnants thereof can be extracted from under the rail. This is a somewhat time consuming and difficult operation and also results in the destruction of the tie, ruining whatever salvage value it may have had.

The method and apparatus of this invention enable the removal and replacement of railroad ties relatively rapidly and easily as compared with prior art techniques, leaving the removed tie substantially intact. The method and apparatus of this invention accomplish this significant improvement over the prior art by coupling high-level sonic energy to the tie and while such energy is being so coupled biasing the tie downwardly to cause it to work away from the rails until it is completely free therefrom. While continuing to sonically energize the tie to loosen it from the earthen material in which it is embedded and to fluidize such earthen material, the tie is pulled laterally out from under the rails. Sonic energy can also be utilized by means of the device of the invention to compact fresh ballast around a new tie in the installation thereof.

In the preferred embodiments of the device of the invention sonic energy is provided by means of orbiting-mass oscillators, the vibrational output of which is coupled to a bar member which in turn is supported on a U-shaped mounting. The mounting is placed on the tie and the oscillators are rotatably driven at a frequency such as to cause the resonant vibration of a vibration system including the bar member, the mounting member and the tie. The bar member may be cylindrical in configuration and caused to vibrate gyrationally, this type of sonic action being especially effective in loosening the tie.

It is therefore an object of this invention to provide an improved method and apparatus for removing members from earthen material in which they are embedded.

It is a further object of this invention to provide a method and apparatus for removing and installing railroad ties which is more rapid and efficient than prior art techniques.

It is still another object of this invention to provide means for utilizing sonic energy to efficiently and rapidly remove railroad ties.

It is still a further object of this invention to provide an improved method and apparatus for removing railroad ties in which the railroad ties are left substantially intact.

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

FIGS. 1*a*–1*c* are a series of illustrations illustrating the method of the invention;

FIG. 2 is a side elevation view of a first embodiment of the device of the invention;

FIG. 3 is an end elevation view of the embodiment shown in FIG. 2;

FIG. 4 is an illustration showing an elliptical bar member which may be utilized in the device of the invention;

FIG. 5 is a side elevation view of a second embodiment of the device of the invention;

FIG. 6 is a cross-sectional view taken along the plane indicated by 6—6 in FIG. 5; and

FIG. 7 is a schematic view illustrating the utilization of the device of the invention for compacting ballast in the installation of tie members.

In order to facilitate the comprehension of the operation of the devices and method of the invention, it is helpful to make an analogy between an electrical resonant circuit and a mechanical resonant circuit. This type 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 (such as friction) R_m is equated with electrical resistance R; mechanical impedance Z_m is equated with electrical impedance Z_e.

Thus it can be shown that if a member is elastically vibrated by a sinusoidal force $F_0 \sin \omega t$, ω being equal to 2π 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 ωM 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 ωM and $1/\omega C_m$ cancelling each other out. Under such a resonant condition, velocity of vibration u is at a maximum, effective power factor is unity, and energy is most efficiently delivered to the object being vibrated. It is such a high efficiency resonant condition in the elastic system being driven that is preferably utilized in the methods and devices of this invention to achieve the desired end results.

It is to be noted by reference to Equation 1 that velocity of vibration u is highest where impedance Z_m is lowest, and vice versa. Therefore, a high-impedance load will tend to vibrate at relatively low velocity, and vice versa. Thus, at an interface between high- and low-impedance elements, a high relative movement results by virtue of such impedance mismatch which, as in the equivalent electrical circuit, results in a high reflected wave. In the device of

this invention, while the earthen material basically acts as a resistive load, there is some impedance mismatch between the railroad tie and the ballast material holding such tie, particularly at the very top surface of the ballast which is utilized to advantage to help free the tie from such material.

Just as the sharpness of resonance of an electrical circuit is defined as the Q thereof, and is indicative of the ratio of energy stored to the energy used in each cycle, so also the Q of the mechanical resonant circuit has the same significance and is equal to the ratio between ωM and R_m. Thus high efficiency and considerable cyclic motion can be achieved by designing the mechanical resonant circuit for high Q, as, for example, by utilizing a metallic bar member having high elasticity and mass.

Of significance in the implementation of the method and devices of this invention, is the high acceleration of the components of the elastic resonant system that can be achieved at sonic frequencies. The acceleration of a vibrating mass is a function of the square of the frequency of the drive signal times the amplitude of vibration. This can be shown as follows:

The instantaneous displacement of y of a sinusoidally vibrating mass can be represented by the following equation:

$$y=Y \cos \omega t \qquad (2)$$

where Y is the maximum displacement in the vibration cycle and ω is equal to $2\pi f$, f being the frequency of vibration.

The acceleration a of the mass can be obtained by differentiating Equation 2 twice, as follows:

$$a=\frac{d^2y}{dt^2}=-Y\omega^2 \cos (\omega t) \qquad (3)$$

The acceleration a thus is a function of $Y\times(2\pi f)^2$. At resonance, Y is at a maximum, and thus even at moderately high sonic frequencies, very high accelerations as achieved making for correspondingly high vibrational forces.

It is to be noted that in the device of this invention the mass and compliance for forming the resonantly vibrating system are furnished by the structural members of such system themselves such that the earthen formation is not incorporated in such system. The earthen material, from which the tie is to be freed, under such conditions, acts as a friction load which provides no large reactive components. This results in a random vibration of the earthen particles, rather than a lumped coherent vibration from a reactance, with a considerable relative motion between the separate grains. It is believed that each of the individual irregular grains when energized by the sonic energy in this fashion separately vibrates in a random path with a relatively fixed radius of vibration which changes in direction but remains fixed in magnitude. Such random vibration effectively separates the particles so that they do not adhere to each other and are thus kept in a highly fluid condition. The net result is a high degree of fluidization of the earthen structure.

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.

It is also to be noted that an orbiting-mass oscillator is utilized in the preferred embodiments of the invention that automatically adjusts its output frequency to maintain resonance with changes in the characteristics of the load. Thus, in the face of changes in the effective mass and compliance presented by the load, the system automatically is maintained in optimum resonant operation by virtue of the "lock in" characteristics of applicant's unique orbiting-mass oscillator. The orbiting-mass oscillator

automatically changes not only its frequency but its phase angle and therefore its power factor with changes in the resistive impedance load to assure optimum efficiency of operation at all times. The vibrational output from such an orbiting-mass oscillator is gyratory and has an output with a rotary force vector. This rotary force vector has a constantly changing resultant force and motion in any particular direction. This means that the effective output impedance goes through a cyclic pattern such that as the impedance of the ballast material changes, at least some portion of each cyclic pattern will provide optimum sonic activation of such material. The rotary sonic action provided by virtue of applicant's orbiting-mass oscillators thus affords specific advantages to the implementation of the method and apparatus of this invention.

Refering now to FIGS. 1*a*–1*c*, the utilization of the method of the invention for removing railroad ties is illustrated. As shown in FIG. 1*a*, the spikes (not shown) which have been holding rail **11** to tie **12** have been removed. U-shaped mounting member **14** is placed on tie **12** near the center thereof. Mounting member **14** has a bar member **15** supported thereon, this bar member being vibrationally driven by sonic oscillator **16**. Sonic oscillator **16**, which is preferably of the orbiting-mass type, is rotatably driven by drive shaft **18** which receives its drive power from gasoline engine **20** via drive belt **21**. Engine **20** is supported on weight member **22** which is resiliently mounted on mounting **14** by means of springs **25**. Weight **22** biases mounting **14** against tie **12** to provide tight sonic coupling between the tie and the mounting, and to urge the tie downwardly away from rails **11**. Springs **25** vibrationally isolate the vibrational system which includes mounting **14**, bar **15** and tie **12**, from the weight and engine drive system.

In carrying out the method of the invention, the entire unit is lifted into position (as shown) with the mounting resting on the tie near the center thereof, by means of cables **27** which are operated by an appropriate lift mechanism on a railroad service car (not shown). Engine **20** is then started so that it rotatably drives oscillator **16**, thereby sonically energizing bar member **15**, mounting member **14** and tie **12**. Engine **20** is adjusted to provide sonic resonant vibration of the vibrating system including the aforementioned bar, mounting and tie members. With such sonic energization earthen material **30** starts to fluidize and separate away from the tie, the tie thus becoming loosened. With such loosening of the tie and fluidization of the earthen material, the bias weight forces the tie downwardly into the earthen material away from rail **11**. The sonic energization is continued until tie member **12** has moved a downward distance of about one to two inches away from the rails.

Cable **32** is connected to tie **12** by means of spike **33**. When the tie has been driven about one to two inches away from rails **11**, the tie is pulled laterally out from under the rails by means of cable **32**, the sonic energization being continued during this second procedure. When the tie **12** has been pulled to the position where its further progress is impeded by the abutment of mounting **14** against the rail, the mounting is repositioned as indicated in FIG. 1*b*, to straddle the rail. The sonic energization and pulling by means of cable **32** is resumed until further movement is again impeded. The mounting member **14** is then again repositioned as indicated in FIG. 1*c*, outside of the rail with the final removal of the tie being accomplished with the simultaneous sonic energization and lateral pulling operations utilized heretofore.

Referring now to FIGS. 2 and 3, a first embodiment of the device of the invention is illustrated. U-shaped mounting **14** is placed on tie **12**. The bottom portions of mounting **14** have serrations **14***a* formed therein which cause such portions to grip the tie by virtue of the biasing weight applied to mounting **14** by weight member **22**. Cylindrical bar member **15** is shrink-fitted into mounting **14**.

Oscillator units **16** are in turn shrink-fitted on the ends of bar member **15**. Each oscillator unit **16** comprises an eccentric rotor **16***a* having a gear ring **16***b* attached thereto. Gear ring **16***b* rides around in the geared raceway **16***c* formed in the inner wall of the oscillator housing **16***d*. The rotor is maintained in its eccentric position by means of pin member **16***e* which protrudes therefrom and rides around on a similar pin member **16***f* protruding from the oscillator housing. The oscillator rotors **16***a* are rotatably driven by flexible shafts **40** which in turn are driven through splined ball and socket couplings **41** via shaft **42**. Shaft **42** is driven by a belt and pulley drive **21** coupling shaft **42** to the output shaft **43** of engine **20**.

The rotors **16***a* of oscillator **16** are driven in phase, to provide sonic energy to the ends of bar member **15**. The frequency of rotation of rotors **16***a* is adjusted to provide resonant vibration of the vibration system comprising the bar member **15**, the mounting **14** and tie **12**. Biasing weight **22** is resiliently supported on mounting **14** by means of isolating springs **25**, the opposite ends of such springs being attached to weight **22** and mounting **14**, respectively, by suitable clamping means (not shown). The entire unit is positioned in place and removed, when the operation has been completed, by means of cables **27** which are attached to weight member **22** and may be operated by a suitable lift mechanism on a railway service car.

It is to be noted that the excitation of bar member **15** with a circular vibration pattern is particularly suited to efficient loosening of the ballast around the tie in view of the constantly changing force vectors and the constantly changing output impedance vector inherent thereto. This enables an optimum impedance match between the tie and the ballast at some one instant during the vibration cycle, thereby assuring proper sonic excitation of the ballast material as it rapidly changes from a high- to a low-impedance with its loosening and fluidization.

Referring now to FIG. 4, an elliptical bar member **15**, which may be utilized in the device of the invention in lieu of the cylindrical bar member of the embodiment of FIGS. 2 and 3, is illustrated. The use of such an elliptical bar member has advantages where sonic excitation predominantly along a single axis is desired rather than the circular vibration described in connection with the previous embodiment. Major and minor axes of the elliptical bar member will each have separate resonant vibration frequencies such that vibration along one or the other of these axes can be predominantly achieved by selecting one or the other of these frequencies respectively. Thus, in a special situation where it is found that vibration along a single axis is needed to provide the desired loosening and fluidization effects, an elliptical bar member can be utilized and either lateral or longitudinal vibration achieved by appropriate selection of the vibration frequency.

Referring now to FIGS. 5 and 6, a second embodiment of the device of the invention is illustrated. This second embodiment is particularly suited for situations where high power and/or high frequency of vibration is required. This second embodiment also has the advantage of more efficiently applying gyratory vibrational energy to the bar member. As shown in FIG. 5, oscillators **16** are shrink-fitted on the ends of bar **15** and are rotatably driven by means of gear trains **45** coupled to the output shafts of engine **20** by means of drive shafts **47**. The housings for the gear trains **45** are supported on weight member **22** by means of support members **50**. Mounting **14** is similar in configuration to that described in the first embodiment and weight member **22** is similarly supported on the mounting by means of springs **25**.

Referring now particularly to FIG. 6, the details of oscillators **16** and their associated drive mechanisms are illustrated. The output gear **51** of gear train **45** rotatably drives gear **52** which is attached to shaft **53**. Shaft **53** has a socket **54** at the end thereof, which is splined and forms a ball and socket joint with splined ball member **60**. Ball member **60** is fixedly attached to shaft **62** which has a crown gear **63** attached to the end thereof. Gear **63** forms a spline joint with splined annular portion **66** of rotor drive member **67**. Rotor drive member **67** is rotatably mounted on ball bearings **70**. The splined joints between ball member **60** and socket member **54** and crown gear **63** and splined portion **66** furnish play in the drive system which avoids undue strain on such system with the operation of the oscillator.

Rotor member **16***a* has a spur gear **16***b* attached thereto which rides around in a mating ring gear **16***c* coincident with the raceway in the oscillator housing **16***d*. The rotor has a pin member **16***e* which rides around a pin member **67***a* protruding from rotor drive member **67**. Rotor member **16***a* thus rides around a raceway formed in its housing in the same manner as the rotor described in connection with the first embodiment. In this instance, however, the drive mechanism is coupled to the rotor in such a fashion that the drive shaft need not greatly flex as the rotor rotates, and thus is not subjected to the load forces involved in the oscillator of the previous embodiment. This enables more efficient operation which is especially necessary in the cases of high-frequency and/or high-power operation.

It is to be noted that the first embodiment by virtue of the off-center relationship between the oscillator units and the gyratory bar provides a torsional component to the vibration system which effects a more complex sonic action in the tie to further aid the fluidization effects.

Referring now to FIG. 7, the utilization of the device of the invention for compacting fresh ballast around a tie is schematically illustrated. For this purpose, tamping shoes **75** in the form of flat plates may be utilized. The U-shaped mounting member **14** may be placed so as to straddle tie **12** and while resting on fresh ballast **78** is sonically activated to cause the particles of the ballast to fluidize and when the sonic energy is released to fall in place in tight compaction against the tie. Thus the sonic energy can be utilized not only to remove ties but also in their installation.

The method and apparatus of this invention thus provide highly effective means for the removal and replacement of railroad ties. It is to be noted that this method and apparatus can also be utilized to equal advantage for installing and removing other similar types of apparatus, such as pipes, structural members and the like.

While the method and apparatus 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 limitation.

I claim:

1. A method for removing a railroad tie from under rails, comprising:

removing the spikes holding the rails to the tie;

coupling a resonator member to said tie;

coupling an orbiting mass oscillator to said resonator member;

driving said oscillator at a frequency such as to cause resonant vibration of said resonator member and said tie;

while said tie is being resonantly vibrated, biasing the tie downwardly to cause it to work away from the rails and completely free therefrom; and

while continuing to sonically energize the tie to fluidize the earthen material in which it is embedded, pulling the tie laterally from under the rails.

2. The method as recited in claim **1** wherein the sonic energy used has a rotating force vector.

3. The method as recited in claim **1** wherein the bar and oscillator are periodically removed from the tie to permit the tie to move under the rails as the tie is pulled laterally and then replaced in a central position on the tie clear of the rails

4. In combination, earthen material, a member embedded in the earthen material and a device for sonically energizing said member comprising:

a mounting placed on said member;

a bar attached to said mounting;

an orbiting-mass oscillator, the vibrational output of said oscillator being coupled to said bar; and

means for driving said oscillator at a frequency such as to cause resonant vibration of the vibration system including said bar, said mounting, and said member,

whereby high-level sonic energy is imparted to said earthen material.

5. The combination as recited in claim 4 wherein said mounting is U-shaped.

6. The combination as recited in claim 4 wherein said member comprises a railroad tie and additionally including biasing means for urging said mounting downwardly against said tie.

7. The combination as recited in claim 6 wherein said biasing means comprises a weight member and said driving means comprises a motor mounted on said weight member, and means for resiliently supporting said weight member on said mounting.

8. The combination as recited in claim 4 wherein said oscillator is attached directly to said bar substantially in coaxial relationship with the longitudinal axis thereof.

9. The combination as recited in claim 4 wherein said oscillator is mounted on said mounting with its rotation axis offset from the longitudinal axis of said bar.

10. The combination as recited in claim 4 wherein said bar is cylindrical.

11. The combination as recited in claim 4 wherein said bar member has an elliptical cross-section

12. A device for removing a railroad tie from the ground, comprising:

a U-shaped support mounting, the free ends of the legs of said mounting resting on said tie;

an elongated bar member attached to said mounting;

a biasing weight member;

means for resiliently supporting said weight member on said mounting; and

means for resonantly vibrating said bar member, said mounting and said tie at a sonic frequency including orbiting-mass oscillator means, the vibrational output of said oscillator means being coupled to said bar member and motor means mounted on said weight member for rotatably driving said oscillator means, whereby the sonic energy loosens the tie from the ground and fluidizes the ground to permit the removal of the tie therefrom.

13. The device as recited in claim 12 wherein said bar member is cylindrical and said oscillator is adapted to impart a rotating force vector thereto.

14. The device as recited in claim 12 wherein said bar member has an elliptical cross-section.

15. The device as recited in claim 12 wherein said oscillator means is mounted directly on said bar member substantially in coaxial relationship with the longitudinal axis thereof

16. The device as recited in claim 12 and further including means for pulling said tie laterally.

17. The device as recited in claim 12 wherein said oscillator means comprises a pair of oscillator units coupled to opposite ends of said bar member, said oscillator units being driven in phase with each other

18. A device for the removal and replacement of railroad ties in an earthen formation, comprising:

a U-shaped support mounting;

an elongated bar member attached to said mounting;

a biasing weight member;

means for resiliently supporting said weight member on said mounting; and

means for resonantly vibrating said bar member and said mounting at a sonic frequency including orbiting-mass oscillator means, the vibrational output of said oscillator means being coupled to said bar member and motor means mounted on said weight member for rotatably driving said oscillator means.

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U.S. Cl. X.R.

171—16