Sept. 20, 1960 J. M. MORRIS 2,952,950

VIBRATORY MILL

Filed April 23, 1958 3 Sheets-Sheet 1

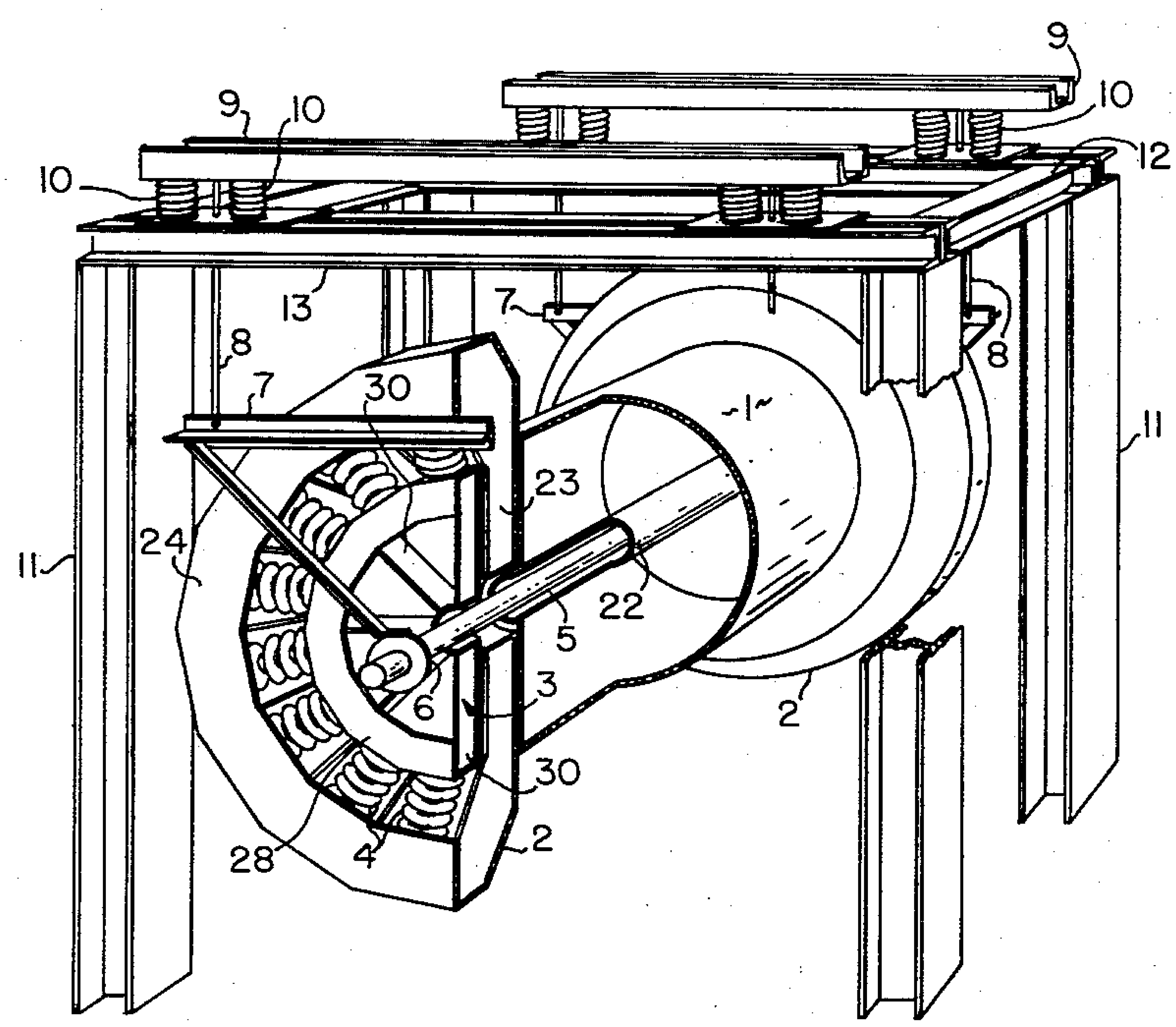

Fig. I

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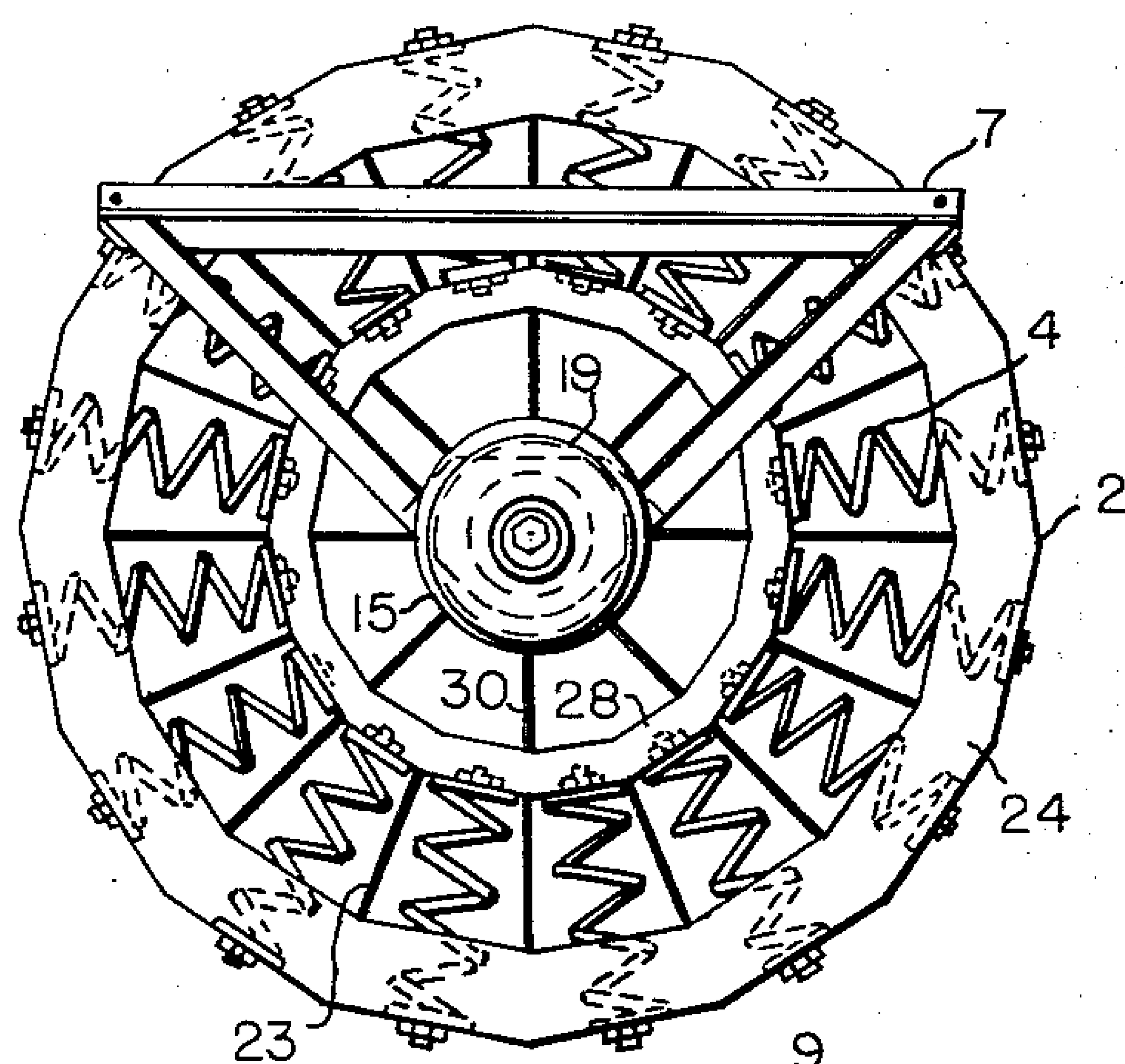

Fig. II

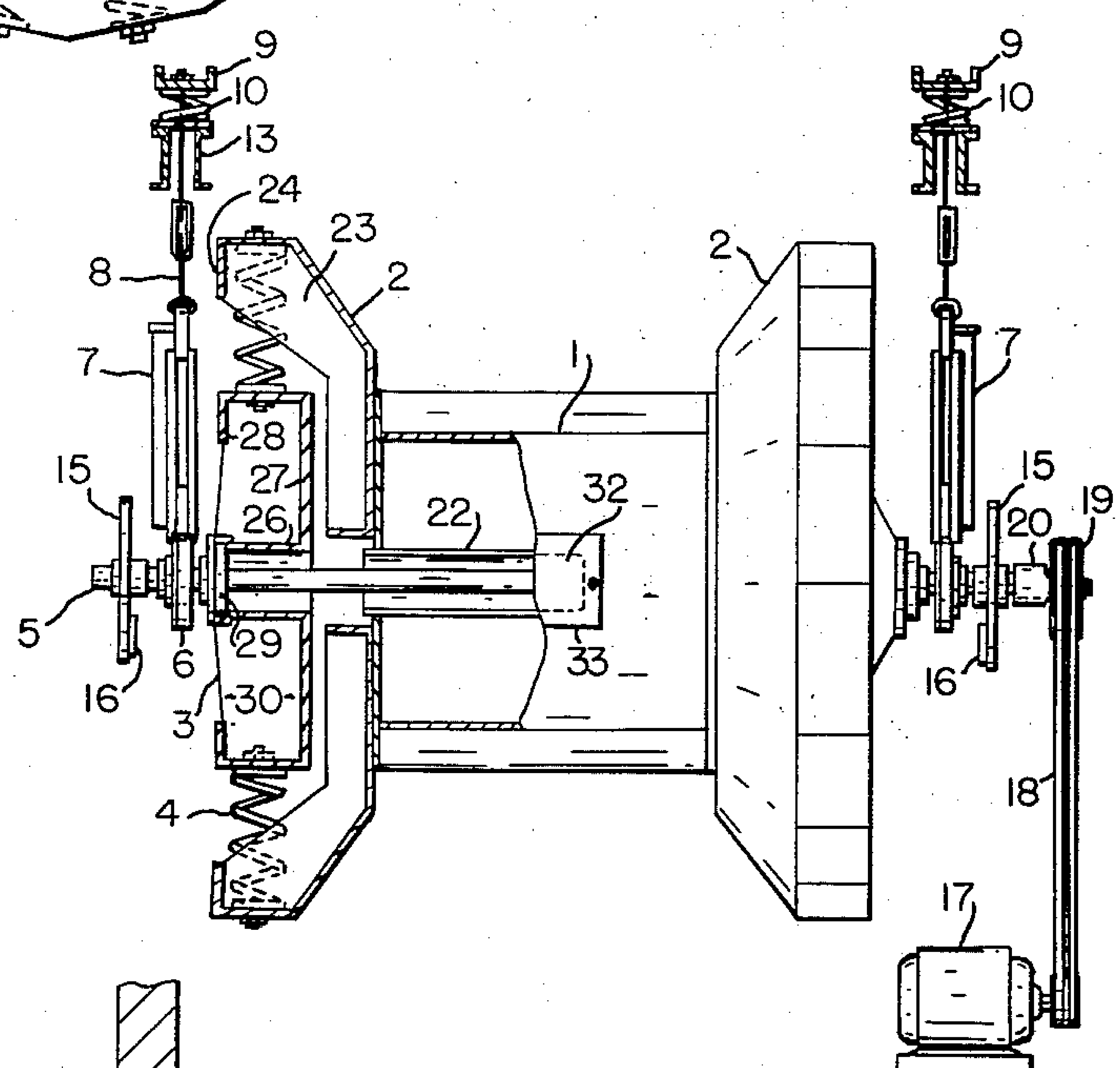

Fig. III

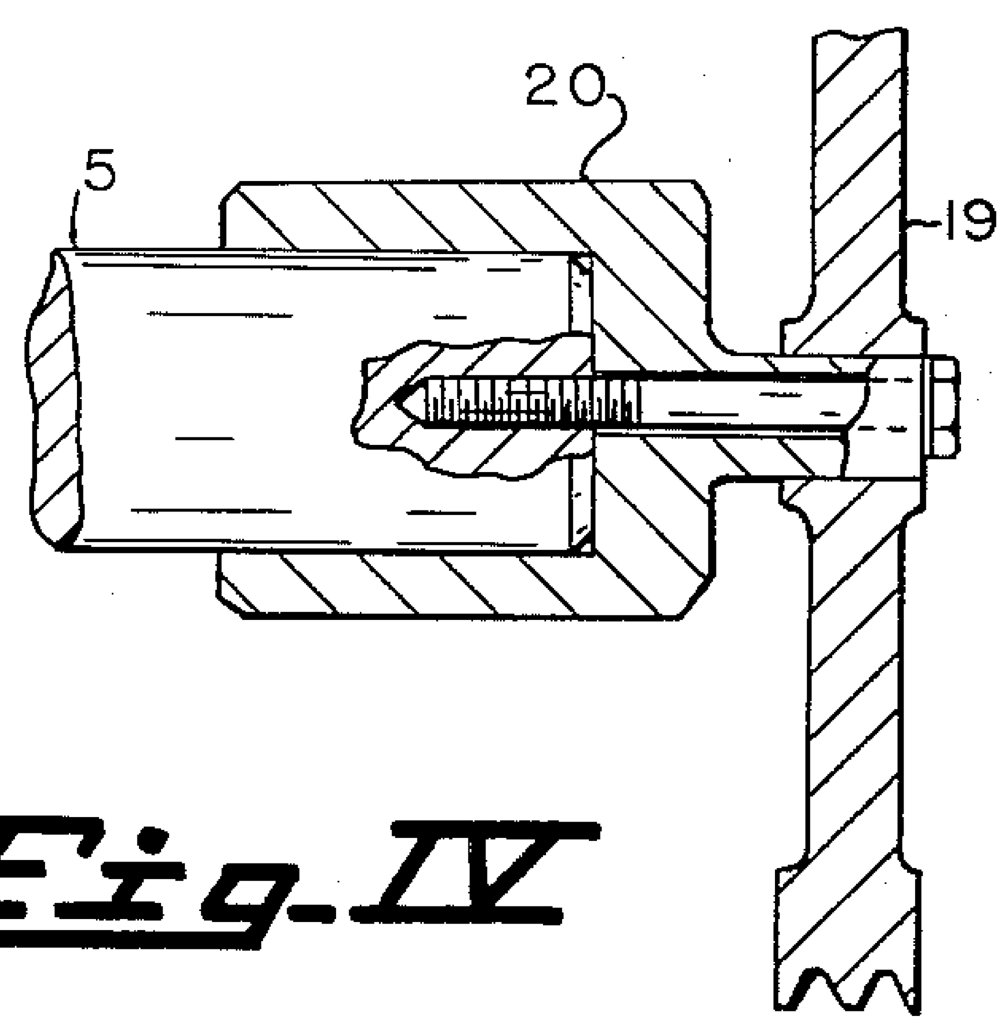

Fig. IV

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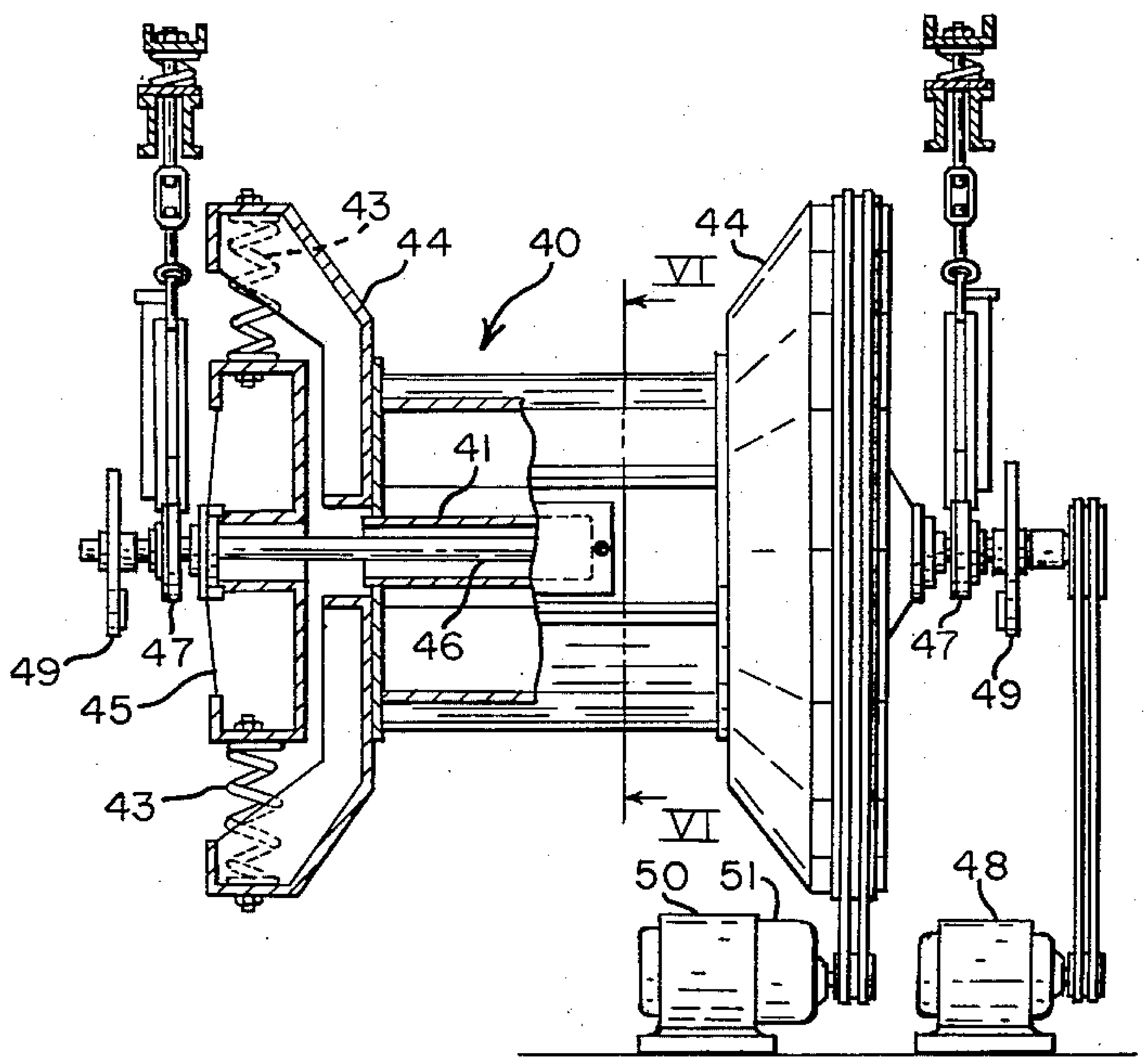

Fig. V

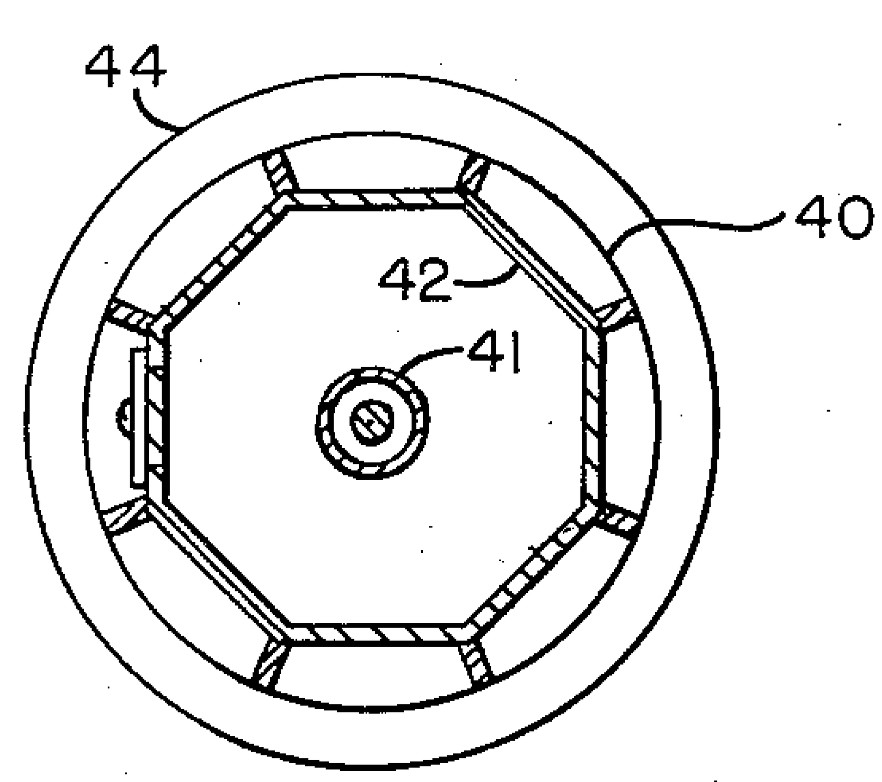

Fig. VI

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VIBRATORY MILL

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11 Claims. (Cl. 51—164)

This invention relates to vibratory apparatus and in particular to a tumbling mill employing vibration to agitate the material in the mill.

In many commercial manufacturing processes the work is polished, deburred, or otherwise treated by placing the work together with a treating medium in a container and slowly rotating the container about a generally horizontal axis to produce a rubbing action between the work pieces and the treating medium as the material tumbles about in the container. It has been found that the rubbing action may be produced by vibration imparted to the container. Systems operating on this principle have been constructed in small or laboratory sizes but have not been satisfactory in larger sizes because of the difficulty of generating and transmitting sufficient vibratory force to vibrate a large heavy container. The principal difficulty encountered in large size apparatus is the high stress concentration that occurs in certain parts of the structure.

The principal object of this invention is to provide a vibratory tumbling mill the parts of which are arranged to distribute and minimize the mechanical stress in the parts.

Another object of the invention is to provide a force distribution system for a vibratory tumbling mill to distribute the vibratory force that is applied to the container and minmize the concentration of stress in any part of the mill.

Another object of the invention is to provide a compact vibratory tumbling mill in which the material container may be slowly rotated during operation by means independent of the vibratory force generating means.

A still further object of the invention is to provide a tumbling mill vibration exciter that provides an orbital vibration of substantial amplitude without transmitting equivalent vibratory force through the rotating bearings of the drive shaft.

A still further object of the invention is to provide a tumbling mill vibration exciter that is elastically coupled to a work member and that is operated near or at its resonant frequency.

A still further object of the invention is to provide a tumbling mill in which an annular material container is resiliently mounted in impulse members which are journaled on an eccentrically weighted rotating shaft.

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

According to the invention the improved tumbling mill comprises a resiliently supported drive shaft, eccentric weights mounted on the drive shaft, at least one vibration exciter mass journaled on the drive shaft, a material container, and a plurality of springs interconecting the container and exciter mass and forming with the container and exciter mass a vibratory system having a natural frequency, and means for rotating the drive shaft at a speed approximately equal to the natural frequency of the vibratory system.

A preferred form of the invention is illustrated in the accompanying drawings.

In the drawings:

Fig. I is a perspective view, with parts shown in section, of the improved vibratory mill and its supporting structure.

Fig. II is an end elevation of the tumbling mill.

Fig. III is a side elevation, with parts shown in section, of the improved tumbling mill.

Fig. IV is a fragmentary detail showing the mounting of the drive pulley on the end of the shaft so as to minimize the variation in tension in the driving belt between the tumbling mill shaft and its drive motor.

Fig. V is a side elevation, with parts shown in section, of the improved tumbling mill equipped with means for positively controlling the rotation of the mill on its axis.

Fig. VI is a cross section, taken along the line VI—VI of Fig. V, showing a preferred form of container for use in the tumbling mill.

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

A tumbling mill constructed according to the invention includes an annular generally cylindrical container **1** which at each end is supported by end bells **2** resiliently connected to exciter members **3** by way of a plurality of radially arranged coil springs **4**. The exciter members **3** are journaled on a shaft **5** which in turn is carried in bearings **6** mounted on a pair of light triangular frames **7**. The light frames **7** are suspended by links **8** and cross-beams **9** from coil springs **10**. The links **8** are pivoted at each end, that is, to the light frames **7** and to the cross-beams **9**, so that the assembly may swing like a pendulum and the stiffness or rate of the springs **10** is selected to that the system may vibrate vertically at a low frequency.

The springs **10** are supported on a stand comprising I-beam corner pillars or columns **11**, cross-beams **12** extending generally parallel to the length of the container **1** and the shaft **5** and other cross-beams **13** extending parallel to the cross-beams **9**. Beams **13** are each comprised of a pair of channel irons spaced apart to provide space for the links **8** to pass therebetween.

Each end of the shaft **5** carries a flanged hub **15** (Fig. III) carrying eccentric weights **16**. The shaft **5** is rotated by a drive motor **17** connected through a belt **18** to a pulley **19** carried on an eccentric extension **20** of the shaft **5**.

As may be seen in Fig. III, the generally annular container **1** has a central pipe-like portion **22** to provide space through the container **1** for the shaft **5**. The clearance between the shaft **5** and the inside of the pipe member **22** is sufficient to accommodate the vibration of the container **1** with respect to the shaft. The end bells **2**, as may be seen in Figs. I and II, in end elevation are sixteen-sided polygons there being one side for each of the sixteen coil springs **4** for connecting the end bell to the exciter member **3**. The walls of the end bells **2** are reenforced by gusset plates **23** and an annular plate **24** closing the outer margin of the mouth of the bell so as to make a rigid structure having a plurality of pockets to receive the radially outer ends of the springs **4**. The gusset plates are shaped, as may be seen in Fig. III, so that sufficient space is left radially within the cup-shaped bells **2** to accommodate the exciter members **3**.

The exciter members **3**, as may be seen in Fig. III, are also annular cup-shaped structures having a pipe-center **26**, a cup shaped body **27** and a marginal inwardly directed flange **28**. The walls of the member adjacent the inwardly directed flange **28** consists of surfaces parallel to the shaft **5** forming a sixteen-sided polygon corresponding to the shape of the end bells **2**. The springs **4** seat on the flat sides of the exciter member and are rigidly attached thereto. The exciter members 3 include bearings 29 for journaling the members on the shaft 5. For rigidity a number of gusset plates 30 are provided to extend radially from the pipe-center 26 to the outer marginal flange 28 and the sixteen-sided periphery of the exciter members 3. The weight of the exciter members may be adjusted by attaching extra weights preferably in the form of steel plates to the marginal flange 28.

Preferably the two exciter members 3 are adjusted to the same weight to keep the system symmetrical and the combined weight of the exciter members including the drive shaft 5 and weights 16 is preferably in the range between a high limit equal to the weight of the container 1 plus the end bells 2 to a low limit equal to one-tenth of that amount. Thus the ratio of weights of the exciter members to the container plus end bells may vary from 1:1 to 1:10. The springs 4 are selected so that they may cooperate with the end bells 2 and exciter members 3 to form a vibratory system having a natural frequency at the desired operating speed.

This system may execute various types of vibration depending upon the operating speed of the shaft 5. In the desired mode of operation in which the shaft 5 is turned at a speed corresponding to the natural frequency of the resonant system the unbalanced weights 16 provide a centrifugal force that drives the exciter members in orbital paths. This motion of the exciter members in orbital paths generates a centrifugal force acting through their centers of gravity and directed radially outward from the center of the orbital path. Since the centrifugal force is proportional to the radius of the orbital path of the center of gravity it follows that this force increases directly as the amplitude of the motion, that is, the radius of the path. The radius of the orbit is also controlled by the stiffness of the springs 4 and mass of the container 1. If these are selected to provide a natural frequency at the speed of operation as mentioned above then, at this critical speed, the rate of the springs is such that the increase in force from compression of the springs exactly balances the increase in centrifugal force as the radius of the orbital path increases. This is an unstable condition that corresponds to the large amplitude of motion of a linear vibrating system when operated at its natural frequency.

Below this operating speed the mass of the container 1 and the stiffness of the springs 4 tend to restrict the motion or radius of the path of movement of the exciter members 3. At this natural frequency, when the rate of the springs 4 corresponds to the rate of increase of the centrifugal force for a given change in amplitude of the orbital path, the system is unstable corresponding to the resonance condition of a linear system and above this speed the exciter members move only in proportion to the movement of the weights 16 thus limiting the amplitude of vibration.

In this type of vibration generator the force transmitted from the eccentrically loaded rotating shaft 5 through the bearings 29 to the exciter members and through the bearings 6 to the light frame 7 is small compared to the forces transmitted through the springs 4 to the container 1. This difference in magnitude of the forces results from the balancing of the spring force against inertia in what corresponds to a resonant system. Likewise, the distribution of force through the plurality of springs 4 from the exciter members 3 to the end bells 2 prevents any stress concentration in small sections of the structure which would tend to cause failure of such sections.

Another feature of this type of construction is the fact that the assembly of the container 1 plus end bells 2 and exciter members 3 may be rotated continuously on the bearings 29. This makes it possible to use a single access opening 32 in the side of the cylindrical annular container 1 for both loading and unloading the container by positioning such access opening at the top when it is desired to load material into the container and by rotating the container to position the access opening 32 at the bottom when it is desired to discharge the material. Ordinarily the access opening 32 is covered with a cover 33 and the annular container 1 is allowed to rotate slowly under the influence of the orbital vibration acting on the load within the container. This vibration tends to move the load relative to the container much as a conveyor moves a load along the length of the conveyor. This provides thorough mixing of the articles to be processed and the treating medium or processing medium in the container so that all of the material is active in the process.

To prevent or minimize variations in tension in the belt 18 as the shaft 5 vibrates the eccentric extension 20 is provided on the shaft 5 so that the pulley 19 runs eccentrically with respect to the shaft. This eccentricity is in the same direction as the unbalanced weights 16 and the amount of the eccentricity is preferably selected so that the center line or axis of the pulley 19 remains substantially fixed in space as the shaft rotates and revolves about its orbital path along with the orbital motion of the exciter members 3.

As was mentioned the container 1, if unrestrained, rotates under the combined influence of the vibration and load. While this provides good mixing when operating on some materials, other materials tend to stratify with the heavier and finer materials going to the bottom and the larger and lighter particles or pieces of material moving to the top.

This condition can be corrected by positively rotating the container at a slow speed and, if desired, forming the container as a polygon with few sides in lieu of the generally circular form. Such an arrangement is shown in Figs. V and VI.

In this embodiment an annular container 40, having a cylindrical inner tube or wall 41 and a polygonal outer wall 42, is supported on a plurality of coil springs 43 extending radially between inner surfaces of end bells 44 of the container 40 and juxtaposed surfaces of exciter masses 45. The exciter masses 45 are journaled on a shaft 46 which, in turn, is journaled in resiliently supported bearings 47 similar to the bearings 6 shown in Fig. III.

The shaft 46 is belt connected to a drive motor 48 and is equipped with unbalanced weights 49 serving to produce orbital vibration of the exciter masses 45 when the shaft is driven at a suitable speed.

This system is proportioned and tuned the same as the system shown in Figs. I, II and III so that the exciter masses 45 execute relatively large amplitude vibrations while the container 40 moves at the same frequency but at a smaller amplitude of motion.

This system differs from that illustrated in Figs. I, II and III, in that a second motor 50 equipped with a geared speed reducer 51 is belt connected to one of the end bells 44. The motor 50 is preferably reversible so that the container 40 may be rotated either with or contra to the rotation produced by the vibration. The positive rotation of the container 40 in combination with the non-circular periphery of the chamber produces a physical mixing of the materials in the container that is quite effective in preventing the stratification that otherwise occurs.

Preferably the speed of rotation of the container is less than one hundred revolutions per minute. If there is little tendency toward stratification the speed can be very low. Conversely higher speeds are required to maintain uniformity in mixtures being processed in the container if it stratifies readily.

The combination of the intense vibration made possible by the tuned exciter system combined with the thorough mixing action of the slow rotation of the container provide a very effective polishing or burnishing operation. Furthermore, the combination of exciter members resiliently connected to the container and eccentric weight shaft journaled in the exciter members makes it possible to satisfactorily operate commercial sizes of vibratory tumbling mills with a minimum of power and without overstressing any portion of the apparatus.

Various modifications may be made in the specific structure of the vibratory tumbling mill without departing from the spirit or scope of the invention.

I claim:

1. In a vibratory tumbling mill, in combination, a drive shaft, a plurality of resiliently mounted bearings for supporting the drive shaft, a pair of eccentric weights mounted on the drive shaft, a plurality of exciter masses journaled on the drive shaft, a container that is annular in transverse section loosely sleeved over the drive shaft, said container having end bells partially enclosing the exciters and a plurality of springs extending generally radially of the drive shaft from the exciter masses to the container end bells for supporting the container and cooperating with the container and the exciter masses to form a vibratory system, and means for rotating the drive shaft at a speed substantially equal to the natural frequency of the vibratory system.

2. In a vibratory tumbling mill, in combination, a drive shaft, a plurality of resiliently mounted bearings for supporting the drive shaft, a pair of eccentric weights mounted on the drive shaft, a pair of exciter masses journaled on the drive shaft, an annular container that is loosely sleeved over the drive shaft, a plurality of springs arranged to support the container from the exciter masses and form with the exciter masses and container a vibratory system having a natural frequency, and means for rotating the drive shaft at a speed generally equal to the natural frequency.

3. In a vibratory tumbling mill, in combination, a drive shaft, a plurality of resiliently mounted bearings for supporting the drive shaft, a pair of eccentric weights mounted on the drive shaft, a pair of exciter masses journaled on the drive shaft, each of the exciter masses having a plurality of spring seats arranged symmetrically about its periphery, an annular container loosely sleeved on the drive shaft, said container having a pair of end bells partially enclosing the exciter members, each end bell having a plurality of spring seats opposed to the spring seats of the corresponding exciter mass, a plurality of coil springs interposed between the spring seats, said springs cooperating with the exciter mass and container to form a vibratory system having a natural frequency, and means for rotating the shaft at a speed generally equal to the natural frequency of the vibratory system.

4. In a vibratory tumbling mill, in combination, a drive shaft, a plurality of resiliently mounted bearings for supporting the drive shaft, a pair of eccentric weights mounted on the drive shaft, an exciter mass journaled on the drive shaft, an annular container loosely sleeved over the drive shaft, a plurality of springs coupling the container to the exciter mass for supporting the container and cooperating with the container and exciter mass to form a vibratory system having a natural frequency, said springs being symmetrical about the axis of the exciter mass and annular container whereby orbital vibration of the container may be produced, and means for rotating the drive shaft at a speed substantially equal to said natural frequency.

5. In a vibrating tumbling mill, in combination, a drive shaft, a plurality of resiliently mounted bearings for supporting the drive shaft, at least one eccentric weight mounted on the drive shaft, at least one exciter mass journaled on the drive shaft, an annular container loosely sleeved over the drive shaft, said container having a mass at least equal to the mass of the exciter, a plurality of springs that support the container from the exciter mass and that form with said container and mass a vibratory system having a natural frequency, and means for driving the shaft at a speed generally equal to said natural frequency.

6. In a vibrating tumbling mill, in combination, a drive shaft, a plurality of resiliently mounted bearings that support the drive shaft, at least one eccentric weight mounted on the drive shaft, at least one exciter journaled on the drive shaft, an annular container that is loosely sleeved over the drive shaft, a plurality of springs for supporting the container from the exciter and forming with the exciter and container a vibratory system having a natural frequency, said exciter and container being rotatable as a unit on the drive shaft to accommodate changes in load position in the container, and means for rotating the drive shaft at a speed generally equal to said natural frequency to excite orbital vibration of the exciter and container.

7. In a vibratory tumbling mill, in combination, a drive shaft, a plurality of resiliently mounted bearings that support the drive shaft, at least two eccentric weights mounted on the drive shaft, a pair of exciter members journaled on the drive shaft in proximity to the bearings and eccentric weights, an annular container sleeved over the drive shaft and having portions adjacent the exciter members, a plurality of springs connecting the exciter members to adjacent container portions and forming with the container and exciter members a vibratory system having a natural frequency, said exciter members, springs and container being symmetrical with respect to the drive shaft and rotatable on the shaft as an axle, and means for rotating the drive shaft at a speed generally equal to said natural frequency.

8. A vibratory tumbling mill according to claim 7 in which the mass of the container is at least equal to the sum of the masses of the exciter members.

9. A vibratory tumbling mill according to claim 7 in which the mass of the container is not less than twice and not more than ten times the sum of the masses of the exciter members.

10. In a vibratory tumbling mill, in combination, a drive shaft, a plurality of resiliently mounted bearings for supporting the drive shaft, a pair of eccentric weights mounted on the drive shaft, a plurality of exciter masses journaled on the drive shaft, a container that is annular in transverse section loosely sleeved over the drive shaft, said container having end bells partially enclosing the exciters and a plurality of springs extending generally radially of the drive shaft from the exciter masses to the container end bells for supporting the container and cooperating with the container and the exciter masses to form a vibratory system, means for rotating the drive shaft at a speed substantially equal to the natural frequency of the vibratory system, and means for rotating the container.

11. In a vibrating tumbling mill, in combination, a drive shaft, a plurality of resiliently mounted bearings for supporting the drive shaft, at least one eccentric weight mounted on the drive shaft, at least one exciter mass journaled on the drive shaft, an annular container loosely sleeved over the drive shaft, said container having a mass at least equal to the mass of the exciter, a plurality of springs that support the container from the exciter mass and that form with said container and mass a vibratory system having a natural frequency, means for driving the shaft at a speed generally equal to said natural frequency, and means for rotating the container.

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