

May 14, 1940.

S. D. ROBINS

2,200,724

MEANS FOR PRODUCING GYRATORY MOTION

Filed Jan. 18, 1937

3 Sheets-Sheet 1

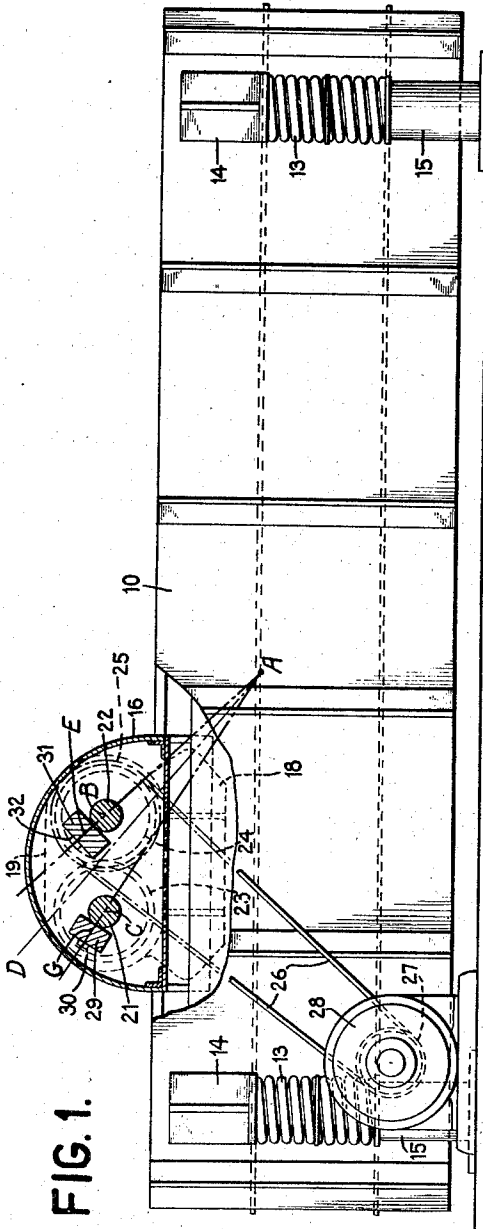
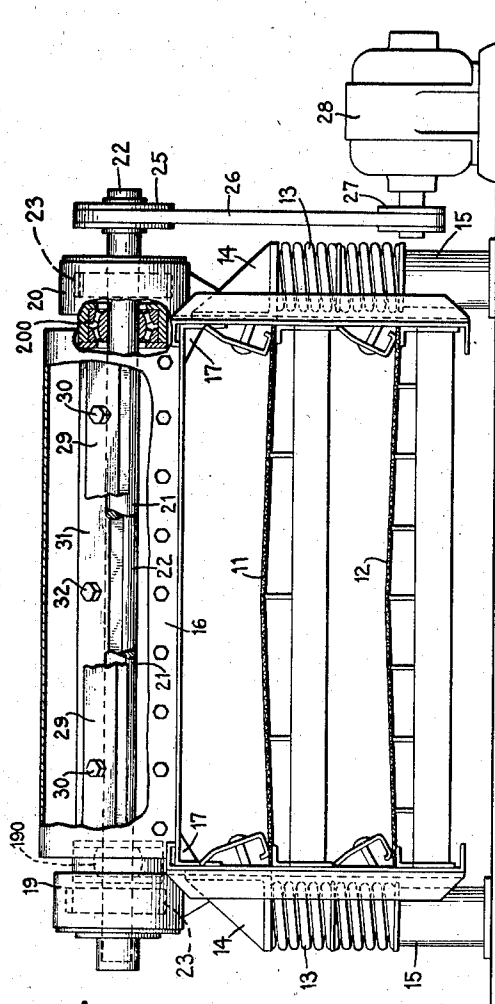


FIG. 2.



INVENTOR
SAMUEL D. ROBINS

BY *H. C. Hiebing*
ATTORNEY

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S. D. ROBINS

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FIG. 3.

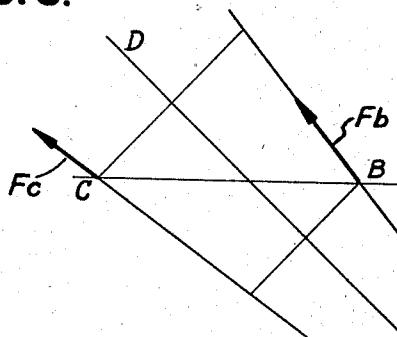


FIG. 4.

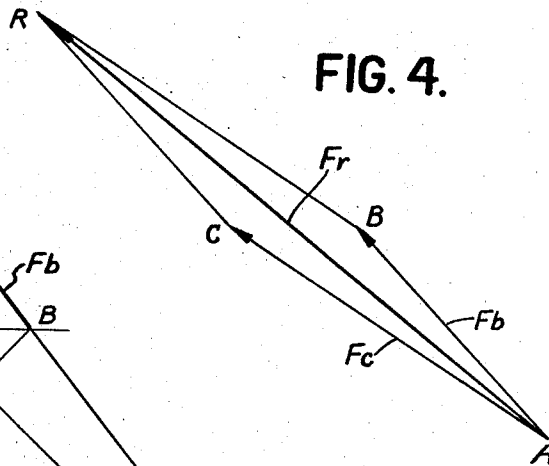


FIG. 5.

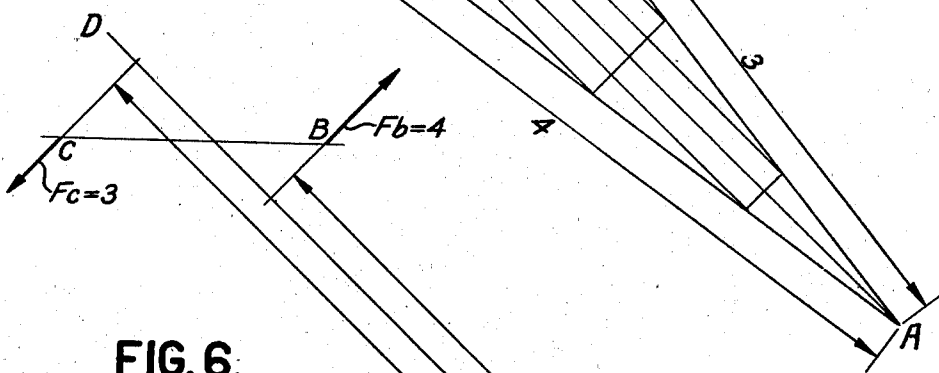
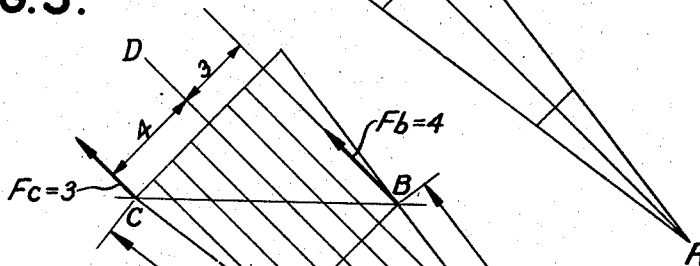


FIG. 6.

INVENTOR
SAMUEL D. ROBINS

BY *H. C. H. H.*
ATTORNEY

May 14, 1940.

S. D. ROBINS

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FIG. 7.

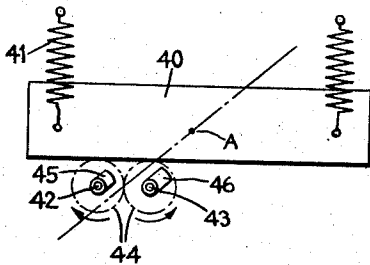


FIG. 8.

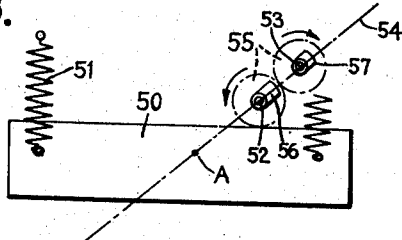


FIG. 9.

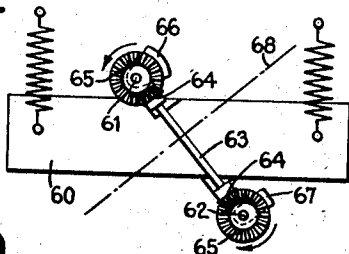


FIG. 10.

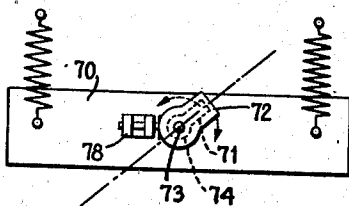


FIG. 10a.

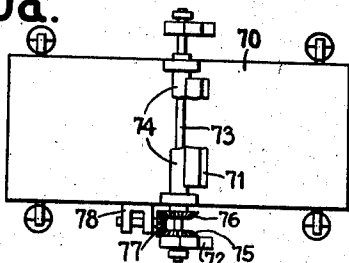


FIG. 11.

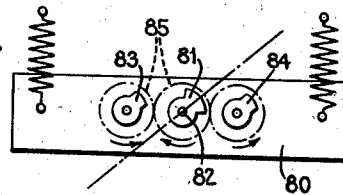


FIG. 12.

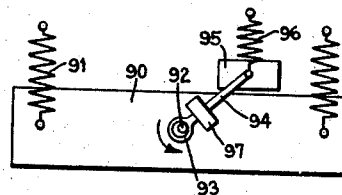


FIG. 13.

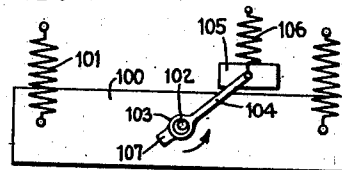


FIG. 14.

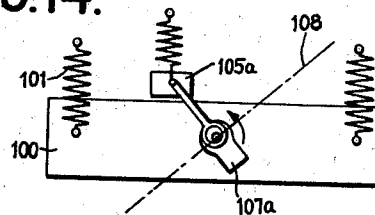


FIG. 15.

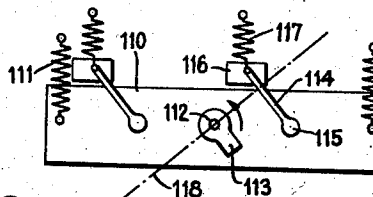
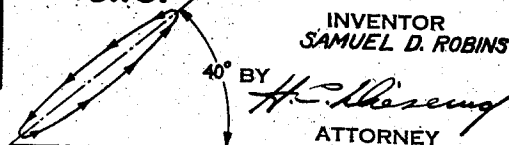


FIG. 16.



INVENTOR
SAMUEL D. ROBINS

BY *H. H. Moser*
ATTORNEY

UNITED STATES PATENT OFFICE

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MEANS FOR PRODUCING GYRATORY MOTION

Samuel D. Robins, New York, N. Y.

Application January 18, 1937, Serial No. 121,077

29 Claims. (Cl. 74-87)

This invention relates to an improved means of imparting a gyratory movement to a freely suspended body or a body otherwise supported for movement in a gyratory path. A particular application of the invention is the production, by the improved means, of a gyratory motion in a screen used for screening coal, stone and the like.

An important feature of the invention is the production of a gyratory motion through a non-circular orbit. This is especially useful in connection with screens.

Heretofore screens have ordinarily been given either a so-called straight line, reciprocatory motion or a circular, gyratory motion. Each of these has certain advantages over the other. A reciprocatory screen has the advantage of more rapidly advancing the material along its surface. However, in doing this there is the danger that material of a size that should pass through the openings of the screen will not do so because it is not presented to any of the openings in quite the right way. A gyratory screen having a circular motion has the advantage of causing the lumps of material, particularly the larger ones, to turn or roll over as they progress and thus they are presented in a variety of different positions to the successive openings. This effects a very good separation of the material into the desired classifications. However, a gyratory screen of this type will advance the material only very slowly unless it is disposed at a fairly steep angle to the horizontal. Sufficient head room is not always available to bring about a desired feeding action.

By imparting a non-circular, substantially elliptical, gyratory motion to a screen the combined advantages of a reciprocatory and circular motion are obtained. A very rapid feeding action is obtained with the screen surface arranged horizontally and at the same time the gyratory motion tends to turn or rotate the lumps so that a very good separation between the different sizes is effected. For uniform and most satisfactory results the motion of the entire screen should be uniform, i. e., all portions of the screen should describe the same path.

A special object of the invention has been to provide particularly simple but effective means for producing a smooth, uniform, non-circular or elliptical, gyratory motion of a screen or other body. This, I accomplish by freely supporting the screen for movement in all directions and imparting to it the effect of a resultant force which is constantly changing in direction and

magnitude applied at its center of gravity. If the resultant force applied at the center of gravity of the screen were indicated as vectors radiating from a point, representing the center of gravity, a line connecting the ends of the vectors would indicate the path or orbit traced by every point on the screen, and this, according to the present invention, would be substantially in the form of an ellipse. Such a resultant of constantly changing direction and magnitude may conveniently be produced by imparting to the screen a rotating force of constant magnitude and at the same time imparting to the screen another force designed to work against and partially counteract or modify the rotating force as the latter passes through its cycle. This may be accomplished in a variety of different ways. The constant rotating force may most easily be created by the rotation of a mass about a point removed from its center, the mass being carried in a suitable way by the body to be gyrated. The modifying force may be created in a simple way, by a non-rotating inertia mass arranged to increase the inertia of the body or its resistance to movement to a greater extent in certain directions than in others. Or the modifying force may be imparted by another rotating mass of appropriate magnitude and in suitable relation to the first rotating mass to provide the desired resultant effect at the center of gravity of the body.

In the preferred arrangement the desired gyratory motion is brought about through the rotation, in opposite directions, of masses of different magnitude or otherwise capable of establishing centrifugal forces of different magnitude. The masses may be arranged to apply their centrifugal forces to the screen or other body directly at the center of gravity of the latter or at points removed from such center but so selected that no moments will be set up about said center. The two masses should be rotated at the same speed to insure a desired synchronous relation between them and their relation should be such that their centrifugal forces at certain instants are created along the same or parallel lines so as to be directly combined in their effects at a chosen angle to the horizontal. For example, I have found that a very desirable screening action is produced by a substantially elliptical motion, the major axis of which is disposed at an angle of about 40° to the horizontal. This may be accomplished by a pair of counter-rotating forces if the forces are coincident or parallel and combined along the desired 40° line

and are coincident or parallel and opposed along a line at right angles to said 40° line.

It will be understood that if the centrifugal forces are applied to the body directly at its center of gravity, no turning moments will be created and the form of the gyratory path of the body will be determined by the relative magnitude of the forces, their sums determining the major axis and their differences the minor axis of the elliptical path or orbit. However, it is not generally convenient to apply the centrifugal forces to a screen directly at the center of gravity or directly in line with such center at opposite sides of the screen. This is for the reason that a shaft extending through the screen at this point will ordinarily fall in or near the path of travel of the material to be screened. Accordingly, a special feature of the invention is the provision of an arrangement by which rotating forces of unequal magnitude may be applied to the screen, or other body, at points removed from its center of gravity and in such a way that a uniform motion will be imparted to all parts of the screen. This I preferably accomplish by establishing certain definite relationships between a pair of revolving masses and the center of gravity of the body to be gyrated. The masses are mounted on the body and impart their centrifugal forces to the body at their centers of rotation, these being spaced from the center of gravity of the body at distances inversely proportional to the magnitude of the centrifugal forces. The unequal centrifugal forces created by the revolving masses are at times directly combined and at other times directly opposed while between these two conditions they have components that combine and components that oppose each other, and the net effect is the resultant of the two forces that is ever-changing in direction and amount. Throughout the continual change in direction of the two forces their relation to the center of gravity of the screen is such that no moments are created about this center.

Other objects, features and advantages of the invention will appear from the detailed description of an illustrative form of the same, as applied to a screen structure, which will now be given in conjunction with the accompanying drawings, in which:

Figure 1 is a side elevation of a screen embodying the invention, a portion being broken away to show in section certain of the operating devices.

Figure 2 is a front elevation of the screen with a portion broken away to disclose the operating devices.

Figure 3 is a diagram illustrating the relationship between certain forces created by the operating devices at one instant in the operation of the screen.

Figure 4 is a diagram resolving the forces of Figure 3 and showing the resultant thereof.

Figure 5 is a view similar to Figure 3, showing the forces existing at a different instant in the operation of the screen.

Figure 6 is a similar force diagram indicating the relationship of the forces after they have passed through 90° from the position indicated in Figure 5.

Figures 7 to 11, inclusive, are schematic views indicating a variety of different arrangements for applying counter-rotating forces to a freely suspended screen frame.

Figures 12 to 15, inclusive, are similar schematic views showing means for imparting an elliptic

motion to a screen through the use of one or more inertia masses, and

Figure 16 is a diagram illustrating the orbital path of each and every point on a screen operated in accordance with Figures 7 to 15, inclusive.

Referring now to the drawings, and more particularly Figs. 1 and 2, there is shown a screen structure including a frame 10 adapted to receive a gyratory motion of the improved type. This frame may be of any suitable construction, and, by way of example, may be provided with a pair of screening surfaces 11 and 12 extending horizontally across the same throughout the length of the frame. The screen elements 11 and 12 may be of any suitable construction and may be secured to the frame in any convenient manner.

Adjacent each of the four corners of the frame there is provided a supporting spring 13 which at its upper end is engaged by a bracket 14 bolted or otherwise secured to the side of the frame. At its lower end each spring engages the top of a suitable support 15 secured to an appropriate foundation, the members 15 and the foundation constituting a main supporting frame. The springs 13 are preferably quite soft and readily compressible so that the natural period of vibration of the springs and supported mass will be low. This will prevent any danger of undue interference with the vibration of the screen at the desired speed and at the same time offers a good insulation against the transmission of vibrations from the live frame to the supporting structure. As indicated, each spring, if desired, may be formed in two sections having a thin plate inserted between their abutting ends.

The devices for imparting a gyratory movement to the screen frame are carried by a housing 16 which extends across the top of the frame and is supported by the latter. It may be secured to the frame in any suitable way, as by means of brackets 17 extending inwardly from the side walls of the frame and plates 18 extending upwardly from the outer faces of these walls. Housings 19 and 20, at the opposite ends of the housing 16, provide bearings 190 and 200 for a pair of shafts 21 and 22, which extend across the top of the frame 10 within the housing 16. These housings 19 and 20, which are firmly secured to the frame 10, furthermore, enclose inter-meshing gears 23 and 24 secured to the opposite ends of the shafts 21 and 22. A pulley 25 secured to an extension of the shaft 22 is connected by a belt 26 with a pulley 27 carried by the shaft of a motor 28, or is otherwise connected with a suitable source of power.

A bar 29 of appropriately chosen mass extends longitudinally of the shaft 21 substantially the full distance between the shaft bearings. This bar may be secured to the shaft in any suitable way, as by means of bolts 30. Similarly, a bar 31 extending longitudinally of the shaft 22 may be secured thereto by means of bolts 32. As best indicated in Figure 1, the bars 29 and 31 are of different sizes in cross-section, so as to provide masses of different magnitude adapted to be revolved, respectively, about the axes of the shafts 21 and 22. The gearing 23, 24 is such that the two shafts will rotate at the same angular speed but in opposite directions. As they are rotated, centrifugal forces will be developed which for each mass at any instant will be along a radial line connecting the center of the mass with the axis of rotation. Thus, if B designates the axis

of the shaft 22 and E designates the center of the mass 31, the centrifugal force will always be radially outward along the line BE, the direction of which is, of course, constantly changing. Similarly, if C designates the axis of the shaft 21 and G designates the center of the mass 29, an outward, radial force will be created along the line CG in the course of rotating the shaft 21. For reasons to be presently explained, a definite, angular relationship should exist between the lines BE and CG. Assuming that the center of gravity of the frame 10 together with the superposed operating mechanism, all of which constitutes what may be designated the live frame, is located at the point designated A in Fig. 1, the masses 29 and 31 should be so located that when a straight line may be drawn through the points A, B and E, a straight line may similarly be drawn through the points A, C and G. This means that when the centrifugal force created by one of the masses passes directly through the center of gravity, the centrifugal force created by the other mass will do likewise. Another relationship which should exist between the parts is that the distance from A to B should be to the distance from A to C as the centrifugal force produced by the bar 29 is to the centrifugal force produced by the bar 31. In other words, these centrifugal forces should be inversely proportional to the distances of the centers of rotation of the masses producing them from the center of gravity of the frame structure. In the construction illustrated, the centers of the two masses are equally distant from their axes of rotation, i. e., the distances BE and CG are the same. Accordingly, the masses themselves are inversely proportional to the distances of their axes of rotation from the center of gravity of the frame. In lieu of selecting masses of different magnitude, the distance from B to E might be made greater than the distance from C to G so that the centrifugal forces created by masses of equal magnitude and rotated at the same speed would be inversely proportional to the distances from the points of application of these forces to the center of gravity of the frame.

As a specific example of a construction which I have found to be quite satisfactory, the masses 29 and 31 may be in the ratio of 3 to 4 and the distances AB and AC should then also be in the ratio of 3 to 4. Assuming now that the masses are being rotated in opposite directions at an appropriate speed, say 1100 R. P. M., the forces existing at an instant when the points A, B and E are aligned are illustrated in Figure 3. Here the force created by the mass 31 is indicated by arrow Fb while the force created by the mass 29 is indicated by the arrow Fc. Since these forces pass directly through the center of gravity of the frame, it will be apparent that no turning moment will be applied to the frame and the effect will be merely to impart a translational movement to the entire frame. This movement will be in proportion to the resultant of the two forces. Referring to Figure 4, wherein the forces are indicated on a larger scale, the resultant is designated by the arrow Fr. Its magnitude is nearly but not quite the maximum that is applied to the screen.

Figure 5 indicates diagrammatically the direction and magnitude of the forces when their resultant is greatest. This is when the two forces are acting in the same direction along parallel lines. Considering the typical construction mentioned above, in which the two forces Fb and Fc

are in the ratio of 4 to 3, i. e., the force Fb created by the rotation of the mass 31 is four units and the force Fc created by rotation of the mass 29 is three units, the distance AB will be three units while the distance AC will be four units. Accordingly, it will be clear from Fig. 5 that the moment arms of the forces Fb and Fc with respect to the center of gravity A are in the ratio of three to four and, therefore, the product of one force times its moment arm will be the same as the product of the other force times its moment arm, and there will be no turning moment created about the center of gravity of the body. The resultant force tending to impart bodily movement to the screen will be at its maximum, i. e., the sum of the two forces or seven units. In arriving at the positions indicated by Fig. 5 the centers E and G of the masses 31 and 29 will have turned from the positions indicated in Figs. 1 and 3 through half of the angle BAC. Accordingly, this maximum force created under the conditions indicated in Fig. 5 will be in a direction parallel with the line AD (Figs. 1 and 3) which bisects the angle BAC. Very good screening results will be obtained if this line is disposed at an angle of about 40° to the horizontal, although this may be varied considerably to suit particular requirements.

The relation of the forces after a rotation of the masses 29 and 31 through an angle of 90° from the position indicated in Fig. 5 is shown diagrammatically in Fig. 6. Inasmuch as the masses are rotating at the same angular velocity, the magnitude of the forces will remain the same, i. e., force Fb will continually remain at four units and the force Fc will remain at three units. Moreover, the moment arm of the two forces will remain in the same relation and the forces will tend to create turning moments of equal magnitude in opposite directions about the center of gravity of the frame. Accordingly, there will be no tendency for the frame to rotate about its center of gravity. Since the direction of the forces is diametrically opposite, the resultant will be in the direction of the greater force and parallel with the two forces and will have a magnitude equal to the difference between the two forces. In the typical example illustrated, this resultant will be one unit.

Any number of force diagrams may be drawn to indicate the relation between the two rotating forces at points intermediate those indicated in Figs. 3, 5 and 6. It will be found in all cases that the turning moments about the center of gravity of the body are balanced and if the resultants of the two forces with respect to this center are plotted and a line is drawn through the ends of the arrows, it will be found that a substantially elliptical configuration will be produced, the major axis of the ellipse being seven units in length and the minor axis being one unit. Since the screen frame 10 is supported for relatively free movement in all directions, it will be apparent that the constantly changing resultant, changing not only in direction but in magnitude, will impart a corresponding change in the movement of the frame. After the frame has been set into motion at the desired speed, it will be found to follow through a smooth, substantially elliptical, gyratory path, whose major axis is in the direction AD. As previously stated, the motion so produced has been found ideally suited for the screening of coal, stone and the like. It will be noted that the belt 26 is arranged to extend substantially perpendicular to the major axis AD.

Accordingly, movement of the screen along this major axis will have little or no effect upon the tension of the belt. At the same time the movement of the screen along the minor axis is so small that it is readily permitted by the belt and does not appreciably interfere with the drive of the belt.

A more uniform action of the screen is insured if the upper ends of the springs 13, i. e., the points at which they support the screen frame, are in a plane passing substantially through the center of gravity of the frame.

In a typical unit constructed in accordance with the foregoing, the screen frame together with the gyrating mechanism mounted thereon may weigh, say, one ton. The masses 29 and 31 may suitably be about 75 pounds and 100 pounds, respectively. When these are rotated at a speed of about 1100 R. P. M. an elliptical motion having a major axis slightly under half an inch and a minor axis of about $\frac{1}{8}$ of an inch will be produced. The masses may be rotated in either direction but I have found that most efficient screening will take place if the rotation is such as to produce a motion of the screen frame counter to the movement of the material along its surface. This means that if the material advances from right to left in Figure 1, the mass 29 should be revolved counter-clockwise and the mass 31 clockwise. I have found that the rate of advance of the material along the screen is substantially the same, i. e., about four feet in five seconds, whether the masses are rotated as specified or in the opposite directions. However, the separation of the material is markedly more efficient when the motion of the screen is counter to the movement of the material than when it is in the direction of this movement.

Referring now to Figures 7 to 15, inclusive, there is illustrated schematically a number of modified constructions for accomplishing substantially the same result, i. e., the production of a uniform, substantially elliptic motion. In each of these modifications the arrangement is such as to produce an elliptic motion of the type illustrated in Figure 16, with its major axis inclined at an angle of about 40° to the horizontal in the direction indicated. The ratio of major to minor axis may, however, be varied in each case to suit the particular requirements.

In Figure 7 there is shown a slightly different arrangement particularly suited for use at points at which a smaller amount of head room is available. The screen frame 40 in lieu of being supported from below, may be resiliently suspended from above by means of a series of soft springs 41, one at each corner of the frame, having a very low natural period. A pair of shafts 42 and 43, mounted in suitable bearings secured to the under side of the frame, are geared together by means of gears 44 for rotation in synchronism. The shafts may be driven in any suitable way, as by means of a pulley secured to one of the shafts and a belt connecting it with a source of power in the manner shown in Figures 1 and 2. A mass 45 on the shaft 42 and a mass 46 on the shaft 43 are revolved in opposite directions to create forces of unequal magnitude radially outward from the axes of the respective shafts, these forces being inversely proportional to the distances of the shaft axes from the center of gravity of the frame. The other relationships, explained in connection with the forces in Figures 1 and 2, are also maintained.

Should it be desired to provide an elliptic mo-

tion having a smaller ratio between the major and minor axes, the arrangement shown in Figure 8 may be adopted. The screen 50 may be resiliently supported or suspended by soft springs 51. A pair of shafts 52 and 53, mounted on the frame, are disposed along the line 54 which extends through the center of gravity of the frame at an angle of 40° to the horizontal or whatever other angle is chosen as the major axis of the elliptic motion. It is readily possible with this arrangement to produce an ellipse having a five to one ratio between the major and minor axes without incurring too high tooth velocities on gears 55 connecting the shafts. Thus, the axis of shaft 52 may be two units removed from the center of gravity of the frame while the axis of shaft 53 may be three units removed from said center. Masses 56 and 57, secured to the shafts 52 and 53, respectively, will then be in the ratio of three to two and they will be so positioned as to have their centers simultaneously along the line 54 in the course of rotation.

Figure 9 illustrates another arrangement by which a smaller ratio between the major and minor axes of the ellipse may be produced. In lieu of gearing the shafts 61 and 62, mounted on the frame 60, directly together, they are here connected by means of a shaft 63. Bevel pinions 64 at each end of the shaft 63 mesh with bevel gears 65 on the shafts 61 and 62. These shafts may be disposed at any appropriate points either above or below the frame or one above and one below, as shown. They should, of course, be so disposed that the line bisecting the angle formed between lines connecting the axes of the shafts with the center of gravity of the frame will be in the direction desired for the major axis of the elliptic motion. When the shafts are arranged as shown, the shaft 63 will be disposed along the minor axis of the ellipse. As in the prior constructions, the centrifugal forces produced by the masses 66 and 67 should be inversely proportional to the distances of the axes of the shafts 61 and 62 from the center of gravity 68 of the frame. This arrangement might readily be utilized to provide a three to one ellipse by adopting a two to one ratio between the masses.

In Figure 10 there is schematically shown an arrangement in which the unequal masses 71 and 72 are revolved about the center of gravity of the frame 70. These masses may, if desired, both extend longitudinally of their concentric shafts. However, this will necessitate the provision of a large tube as the shaft for the outer mass, sufficient to allow the inner mass to rotate within it. Accordingly, I prefer to mount one of the masses, preferably the smaller mass 72, at each of the ends of a shaft 73 and the other or larger mass 71 either at the ends of or distributed along the hollow shaft 74 surrounding shaft 73. Any suitable gearing may be employed to connect the shafts 73 and 74 for synchronous rotation in opposite directions. For example, as best shown in Figure 10a, gears 75 and 76 of the same diameter secured to the ends of the shafts 73 and 74, respectively, may be connected by a bevel pinion 77 rotatable in a suitable bracket 78 secured to the side of the frame 70. Either shaft may be driven through a belt and pulley drive of the type shown in Figures 1 and 2. This arrangement allows conveniently for any desired form of elliptic motion since the masses may be of any chosen magnitude. In fact, they may be readily replaceable or interchangeable.

so that ellipses of different ratios between major and minor axes may be produced.

A variation of the Figure 10 arrangement is shown in Figure 11. Here, one mass 81 is mounted upon a shaft 82 carried by the frame 80 at its center of gravity. In lieu of a single second mass of different magnitude from mass 81, a pair of equal masses 83 and 84 are provided, these having a combined mass different from, preferably greater than, the mass 81. All three of the masses are rotated at the same speed by gearing 85, the masses 83 and 84 being driven in the same direction and mass 81 in the opposite direction. The axes about which the masses 83 and 84 are revolved are at equal distances on opposite sides of the center of gravity of the frame; accordingly they provide equal and opposite moments about the center of gravity and there is no tendency to rotate the frame. The masses may be of any chosen magnitude to provide an elliptic motion of desired proportions. They may be disposed either along the shafts or simply at the ends, depending upon the need for conserving vertical space. When the masses in this type of construction extend along the shafts of a multi-deck screen, it is necessary to increase somewhat the spacing between the decks to allow for the free passage of the material along the lower deck without interference with the revolving masses.

The foregoing are some of the variations that may be made to provide elliptic motion through the use of counter-rotating forces. It will be apparent that a variety of other modifications may be made involving different combinations of the various features disclosed and other variations will suggest themselves to those skilled in the art.

Means not involving counter-rotating forces may also be employed to produce the desired elliptic motion. In the form schematically shown in Figure 12, for example, no rotating mass whatever is employed. The screen 90, suspended by means of soft springs 91 at the four corners, has a rotating shaft 92 extending transversely of the screen through its center of gravity. An eccentric 93, secured to the shaft adjacent its end, coacts with a strap portion of an arm 94. Adjacent its free end the arm 94 is secured to an inertia mass 95 which extends across the top of the screen and is suspended from any suitable support by means of a spring 96. Arm 94 preferably extends through the center of the end of the mass and this mass, preferably, has a magnitude substantially equal to that of the frame 90. A second or auxiliary mass 97 of considerably smaller magnitude, say about 10% of the mass 95, is slidable along the arm 94 and may be locked in any adjusted position by a set-screw or in some other convenient way. It will be understood that the arrangement of eccentric, arm and auxiliary mass is duplicated at the opposite side of the screen so as to provide balanced forces at the two sides.

Now, as the eccentric 93 is rotated, the screen frame and the inertia mass 95 will be alternately forced apart and drawn together. If the mass 97 were omitted, this would result in a substantially straight-line reciprocation of the screen frame in the direction of the arm 94. However, the mass 97 induces a considerable deviation from a straight-line motion, the ratio of the longitudinal to the transverse movement varying with the magnitude and position of the mass 97. If the mass is relatively close to the shaft 92,

it will be apparent that a considerable relative movement perpendicular to the arm 94 will take place upon the rotation of the eccentric. The portion of this movement that will be taken by the mass itself and the portion that will be taken by the screen will depend upon the relative weights of the mass and screen. As the mass 97 is shifted along the arm 94, further away from the shaft 92, the relative motion between the mass and frame in the direction of the minor axis of the ellipse is decreased and hence the part of this motion that is taken up by the frame is correspondingly smaller. Moreover, the portion of the total, relative movement in the direction of the minor axis that is taken by the frame decreases as the mass 97 is shifted toward the mass 95 since the force which the eccentric must impart to the arm to rock it about the axis of the inertia mass decreases as the moment arm of the mass 97 with respect to this axis is made smaller. The shifting of the mass 97, therefore, provides a means of readily varying the character of the elliptic motion produced by the eccentric. The ratio between the major and minor axes of the motion produced may be varied to suit the particular requirements, either by changing the magnitude of the mass 97 in relation to the mass 95 or by changing the position of mass 97 in relation to the axis of rotation of the eccentric and the center of mass 95. Simply by way of illustration, let us assume that the two masses 97 combined are of half the magnitude of the mass 95 and the combined weight of all of the masses is equal to that of the frame 90. Let us also assume that the masses 97 are arranged substantially at the eccentric, i. e., at the center of gravity of the frame. The movement of the frame in a direction along the arm 94 will in that case be equal to the eccentricity of the eccentric since the total, relative movement between the frame and masses in this direction will be equally divided between them. In a direction at right angles to this, on the other hand, only the masses 97 will oppose the free movement of the eccentric and since these masses are only one-third the weight of the frame, the movement of the frame in this direction will be only about one-third of its movement along the arm.

Figure 13 illustrates a variation in some respects similar to the foregoing, but in which a rotating mass is employed in lieu of the mass 97. The gyratory body 100 is suspended or otherwise supported by means of relatively soft springs 101, as in the other embodiments. A shaft 102 passes transversely through the screen along its center of gravity and is rotated in any convenient way, as by means of the belt and pulley drive shown in Figures 1 and 2. An eccentric 103 is secured to the shaft 102 adjacent each end and cooperates with the strap portion of an arm 104, the upper free end of which is secured to the end of an inertia mass 105. The latter is similar to the mass 95 and is suspended from some fixed support by means of a spring 106. A mass 107 is bolted or otherwise secured to the shaft 102, preferably in the manner of the masses 29 and 31 of Figure 1. If desired, however, a pair of separate masses may be provided, one at each end of the shaft and secured thereto in any convenient way. In the operation of this form of the invention, the eccentric 103 will tend to produce a straight-line movement of the screen in the direction of the arm 104, the extent of this movement depending upon the relative weights of the screen and mass 105 and the throw of the eccen-

tric. If the screen and mass are of equal weight, the throw of the screen, as a result of the rotation of the eccentric alone, would be equal to the eccentricity of the member 103. However, the actual movement of the screen will be modified by the rotating mass 107 to an extent depending upon the centrifugal force created by this mass. Its effect will be added to that of the eccentric in the direction of the arm 104 so that the extent of movement along this line will be greater than if the mass were omitted. At the same time, however, the rotating mass will impart to the screen a motion transverse to the length of the arm 104. Accordingly, it will be seen that an elliptical motion will be produced and the ratio of the major to the minor axis of the ellipse will depend upon the magnitude of the centrifugal force created by mass 107 and by the magnitude of the inertia mass 105. An ellipse of substantially any desired proportions may be produced in this way. In a typical unit in which the frame 100 weighs a ton, the mass 105 may be, say, 1000 pounds and the mass 107 may be about 50 pounds and may be rotated at about 1100 R. P. M. Eccentric 103 may have an eccentricity of, say, one-quarter inch. An elliptic motion having a quite desirable ratio between its major and minor axes will then be produced.

Should the mass 107 be made so large that its centrifugal force will tend to impart to the screen a greater movement than the eccentric acting against the inertia mass 105, the direction of the major axis of the ellipse will be at right angles to the arm 104 rather than along this arm. This condition is illustrated in Figure 14, in which the mass 107a is indicated as of considerable magnitude. In this construction the mass 105 and the eccentric tend to restrict the movement of the screen in the direction along the arm to an amount less than the movement which the rotating mass would of itself tend to impart to the screen. For this purpose the typical unit specified above for Figure 13 might be modified to provide a somewhat smaller inertia mass 105a and to employ a rotating mass of, say, 200 pounds.

A still further modification is illustrated in Figure 15. Here the desired motion of the screen is derived from the use of a single rotating mass and one or more inertia masses having pivotal connection with the live frame. The screen or other body 110, as before, is supported or suspended by means of soft springs 111, one arranged at each of the four corners of the frame. A shaft 112 extending transversely of the screen passes through the center of gravity. A mass 113 is secured to this shaft and develops a suitable centrifugal force for gyrating the screen upon revolution of the shaft at an appropriate speed. At each side of the screen there is provided a pair of arms 114 connected pivotally with the screen at points 115, arranged in the same plane as the center of gravity of the screen and spaced equal distances from the center of gravity. At their upper ends the arms 114 are secured to inertia masses 116 suspended from any suitable support by means of springs 117. It will be apparent that as the mass 113 rotates, it will impart substantially its full effect to the screen along the line 118 whereas in a direction transverse to this, i. e., parallel with the arms 114, the centrifugal force of mass 113 will be opposed by the inertia of the masses 116. No turning moments will be applied to the screen due to the fact that the mass 113 acts upon the

screen directly at its center of gravity while the inertia masses impart their retarding effects along parallel lines and in the same direction at points equally spaced from the center of gravity and on opposite sides thereof. It is assumed, of course, that the inertia masses 116 will be of equal magnitude so that the retarding forces will be equal.

It will be clear from the foregoing that the path of movement of the screen 110 will be elliptical and the ratio of the major to the minor axis of the ellipse will depend upon the relation between the weight of the live frame and the sum of the weights 116. The larger the masses 116 in proportion to the weight of the frame, the greater will be the ratio between the major and minor axes of the ellipse. In lieu of providing two inertia masses, there may be provided a single mass connected by arms to the frame, either at its center of gravity or at points disposed symmetrically with respect thereto. Or if desired, a greater number of inertia masses may be employed, so long as care is exercised to balance the turning moments about the center of gravity of the frame. The size of the ellipse depends, of course, upon the magnitude of the inertia force produced by the mass 113.

The term "primary force" as used herein and in the appended claims is defined as a force applied through, or in conjunction with, an external source of power as distinguished from mere reactive forces. For example, the rotating masses and the inertia masses in conjunction with positively driven eccentrics apply primary forces to the suspended body. The suspending means apply merely reactive forces.

In connection with all of the forms of the invention which have been merely schematically illustrated, it will be understood that the various devices shown will be duplicated at the two sides of the screen frame wherever required or desirable to provide a well balanced structure. This applies, for example, to the supporting springs, the gearing between counter-rotating shafts, rotating masses provided adjacent the ends of a shaft, eccentrics, and the various arms connecting the inertia masses with the screen frames.

While a variety of different constructions, capable of imparting a gyratory movement to a screen or similar body along an elliptical path, have been described in considerable detail, it will be understood that numerous other modifications than those specifically suggested may be made without departing from the general principles and scope of the invention. The terms and expressions employed herein have been used as terms of description and not of limitation.

What I claim is:

1. A resiliently supported gyrating frame, bearings mounted on said frame, and means journaled in said bearings for transmitting primary forces therethrough to said frame for imparting a uniform substantially elliptical motion to all portions of said frame.

2. In apparatus of the class described a main frame, a body, means for supporting said body for a free gyratory motion with respect to said frame, and means for imparting a uniform substantially elliptical motion to all portions of said body, said means comprising eccentrically mounted oppositely rotating masses of unequal magnitude mounted on said body.

3. In apparatus of the class described a main frame, a body supported by said frame, and means for imparting a uniform substantially

elliptical motion to all portions of said body, said means comprising eccentrically mounted oppositely rotating masses of unequal magnitude carried by said body, the axis of rotation of said masses being substantially at the center of gravity of said body.

4. In apparatus of the class described a main frame, a body, resilient means for supporting said body from said frame, and means for imparting a uniform substantially elliptical motion to all portions of said body, said means comprising a plurality of masses mounted on said body to revolve in opposite directions, said masses being of different magnitude and revolving about different axes eccentric to the centers of gravity of the masses.

5. In apparatus of the class described a main frame, a body, resilient means for supporting said body from said frame, and means for imparting a uniform substantially elliptical motion to all portions of said body, said means comprising a plurality of masses mounted on said body to revolve in opposite directions, said masses being of different magnitude and revolving about different axes eccentric to the centers of gravity of the masses and to the center of gravity of said body.

6. In apparatus of the class described a main frame, a body, resilient means for supporting said body from said frame, and means for imparting a uniform substantially elliptical motion to all portions of said body, said means comprising a plurality of masses revolving in opposite directions, said masses being of different magnitude and revolving about different axes eccentric to the centers of gravity of the masses and to the center of gravity of said body, the magnitude of said masses being inversely proportional to the distances between their axes of rotation and the center of gravity of the body.

7. In apparatus of the class described a main frame, a body, resilient means for supporting said body from said frame, and means for imparting a uniform substantially elliptical motion to all portions of said body, said means comprising a plurality of masses revolving in opposite directions, said masses being of different magnitude and revolving about different axes eccentric to the centers of gravity of the masses and to the center of gravity of said body, the magnitude of said masses being inversely proportional to the distances between their axes of rotation and the center of gravity of the body, said masses being rotated at the same speeds and each having its axis of rotation at the same distance from its center of gravity as the other.

8. In apparatus of the class described a main frame, a body, resilient means for supporting said body from said frame, and means for imparting a uniform substantially elliptical motion to all portions of said body, said means comprising a plurality of masses revolving in opposite directions, said masses being of different magnitude and revolving about different axes eccentric to the centers of gravity of the masses and to the center of gravity of said body, the magnitude of said masses being inversely proportional to the distances between their axes of rotation and the center of gravity of the body, said masses being rotated at the same speeds and each having its axis of rotation at the same distance from its center of gravity as the other, the arrangement of said masses being such that when a straight line passing through the axis of rotation and the center of gravity of one mass

passes through the center of gravity of the body a similar straight line may be drawn through the centers of gravity of the body and other mass and through the axis of rotation thereof.

9. In apparatus of the class described a gyrotory body, means for supporting said body for a free gyrotory motion, means tending to impart a straight line motion to said body, and means for modifying the effect of said last mentioned means, said two last-named means being effective to apply resultant forces at the center of gravity of said body such as to produce a uniform, substantially elliptical motion at all points of said body.

10. In apparatus of the class described a gyrotory body, means for resiliently supporting said body, means for imparting a constant rotating force to said body about a substantially horizontal axis, and means for imparting a second force to said body to modify the effect of said first mentioned force, said two force imparting means being constructed and arranged to apply a resultant force to said body of constantly changing direction and magnitude.

11. In apparatus of the class described a gyrotory body, means for resiliently supporting said body, and a plurality of means for imparting constant rotating forces of different magnitude to said body at different points, the forces rotating about substantially horizontal axes, said force imparting means being constructed and arranged to apply a resultant force to said body of constantly changing direction and magnitude.

12. In apparatus of the class described a gyrotory body, means for resiliently supporting said body, and means for imparting a plurality of forces to said body substantially at the center of gravity thereof, the forces rotating about substantially horizontal axes, the resultant of said forces being of constantly changing magnitude and direction.

13. In apparatus of the class described a gyrotory body, means for resiliently supporting said body, rotating means for imparting a force to said body, and inertia means connected with said body, said rotating means and said inertia means being so constructed and arranged as to impart to said body the effect of a force constantly changing in direction and magnitude applied at the center of gravity of the body.

14. In apparatus of the class described a gyrotory body, means for supporting said body for gyrotory movement, and means for imparting to said body at a pair of points spaced different distances from the center of gravity thereof rotating forces of constant magnitude, said forces being of unequal magnitude and inversely proportional to the distances of the points of application from the center of gravity of said body.

15. In apparatus of the class described a gyrotory body, means for supporting said body for gyrotory movement, and means for imparting to said body at a pair of points spaced different distances from the center of gravity thereof rotating forces of constant magnitude, said forces being of unequal magnitude and inversely proportional to the distances of the points of application from the center of gravity of said body, and said forces being rotated in synchronism in opposite directions and being aligned with said center of gravity at the same instant.

16. In apparatus of the class described a gyrotory body, means for supporting said body for gyrotory movement, and means for imparting to said body at a pair of points spaced different

distances from the center of gravity thereof rotating forces of constant magnitude, said forces being of unequal magnitude and inversely proportional to the distances of the points of application from the center of gravity of said body, and said forces being rotated in synchronism in opposite directions and being alined with said center of gravity at the same instant, a line bisecting the angle between said forces when alined with the center of gravity of said body being disposed at an angle of about 40° to the horizontal.

17. In apparatus of the class described a gyratory body, means for supporting said body for gyratory movement, means for imparting to said body at substantially the center of gravity thereof a force of constant magnitude but continually changing in direction through a predetermined cycle, and means for imposing a greater inertia force in opposition to said force in certain directions than in others.

18. In apparatus of the class described a gyratory body, means for supporting said body for gyratory movement, means for imparting to said body at substantially the center of gravity thereof a force of constant magnitude but continually changing in direction through a predetermined cycle, a mass supported for movement in all directions, and a link connected with said mass and with said body.

19. In apparatus of the class described a gyratory body, means for supporting said body at a plurality of points for a free gyratory motion, means for imparting a constantly rotating force of invariable magnitude to said body, and means for imparting a modifying force to said body at a point removed from said plurality of points to produce a uniform, substantially elliptical motion at all points of said body.

20. In apparatus of the class described a gyratory body, means for supporting said body for gyratory movement, a shaft extending through said body at its center of gravity, an eccentric mounted on said shaft, an inertia mass freely suspended adjacent said body, an arm connected with said mass and having a strap surrounding said eccentric, means for rotating said shaft and eccentric to produce relative movement between said body and mass in the direction of said arm, and means for inducing movement of said body in a direction transverse to said arm.

21. In apparatus of the class described a gyratory body, means for supporting said body for gyratory movement, a shaft extending through said body at its center of gravity, an eccentric mounted on said shaft, an inertia mass freely suspended adjacent said body, an arm connected with said mass and having a strap surrounding said eccentric, means for rotating said shaft and eccentric to produce relative movement between said body and mass in the direction of said arm, and an auxiliary mass adjustably mounted on said arm.

22. In apparatus of the class described a gyratory body, means for supporting said body for gyratory movement, a shaft extending through said body at its center of gravity, an eccentric mounted on said shaft, an inertia mass freely suspended adjacent said body, an arm connected with said mass and having a strap surrounding said eccentric, means for rotating said shaft and eccentric to produce relative movement between said body and mass in the direction of said arm,

and a mass secured to said shaft for rotation therewith.

23. In apparatus of the class described a gyratory body, means for supporting said body for gyratory movement, a shaft extending through said body at its center of gravity, a mass secured to said shaft for rotation therewith, inertia mass means suspended for free movement adjacent said body, and means connecting said body with said inertia mass means.

24. In apparatus of the class described a gyratory body, means for supporting said body for gyratory movement, a shaft extending through said body at its center of gravity, a pair of shafts parallel with said first mentioned shaft extending through said body on opposite sides of said first mentioned shaft and spaced equally therefrom, means for rotating said shafts at the same speed, the shafts of said pair rotating in the same direction and opposite to the rotation of said first mentioned shaft, and a mass secured to each of said shafts for rotation therewith, the masses secured to the shafts of said pair being of equal magnitude.

25. In apparatus of the class described a gyratory body, means for supporting said body for gyratory movement, and means for imparting a uniform, substantially elliptical movement to all portions of said body, said last mentioned means comprising a plurality of parallel shafts mounted on said body in a plane passing through the center of gravity thereof, means for rotating said shafts, and a mass secured to each of said shafts for rotation therewith.

26. In apparatus of the class described a gyratory body, means for supporting said body for gyratory movement, and means for imparting a uniform, substantially elliptical movement to all portions of said body, said last mentioned means comprising a plurality of parallel shafts mounted on said body in a plane passing through the center of gravity thereof, means for rotating said shafts, and a mass secured to each of said shafts for rotation therewith, said shafts being rotated in opposite directions and said masses being of unequal magnitude.

27. In apparatus of the class described, a gyratory body, softly resilient means for supporting said body for free gyratory motion, and means separate from said supporting means comprising moving masses connected to said body whose dynamic effect imparts resultant force to said body in such changing direction and magnitude as to produce a substantially uniform and substantially elliptical motion of the body throughout.

28. In apparatus of the class described a gyratory body, instrumentalities for supporting said body for gyratory motion, and mechanism separate from said instrumentalities connected with said body for producing a substantially uniform and substantially elliptical motion of the body throughout.

29. In apparatus of the class described a gyratory body, instrumentalities for supporting said body for gyratory motion, and mechanism separate from said instrumentalities including a rotating member and a moving mass and connected with said body for producing a substantially uniform and substantially elliptical motion of the body throughout.

SAMUEL D. ROBINS.