May 23, 1961 R. M. CARRIER, JR 2,985,281

VIBRATORY EQUIPMENT USING AIR SPRINGS

Filed Nov. 17, 1958 3 Sheets-Sheet 1

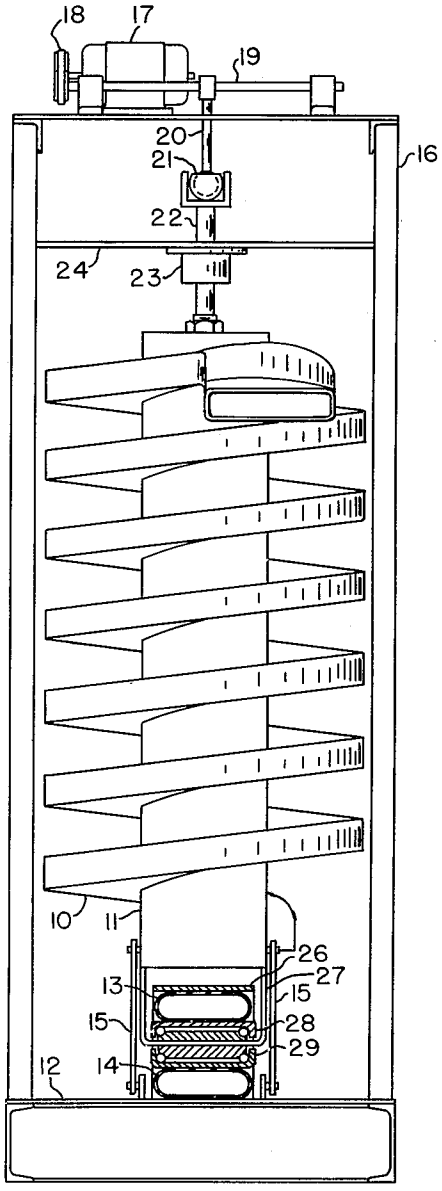


Fig. 1

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Filed Nov. 17, 1958 3 Sheets-Sheet 2

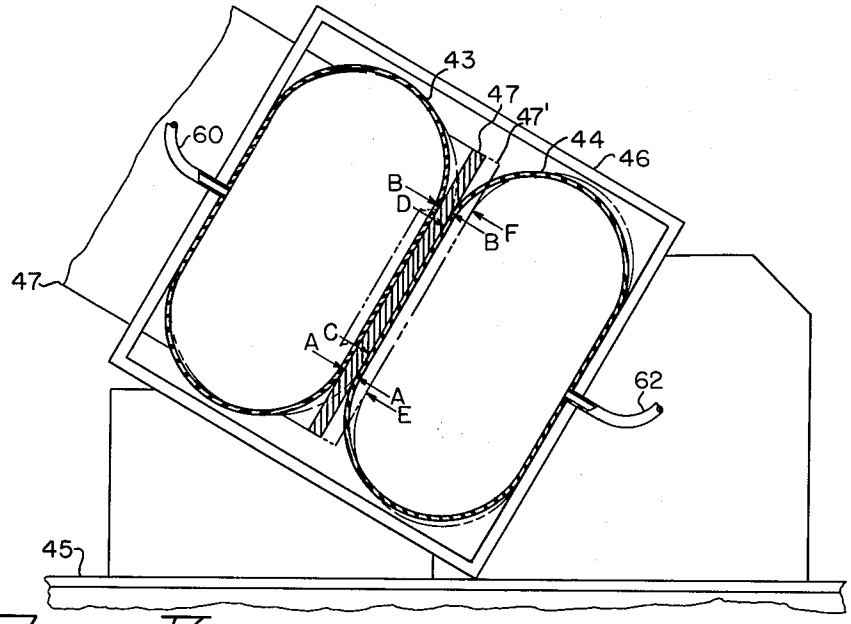


Fig. V

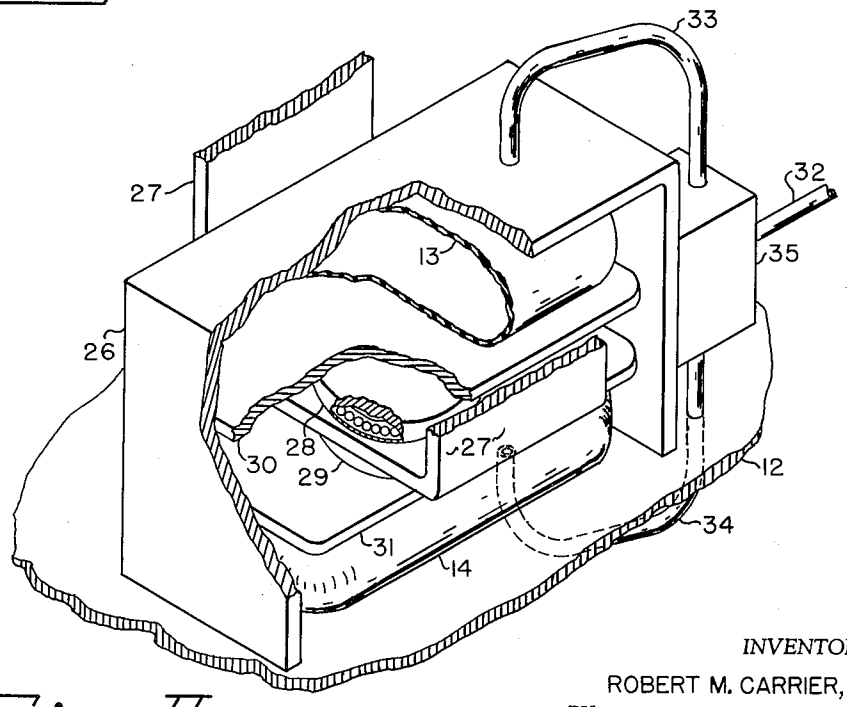


Fig. II

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Filed Nov. 17, 1958 3 Sheets-Sheet 3

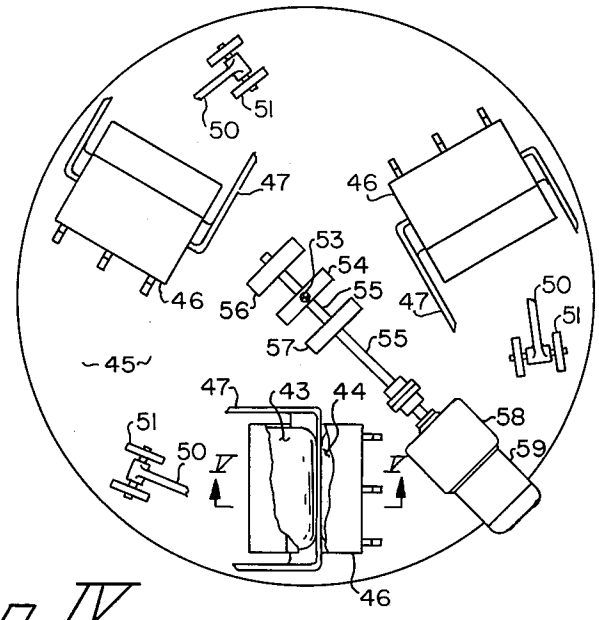


Fig. IV

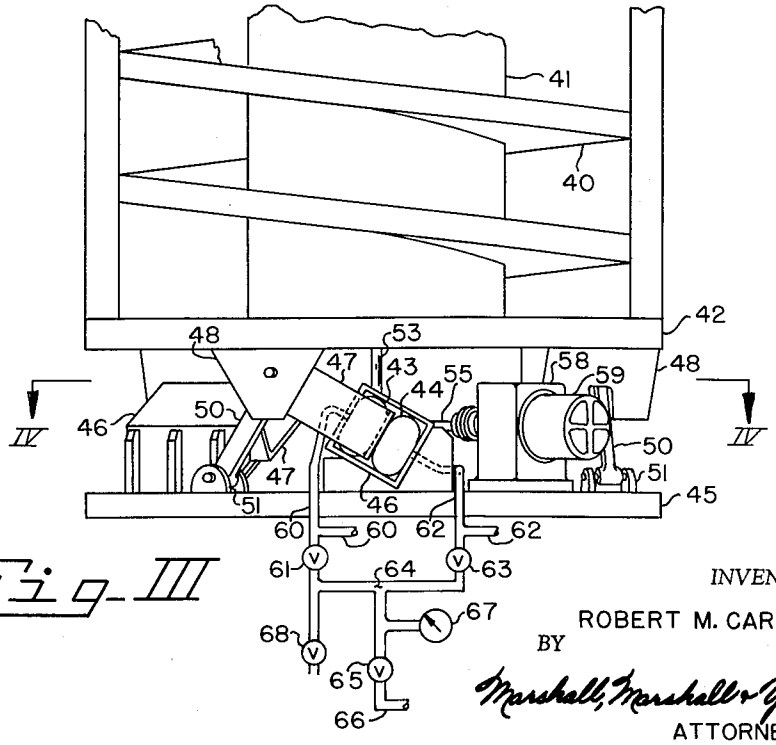


Fig. III

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United States Patent Office 2,985,281 Patented May 23, 1961

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VIBRATORY EQUIPMENT USING AIR SPRINGS

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10 Claims. (Cl. 198—220)

This invention relates to vibratory equipment and in particular to an improved elastic supporting and driving means for such vibratory equipment.

Vibratory equipment, particularly in the larger sizes, is designed to operate as a natural frequency or resonant system so as to minimize the driving force required to produce the desired vibration. In any such resonant system it is necessary to have one or more resilient elements, usually steel springs although other materials such as wood have been used, to support and interconnect the vibratory masses comprising the vibratory system. The vibratory masses ordinarily include the work member, a conveyor or other such structure, and a base which may or may not be vibrationally isolated from the earth or building frame. If the base is solid with the foundation it and the foundation must be able to withstand the maximum accelerating forces required to vibrate the work members through the desired stroke at the operating frequency. To minimize the forces transmitted to the earth or the building foundation or building frame it is customary, in large units, to provide a counterbalance weight or mass resiliently coupled to the work member and moving in opposite phase to provide the accelerating forces without transmitting a reaction force to the building.

When the work member is a conveyor it is often necessary to select particular operating speeds and strokes in order to match the conveying characteristics of the conveyor to the characteristics of the material. For example, some hard brittle materials are best conveyed with a short rapid vibratory stroke while spongy materials often require a slower frequency of operation with a correspondingly longer stroke. One of the difficult problems in large size units, if fairly long strokes are required, is to secure enough spring strength and spring rate in the available space for mounting the springs. Thus a steel spring capable of carrying a certain load and having a given rate requires a certain minimum space. The required space for the springs sets a definite limit to the size of certain types of vibratory equipment.

The principal object of this invention is to provide resilient elements for large scale vibratory equipment that provide high load carrying capacity and high spring rates in a small volume.

Another object of the invention is to provide vibratory resilient elements that are economical to produce in large sizes and that are efficient in operation.

A still further object of the invention is to provide resilient elements for a vibratory system, the spring rates of which can be varied over wide ranges without disturbing the relative positioning of the parts or requiring any mechanical adjustment of the parts.

These and more specific objects and advantages are apparent from the following description of a preferred form of the invention.

According to the invention the work member of a vibratory system is supported from its base by means of a plurality of pneumatic chambers having flexible side

walls arranged so that the force is transmitted through the gas in the pneumatic chambers. The chambers or pneumatic air bags are arranged in pairs acting in opposite directions, i.e. one air bag of each pair tends to drive the work member forward while the other air bag of the pair tends to drive it in reverse. The air bags or air chambers thus are effectively in push-pull in that they oppose each other insofar as static or average force is concerned but aid each other in resisting relative motion between the vibratory work member and its base. This arrangement permits the spring rate of the system, which is dependent upon the air pressure in the air bags, to be varied over wide ranges without changing the static position of the work member with respect to the base.

Preferred embodiments of the invention are illustrated in the accompanying drawings.

In the drawings:

Fig. I is a side elevation, partly in section, illustrating a spiral conveyor carried on a pair of air bags serving as the coupling springs supporting the conveyor from its base.

Fig. II is a greatly enlarged isometric view of the air bag supporting system of the conveyor shown in Fig. I.

Fig. III is a fragmentary elevational view of another arrangement of a plurality of pairs of air bags for supporting a vibratory conveyor.

Fig. IV is a horizontal section of the supporting system illustrated in Fig. III as seen from the line IV—IV of Fig. III.

Fig. V is an enlarged vertical section through a pair of air bags as seen from the line V—V of Fig. IV.

These specific figures and the accompanying description are intended merely to illustrate the invention and not to impose limitations on its scope.

In the apparatus shown in Fig. I a helical conveyor trough **10** is supported on a central support tube **11** which in turn is resiliently supported from a base **12** by a pair of air bags **13** and **14** which are a form of pneumatic or gas filled expansible chamber. A plurality of inclined links **15**, connecting the lower end of the central column **11** to the base **12**, force the column **11** to follow a helical path as it moves up and down on the resilient air chambers **13** and **14**.

A drive mechanism for imparting vibratory force to the central column **11** and helical trough **10** is shown mounted on the top of a framework **16** erected from the base **12** and extending upwardly beyond the upper end of the column **11**. The drive mechanism comprises an electrical motor **17** that is connected through belt **18** to an eccentric drive shaft **19** which in turn is connected through a connecting rod **20** and ball and socket point **21** to the upper end of a vertical shaft **22** extending upwardly from the upper end of the column **11**. The shaft **22** extends through a guide bearing **23** mounted in a cross member **24** of the frame **16**. The ball and socket joint **21** between the connecting rod **20** and the vertical shaft **22** accommodates the rotary component of the helical motion of the conveyor **10** and column **11** while it transmits the vertical drive force from the eccentric shaft **19** to the conveyor column **11**. Ordinarily such a helical vibratory conveyor would be driven from the bottom rather than from the top for greater simplicity and stability in construction and operation. The arrangement illustrated was selected for the purpose of avoiding congestion in the illustration at the lower portion of the mechanism.

In the arrangement shown in Fig. I the air bags or air cushions **13** and **14** are confined within a U-shaped frame **26** (see also Fig. II) attached to the base **20**. A stirrup **27**, also U-shaped in form, attached to the lower end of the column **11** passes horizontally between the air cham-

bers 13 and 14 and is separated from each by thrust bearings 28 and 29. The thrust bearings 28 and 29 are included to accommodate the rotary component of motion of the helical conveyor 10 without imposing torsional strains on the air chambers 13 and 14. The thrust bearings 28 and 29 include pressure plates 30 and 31 arranged to distribute the force applied through the thrust bearings to the adjacent air chambers.

Means such as an air line 32 with branch leads 33 and 34 are provided for inflating the air chamber 13 and 14. Preferably a compound valve arrangement 35 is included in the junction block between the pipe 32 and the pipes 33 and 34 so that air can be supplied or trapped in either of the air chambers at the desired operating pressure without having communication between the chambers.

In this arrangement the air chamber 14 supports the weight of the helical conveyor 10 including its central support column 11 and in addition provides the upward accelerating force during vibratory motion. The opposing air chamber 13 pushes downwardly on the stirrup 27 and thus provides the excess of downward acceleration force required over that provided by the force of gravity to provide the desired tuning of the system. The air chambers 13 and 14 thus act as resilient support members that are tuned to the mass of the vibratory conveyor to form a resonant system at the operating speed.

While the air chambers 13 and 14 are shown as being of substantially equal size they may be arranged so that the chamber 14 has greater effective area than the chamber 13 to carry the weight of the conveyor that is carried on the chamber 14. The actual difference in effective areas of the air chambers 13 and 14 may be in the order of a fifth to a quarter of the effective area of one of the chambers because the vibratory force required to tune the system including the conveyor 11 when operated with the inclined links 15 which serve to convert the vertical force to a force along the helical path requires a total vibratory force in the order of several times the weight of the conveyor assembly. This requires that the air chamber 13 supply approximately from 60 to 80 percent as much force as the air chamber 14 and, if the static pressures in the chambers are equal, that the effective area of the chamber 13 be from 60 to 80 percent of that of the chamber 14.

When the chambers are confined between parallel plates, as illustrated, the effective area of the chambers changes proportionally to the deflection. As a chamber is compressed more and more of its flexible side wall is brought into contact with the parallel plates thus increasing the effective area. Therefore if the air chambers are initially of the same effective area and are pumped up to a suitable pressure the applying of the weight of the conveyor merely causes the lower chamber to compress slightly thereby increasing its effective area at the same time that the upper air chamber expands and decreases its effective area.

The effective spring rate of the air chambers varies with the average pressure of the gas in the chambers. The pressure changes in accordance with the changes in volume of the chamber according to the ordinary adiabatic pressure—volume relations of a confined gas. Additionally the chambers exhibit a spring rate factor, also proportional to the average pressure because of the changes in effective area of the chambers with compression or expansion. The latter effect is present at constant gas pressure which may be obtained for example if the valve 35 is opened so that gas may circulate freely from one chamber to the other. Since the spring rate can be adjusted merely by changing the gas pressure in the air chambers the natural frequency of operation of the conveyor on the air springs may be easily adjusted to correspond to any desired operating speed as determined by the motor 17 and the pulleys carrying the belt 18.

In the arrangements shown in Figs. I and II the air bags of air chambers apply force along the axis of the conveyor rather than along the path of vibratory movement. This arrangement is suitable primarily when a long stroke at low speed is used. However, many conveyors are operated at higher speeds and an alternative arrangement is desirable. In the alternative arrangement the springs, either the flexible side wall air chambers or ordinary helical springs, are positioned to act directly along the desired path of vibratory movement. This arrangement very materially reduces the forces in the inclined struts used to guide the conveyor as well as making it possible to apply much larger forces to the conveyor itself.

In the arrangement shown in Fig. III flexible side wall air chambers are employed to support and provide the resilient force for vibration of a helical conveyor and are arranged to act directly along the path of the helical motion of the conveyor. In this arrangement, a helical conveyor 40 having a central column 41 supported from a vibratory base 42 constitutes the mass of the system to be vibrated. A plurality of pairs of expansible, flexible side wall air chambers each comprising chambers 43, 44 are arranged symmetrically about the axis of the conveyor and between the vibratory base 42 and a foundation or firm base 45. The flexible side wall chambers 43, 44 are supported in box-like open-sided frames 46 secured to the lower or foundation base 45. The air chambers are connected to the vibratory base 42 by means of stirrups 47, similar to the stirrup 27, that are rigidly attached to depending brackets 48 of the base 42.

Inclined struts 50 extending from brackets 51, mounted on the base 45, to the depending brackets 48 are directed along a line generally perpendicular to the line of vibratory motion, i.e. the axis of the stirrups 47, and are provided with flexible joints or pivot points at each end so as to accommodate the rotary or twisting movement as the upper ends of the struts follow the helical motion of the vibratory base 42.

Vibratory motion for driving the helical conveyor is applied in a vertical direction through a connecting rod 53 driven from its lower end by an eccentric 54 mounted on a drive shaft 55 journaled in bearings 56 and 57. The drive shaft 55 is driven through a gear box 58 from a motor 59 mounted on the base 45. While not shown in the drawings, the connecting rod 53 may include a frictional slip joint, a hydraulically restrained lever, or any of a number of similar arrangements to reduce the starting load on the motor before the system reaches its resonant operating speed. Such force reduction systems are well known and will not be further described.

In the arrangement of Fig. III the flat bottomed portion of the stirrup 47 passing between the air chambers 43 and 44 extends generally along a radius of the base 42 so that the lateral motion of the bottom portion of the stirrup 47 with respect to frame 46 is quite small as it follows the helical vibratory motion of the conveyor. The bottom ends of the side walls of the stirrup 47 extend generally tangent to cylinders concentric with the axis of the conveyor. This provides a minimum of relative lateral movement between the stirrup 47 and the box-like frame 46 holding the air chambers.

In the arrangement shown in Fig. III all of the upper air chambers 43 are interconnected through piping 60 controlled by a valve 61 while the chambers 44 are similarly interconnected by piping 62 that is controlled by a valve 63. The valves 61 and 63 are connected to a T 64 that is connected through valve 65 to an air pressure supply line 66. A pressure gauge 67 may be connected to the T section 64 as an aid to adjusting the system to the proper air pressures as related to the vibratory speed of operation. A valve 68 connected to the T 64, when opened along with the valve 61 or 63 exhausts air from the air bags.

While the air bags have been shown as the resilient elements of a helical conveyor they may also be similarly used instead of coil springs or leaf springs in straight conveyors.

The action of the flexible side-walled air chambers **43** and **44** is illustrated in Fig. V wherein the normal or undeflected position of the side walls and the stirrup **47** with respect to the casing of the box-like frame **46** is illustrated in the solid lines and a deflected position of the members is illustrated by dot-dash lines. To avoid confusion only the outer outline of the side walls of the chambers are shown in the deflected position. Preferably the walls of the air chambers **43** and **44** are made of rubber or similar material reinforced with fabric so that such side walls are flexible but substantially non-stretchable. If the side walls are perfectly flexible the portions unsupported by contact with either the frame **46** or the web or bottom of the stirrup **47** take a form that is semi-circular in cross section. The effective area of each of the air chambers, assuming flexible side walls, is the area of the chamber wall that is actually in contact with the adjacent surfaces of the frame **46** or stirrup **47**. This wall area that is in contact varies with the compression or expansion of the chambers as illustrated by the dot-dash lines. Thus in the normal or static position, indicated in the solid lines, the area is that within boundaries indicated by points A and B which are the dividing points between the supported portions and unsupported portions of the side wall. The tension in the side walls of the chambers prevents the air pressure acting on the unsupported portions of the side wall from exerting any force on the stirrup **47** or frame **46**.

In the deflected position, assuming the stirrup **47** to have moved downwardly to the position **47'**, the upper air chamber **43** expanded and since the side wall is non-stretchable the points of tangency moved in to points C and D thus decreasing the effective area of the expanding chamber **43**. At the same time the points of tangency of the side walls of the chamber **44** moved outwardly to points E and F thus increasing the effective area of the compressed air chamber. This change in effective area takes place regardless of the air pressure in the chambers and may, if desired, be employed to locate the static position of the conveyor so that at such static position the weight of the conveyor is supported by the air pressure acting on the difference in the effective areas thus allowing the chambers to be operated at the same average pressure.

As was mentioned before the effective spring rate of the air chambers varies according to the pressure in the chambers, the compression ratio which is the percentage change in volume for a given movement of the stirrup **47**, and the effective change in effective area with such movement. The dependence of the spring rate on the average gas pressure provides an easy way of adjusting the spring rate of the system. Likewise the use of the air springs in opposition to each other, the air chambers **43** and **44** are effectively in push-pull since one expands as the other contracts, makes it possible by change in pressure to change the effective spring rate of the combination of the two air springs without changing the static force applied to the conveyor and thus its height above the base. If only one such spring were used any change in pressure results in a corresponding change in height and little change in spring rate.

In addition to its feature of easy control the flexible side walled air chamber used as a spring also affords much greater spring rates in a given volume than can be obtained in other ways. Thus the energy storage of the gas is considerably greater for the overall volume occupied than is the storage of energy in a steel spring adapted to permit the same relative movement.

Various modifications may be made in the details of construction without losing the advantages of the improved resilient support or departing from the scope of the invention.

Having described the invention, I claim:

1. In a system for doing work by vibration, in combination, a work member to be vibrated, a support having spaced apart opposing surfaces, a pair of gas filled expansible chambers superposed in series between said surfaces, each of said chambers having flexible substantially non-stretchable side walls, means interposed between said chambers and supportingly connected to said work member, means for applying vibratory force to said work member at a substantially constant frequency, and means for adjusting the gas pressure in said expansible chambers in the pressure at which said chambers cooperate with the mass of the work member to form a system having a resonant frequency substantially equal to said constant frequency.

2. In a system for doing work by vibration, in combination, a vibratory work member, a support having spaced apart opposing surfaces, a pair of gas filled expansible chambers superposed in series between said surfaces, each of said chambers having flexible substantially non-stretchable side walls, rigid means interposed between said chambers and connected to said work member, means for adjusting the gas pressure in said chambers such that said chambers and said work member form a vibratory system having a natural frequency that varies with said gas pressure, and means for applying vibratory force to said work member.

3. In a system for doing work by vibration, in combination, a vibratory work member, a support having spaced apart opposing surfaces, a pair of gas filled expansible chambers superposed in series between said surfaces, each of said chambers having flexible substantially non-stretchable side walls, rigid means interposed between said chambers and connected to said work member, means for adjusting the gas pressure in said chambers such that said chambers and said work member form a vibratory system having a natural frequency, means for applying vibratory force to the work member at a frequency generally equal to said natural frequency, and means for guiding said work member along a path relative to the support that is generally normal to said opposed surfaces.

4. In a system for doing work by vibration, in combination, a member to be vibrated along a helical path, a support having a plurality of pairs of opposed surfaces spaced about the axis of the helical path, said surfaces being generally normal to the helical path, a pair of gas-filled expansible chambers positioned in series between each pair of surfaces, means interposed between said chambers and supportingly connected to said member, means for adjusting the gas pressure in the chambers, said member and said chambers forming a vibratory system having a natural frequency that varies with the gas pressure in the chambers, and means for applying vibratory force to the member at a frequency generally equal to the natural frequency of the vibratory system.

5. In a system for doing work by vibration in combination, a member to be vibrated along a helical path, a support having a plurality of pairs of opposed surfaces spaced about the axis of the helical path, said surfaces being generally normal to the helical path, a pair of expansible gas filled chambers superposed in series between each pair of opposed surfaces, each of said chambers having flexible substantially nonstretchable side walls, means interposed between said chambers and supportingly connected to said member, means for applying vibratory force to the member at a substantially constant frequency, means for adjusting the gas pressure in the chambers so that the natural frequency of the vibratory system composed of the member and the gas filled chambers is substantially equal to the frequency of the applied force, and means for guiding the member along the helical path.

6. In a system for doing work by vibration, in combination, a helical conveyor to be vibrated along a helical path, a support having a pair of spaced apart surfaces the planes of which are normal to the axis of the helical path, a pair of expansible gas filled chambers superposed in series between said surfaces, each of said chambers having flexible substantially non-stretchable side walls, a rigid member interposed between the chambers and attached to said helical conveyor, means for applying vibratory force to said conveyor at a substantially constant frequency, means for adjusting the pressure of the gas in the chambers so that said conveyor and chambers form a resonant system having a natural frequency generaly equal to said constant frequency, and means for guiding the conveyor for movement along the helical path.

7. In a system for doing work by vibration, in combination, a work member to be vibrated, means for applying vibratory force to the member at a generally constant frequency, a support member, and resilient means connecting the work member and the support member and forming with the work member a vibratory system having a natural frequency, said resilient means comprising at least one pair of expansible gas filled chambers arranged in opposition to each other and each connected between the work member and the support member, and means for adjusting the gas pressure in said chambers to vary the spring rate of said chambers.

8. In a system for doing work by vibration, in combination, a work member to be vibrated, means for applying a vibratory force to the member at a substantially constant frequency, a support member, resilient means connecting the work member to the support member and forming with the member a resonant vibratory system, said resilient means comprising at least one pair of expansible gas filled chambers arranged in opposition to each other, each of the chambers having flexible substantially non-stretchable side walls, and means for adjusting the gas pressure in the chambers to vary the effective spring rate of the resilient means.

9. In a system for doing work by vibration, in combination, a work member to be vibrated, a support member, a first of said members having at least one pair of spaced apart opposed surfaces, said surfaces being generally normal to the line of action of vibratory forces acting on said work member, a pair of gas filled expansible chambers superposed in series between said opposed surfaces, means interposed between said chambers and supportingly connected to the second of said members, means for adjusting the gas pressure in the chambers, said work member and said chambers forming a vibratory system having a natural frequency that varies with the gas pressure in the chambers, and means for applying vibratory force to the work member.

10. In a system for doing work by vibration in combination, a member to be vibrated, a support having at least one pair of spaced apart opposed surfaces, a pair of expansible gas filled chambers superposed in series between the pair of opposed surfaces, each of said chambers having flexible substantially non-stretchable side walls, means interposed between said chambers and supportingly connected to said member, means for applying vibratory force to the member at a substantially constant frequency, and means for adjusting the gas pressure in the chambers to adjust the natural frequency of the vibratory system composed of the member and the gas filled chambers with respect to the frequency of the applied force.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 2,985,281 May 23, 1961

Robert M. Carrier, Jr.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 2, line 51, for "point" read -- joint --; line 69, for "base 20" read -- base 12 --; column 3, line 10, for "chamber" read -- chambers --; column 6, line 14, for "in" read -- to --.

Signed and sealed this 13th day of February 1962.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

DAVID L. LADD
Commissioner of Patents