73-666 SN
OR 2,220,164

DEVICE FOR PRODUCING VIBRATIONS

Filed Sept. 27, 1938 4 Sheets-Sheet 1

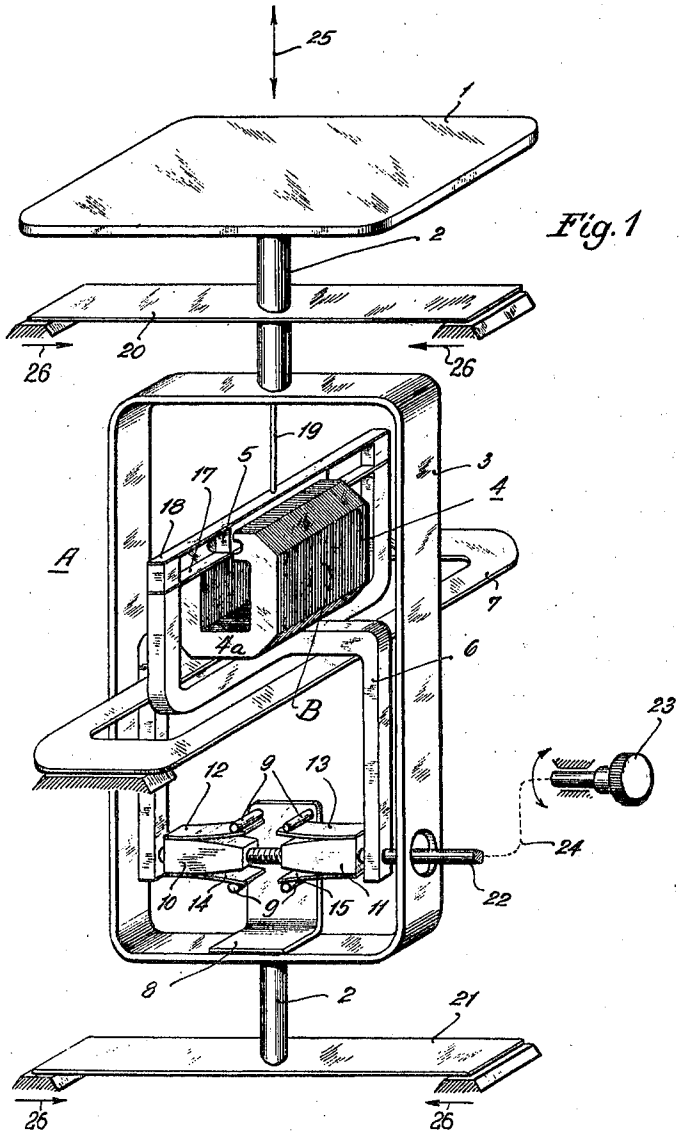


Fig. 1

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Hermann List
ATT'Y: Otto Lerch

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Fig. 2

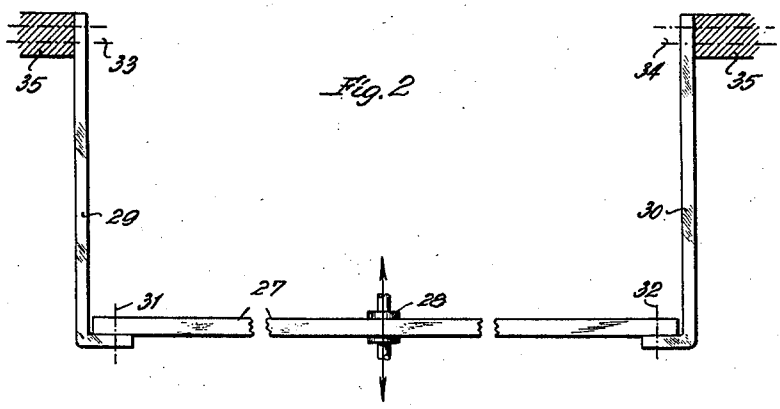


Fig. 5

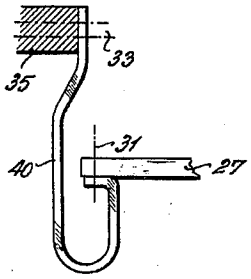


Fig. 3

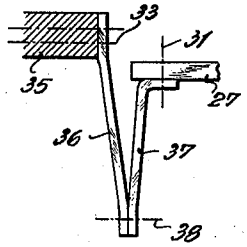


Fig. 4

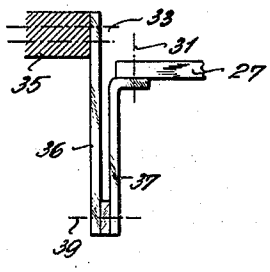


Fig. 6

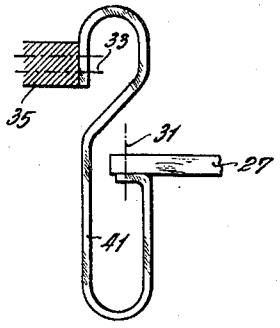


Fig. 8

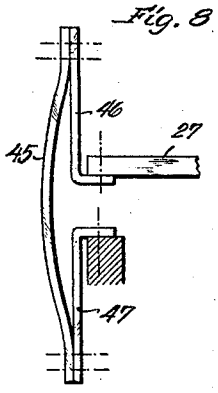
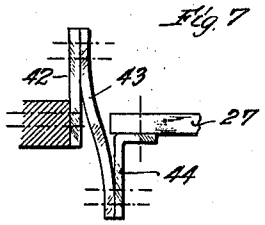


Fig. 7



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Fig. 9

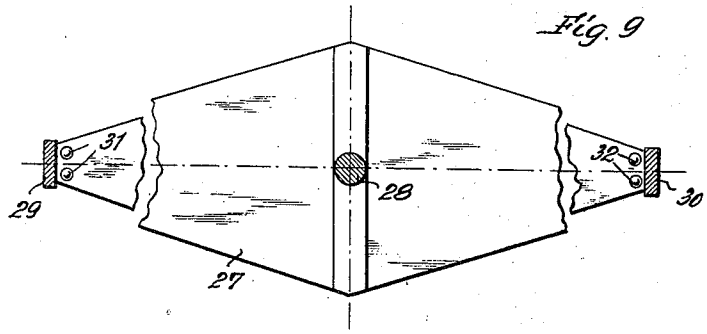


Fig. 10

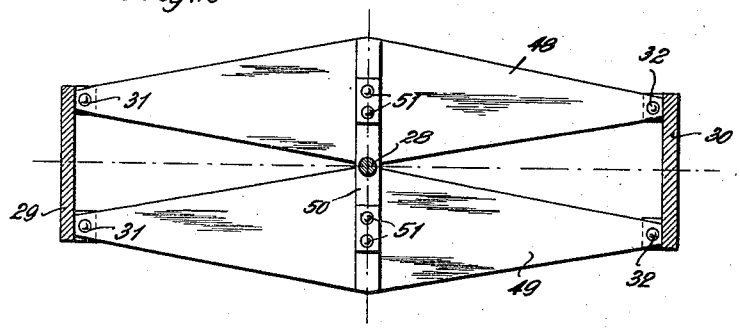
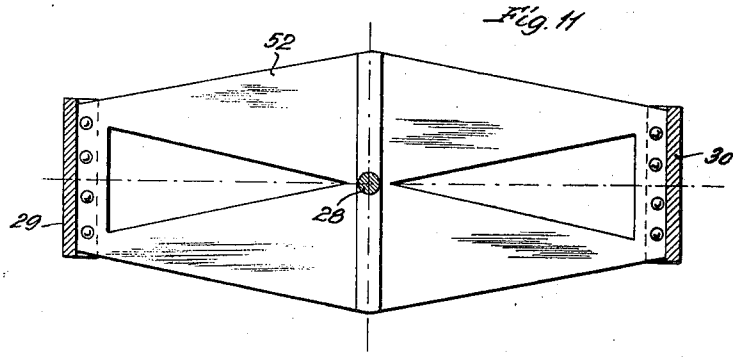


Fig. 11



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Fig. 12

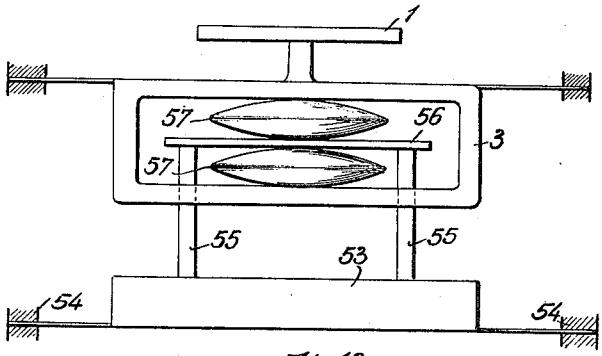


Fig. 13

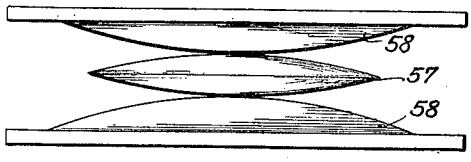


Fig. 14

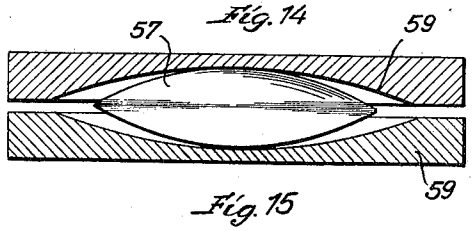
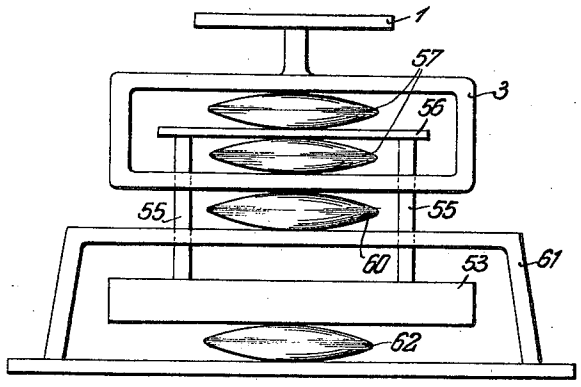


Fig. 15



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UNITED STATES PATENT OFFICE

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DEVICE FOR PRODUCING VIBRATIONS

Heinrich List, Berlin-Lichterfelde, Germany

Application September 27, 1938, Serial No. 231,873
In Germany October 1, 1937

19 Claims. (Cl. 73—51)

This invention relates to a device for producing vibrations such as may be employed for many technical purposes, e. g. for sorting or screening goods in bulk, for conveyor plants, but especially for testing articles to determine how they withstand the effects of vibration.

It is an object of the present invention to reduce to minimum the amount of vibration which is transmitted to the frame structure of such a device whereby the stand can be made of a lighter construction.

It is a second object of the invention to render the natural frequencies of the vibrating masses in the device adjustable so that they may be made to conform to different operating conditions.

It is a third object of the invention to provide means for compensating for variation in the vibrating masses in such a device, arising, for example, from the application of different loads.

It is a fourth object of the invention generally to improve the efficiency of such devices.

Examples of the invention will now be described with reference to the accompanying drawings, whereon:

Fig. 1 is a diagrammatic perspective view of one embodiment of the invention.

Figs. 2 and 8 illustrate in front elevation modifications of certain details of the invention.

Figs. 9 to 11 illustrate in plan view different forms which may be adopted for certain of the leaf springs shown in Fig. 1.

Figs. 12 to 15 illustrate in front elevation further modifications of certain details of the invention.

In all the embodiments, essential features are two vibratable masses and a power unit applied to the masses to vibrate them in opposition to one another. In the embodiment illustrated in Fig. 1 the power unit is constituted as an electro-magnetic vibrating-armature motor 4 of which the relatively heavy stator field unit 4a or stator as it may for convenience be referred to (the winding being omitted from the drawing in the interests of clearness) and its supporting means form one of the masses indicated generally by B, and the relatively light armature 5 of the motor constitutes part of and engages the second mass A and vibrates the latter, which is also resiliently supported in the frame structure of the device of which, in the interests of clearness, only parts, as at 7a, are shown. Included in the second mass is a support for the articles to be tested, the support being constituted as a table 1 which is made from aluminium or the like. This table is fixed to a column 2, also of light material, which is interrupted by a frame 3 enclosing the power unit. The armature 5 is mounted for vibratory movement in an air-gap of the stator flux path, which as shown in the drawing is closed except for the air-gap. Flat springs 17 and 18 are used to connect the armature to the stator so as to ensure rectilinear movement of the armature and a rod 19 rigidly connects the armature to the table 1, column 2, and frame 3.

Although the power unit in this embodiment is an electro-magnetic vibrating-armature motor, it will be obvious that it is possible also to employ other devices, for example, mechanical hydraulically or pneumatically operated devices, since it is particularly easy to regulate the stroke of such driving arrangements by means known per se. For example, it is possible to act on the springs 17 and 18 by means of a rotating eccentric-like cam carried by the mass B.

In the embodiment illustrated, the stator 4a is mounted over a frame member 6 and, by resilient means constituted as one or more powerful leaf springs 7, is supported by the frame structure 7a at each end. (The support at the rear end of the spring is obscured.) It is pointed out however that, without departing from the scope of the invention, the stator 4a, together with its associated parts, may also be mounted by means of its spring 7 in the frame 3 of the mass A, so that then only the mass A is resiliently supported directly on the frame structure. The resilient means for supporting the mass A on the frame structure is constituted as leaf springs 20, 21.

On the column 2 of the mass A there is provided a support constituted by a bracket 8 carrying lugs or pins 9 which engage resilient elements 12, 13, 14 and 15. The resilient elements are constituted as leaf springs and are anchored, each at one end, on the mass B, through the intermediary of a screw-threaded shaft 22 journalled on the frame member 6, and of attachments constituted as nuts 10 and 11 on this shaft. A pair of the springs (12—15) are secured on each attachment and are held thereby superimposed one above the other and each attachment is provided with curved bearing surfaces which converge away from the attached ends of the corresponding springs. These surfaces cooperate with the proximal surfaces of the springs and define their maximum deflection towards each other. There are a pair of lugs 9 for each pair of springs and they bear against the distal surfaces of the springs.

The springs 12, 13, 14 and 15 and the asso-

ciated parts constitute a coupling between the masses A and B, which coupling is additional to the couplings between the masses and the frame structure. By adjusting this coupling the natural frequency of the vibrating system as a whole can be varied simply and accurately and at the same time the amplitudes of the masses are limited or kept constant in dependence upon the load. To permit adjustment of the coupling to be effected, the screw shaft **22** is provided with opposite handed screw-threads so that, on rotation of the shaft, the attachments **10**, **11** are moved uniformly towards or away from one another, thus varying the effective lengths of the springs **12**—**15**. The shaft **22** can be adjusted externally by an adjustment member **23** through the intermediary of a flexible shaft **24**, indicated diagrammatically by the dotted line.

The table **1** is connected through the column **2** and the frame **3** with the armature **5** of the motor **4** by a rod **19** and constitutes, together with the springs **20**, **21**, one vibrating mass A, the springs **20**, **21** being constructed as leaf or bow springs to ensure satisfactory rectilineal guiding. The second vibrating mass consists of the stator part 4^a of the vibratory motor **4**, the frame **6**, the adjustable elements and the shaft **22**. This second mass B is mounted by means of the leaf springs **7**, in the frame structure. As already mentioned, it may however be supported in the frame **3** of the mass A.

The embodiment described operates as follows:

If the motor **4** is excited, for example, by alternating current, the armature is caused to vibrate and it transmits the vibratory motion at the selected frequency to the column **2** and the parts associated constituting mass A, and by virtue of the reaction the stator 4^a and the parts connected therewith, being like the armature free to vibrate in relation to the frame structure 7^a, are also set in vibration. Due to the employment of leaf springs to support the vibrating masses each of them can only oscillate in the direction of the arrow **25** and since the two masses are coupled with one another through the spring elements **12**—**15**, it is always possible to produce a state of resonance by the choice of the coupling.

On application of an article to be tested, say, one of the two oppositely vibrating masses is varied, and in order to maintain the desired co-relationship between the masses, even with such a variation of one of the masses, the resilient coupling between one of the masses (in this case the mass A) and the frame structure is made adjustable, since it is important that the common centre of gravity of the oppositely vibrating masses remains at rest during vibration as it is by virtue of this that a minimum of vibration is transmitted to the frame structure. This is the case when the ratio of the coupling factors between mass A and the frame structure and between mass B and the frame structure is equal to the ratio of mass A to mass B coupling factor as a measure of the firmness or tightness of the coupling between the two coupled parts, the factor being unity when the coupling is rigid and being zero when the masses are without effective coupling. Therefore, with the coupling between mass B and the frame structure remaining constant, the coupling between mass A and the frame structure must be made firmer according to how much larger the mass A becomes, and vice versa. The adjustability of the coupling can be attained by displacing the anchorages for the springs **20** and **21** in the direction of the arrows **26**. The variation of the coupling may, however, also be effected in any other suitable manner. It is also important that the resonant frequencies of the oscillatable system constituted by the springs **20** and **21** and mass A and of the oscillatable system constituted by the spring **7** and mass B are such that they are sufficiently far outside the operative-frequency range of the device, i. e., substantially above or below the number of resonant-operation vibrations, i. e., the resonant frequency of the two-mass system.

The leaf springs coupling the masses A and B to the frame structure are connected at their centres to the respective masses and at their ends are supported directly or indirectly by the frame structure and Figs. 2 to 8 show in detail means for connecting the ends as stated which means, for the sake of clearness have only been indicated very diagrammatically in Fig. 1. In order to obtain rattle-free working, rigid connections between the ends of the springs and the supports therefor are not employed. It is important that the contraction (i. e., the decrease in distance between the ends) of the leaf springs which occurs during flexing is possible without the anchorages or securing members being subjected to substantial bending stresses. In Fig. 2, **27** represents a straight flat spring (which conveniently could represent any of springs **7**, **20** or **21**), in the middle of which is secured, for example, the armature of the vibratory motor by means of a rod **28**. The spring can conveniently have a double-triangular or a double-trapezoidal shape, when viewed in plan—as will be described later—and is thus substantially wider at the middle than it is at the ends. In this way, the specific stressing of the spring is approximately equal at all cross-sections and, moreover, the material is used most economically and the weight is kept at its lowest limit. Resilient intermediate members **29** and **30** are rigidly connected to the ends of the spring by screws or rivets at **31**, **32**, or even by spot welding. The other ends of the intermediate members **29**, **30**, i. e., those not connected to the spring, are rigidly connected to rigid parts **35** of the frame structure, by means of rivets or screws at **33**, **34**. The resilient members being of elongated shape are flexibly resilient so that they are adapted to yield mainly in a direction transverse to the direction of vibration of the middle of the spring **27**, so that when the latter vibrates, the intermediate members are subjected practically only to tensional stresses and only to very slight bending stresses because of the "contraction" of said spring **27**, whereas the spring itself receives only a pure bending stress and no appreciable tensile stress.

The modifications according to Figs. 3 and 4 show two possible forms having the object of reducing the height of the assembly. Each of the resilient intermediate members is composed of two overlying parts **36**, **37**, which are connected together in series to form a unit, i. e., they are interconnected at their one ends **38** by screws, rivets or welding and at their other ends are connected respectively to the rigid part **35** by fixing means **33** and with the end of the leaf spring by fixing means at **31**. These parts **36**, **37** can either, as shown in Fig. 3, be slightly bent so that they only make contact at the ends at which they are connected or, as shown in

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Fig. 4, they can be held at a small distance apart by a spacing member **39**.

In Fig. 5 the intermediate member **40** is of U-shape in front elevation with the left hand limb longer than the right hand limb. In Fig. 6, the intermediate member is of S-shape. In Fig. 7, the intermediate member is made up of three parts **42**, **43**, and **44**, which are joined together to form an N-shaped unit. And in Fig. 8, the intermediate member also consists of three parts **45**, **46** and **47** which are combined to form a double V-shaped unit.

Figs. 9 to 11 illustrate three examples of leaf springs which may be used for supporting the vibrating masses. The simplest form is shown in Fig. 9, in which the spring **27** has a double-trapezoidal shape in plan, the longer of the parallel sides of the trapezoids being coincident.

In Fig. 10, two springs as shown in Fig. 9 are used, connected together at their centres by a connecting piece, in order to give increased rigidity against distortion. Two double-trapezoidal springs **48**, **49** are connected at both ends to the intermediate members **29**, **30** by fixing means **31**, **32** as described with reference to Fig. 2.

Fig. 11 shows a further modification with the same advantages. In this form, instead of using two separate double-trapezoidal springs, one double trapezoidal spring **52** is employed having comparatively wide ends, and from the surface of the spring two triangular areas are stamped out, the apices of the triangles pointed towards the centre of the spring and the bases being parallel to the spring ends.

An approximately equal specific bending load at all cross-sections of the spring and thus a very favourable utilisation of weight is common to these three modifications, and this is particularly important with the very rapidly alternating load which occurs with high frequencies of vibration. In the modifications illustrated in Figs. 12 to 15, pneumatic cushions **57** are employed instead of metallic springs. In Fig. 12, 1^a indicates an article table which is rigidly connected with the frame 3^a. The supporting of the mass consisting of the vibratory table and the frame, etc., is effected in any suitable manner. The second mass consists of a plate **53**, which is suitably supported at **54** and is connected by stays **55** with a plate **56** within the frame 3^a. Between the two masses, i. e. between the plate **56** and the frame 3^a, there is provided in this example, instead of the springs **12**—**15** shown in Fig. 1, pneumatic cushioning means constituted as a pair of double-convex lens-shaped air cushions which are filled in any suitable manner with compressed air. The internal pressure is adjustable and represents a measure of the natural frequency of the oscillatable system consisting of the two masses, coupled together by the resiliency of the air cushions. Variation of the internal pressure therefore causes an alteration in the setting or "tuning" of the system.

The shape of the vibration characteristic of the pneumatic cushions can be greatly influenced by the shape of the bearing surfaces upon which the air cushions roll when flexed. Fig. 13 is a detail view of a device in which the bearing surfaces **58** are convex. Such an arrangement has a weaker progressive characteristic than the modification according to Fig. 12, in which the bearing surfaces are plane. In the embodiment according to Fig. 14, the bearing surfaces **59** for the air cushions **57** are concave. This gives a stronger progressive characteristic than the embodiment according to Fig. 12. In the example illustrated in Fig. 15, not only the springs **12**—**15**, but also the springs **7**, **20** and **21** of Fig. 1 are replaced by pneumatic cushions. The frame 3^a is supported by an air cushion **60** on the stationary frame **61**, whereas the second mass **53** (i. e. B in Fig. 1) is resiliently supported on the frame structure in the same way by an air cushion **62**.

It will be appreciated that Figs. 12 and 15 are only diagrammatic views of devices employing pneumatic cushions, the power unit applied to the masses to vibrate them in opposition to one another having been omitted in the interests of clearness. The power unit may be for example substantially similar to that illustrated in Fig. 1 and to allow the introduction of such a power unit the leaf springs shown in Fig. 12 and the cushions **60** and **62** shown in Fig. 15 would in practice be more widely spaced apart than they are shown to be in the drawings.

I claim:

1. A device for producing vibrations comprising two vibratable masses, a relatively fixed structure resilient means supporting said masses on said structure, a power unit applied to said masses to vibrate them in opposition to one another, a resilient coupling between said masses, said resilient coupling being additional to said resilient supporting means, and means for adjusting said resilient coupling to vary the natural frequency of the device.

2. A device for producing vibrations comprising a frame structure, two vibratable masses, a power unit applied to said masses to vibrate them in opposition to one another, and resilient couplings between the respective masses and the frame structure; said couplings being so dimensioned that the associated coupling factors are proportional to the ratio of the two masses, and a resilient coupling between the masses that is additional to said resilient couplings between the masses and the frame structure, and means for adjusting said additional resilient coupling so as to vary the natural frequency of the device.

3. A device for producing vibrations comprising a frame structure, two vibratable masses, a power unit applied to said masses to vibrate them in opposition to one another, a resilient coupling between said masses, resilient coupling means between each of said masses and the frame structure, and means for adjusting the resiliency of the coupling means between one at least of said masses and the frame structure independently of the resiliency of the coupling means between the other of said masses and the frame structure.

4. A device for producing vibrations comprising two vibratable masses, an article support connected to one of said masses, a resilient coupling between said masses, resilient means supporting said masses and a power unit applied to said masses to vibrate them in opposition to one another, the power unit being constituted as an electro-magnetic motor comprising a field unit connected to one of said masses and including a flux path which is closed except for an air-gap, an armature connected to other of said masses and disposed at said air-gap, and a leaf spring connected at its ends to the stator and intermediate its length to the armature, said leaf spring permitting relative vibratory movement between the armature and the stator and constraining the armature to rectilinear movement.

5. A device for producing vibrations comprising a frame structure, two vibratable masses, a power

unit applied to said masses to vibrate them in opposition to one another, and resilient couplings that mount the masses on the frame structure; there being a coupling for each mass and said couplings comprising each at least one leaf spring supported at its ends in the case of one at least of the masses directly upon the frame structure and intermediate its ends to the corresponding mass, the springs for the two masses being disposed in parallel planes and mounting the masses for relative rectilinear vibratory movements in a direction generally normal to said planes.

6. A device for producing vibrations comprising two vibratable masses, a power unit applied to said masses to vibrate them in opposition to one another, resilient means supporting said masses, a resilient coupling between the masses, said resilient coupling being constituted by a pair of leaf springs, an attachment on one of the masses and having secured to it one end of each of the pair of leaf springs, the leaf springs being superimposed in parallel planes spaced apart in the direction of the vibratory movement of the masses, and the attachment being formed with curved bearing surfaces for the proximal surfaces of the leaf springs, which bearing surfaces converge from the attached ends of the springs and define the maximum deflection of the springs towards each other, a pair of abutments on the other of the masses, each of said abutments bearing on the distal surface of the corresponding leaf spring, and adjustment means for moving the attachment towards and away from the abutments.

7. A device for producing vibrations comprising two vibratable masses, a power unit applied to said masses to vibrate them in opposition to one another, resilient means supporting said masses, and a resilient coupling between the masses, said resilient coupling being constituted by at least one leaf spring, an attachment constituted as a nut and having secured to it the leaf spring, an abutment on one of the masses bearing on the leaf spring, a screw shaft journalled at the other of the masses and having mounted thereon the attachment, an adjustment member for rotating the screw shaft and a flexible coupling between the adjustment member and the screw shaft.

8. A device for producing vibrations comprising a frame structure, two vibratable masses, resilient means supporting said masses on the frame structure and coupling one mass to the other mass, said resilient means including pneumatic cushioning means formed with arcuate bearing surfaces to make rolling contact with the coupled parts, and a power unit applied to said masses to vibrate them in opposition to one another.

9. A device for producing vibrations comprising a frame structure, two vibratable masses, resilient means supporting said masses on the frame structure and coupling one mass to the other mass, said resilient means including pneumatic cushions having surfaces that bear respectively on surfaces of coupled parts, surfaces on the cushions being part-spherical to make rolling contact with the coupled parts and surfaces on the coupled parts being convex so as to provide a relatively weak progressive characteristic of the respective pneumatic cushions.

10. The device according to claim 5 and further comprising resilient intermediate elements connecting the ends of the leaf springs with supports for said ends, the ends of each said elements being connected respectively to the respective support and the corresponding end of the leaf spring and each unit being adapted to yield, as allowed by its resiliency, mainly in a direction transverse to the direction of said relative rectilinear vibratory movement.

11. The device claimed in claim 5 and further comprising flexible resilient elongated elements connecting the ends of the leaf springs with supports for said ends, the ends of each of said elements being connected respectively to the respective support and the corresponding end of the leaf spring, and each element being disposed with its length substantially normal to the plane of the leaf spring.

12. The device according to claim 5 wherein the leaf springs have, when viewed in plan, substantially the shape of two adjacent trapezoids, the longer of the parallel sides of the trapezoids being coincident and the shorter parallel sides defining the ends of the spring.

13. A device for producing vibrations comprising a frame structure, two vibratable masses, a power unit applied to said masses to vibrate them in opposition to one another, and resilient couplings that mount the masses on the frame structure, there being a coupling for each mass and one at least of said couplings comprising two leaf springs disposed in parallelism in the same plane, and a connecting piece connected to the leaf springs between their ends, the corresponding vibratable mass being connected to the connecting piece between the leaf springs, and supports for the ends of the leaf springs, there being a support common to each pair of adjacent ends.

14. The device according to claim 5, wherein the leaf springs have each when viewed in plan substantially the shape of two trapezoids in abutting relationship, the longer of the parallel sides of the trapezoids being coincident and the shorter of the parallel sides defining the ends of the spring, said leaf spring being formed with two triangular shaped openings which have apices pointing towards the centre of the spring and bases parallel to the shorter of the parallel sides of the trapezoids.

15. A device for producing vibrations comprising two vibratable masses, a relatively fixed structure, resilient means supporting said masses on said structure, a power unit applied to said masses to vibrate them in opposition to one another, a resilient coupling between said masses, said resilient coupling being additional to said resilient supporting means, and means for adjusting said resilient coupling to vary the natural frequency of the device, the resiliency of said resilient supporting means being so dimensioned that the natural frequencies of the respective masses taken separately and each with the means supporting it on the fixed structure are substantially outside the operative frequency range of the device.

16. A device for producing vibrations comprising a frame structure, two vibratable masses, a power unit applied to said masses to vibrate them in opposition to one another, a resilient coupling between said masses, resilient coupling means between each of said masses and the frame structure, means for adjusting said resilient coupling between the masses to vary the natural frequency of the device, and means for adjusting the resiliency of the coupling means between one at least of said means and the frame

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structure independently of the resiliency of the coupling means between the other of said masses and the frame structure.

17. A device for producing vibrations comprising a frame structure, two vibratable masses, a power unit applied to said masses to vibrate them in opposition to one another, and resilient couplings that mount the masses on the frame structure; there being a coupling for each mass and said couplings comprising each at least one leaf spring-supported at its ends in the case of one at least of the masses directly upon the frame structure and intermediate its ends to the corresponding mass, the springs for the two masses being disposed in parallel planes and mounting the masses for relative rectilinear vibratory movements in a direction generally normal to said planes, and further comprising a resilient coupling between said masses which is additional to the resilient couplings that mount the masses, and means for adjusting said resilient coupling to vary the natural frequency of the device.

18. A device for producing vibrations comprising a frame structure, two vibratable masses, resilient means supporting said masses on the frame structure and coupling one mass to the other mass, said resilient means including pneumatic cushions having surfaces that bear respectively on surfaces of coupled parts, surfaces on the cushions being part-spherical to make rolling contact with the coupled parts and surfaces on the coupled parts being concave so as to provide a relatively strong progressive characteristic of the respective pneumatic cushions.

19. The device claimed in claim 5 and further comprising elements connecting the ends of the leaf spring with supports for said ends, the ends of each of said elements being connected respectively to the respective support and the corresponding end of the leaf spring and each of said elements being formed from a plurality of relatively short overlying flexibly resilient members connected together in series.

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