Oct. 3, 1967

R. A. KOETTERS

3,344,995

METHOD AND APPARATUS FOR DISINTEGRATING CONCRETE AND LIKE MATERIALS

Filed July 15, 1964

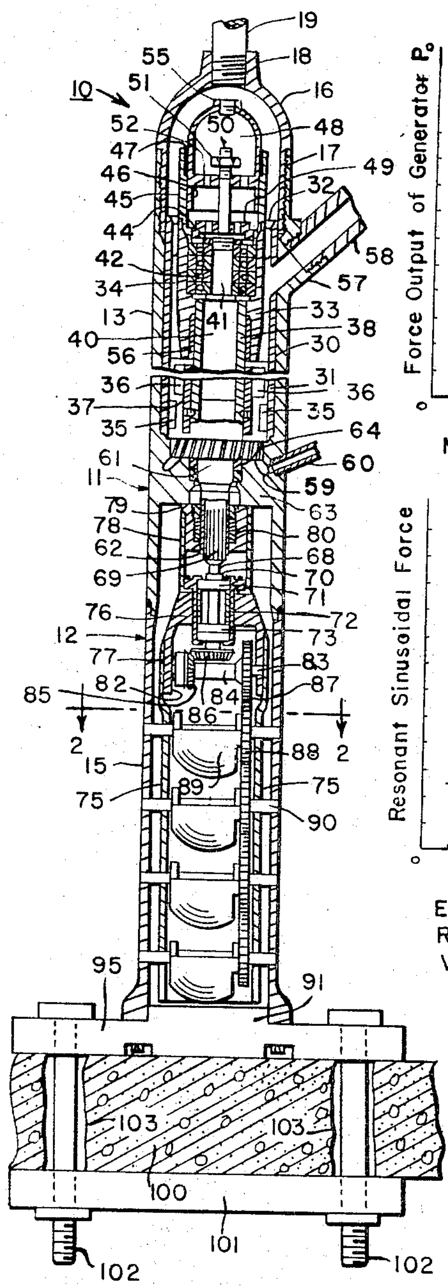
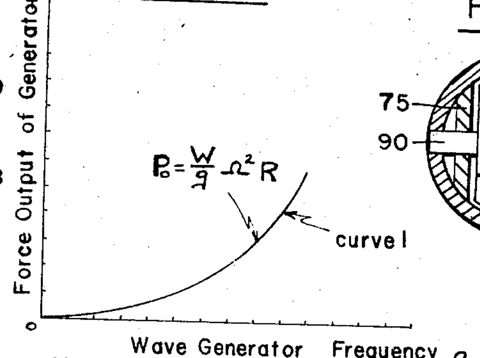


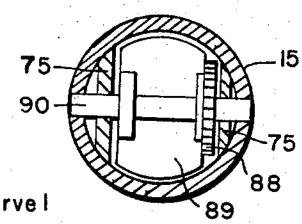
FIG. 1

FIG. 4



Max. Theoretical Force Output of Wave Generator for Various Frequencies

FIG. 2



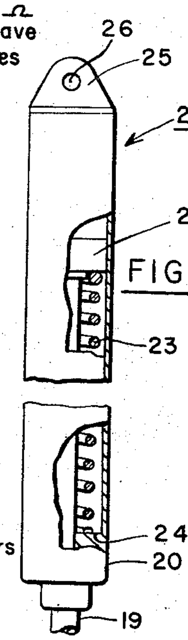
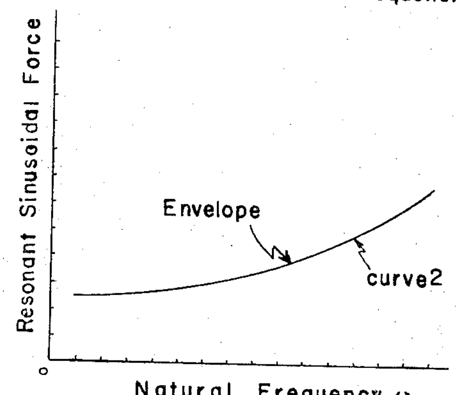


FIG. 3



Envelope of Sinusoidal Forces P at Resonance Required for Failure of Various Concrete Structural Members

FIG. 5

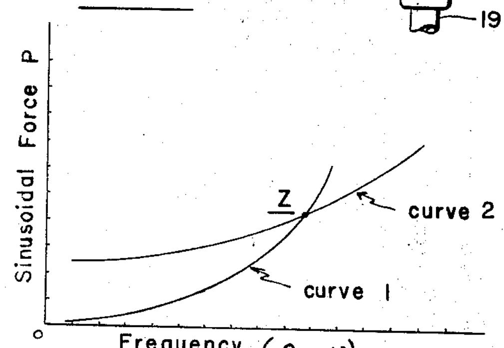


FIG. 6

INVENTOR.
Ronald A. Koetters

BY

Pearce and Schaeperklaus
Attorneys

United States Patent Office

3,344,995

Patented Oct. 3, 1967

3,344,995

METHOD AND APPARATUS FOR DISINTEGRATING CONCRETE AND LIKE MATERIALS

Ronald A. Koetters, 120 E. Mitchell Ave., Cincinnati, Ohio 45217

Filed July 15, 1964, Ser. No. 382,788

8 Claims. (Cl. 241—1)

This invention relates to the art of demolishing concrete structures, and in particular, relates to a device and method by which concrete objects and structures are demolished or disintegrated by a relatively small varying force in the nature of a dynamic sinusoidal load, applied in a highly frequent manner over a relatively short span of time.

An object of this invention is to provide a unique technique for disintegrating concrete by economical means and methods that reduces the cost of razing a building, structure, edifice, or the like which includes such concrete masses.

Another object of this invention is to provide a novel method involving a highly effective force produced by a sonic-mechanical apparatus as an energy source for a dynamic load, to knock down or otherwise disintegrate concrete construction, reinforced and otherwise.

These and other objects and advantages will be apparent to those skilled in the art to which this invention pertains, or with which it is most nearly connected, by a full and complete reading of the following description and appended claims thereto, taken in connection with the accompanying drawing in which:

FIG. 1 is an elevational view, partly in section, of a device by which application of my invention or discovery is carried out;

FIG. 2 is a view taken on line 2—2 of FIG. 1;

FIG. 3 is a view, partly in full view and partly in elevational section, of a suspending device used with the appratus shown in FIG. 1; and

FIGS. 4, 5, and 6 are graphs illustrating relationships between sinusoidal forces and frequencies utilized in determining resonant conditions under which failure occurs, and which are more fully explained in the following description.

It should be understood that this invention pertains to disintegration of both non-reinforced and reinforced concrete members, determinate and indeterminate, planar and spacial, unless the description expressly points out otherwise, and the use of either of the terms "reinforced concrete" or "concrete" is to be understood as not necessarily omitting the inclusion of the other.

Presently there are several well known and long employed methods used for removing existing concrete structures. The particular technique employed at any one time has depended principally on the extent of the demolition required, the size of the structure or structures, and the area in which same are located, i.e. in rural or congested areas. The most common techniques heretofore employed have been the sledge hammer and other small hand tools, pneumatic tools, explosives (principally commercial and military TNT and plastic charges), and a "headache ball" which is a concrete or steel ball usually dropped repeatedly from a power crane and lifted by a cable. The employment of a helicopter to suspend a half ton headache ball for building demolition purposes has been used in late years.

The above noted techniques for demolishing concrete are examples that have never developed beyond an embryonic stage of demolition practice. They are primarily characterized by sheer physical weights acting through a distance, exerting a force by which concrete is smashed, deformed or otherwise broken up. Early constructed buildings and bridges of reinforced concrete are just in the last few years becoming obsolete, and need to be disposed of or replaced. The demolition costs incurred as reflected by the above practices are exorbitant and in some cases prohibitive.

In the conventional methods of destroying reinforced concrete structures, as noted above, work is applied to the structural system by successive relatively slow acting force impulses of various magnitudes over arbitrary intervals or durations of time until structural failure occurs. Such a loading is time consuming, and is a crude form of dynamic loading because the rate of loading is arbitrarily imposed and not efficiently or effectively controlled.

It should be understood that dynamic loadings in general change the static strength of materials two ways: by producing fatigue in the material and by the rate of straining. Fatigue is failure of material due to the action of repeated application of stress with magnitude less than that required to cause failure in one loading. Both concrete and reinforcing steel are subject to fatigue failure. It is improbable that statically applied loadings of such magnitude can be applied often enough to such structures to produce this type of failure within the life of such structures. However, oscillating dynamic loadings, on the other hand, repeatedly applied in sufficient cycles of load application, may produce fatigue failure within the life of the structure. My invention or discovery is not based primarily on this theory by which fatigue failure is produced, although it is evident that possibly some fatigue may accompany, or come into play with, the manner by which structures are failed by my method.

Rate of straining materials also affects the strength of materials. Both concrete and reinforcing steel, individually and in combination, exhibit higher yield and ultimate strengths during rapidly applied straining than under slow rates of strain. This change in the ultimate strengths of either of these two materials, or such materials in combination, needs to be overcome by dynamic loadings necessary for failure by deflection of the structural member (a physical oscillating motion of the member causing strain) when the member is subject to high intensity loading of magnitudes not necessarily greater than what is required for failure in one loading. Thus, to carry into effect or execution of my invention or discovery, a high rate of straining is my principal concern to effectuate in a structural member the deflection required to breach the ultimate bending or the flexural breaking strength of the concrete member.

In my method, structural failure occurs as a result of the production of resonance phenomena occurring in addition to work being stored and expended upon a structural system. In other words, a sinusoidal force is applied to the system at the same frequency with which the system vibrates. In this application of the resonance phenomena, a varying or sinusoidal force is applied repeatedly in a short span of time. Very briefly, the phenomena is achieved in the following manner, as expressed mathematically. The summation of forces on the structural system is equated with the mass of the system times the resulting acceleration attained in the system. An apparatus in the form of a wave generator delivers a transverse dynamic sinusoidal sonic load of the form $P=P_0 \sin \Omega t$ with a maximum force P_0. The circular frequency Ω of the applied force P is adjustable by adjustment of the apparatus as hereinafter described. Ω varies with the natural circular frequency ω of the system. The other forces involved are, namely, the characteristic stiffness force and the internal damping force of the structure. Mathematically manipulating the above noted equality, it is observed that the damping force can be made negligible, and in practice, damping will be overcome when the wave generator produces a frequency of force Ω equal to the natural frequency ω of the system, except as hereinafter described in conjunction with FIGS. 4, 5, and 6. In other words, the apparatus utilized in generating a sinusoidal force includes a magnitude sufficient to overcome the damping and stiffening forces of the structure that tend to prevent failure.

The maximum force P_0 may be expressed by the following equation:

$$P_0=\frac{W}{g}\Omega^2 R$$

where W is the total weight of the mass or masses in the apparatus that contribute to development of the sinusoidal force, g is the acceleration due to gravity, Ω is the angular speed of said masses, and R is the distance from the center of rotation to the center of each mass that is utilized in the apparatus. It may be observed that the maximum absolute amplitude or magnitude of the force output developed increases as the square of angular speed Ω of the masses, and because of this, failure of many structural members can be obtained in modes higher than the fundamental mode. It may occur that at a fundamental or lower mode of vibration, the force output is not sufficiently large enough to exceed the ultimate load of the structural system under resonance conditions. Under these conditions, since the apparatus puts out a maximum amplitude of force proportional to the square of the angular speed of the masses, failure of these structural members can be obtained in a higher mode of vibration, as explained in conjunction with FIGS. 4, 5, and 6 hereinafter. This can be accomplished despite the heretofore difficulty or hindrance normally encountered in structures in which damping exists. It is to be remembered that resonance occurs when the angular speed of rotation of the masses Ω is coincident with the natural circular frequency of the system ω including higher harmonic modes of vibration therein.

FIGS. 4, 5, and 6 comprise graphs showing the relationships between a wave generator force output with frequency of output, the sinusoidal force required for failure of structural members having a natural frequency ω, and a composite or superposition of the graph in FIG. 5 with the graph of FIG. 4, respectively. In the graph of FIG. 4, it is observed that the maximum force output of the wave generator varies with the square of its frequency Ω. As the frequency of the generator increases, its force output increases in proportion to the square of such frequency. The graph of FIG. 5 plots the envelope of sinusoidal forces at resonance required for failure of various structural members including simply supported one-way concrete slabs, fixed end concrete columns, fixed ended concrete beams, and two-way flat slabs, at various modes of vibration, fundamental and higher. Such envelope, graphically portrayed as a single curve in FIG. 5, represents the maximum force necessary for all structures to cause failure thereof. For example, were a curve drawn to the same scale as the scale for the envelope, for each of the above noted types of members, it is observed that its initial ordinate is never greater than that of the envelope, and its slope is lesser or greater than the envelope shown, but no where would such curve exceed the coordinates of the envelope.

It will be noted generally from the graph of FIG. 5 that the higher the harmonic frequency for a structural member, the more force is required to fail the member.

FIG. 6 is a superposition of FIG. 5 on FIG. 4. It will be observed that the slope of the force output generated versus frequency (curve **1**) increases faster with frequency than the slope of the envelope of the sinusoidal forces versus frequency (curve **2**) required for failure of the noted structural members. This FIG. 6 shows graphically the approach heretofore explained above whereas failure of structures indestructible in the fundamental or lower modes of vibrations can be accomplished at higher modes

because of the faster rate of increase of the force output of a wave generator with increase in frequency over the rate of increase of the force under resonant conditions versus increasing frequency to cause failure of structures. In other words, in the range of frequencies to the left of point Z, although the rate of change of force shown in curve **1** is greater than the rate of change of force in curve **2**, a wave generator may not yet generate a sufficiently large force output at any of such frequencies to cause failure in the structural members. However, as the range of frequencies approach point Z and continue to increase in value to the right of point Z, it will be observed that such an apparatus generates a force output sufficiently large to cause failure in the member or members where such force lies between the two curves **1** and **2** to the right of point Z. Thus, at a harmonic frequency or higher mode of vibration for the structural system, to the right of point Z, failure occurs in the system.

It should now be apparent that from the immediate paragraph above concerning use of a harmonic frequency or higher mode of vibration by which failure of the structural system occurs, and as illustrated by the graph of FIG. 6, the claimed subject matter of this invention extends to the generation of forces having not only an equality of frequencies between that of the generator and the natural frequency of the system, but that the claimed invention contemplates generation of a hamonic frequency or of higher mode of vibration which is in equality with a harmonic frequency or higher mode of vibration in the system other than its natural frequency.

According to one practice of my invention I generate a comparatively large amplitude transverse sonic wave in a concrete member, using a sonic wave generator capable of providing an output frequency resonant to that of the system comprising the structural member to be disintegrated and the apparatus.

I couple this sonic wave generator effectively to a location on the structural member near the anticipated maximum ordinate of the deflection influence lines for such member. In operation, the wave generator is stiffly coupled to the concrete member, and it delivers a large amount of sinusoidal force energy to the member establishing a large amplitude transverse wave therein, cusing such member to oscillate. The reason for the sinusoidal nature of the applied load rather than for application of any other type of dynamic load is because the maximum amplitude of the force required for demolition by a sinusoidal load is appreciably less than for any other type, due to an intrinsically high dynamic load factor inherent in a sinusoidal load of frequency equal to the natural frequency of the structure. In regard to such a factor, in the structures encountered, the maximum magnitude of the force output required to cause failure under resonant conditions, is from ⅓ to ⅛ the force necessary to cause failure by statically applied forces. This observation includes the effects of damping and stiffness forces of the structure heretofore mentioned, and the higher strength exhibited by concrete material under dynamic conditions over static strengths. The factor which releates static force to the dynamic force is called the dynamic load factor.

As the applied frequency is increased to provide for generation of increasing frequency that approaches the natural frequency of the system, the amplitude of deflection of the structure markedly increases. When this phenomena involving high amplitude of deflection is observed, the wave generator is operated at this frequency until the structure fails and disintegrates. The well known resonance phenomena exists and has occurred. Due to end or boundary conditions of certain indeterminate structural members, however, it is necessary in some instances to follow or readjust to the changing or changed mode of vibration of the system to cause failure at other points not local to the first point of failure.

With reference now to FIGS. 1, 2, and 3, a wave generator **10**, utilized in the practice of my invention, comprises a motor, illustratively and preferably a turbine, generally designated by numeral **11**, and a wave generator unit, generally designated by numeral **12**, driven by the motor hereinafter referred to as the turbine. Turbine **11** comprises a tubular case or housing **13**, on the bottom of which an external cylindrical housing **15** for wave generator **12** is welded. It will be seen that the turbine housing **13** and wave generator housing **15** are thus rigidly interconnected.

The housing for the turbine is completed at the upper end by a cap **16** screw-threaded to the upper end of housing **13**, as at **17**, and furnished at the top with a screw-threaded socket **18** receiving the lower screw-threaded end of a suspension rod **19**. This rod **19** (see FIG. 3) protrudes from the cylindrical case **20** of a suspension means **21**, and has at its upper end an enlarged head **22** slidable inside case **20** and supported on the upper end of a coil compression spring **23** seated at its lower end on upwardly facing shoulder **24** at the bottom end of case **20**. The upper end of case **20** is provided with a bracket **25** formed with an eye **26** for connection to means (not shown) such as a block used on the end of a cable mounted from the end of a crane.

Snugly received inside turbine case bore **30** is the outer sleeve member **31** of a spider **32**, which includes also an inner sleeve member **33** annularly spaced inside sleeve **31**, and connected thereto by means of webs such as indicated at **34**. Thus, fluid spaces extend vertically between the inner and outer sleeves of spider **32**. The outer sleeve **31** extends on downwardly a substantial distance below the lower end of inner sleeve **33** and serves as a mounting sleeve for vertically spaced sets of turbine stator blades **35**. Although but one such set of stator blades **35** appears in FIG. 1, it will be understood that in practice, a number of such sets may be provided, the remainder sets not appearing in FIG. 1 because of the broken out section.

Alternating with the sets of stator blades **35** are sets of turbine rotor blades **36** formed on a sleeve **37** tightly mounted on a hollow turbine shaft or sleeve **38**, the lowermost being on the shaft or sleeve **38**, as clearly shown. The turbine blades may be conventional, and further detailed illustration or description will accordingly not be necessary. As stated, there may be a number of alternating turbine stator or rotor blade units, as required.

The aforementioned hollow turbine shaft or sleeve **38** is tightly mounted on a solid turbine shaft **40**, which has an upper reduced section **41** supported by inner race rings of thrust bearings **42** fitted inside sleeve **33**, with a nut **44** threaded on the upper extremity of shaft section **41** securing the inner race rings of the bearings in assembly. An oil cylinder **45** is reduced and screw-threaded at its lower end into the upper end of sleeve **33**, and engages and secures the outer race rings of the bearings **42**.

Telescopically receivable within oil cylinder **45** is a cylindrical chamber member **46**, with suitable packing being provided at **47** to prevent leakage of oil contained with the expansive and contractive enclosure **48** thus provided. A perforate spider **49** mounted in the lower end portion of cylinder **46** carries an upwardly extending stem **50** having threaded on its upper end a stop nut **51**, and the chamber member **46** has a perforate spider **52** extending thereacross and centrally bored for passage of stem **50**. Oil is initially poured inside the oil cylinder **45** through a filler opening in the top of cylinder **46**, normally closed by a plug **55**. This oil lubricates bearings **42**. Seals **56** are placed between the upper end of turbine shaft or sleeve **38** and the lower end portion of sleeve **33**. The purpose of the telescopic arrangement of the chamber **46** within the cylinder **45** is to provide for expansion of the oil body within the apparatus with temperature rise during operation, and also to place the lubricant inside the chamber and bearing system under a slight pressure during operating conditions, as will be explained hereinafter whereby any leakage that occurs will be outwardly of the oil containing system.

The side wall of turbine case **13** is formed, at a point above the turbine blades, with a fluid inlet fitting **57** to which a liquid supply hose **58** is threadedly coupled, and sleeve **31** is ported as shown, opposite this inlet, whereby turbine drive liquid may be supplied to the annular space between sleeves **31** and **33**. This liquid flows downwardly to and through the successive turbine rotor and stator blades, driving the turbine shaft. Below the turbine blades, the liquid is received in an annular channel **59**, to be discharged via an outlet port as shown, and to which is coupled return hose **60**.

Hollow turbine shaft or sleeve **38** is reduced below the lowermost set of turbine blades, as at **61**, and is then further reduced and formed as an internally splined, tubular member **62** which drives the presently mentioned generator shaft. The walls of turbine case **13** are thickened between the lowermost set of turbine blades, as indicated at **63**, and formed with a cup to receive packing **64** around the shaft section **61**.

Wave generator **12** has a vertical drive shaft **68** including an upper section **69** splined within the reduced lowermost tubular section **62** of the turbine shaft, and thus driven by the latter.

The shaft **68** has a downwardly facing shoulder **70** supported by a thrust bearing **71** mounted within the upper end of a bearing housing **72**, in the lower end of which are radial bearings **73** for the shaft. Two parallel vertical cheek plates **75** are welded along their longitudinal edges to the inside surface of turbine housing **15** (FIG. 2), and extend substantially from the top of the bottom of housing **15**. A supporting head **76** extends across housing **15** between upper reduced thickness portions **77** of cheek plates **75**, and is welded to housing **15** and to the cheek plates. This head **76** is centrally bored to receive bearing housing **72**, and the latter is flanged at the top for support by said head, as shown. Between the flange of the bearing housing and head **76** is located an inwardly turned, mounting flange on the lower end of a sleeve **78** that supports a head **79** in which is mounted packing **80** for turbine shaft portion **62**.

Head **76** is formed with depending mounting plates **82** fitted snugly between cheek plate portions **77**. These plates **82** carry a transverse shaft **83** on which is rotatably mounted a gear sleeve **84** provided with a bevel gear **85**, with which is meshed a bevel gear **86** on the lower end of generator driver shaft **68**, so that the gear sleeve is driven by shaft **68**. Gear sleeve **84** also carries a spur gear **87**, which meshes with a spur gear **88** on the upper of a series of eccentrically weighted rotors **89** mounted in vertically spaced relation between cheek plates **75**. Each rotor **89** has such a spur gear **88**, and each such gear **88** meshes with the gear **88** next below, as shown. Each rotor **89** is rotatably mounted on a horizontal axle shaft **90** extending through cheek plates **85** and mounted tightly in the side wall of housing **15**. The rotors consist essentially of unbalanced inertia weights, located to the side of the shafts **90**. The several rotors are all arranged so that their unbalanced weights move up and down in unison, which is accomplished if, for instance, they are all initially positioned with the weights at the bottom, as in FIG. 1. Housing **15** is closed at the bottom by a closure member **91**, and a quantity of oil placed inside the enclosure is splashed upwards by the revolving rotors and lubricates the various bearings of the generator.

Concentrically mounted upon closure **91** and extending in a lateral manner from casing or housing **15** is a circular adaptor plate **95** preferably formed integrally with a closure **91**. Adapter plate **95** engages or is otherwise put into direct physical registry with a concrete member **100** that extends transversely of the axis of the wave generator **10**. A corresponding adaptor plate **101** engages the other side of concrete member **100**, and is securely connected to adaptor plate **95** on closure **91** by means of a plurality of nutted bolts **102** that extend from one plate **95** to the other plate **101** through bores **103** drilled through concrete member **100**. These plates **95**, **100** should be of sufficient bearing area on the concrete surface of member **100** to provide for distribution of the maximum amplitude of sinusoidal force to prevent a bearing failure and thereby not hinder the desired flexural bending failure of the structure.

As will be evident, each eccentrically weighted rotor exerts a thrust on its mounting shaft **90** as it rotates thereabout. Assuming a transverse mode of vibration to be desired in laterally extending concrete member **100**, only the thrust imparted to such member, or other members, in a direction perpendicular to its longitudinal axis direction is, however, useful, for such transverse wave generation. As will be seen, alternate rotors turn in opposite directions, so that lateral component forces are cancelled while, owing to the fact that the rotors move vertically in unison, vertical components of thrust or force are additive. The turbine driven wave generator accordingly comprises a simple, but powerful, device for producing a vertically directed, alternating sinusoidal force, with no unbalanced lateral force components. The device comprises essentially a series of longitudinally (of the generator unit itself) reciprocating inertia weight elements which oscillate along a vertical direction line with simple harmonic motion, and which exert an alternating sinusoidal force on their respective mounting shafts, and thence on housing **15** in accordance with the vertical component of acceleration and deceleration.

The resulting reaction in housing **15** is a vertically directed, alternating sinusoidal force of great magnitude, which is transmitted to the pair of plates **95**, **101**, and thence to the laterally extending concrete member **100**. The parts between the wave generator housing and the concrete member will be seen to afford a stiff or rigid coupling therebetween.

Liquid, preferably water, is provided for delivery through hose **58** into turbine case **13**. A centrifugal pump (not shown) pumps the liquid from a reservoir into hose **58**. The liquid passes downwardly from hose **58** through the turbine stator and rotor units, rotating the turbine rotor shaft, and is returned to its reservoir via hose **60**. In passing, it may be mentioned that the static back pressure within the upper portion of the turbine housing will be greater than that at a distance below the liquid inlet port at hose **58**, for example, at the location of seal **56**, with the result that telescopic chamber member **46** is under a small pressure differential, and exerts a small pressure on the oil body contained therein, contained therein, contributing a tendency for leakage of oil outwardly of the oil system, in preference to leakage of water into the oil system.

The rotating turbine shaft rotates the wave generator drive shaft **68** and through the described gearing, rotates the unbalanced rotors **89**. As previously set forth, this creates synchronized, alternating, vertically oriented sinusoidal forces applied to the rotor shafts and thence to concrete member **100**.

In the event that wave generator **10** is utilized for failing a column, rectangular cross-sectional members, or the like, in place of plates **95**, **101**, a metallic strap may be fastened to or made integral with closure **91**, and thereafter wrapped around the girth of such a member, in physical relation thereto, to transmit the sinusoidal forces developed in generator **10** thereto. Suitable clasps, bolts and nuts, buckles, or the like, may be used to hold securely the strap about such a member.

The so applied alternating sinusoidal forces send alternating waves of compression and tension travelling through member **100**, and when the frequency of such force or forces is in the range of the resonant frequency of said member, a consequent build-up of deflection of vibration amplitude occurs.

The spring suspension device **21** from which wave generator **10** is hung has low stiffness, and hence acts effectively to prevent transmission of wave energy to its supporting system. Actually in practice, the turbine, wave generator, and adapting plates **95**, **101**, being stiffly or rigidly coupled to concrete member **100**, become a part of a vibratory structural system.

The system as described automatically seeks and operates at the resonant frequency of the concrete member. Any carburetor-type internal combustion engine, such as is here to drive the pump which supplies the liquid to the turbine, has inherent torque-responsive characteristics. An internal combustion engine, operating at fixed throttle, is inherently and automatically self-governing when driving the resonant system to supply maximized torque at a speed corresponding always with the resonant frequency of the system. In an alternative fashion, using an engine of this type, manual throttle control is relied on to regulate the speed of the engine to follow the resonant frequency of the system as this frequency changes as described above.

After attaching the apparatus **10** to the structure at its anticipated point of greatest deflection, the speed of revolution of the unbalanced rotors is increased while continually watching the structure for occurrence of resonance. Resonance conditions are determined by observing the oscillating or deflecting behavior of member **100**. When these conditions occur, such speed of the generator is maintained until yielding takes place. In determinate or simple structures, failure occurs at this point. In other cases, the vibrational amplitude of the member will gradually subside because the modulus of elasticity will have decreased. The frequency of the wave generator is thence changed to or made to follow the new resonating frequency. This procedure is repeated until the concrete fails, disintegrates, or otherwise spalls from its reinforcing steel.

The application of my invention or discovery is not limited to concrete structural materials, and is applicable to other stiff or rigid-like materials, such as bituminous materials, brick and other masonry materials, timber, laminated wood and wood-like materials, plastics, and any other material of a nature to which my method may be applied whereby such material or materials are fractured, or otherwise fails or disintegrates.

Pursuant to the requirements of the patent statutes, the principle of my invention has been explained and exemplified in a manner so that it can be readily practiced by those skilled in the art to which it pertains or with which it is most nearly connected, such exemplification including what is presently considered to represent the best embodiment of the invention. However, it should be clearly understood that, within the scope of the appended claims, the invention may be practiced otherwise than as specifically described herein and exemplified herein, by those skilled in the art, and having the benefit of this disclosure.

That which is claimed as patentably novel is:

1. A method of disintegrating a material thickness comprising coupling to said thickness a wave generator capable of producing a dynamic sinusoidal alternating force, generating in said wave generator a sinusoidal force having a frequency Ω in a range of frequencies substantially equal to the frequency ω of the material thickness to be disintegrated, and maintaining substantially the equality of said frequencies $\Omega=\omega$ until said structural material thickness fails and disintegrates.

2. A method of disintegrating a concrete material thickness comprising coupling to said concrete material thickness a wave generator capable of producing a dynamic sinusoidal alternating force, maintaining said generator at a frequency Ω resonant to the frequency ω of said thickness, whereby failure of said thickness results upon the successive dynamic sinusoidal loads applied thereto.

3. A method of disintegrating a concrete material thickness comprising coupling to said thickness a wave generator capable of producing a dynamic sinusoidal alternating force, generating in said wave generator a sinusoidal force having a frequency Ω in a range of frequencies substantially equal to the frequency ω of the material thickness to be disintegrated, and maintaining

substantially the equality of said frequencies $\Omega=\omega$ until said concrete material thickness fails and disintegrates.

4. A method of failing a concrete structural member comprising, stiffly coupling a wave generator to a laterally extending concrete member at the anticipated maximum ordinate of the deflection influence lines for said member, generating in said generator a transverse sinusoidal force that is transmitted to said member through such coupling, maintaining a frequency Ω of said force commensurate with a frequency ω of the structural system including said member and wave generator apparatus, following the frequency ω of said system with the frequency Ω of the generator as the vibration of said system increases in amplitude and the frequency ω changes with the system as said concrete member is failing.

5. A method of disintegrating a material thickness comprising coupling to said thickness a wave generator capable of producing a dynamic sinusoidal alternating force, generating in said wave generator a sinusoidal force having a harmonic frequency in a range of frequencies substantially equal to the harmonic frequency of the material thickness to be disintegrated, and maintaining substantially the equality of said harmonic frequencies until said structural material thickness fails and disintegrates.

6. A method of disintegrating a concrete material thickness comprising coupling to said concrete material thickness a wave generator capable of producing a dynamic sinusoidal alternating force, maintaining said generator at a harmonic frequency resonant to the harmonic frequency of said thickness, whereby failure of said thickness results upon the successive dynamic sinusoidal loads applied thereto.

7. A method of disintegrating a concrete material thickness comprising coupling to said thickness a wave

generator capable of producing a dynamic sinusoidal alternating force, generating in said wave generator a sinusoidal force having a harmonic frequency in a range of frequencies substantially equal to the natural frequency of the material thickness to be disintegrated, and maintaining substantially the equality of said harmonic frequencies until said concrete material thickness fails and disintegrates.

8. A method of failing a concrete structural member comprising, stiffly coupling a wave generator to a laterally extending concrete member at the anticipated maximum ordinate of the deflection influence lines for said member, generating in said generator a transverse sinusoidal force that is transmitted to said member through such coupling, maintaining a harmonic frequency of said force commensurate with the harmonic frequency of the structural system including said member and wave generator apparatus, following the harmonic frequency of said system with the harmonic frequency of the generator as the vibration of said system increases in amplitude and the harmonic frequency of the system changes as said concrete member is failing.

References Cited

UNITED STATES PATENTS

1,952,953	3/1934	Templin	73—67.3
2,308,517	1/1943	Konnerth	299—14
2,660,881	12/1953	Van Degrift	73—67.3 X
2,975,846	3/1961	Bodine	175—19
3,039,296	6/1962	Destuynder et al.	73—67.2
3,116,862	1/1964	De Gorter	225—2
3,224,253	12/1965	McKay	73—67

ANDREW R. JUHASZ, *Primary Examiner.*