Feb. 2, 1965 H. J. THOMPSON 3,167,884

SPHERE LAPPING MACHINE AND METHOD

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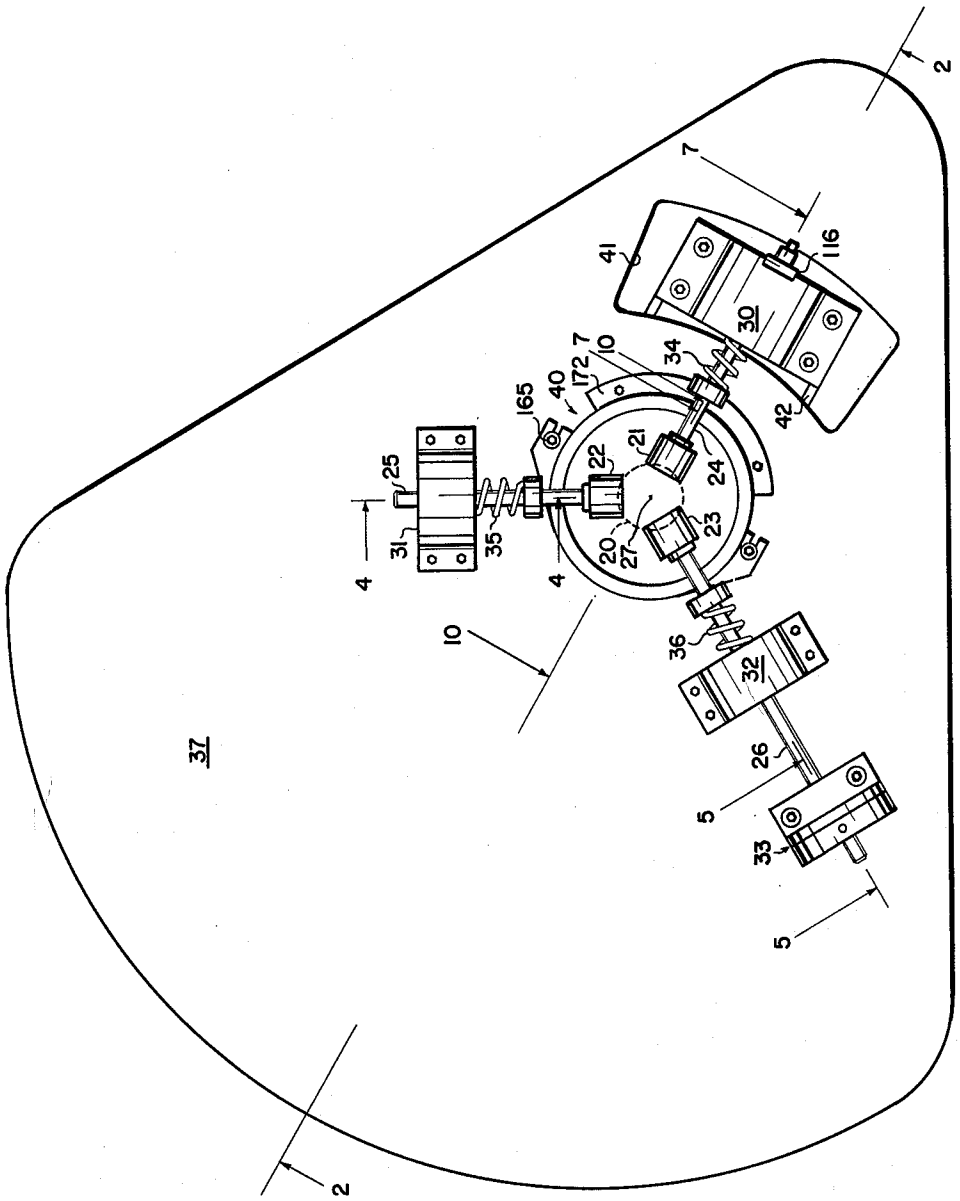



FIG. 1

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SPHERE LAPPING MACHINE AND METHOD

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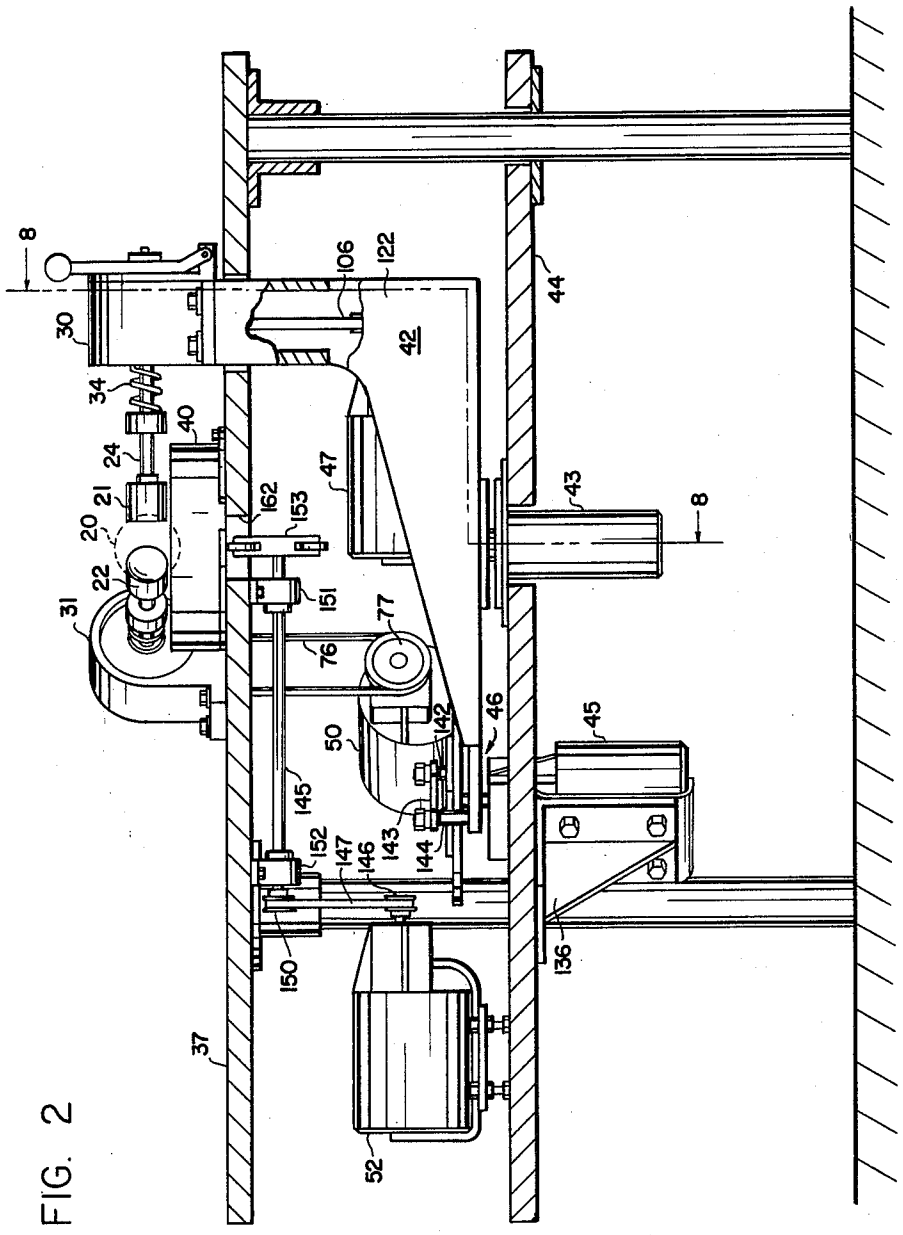



FIG. 2

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SPHERE LAPPING MACHINE AND METHOD

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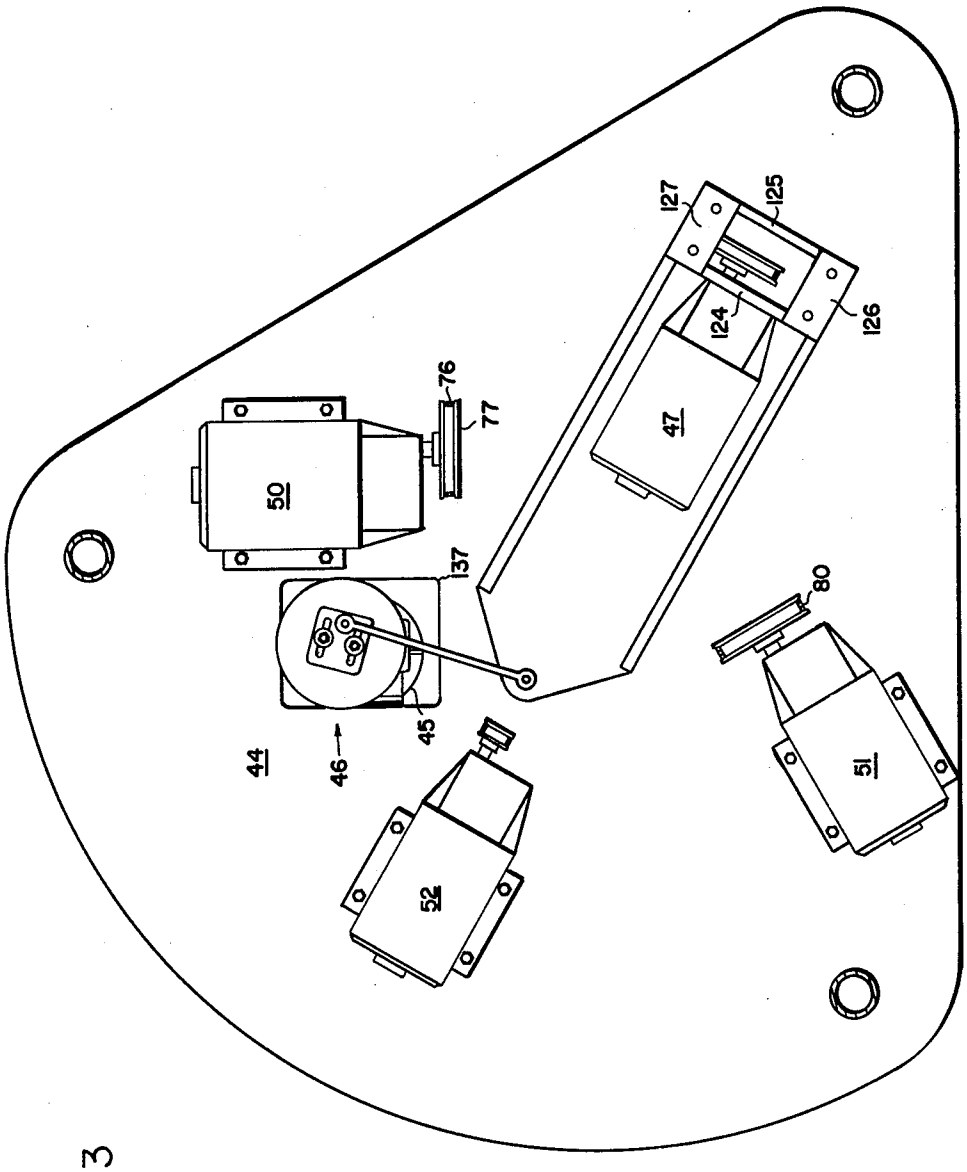



FIG. 3

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SPHERE LAPPING MACHINE AND METHOD

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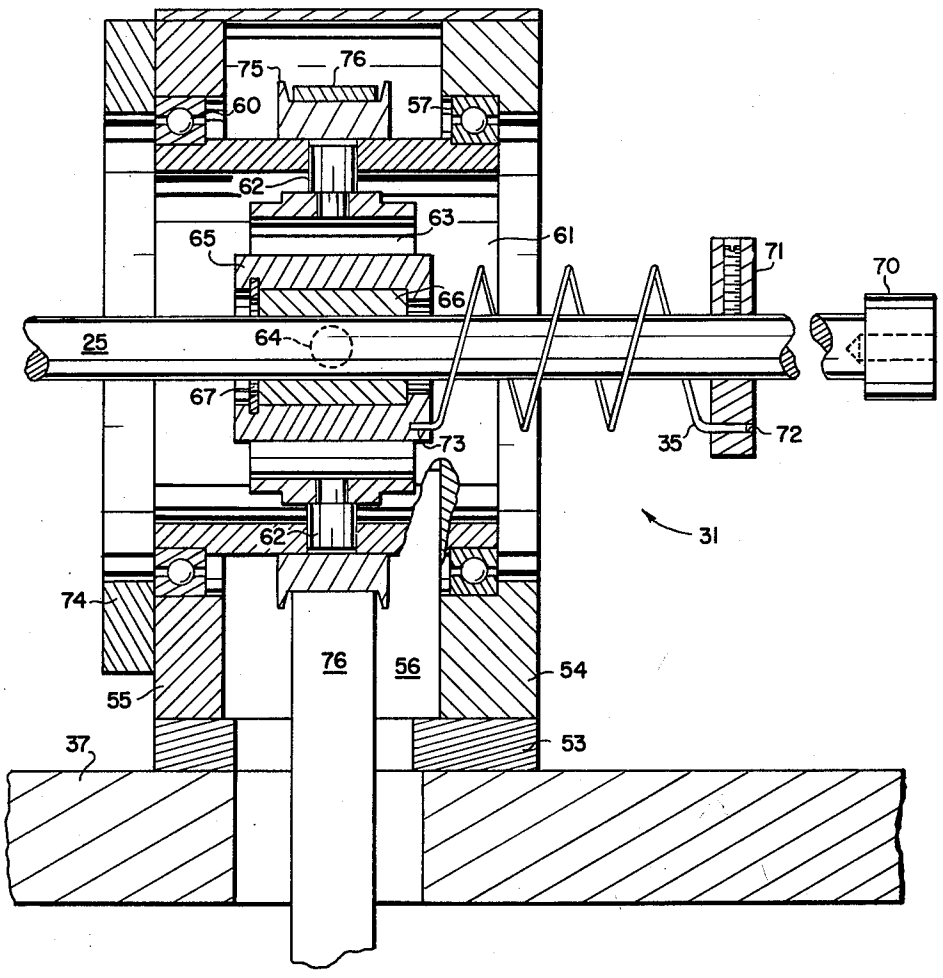



FIG. 4

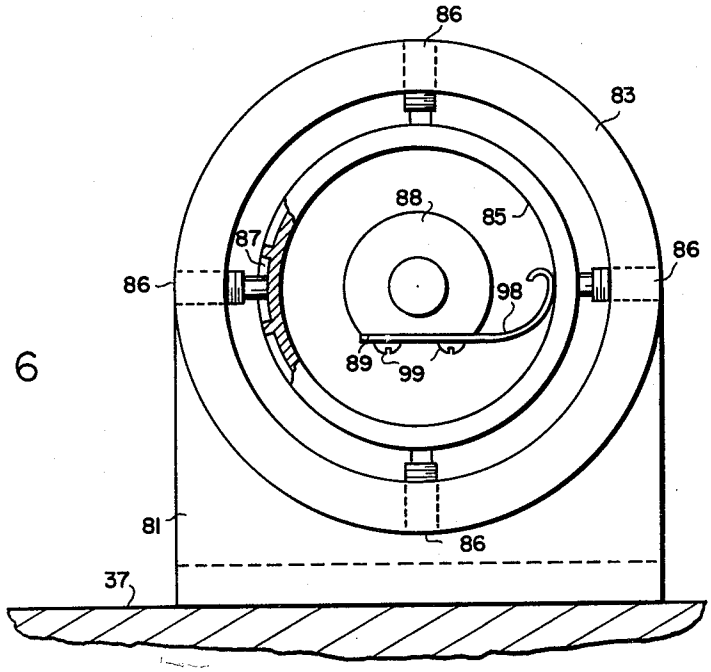
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SPHERE LAPPING MACHINE AND METHOD

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FIG. 6



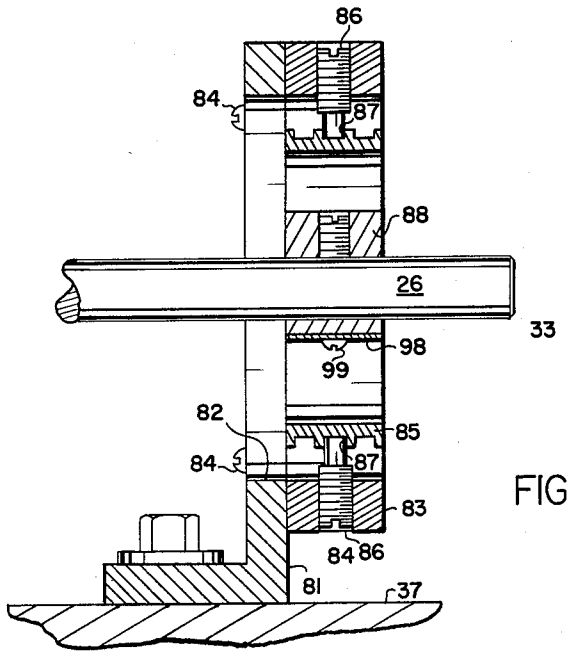




FIG. 5

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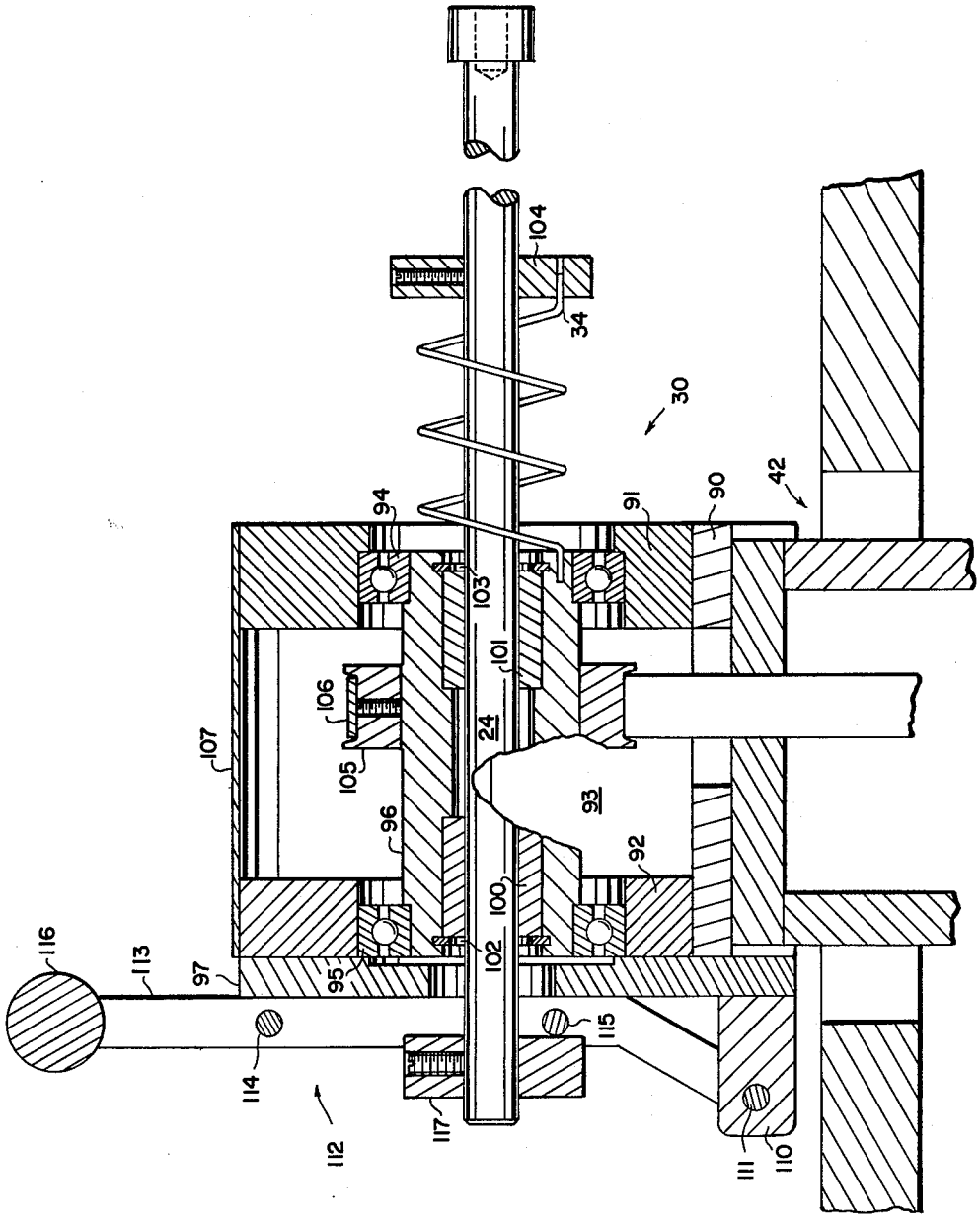



FIG. 7

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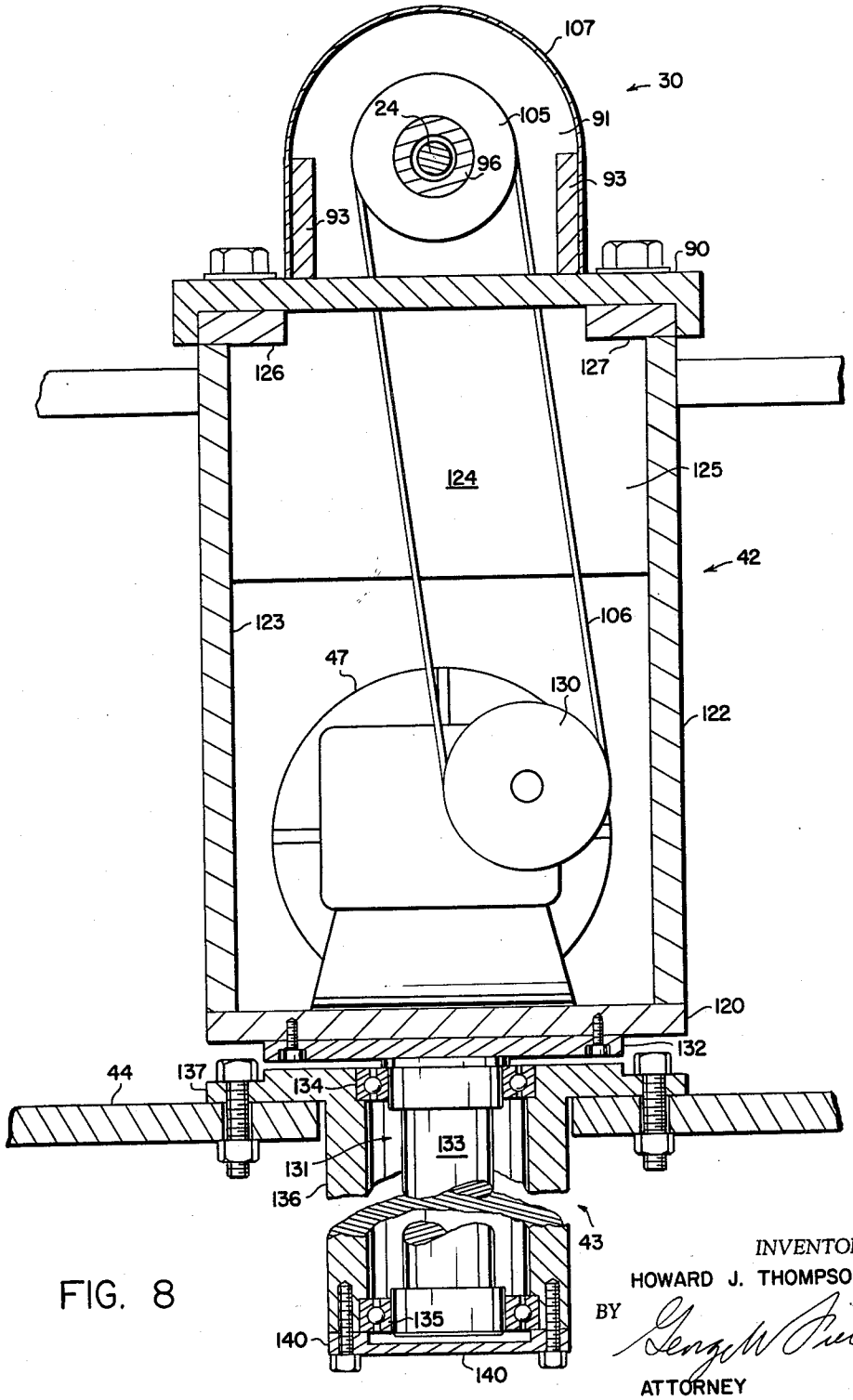



FIG. 8

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SPHERE LAPPING MACHINE AND METHOD

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FIG. 11

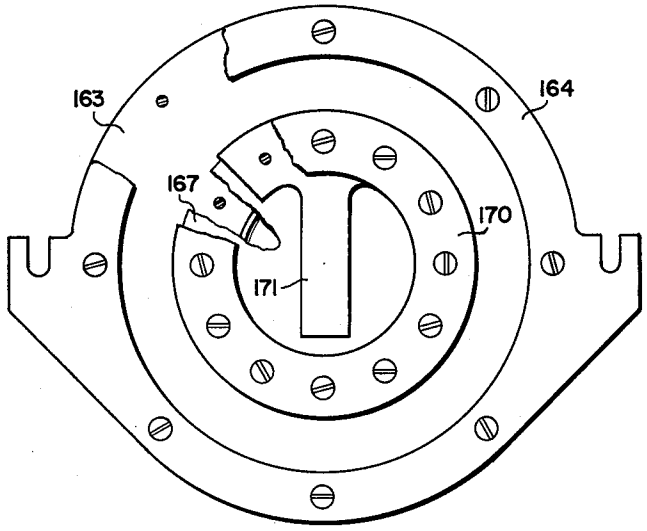
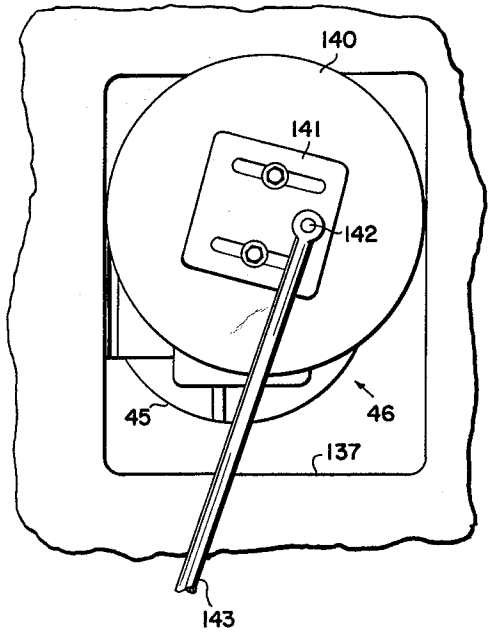



FIG. 9




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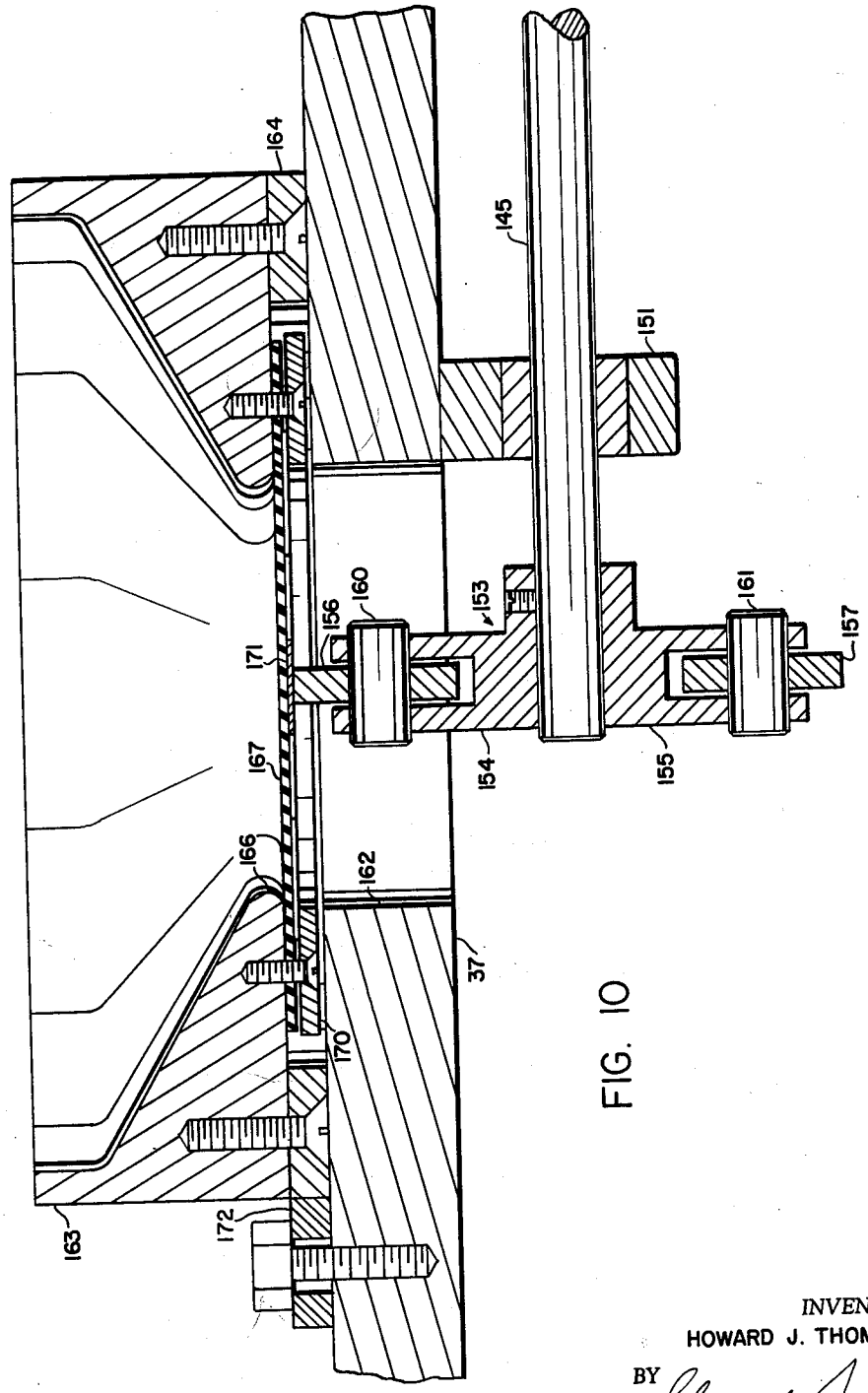



FIG. 10

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United States Patent Office 3,167,884 Patented Feb. 2, 1965



3,167,884

# SPHERE LAPPING MACHINE AND METHOD

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14 Claims. (Cl. 51—3)

This invention relates to means for automatically producing spheres having a sphericity far in excess of anything commercially obtainable, even by the most careful nonautomatic process. The need for rotors which are spherical within a very few millionths of an inch arose in connection with ultra precise gyroscopes for inertial navigation. The rotor must be spherical to a high order and sphere grinding methods hitherto satisfactory were found hopelessly inadequate for producing rotors meeting the most stringent requirements.

An object of the invention is to provide novel means and method for automatically producing spheres of an extremely high sphericity.

Another object is to provide means for rotating a sphere about its center, which means operates inherently to produce random movement of the sphere.

A more specific object of the invention is to provide separate lapping means including a plurality of laps rotatable about normally horizontal axes which intersect at a common point, the laps being hollow and providing the sole support for the sphere, together with means for angularly oscillating one of the shafts through a limited angle in a horizontal plane, and means for continuously supplying lapping slurry to the surface of the sphere.

A further object of the invention is to provide such means combined with means for biasing one of the shafts so that it tends to move out of its normal radial alignment with respect to the sphere.

Various other objects, advantages, and features of novelty, not individually enumerated above, which characterize my invention are pointed out with particularity in the claims annexed hereto and forming a part hereof. However, for a better understanding of the invention, its advantages, and objects attained by its use, reference should be had to the subjoined drawing, which forms a further part hereof, and to the accompanying descriptive matter, in which I have illustrated and described a preferred embodiment of my invention.

In the drawing, FIGURE 1 is a top view of the apparatus, FIGURE 2 is a vertical section taken generally along the line 2—2 of FIGURE 1, FIGURE 3 is a top view of the shelf of the apparatus, FIGURE 4 and FIGURE 5 are sectional views along the lines 4—4 and 5—5 of FIGURE 1, FIGURE 6 is an end view of the structure shown in FIGURE 5, FIGURE 7 is an enlarged section along the line 7—7 of FIGURE 1, FIGURE 8 is an enlarged section along the line 8—8 of FIGURE 2, FIGURE 9 gives linkage details, FIGURE 10 is an enlarged sectional view along the line 10—10 of FIGURE 1, and FIGURE 11 is a fragmentary view showing details of a portion of the apparatus, parts being broken away for clarity of illustration.

The general nature of my apparatus may be seen in FIGURES 1, 2 and 3. A sphere to be lapped, shown by a broken line and identified by reference numeral 20, is supported solely by a plurality of hollow laps 21, 22, and 23 fastened to first ends of a horizontal shaft 24 and a pair of further shafts 25 and 26. The axes of shafts 24, 25, and 26 normally intersect at point 27 where the center of the sphere is located, so that the shafts extend radially with respect to the sphere.

Shaft 24 is carried in a first mounting 30 which maintains the shaft with its axis horizontal and passing through point 27, but permits it to rotate about its own axis and



to move linearly along its axis. Shaft 25 is carried in a mounting 31 which permits rotation and translation of the shaft around and along its axis, and also permits limited pivotal movement of the shaft about a point lying on the axis of shaft 25 and in the horizontal plane containing the axis of shaft 24. Shaft 26 is carried in a mounting 32 like mounting 31, and is extended to pass through a biasing device 33. Resilient members in the form of springs 34, 35, and 36 have as one of their functions to urge the shafts, and hence the laps, toward point 27, to engage the surface of the sphere and support it without necessity of any support member directly under it. As a second function, the resilient members transmit rotation to the shafts.

Mountings 31 and 32 and biasing device 33 are secured to a table top 37, to which is also removably secured a basin assembly 40 which is designed to continuously supply lapping slurry to the lowermost surface of the sphere. The table top is provided with an aperture 41 in which a support member 42 may move to cause angular oscillation of mounting member 30 through a restricted angle about point 27, so that the axis of shaft 24 traces a normally horizontal plane.

Support member 42 is mounted for movement about a vertical axis provided by a bearing assembly 43 carried on a table shelf 44, and is oscillated by a motor 45 through a suitable mechanical linkage 46. Further motors 47, 50, and 51 are provided for causing rotation of shafts 24, 25, and 26 respectively, about their axes, motor 47 being carried on support member 42, and motors 50 and 51 being mounted on shelf 44. The shelf also mounts a further motor 52 for driving an agitator. The table top is of course apertured to pass driving belts for motors 50 and 51, and to permit operation of the agitator. The principal components outlined above will now be described in detail.

Mounting 31 is shown in FIGURE 4 to comprise a base plate 53, a front plate 54, a back plate 55, and side plates 56, all welded together to form a unitary structure. Front plate 54 is bored and shouldered to receive a bearing 57, and back plate 55 is bored to receive a bearing 60. A gimbal housing 61 is carried in bearings 57 and 60, and is apertured at diametrically opposite points to receive a pair of pins 62 which pivotally carry a gimbal ring 63, the latter being apertured at diametrically opposite points to receive further pins, as suggested at 64, to pivotally support a bushing retainer 65. The axes of pins 62 and 64 intersect at right angles on the axis of shaft 25, which is carried in a bushing 66 held in retainer 65 by a snap ring 67. Shaft 25 is enlarged at its front end, as indicated at 70, to mount lap 22, and carries a collar 71 which is drilled at 72 to receive one end of spring 35: the other end of the spring is received in a similar bore 73 in retainer 65. A centrally bored stop plate 74 retains bearing 60 and hence housing 61 in place. A pulley 75 is secured externally to housing 61, for driving by a belt 76 which extends downward through apertures in base plate 53 and table top 37 to be driven by a pulley 77 on the shaft of motor 50 (FIGURE 3).

Mounting 32 is constructed like mounting 31, and is driven by a belt 80 from motor 51 (FIGURE 3). Biasing device 33 is shown in FIGURES 5 and 6 to comprise a mounting bracket 81 having a large bore 82 which agrees with the inside diameter of a mounting ring 83 secured to it by suitable means 84. A contact drum 85 is supported within ring 83 by relatively long set screws 86, which are received in recesses 87 in the wall of drum 85. By suitably adjusting set screws 86, the center of drum 85 may be displaced to a limited extent from that of ring 83. Shaft 26 carries a hub 88 which is flattened at 89 to engage a leaf spring 98 fastened thereto by means 99 and formed at the other end to engage drum 85. Device

33 is mounted on table top 37 in such a position that when shaft 26 is in its normal alignment, and drum 85 is positioned centrally in ring 83, leaf spring 92 exercises the same biasing force on shaft 26 throughout its rotation.

Mounting 30 is shown in FIGURES 7 and 8 to comprise a flanged base plate 90, a front plate 91, a back plate 92, and side plates 93 welded together to form a unitary structure. Front plate 91 is bored and shouldered to receive a bearing 94, and back plate 92 is bored to receive a bearing 95. A hollow shaft 96 is carried in bearings 94 and 95, the later being held in position by a stop plate 97 secured to back plate 92 by suitable means and bored to pass shaft 24 freely. The ends of hollow shaft 96 are counter-bored to receive bushings 100 and 101, which are held in place by snap rings 102 and 103 respectively. Hollow shaft 96 is bored to receive one end of spring 34, the other end being received in a bore in a collar 104 secured to shaft 24. A pulley 105 is secured to shaft 96 and is driven through a belt 106 by motor 47 (FIGURE 2). A dust cover 107 may be fastened to plates 91 and 92 in any suitable fashion.

A boss 110 is secured to the bottom of stop plate 97 and is bored to pivotally receive the shaft 111 of a handle generally identified by reference numeral 112 and comprising a pair of side plates 113 joined by intermediate bars 114 and 115 and a hand grip 116. Shaft 24 carries a second collar 117, and under the action of spring 34, which is normally compressed, collar 117 remains in engagement with bar 115. When handle 112 is mechanically pivoted in a counterclockwise direction about member 111, bar 115 acts on collar 117 to displace shaft 24 to the left as seen in FIGURE 7. The lap carried on shaft 24 can thus be displaced sufficiently to allow a sphere to be inserted into or removed from the lapping position.

Motor 47 is mounted on the bottom 120 of bracket 42 having side walls 122 and 123 connected by end plates 124 and 125 and top plates 126 and 127, all welded together to form a unitary structure. The top plates support base plate 90 of mounting 30, setting between the flanges thereof, and being secured thereto by suitable fastening means. Base plate 90 is apertured and plates 126 and 127 are spaced to permit the passage of belt 106 from pulley 105 to a drive pulley 130 on the shaft of motor 47. The latter is preferably a reversible variable speed motor, as are motors 45, 50, 51 and 52.

Bracket 42 is mounted on a bearing assembly 43 comprising a pivot member 131 having an upper flange portion 132 bolted to the underside of the bracket and a pivot 133 extending vertically downward therefrom. The shaft is carried in bearings 134 and 135 contained in a socket 136 secured by a flange 137 to table shelf 44 and closed by a cap member 140. The axis of pivot 133 extends vertically to pass through the point of normal intersection of the axes of shafts 24, 25 and 26.

Motor 45 is mounted, with its axis vertical, on a bracket 136 suspended under an aperture 137 in table shelf 44: it is connected to oscillate bracket 42 through a limited angle about the axis of bearing assembly 43 by means of linkage 46 shown in FIGURE 9. A disc 140 is mounted on the shaft of motor 45, and to this disc is adjustably attached a slotted plate 141 carrying a pintle 142. A connecting rod 143 joins pintle 142 with a second pintle 144 carried on the end of the bracket 42. By sliding plate 141 on drum 140 in the direction of the slots in the former, the radius of rotation of pintle 142, and hence the amplitude of oscillation of bracket 42, may be adjusted.

Motor 52 is shown in FIGURE 2 to be mounted on table shelf 44, and is arranged to drive a shaft 145 through a pulley 146, a belt 147, and a further pulley 150 carried on one end of the shaft, which is supported in pillow blocks 151 and 152. Secured to the other end of the shaft 145, as is better shown in FIGURE 10, is a cross member 153 having oppositely extending arms 154



and 155 in which rollers 156 and 157 are carried on pivots 160 and 161. The dimensions of member 153 are such that during rotation of shaft 145 rollers 156 and 157 alternately pass through an aperture 162 in table top 37 and project slightly thereabove.

As shown in FIGURES 10 and 11, basin assembly 40 is mounted on table top 37 over aperture 162. It comprises a basin 163 secured to a mounting plate 164 which in turn is removably fastened to the table top by mounting screws 165. Basin 163 has a vertical side wall and a bottom which tapers downwardly and inwardly toward a large central aperture 166, the latter being closed by a flexible elastic diaphragm 167 secured to the under surface of basin 163 by suitable means including a clamp ring 170. A generally T-shaped wear plate 171 of thin Phosphor bronze is clamped between ring 170 and diaphragm 167 for engagement by rollers 156 and 157. As shown in FIGURE 1, an arcuate guide plate 172 is fastened to table 137 to facilitate replacement of basin assembly 44 after removal for cleaning.

In use, basin 163 is filled with lapping slurry and suitable laps are mounted on shafts 24, 25, and 26. Handle 116 is displaced to the right as seen in FIGURE 1, a sphere to be lapped is placed against laps 22 and 23, and handle 116 is released. Due to the action of springs 34, 35, and 36, the sphere is supported solely between laps. Motor 52 is set in operation and causes slurry to be splashed upwardly against the under surface of the sphere. Now, the remaining motors are set in operation and random rotation of the sphere in the laps takes place. Control of the rotation may be exerted by varying the tension in springs 34, 35, and 36, the speed of motors 45, 47, 50, and 51, and the position of drum 85 in ring 83. My apparatus has been found to produce a more nearly random sphere movement than apparatus heretofore have known, and this is believed to be due in part to the fact that the biasing effect of gravity has been removed by so arranging the structure that neither supporting means nor lapping means engage the sphere to be grounded from beneath at its center.

Numerous objects and advantages of my invention have been set forth in the foregoing description, together with details of the structure and function of the invention, and the novel features thereof are pointed out in the appended claims. The disclosure, however, is illustrative only, and I may make changes in detail, especially in matters of shape, size, and arrangement of parts, within the principle of the invention, to the full extent indicated by the broad general meaning of the terms in which the appended claims are expressed.

I claim as my invention:

1. Means for causing random rotation of a sphere comprising, in combination: a plurality of hollow friction members mounted on the converging ends of a like plurality of horizontal shafts radial to the sphere to engage the surface thereof at areas centered at points substantially equally spaced about a great circle thereof; means causing rotation of said members about the axes of said shafts at independently adjustable rates; and means causing angular oscillation of one of said shafts, in a horizontal plane, about the center of the sphere.

2. Means for causing random rotation of a sphere comprising, in combination: a plurality of hollow friction members mounted on the converging ends of a like plurality of horizontal shafts radial to the sphere to engage the surface thereof at areas centered at points substantially equally spaced about a great circle thereof; means causing rotation of said members about the axes of said shafts at independently adjustable rates; and means resiliently acting on one of said shafts to tend to displace it angularly from its normal radial orientation relation to said sphere.

3. Means for causing random rotation of a sphere comprising, in combination: a plurality of hollow friction members mounted on the converging ends of a like

plurality of horizontal shafts radial to the sphere to engage the surface thereof at areas centered at points substantially equally spaced about a great circle thereof; means causing rotation of said members about the axes of said shafts at independently adjustable rates; means causing angular oscillation of one of said shafts, in a horizontal plane, about the center of the sphere; and means resiliently acting on another of said shafts to tend to displace it angularly from its normal radial orientation relation to said sphere.

4. Means for causing random rotation of a sphere comprising, in combination: a plurality of hollow friction members mounted on the converging ends of a like plurality of horizontal shafts radial to the sphere to engage the surface thereof at areas centered at points substantially equally spaced about a great circle thereof; means causing rotation of said members about the axes of said shafts at independently adjustable rates; means causing angular oscillation of one of said shafts, in a horizontal plane, about the center of the sphere; means resiliently acting on another of said shafts to tend to displace it angularly from its normal radial orientation relation to said sphere; and means for projecting fluid upwardly to impinge upon the unsupported lowermost surface of the sphere.

5. In combination: a container having side walls and a bottom including a peripheral downwardly slanting portion and a central open portion; a flexible diaphragm of resilient material closing said open portion; a metallic tongue underlying said diaphragm; and rapping means operable to impact said tongue from below so as to splash fluid in said container upwardly at the center thereof.

6. In combination: a shaft; a collar on said shaft; a bushing receiving said shaft for relative movement therebetween; inner and outer gimbal rings mounting said bushing for limited rotation about each of a pair of axes normally perpendicular to each other and to the axis of said shaft; means mounting said outer gimbal ring for rotation about an axis normally aligned with the axis of said shaft; and resilient means connecting said collar to said bushing for positioning said shaft axially with respect to said bushing and for transmitting rotation from said bushing to said shaft.

7. In combination: a shaft; a collar on said shaft; a bushing receiving said shaft for relative movement therebetween; inner and outer gimbal rings mounting said bushing for limited rotation about each of a pair of axes normally perpendicular to each other and to the axis of said shaft; means mounting said outer gimbal ring for rotation about an axis normally aligned with the axis of said shaft; a radially resilient member carried on said shaft; a hollow member having an inner circular wall of substantially the radius swept by said resilient member as a result of rotation of said shaft; adjustable means mounting said hollow member for engagement by said resilient member; and means for adjusting said adjustable means to vary the eccentricity of said circular wall with respect to the axis of rotation of said shaft, to apply a transverse bias force thereto which varies as said shaft rotates.

8. The method of lapping a convex spherical body which comprises supporting the body solely in several hollow laps rotatable about intersecting substantially horizontal axes, causing rotation of said laps about said axes at predetermined rates, and causing independent angular oscillation of one of the laps, in the horizontal plane, about the point of intersection of the axes as a center.

9. In combination: a first shaft having a horizontal axis passing through a first point; means mounting said first shaft for translation along and rotation about said horizontal axis; a plurality of further shafts having axes passing through a plurality of further points lying in the horizontal plane containing said horizontal axis; means mounting said further shafts for translation along and rotation about their respective axes and for limited pivotal movement about said further points, so that the axes of all three shafts are normally coplanar and normally intersect at said first point; hollow laps mounted at the ends of said shafts which are directed toward said first point; resilient means normally urging said shafts toward said first point so that a sphere of predetermined radius may be supported solely in said laps; means for causing said rotation of said shafts at predetermined speeds and in predetermined directions; and means for causing continuous limited angular oscillation of said first shaft in said horizontal plane about said first point as a center.

10. In combination: a first shaft having a horizontal axis passing through a first point; means mounting said first shaft for translation along and rotation about said horizontal axis; a pair of further shafts having axes passing through a pair of further points lying in the horizontal plane containing said horizontal axis; means mounting said further shafts for translation along and rotation about their respective axes and for limited pivotal movement about said further points, so that the axes of all three shafts are normally coplanar and normally intersect at said first point; hollow laps mounted at the ends of said shafts which are directed toward said first point; resilient means normally urging said shafts toward said first point so that a sphere of predetermined radius may be supported solely in said laps; means for causing said rotation of said shafts at predetermined speeds and in predetermined directions; and means for causing continuous limited angular oscillation of said first shaft in said horizontal plane about said first point as a center.

11. In combination: a first shaft having a horizontal axis passing through a first point; means mounting said first shaft for translation along and rotation about said horizontal axis; a plurality of further shafts having axes passing through a plurality of further points lying in the horizontal plane containing said horizontal axis, the angles between adjacent pairs of said axes being normally substantially equal; means mounting said further shafts for translation along and rotation about their respective axes and for limited pivotal movement about said further points, so that the axes of all three shafts are normally coplanar and normally intersect at said first point; hollow laps mounted at the ends of said shafts which are directed toward said first point; resilient means normally urging said shafts toward said first point so that a sphere of predetermined radius may be supported solely in said laps; means for causing said rotation of said shafts at predetermined speeds and in predetermined directions; and means for causing continuous limited angular oscillation of said first shaft in said horizontal plane about said first point as a center.

12. In combination: a first shaft having a horizontal axis passing through a first point; means mounting said first shaft for translation along and rotation about said horizontal axis; a plurality of further shafts having axes passing through a plurality of further points lying in the horizontal plane containing said horizontal axis; means mounting said further shafts for translation along and rotation about their respective axes and for limited pivotal movement about said further points, so that the axes of all three shafts are normally coplanar and normally intersect at said first point; hollow laps mounted at the ends of said shafts which are directed toward said first point; resilient means normally urging said shafts toward said first point so that a sphere of predetermined radius may be supported solely in said laps; means including said resilient means for causing said rotation of said shafts at predetermined speeds and in predetermined directions; and means for causing continuous limited angular oscillation of said first shaft in said horizontal plane about said first point as a center.

13. In combination: a first shaft having a horizontal axis passing through a first point; means mounting said first shaft for translation along and rotation about said

horizontal axis; a plurality of further shafts having axes passing through a plurality of further points lying in the horizontal plane containing said horizontal axis; means mounting said further shafts for translation along and rotation about their respective axes and for limited pivotal movement about said further points, so that the axes of all three shafts are normally coplanar and normally intersect at said first point; hollow laps mounted at the ends of said shafts which are directed toward said first point; resilient means normally urging said shafts toward said first point so that a sphere of predetermined radius may be supported solely in said laps; means for causing said rotation of said shafts at predetermined speeds and in predetermined directions; means for causing continuous limited angular oscillation of said first shaft in said horizontal plane about said first point as a center; and means for continuously supplying lapping slurry to a phere suspended in said laps.

14. In combination: a first shaft having a horizontal axis passing through a first point; means mounting said first shaft for translation along and rotation about said horizontal axis; a plurality of further shafts having axes passing through a plurality of further points lying in the horizontal plane containing said horizontal axis; means mounting said further shafts for translation along and rotation about their respective axes and for limited pivotal movement about said further points, so that the



axes of all three shafts are normally coplanar and normally intersect at said first point; hollow laps mounted at the ends of said shafts which are directed toward said first point; resilient means normally urging said shafts toward said first point so that a sphere of predetermined radius may be supported solely in said laps; means for causing said rotation of said shafts at predetermined speeds and in predetermined directions; means for causing continuous limited angular oscillation of said first shaft in said horizontal plane about said first point as a center; and means supplying a biasing force to one of said further shafts tending to rotate it, about the associated further point, away from the position in which it passes said first point.


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