Sept. 14, 1948. T. C. VAN DEGRIFT ET AL 2,449,429

BALANCING MACHINE

Filed Dec. 8, 1943 11 Sheets-Sheet 1

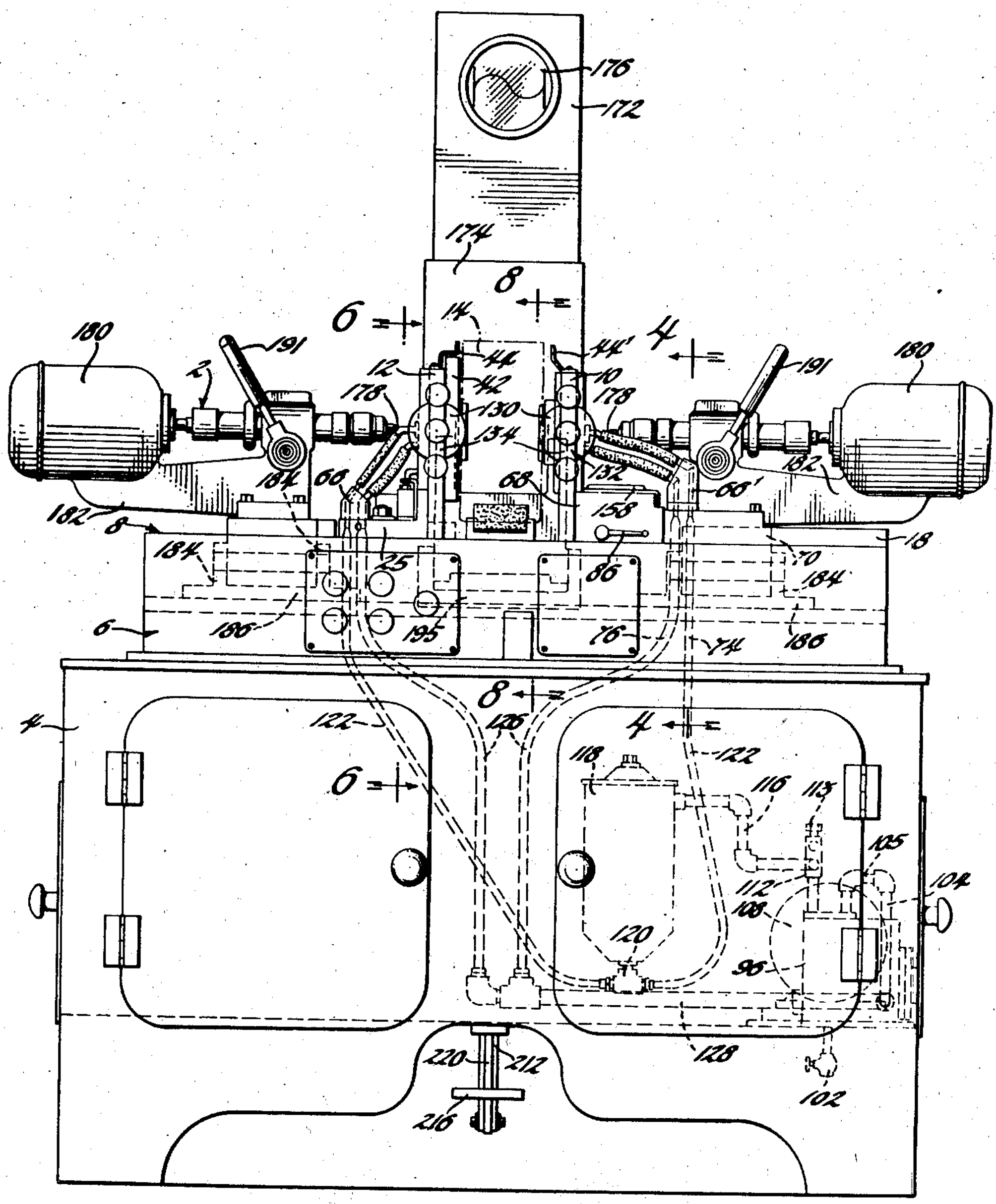

Fig. 1

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BALANCING MACHINE

Filed Dec. 8, 1943 11 Sheets-Sheet 2

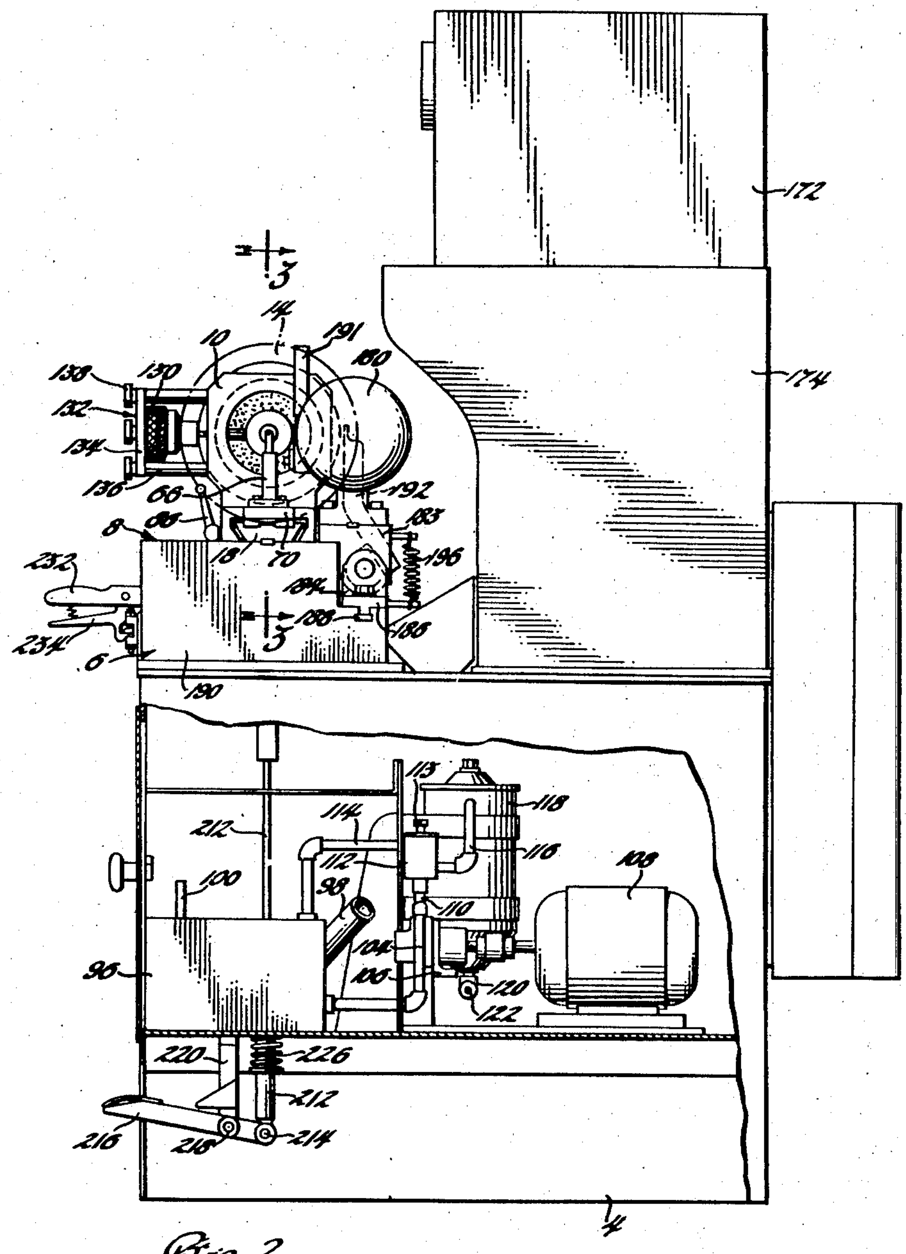

Fig. 2

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BALANCING MACHINE

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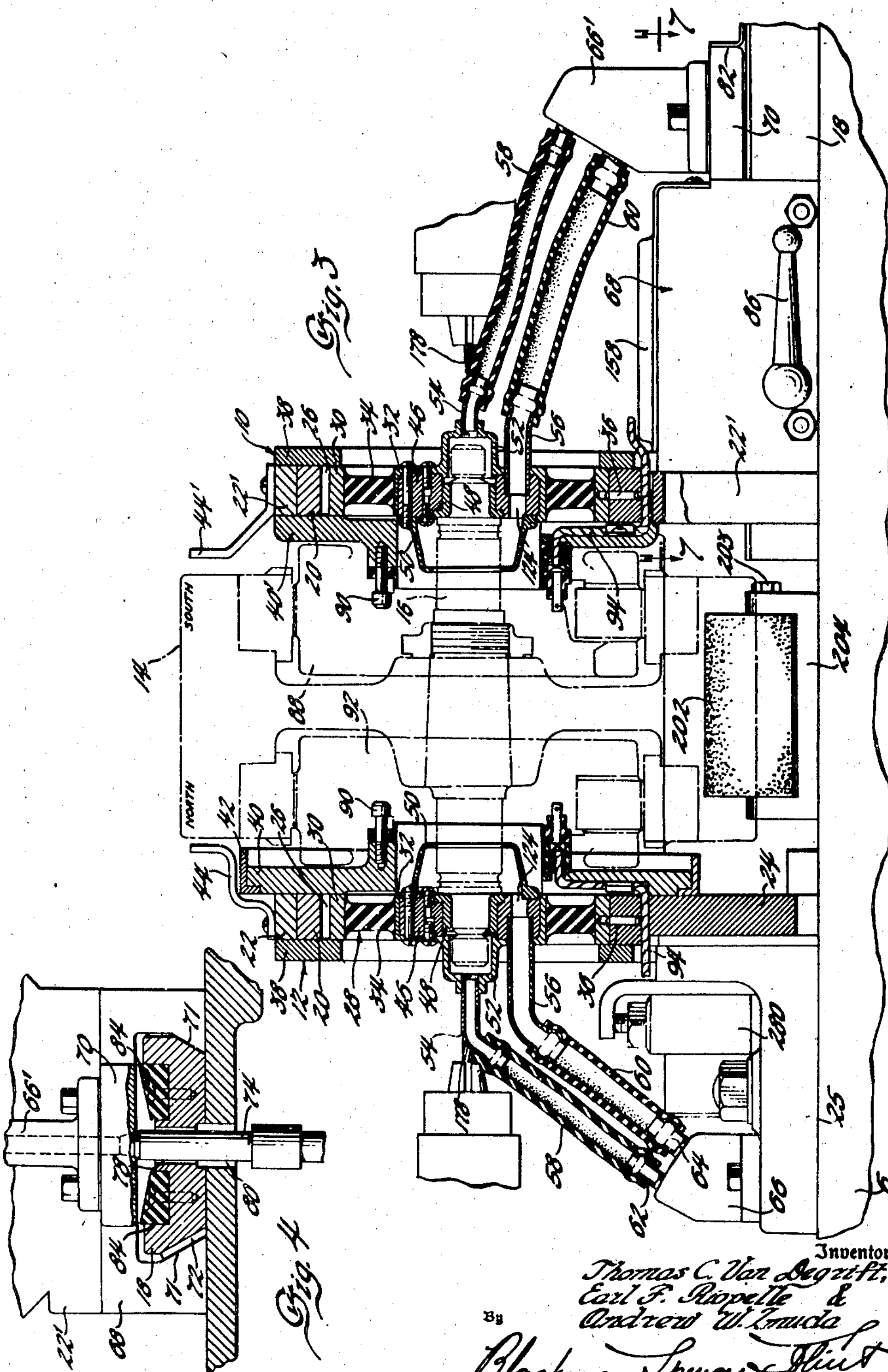

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BALANCING MACHINE

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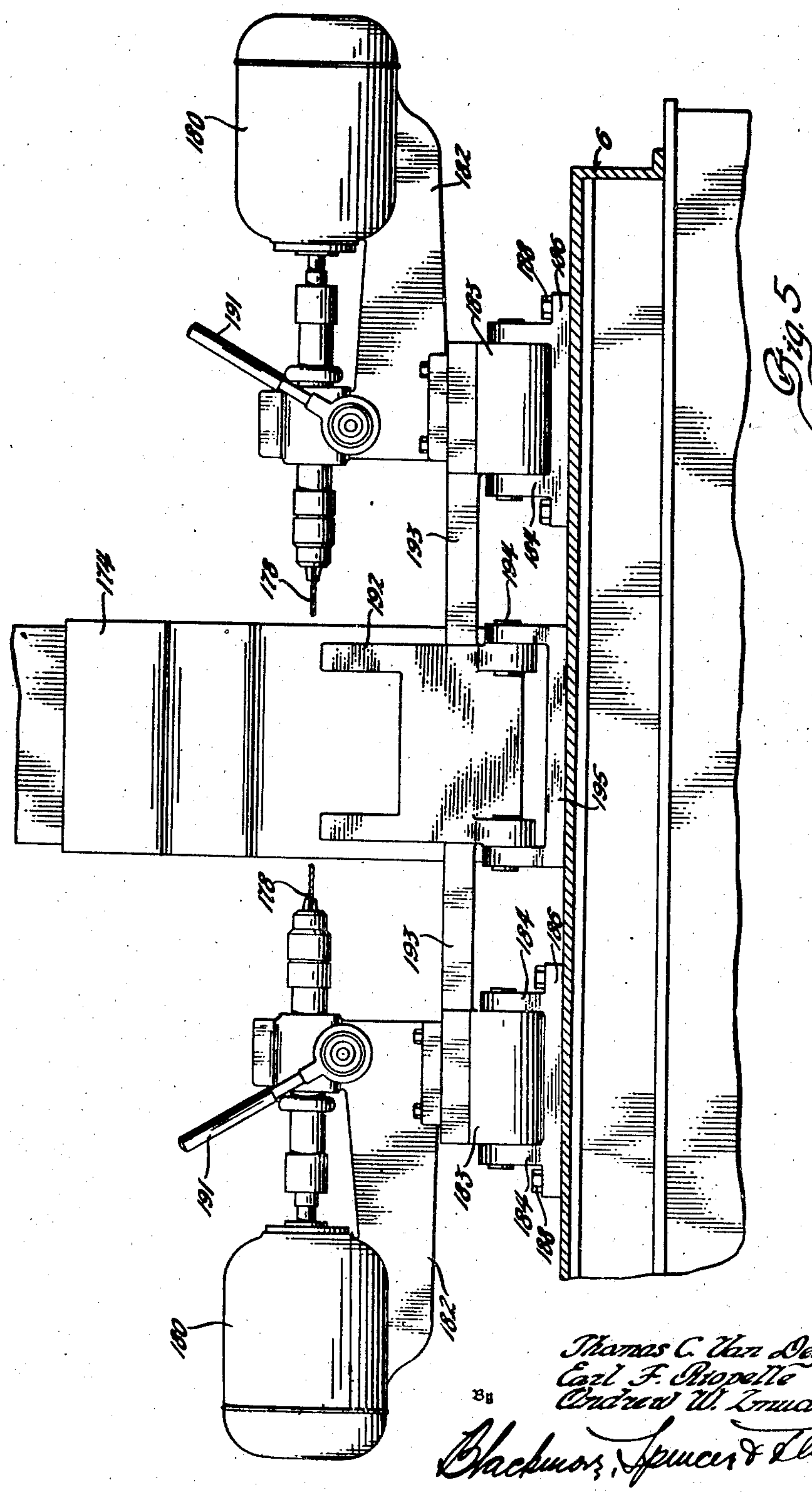

Fig. 5

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BALANCING MACHINE

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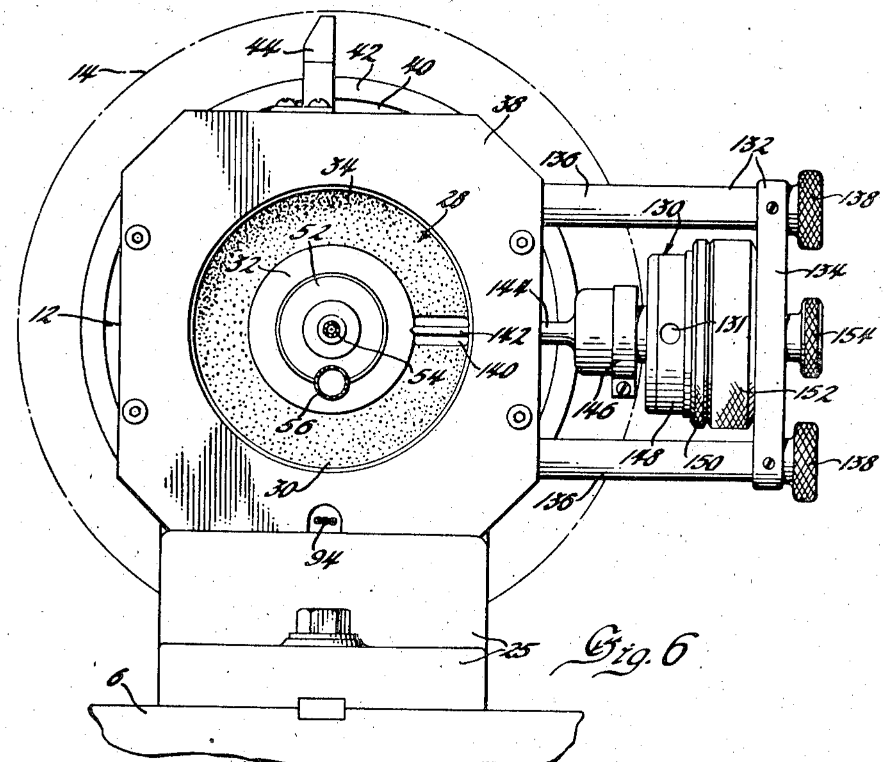

Fig. 6

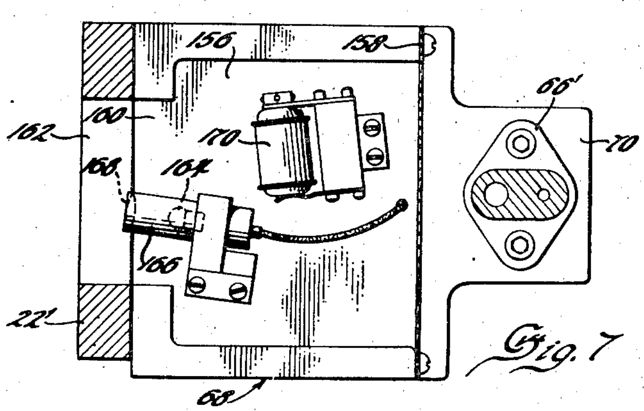

Fig. 7

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BALANCING MACHINE

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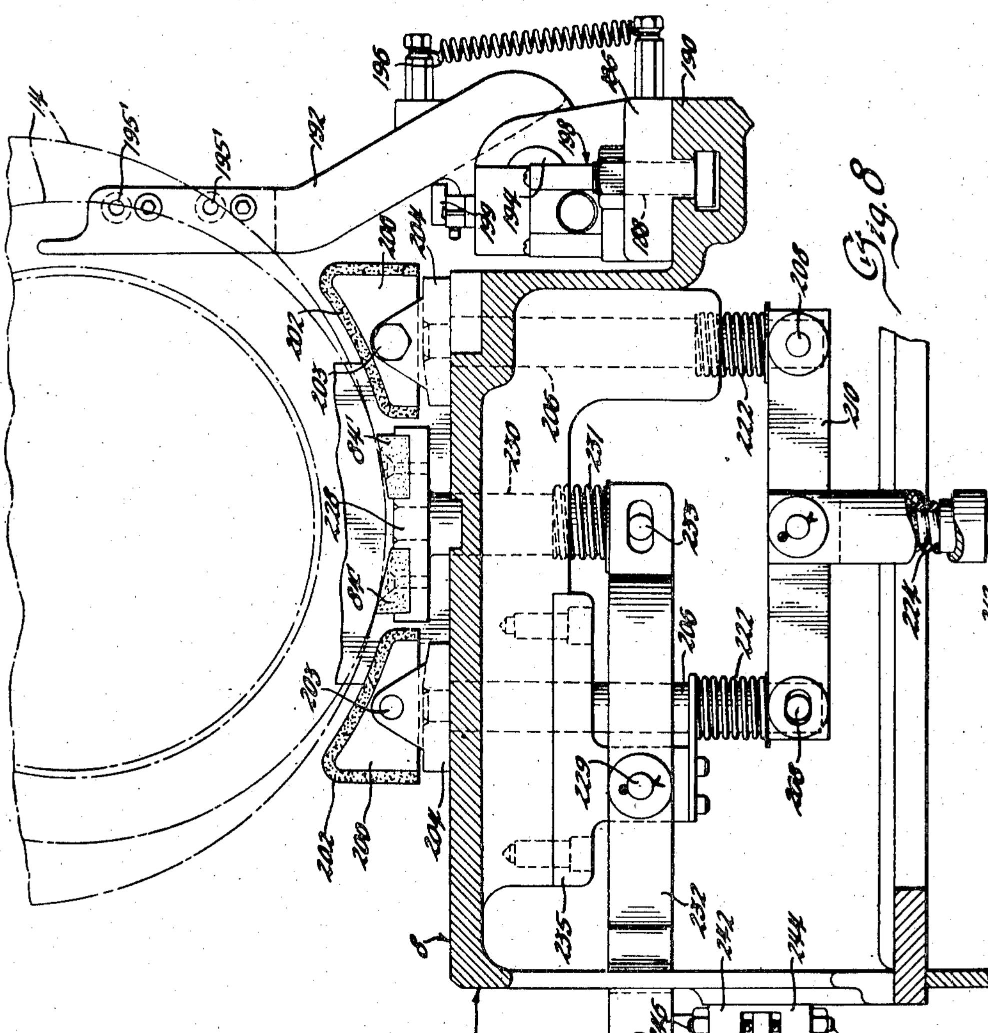

Fig. 8

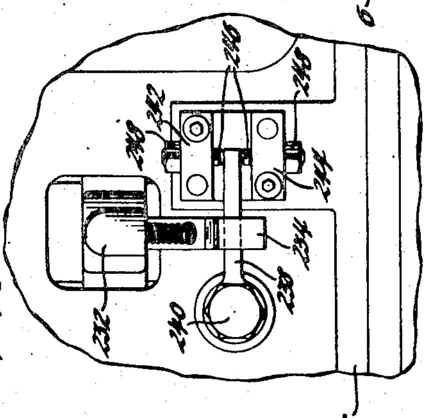

Fig. 9

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BALANCING MACHINE

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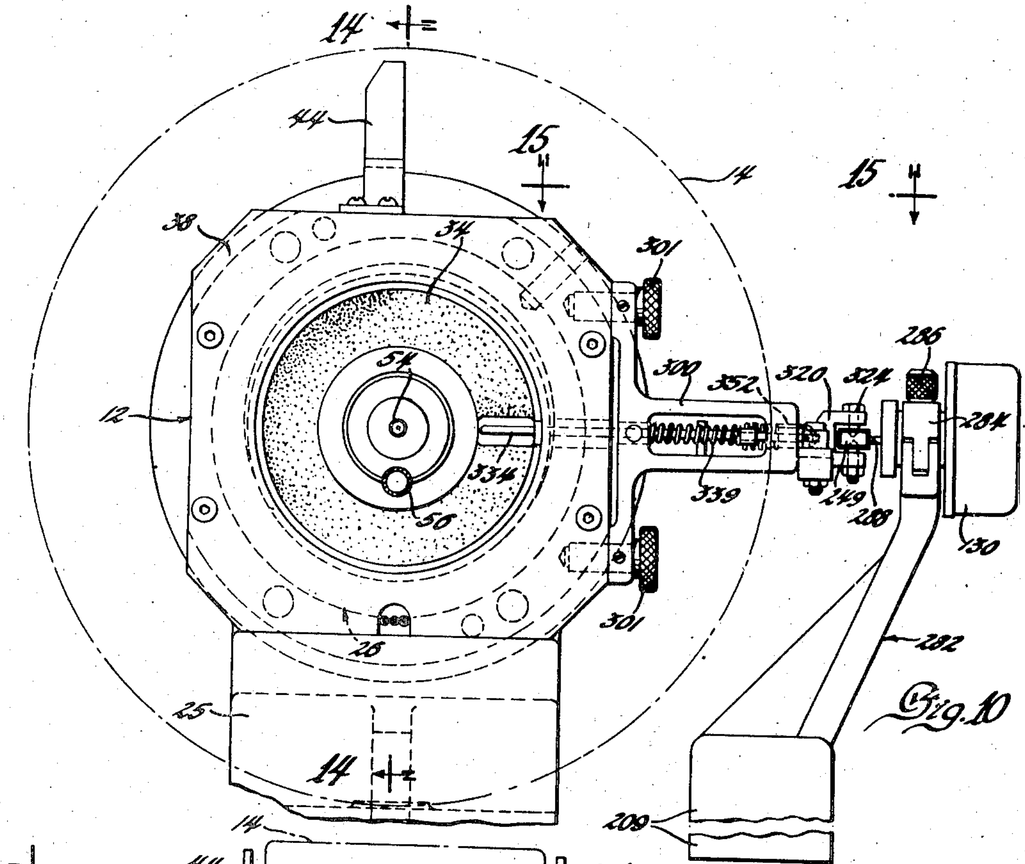

Fig. 10

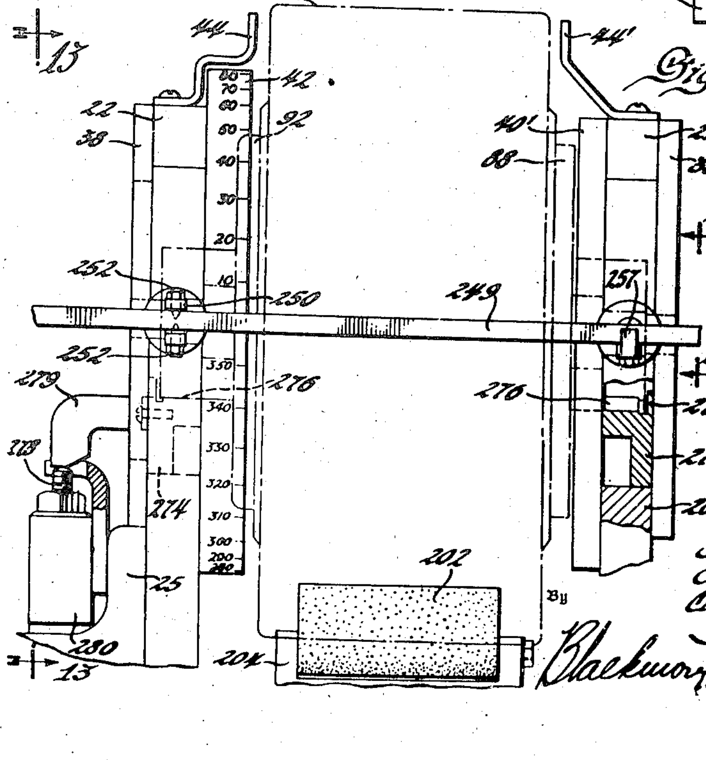

Fig. 11

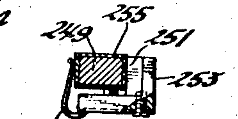

Fig. 11a

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BALANCING MACHINE

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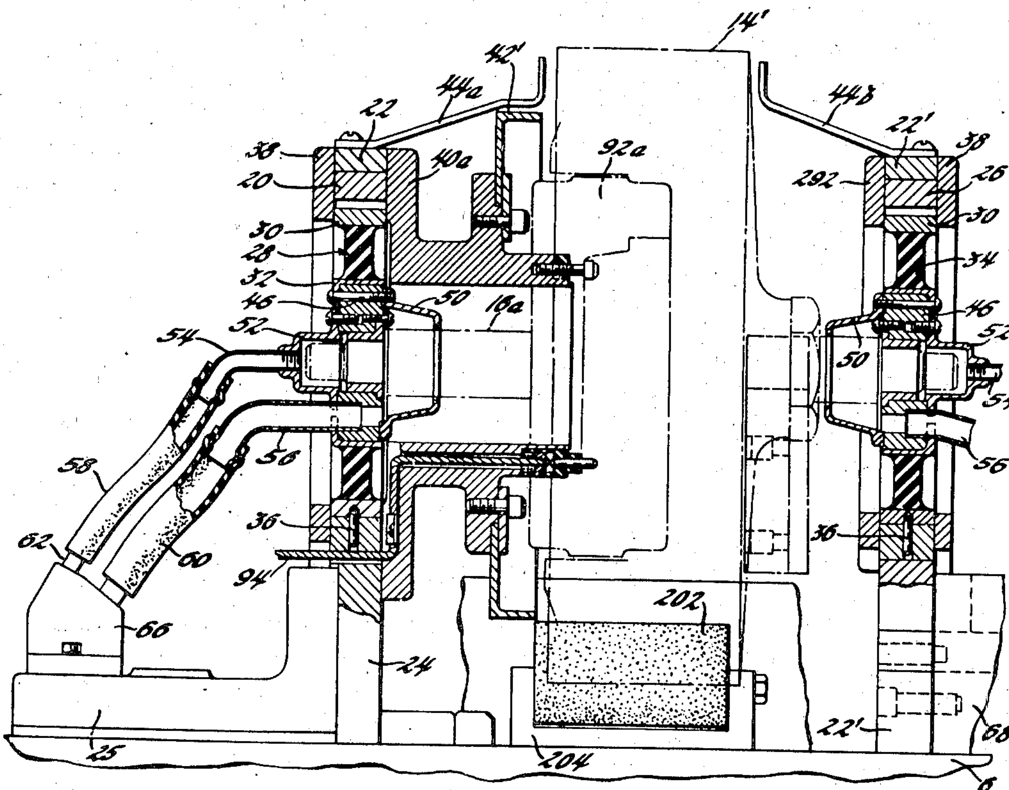

Fig. 12

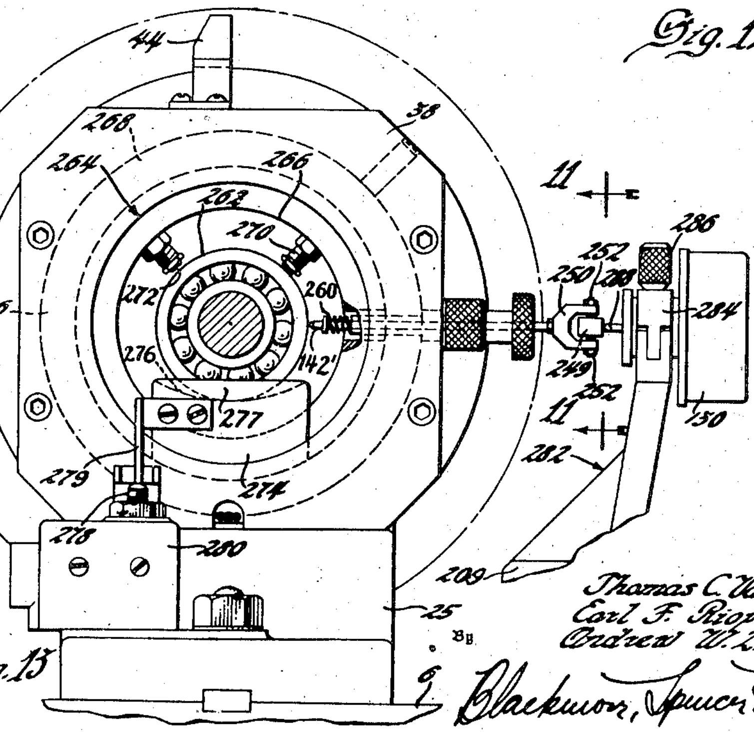

Fig. 13

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BALANCING MACHINE

Filed Dec. 8, 1943 11 Sheets-Sheet 9

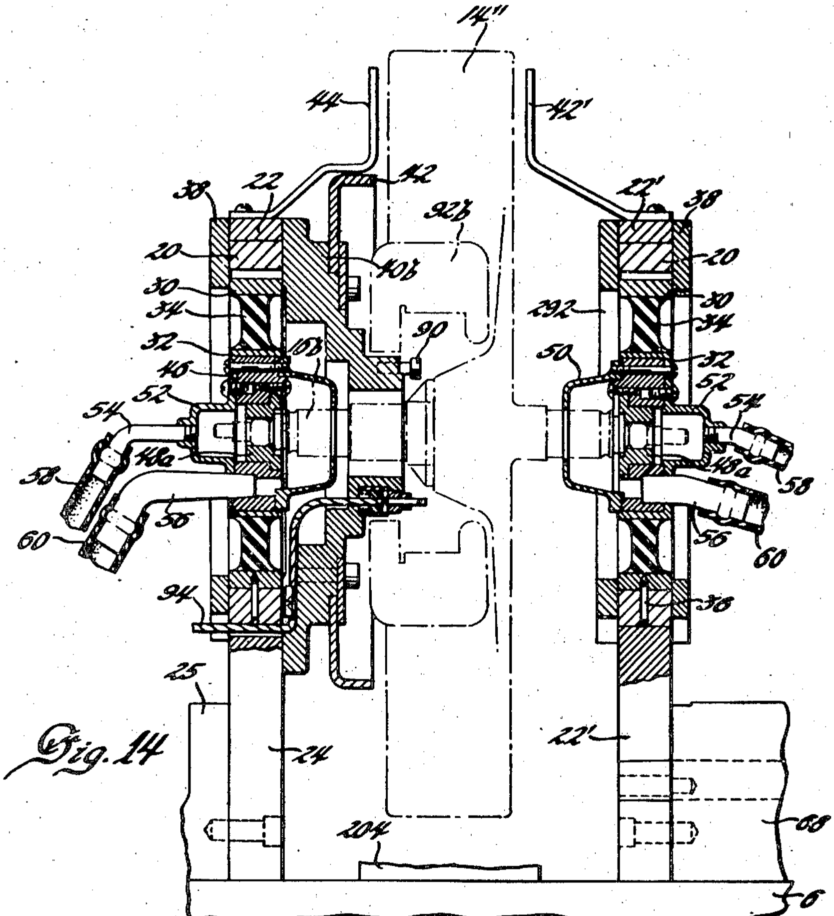

Fig. 14

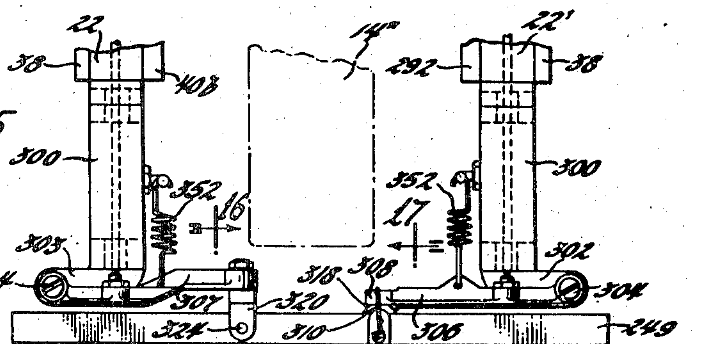

Fig. 15

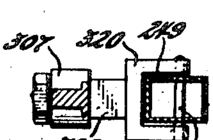

Fig. 16

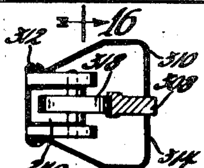

Fig. 17

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BALANCING MACHINE

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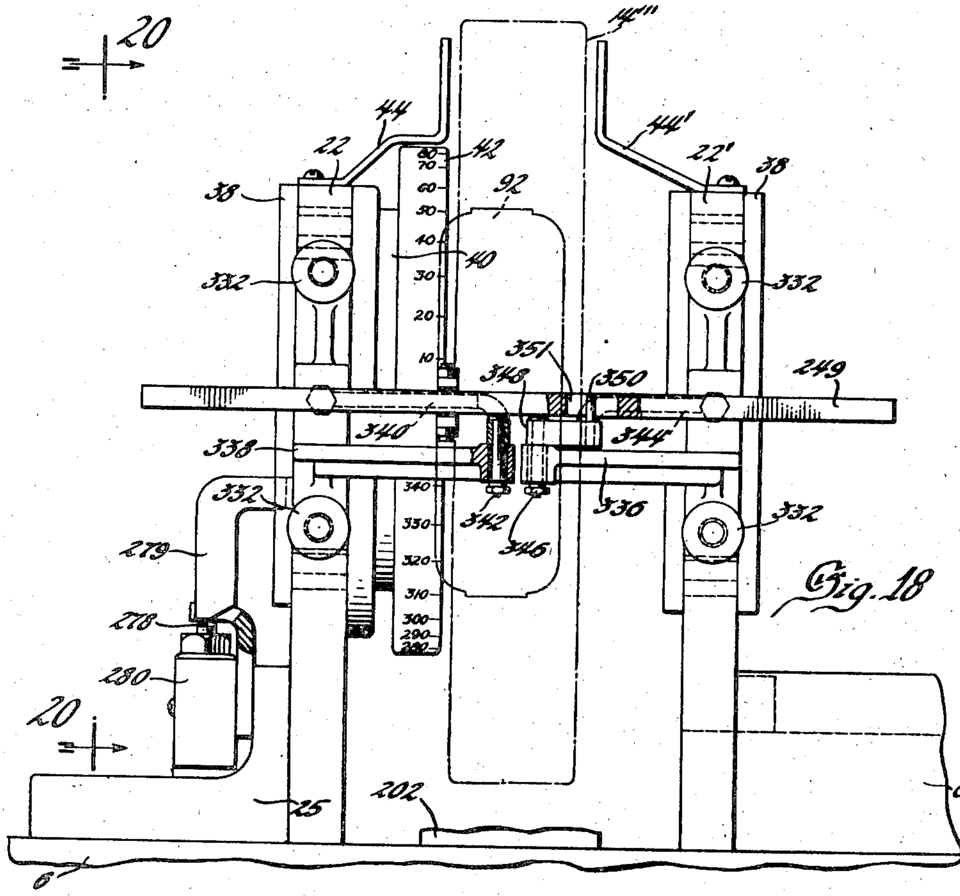

Fig. 18

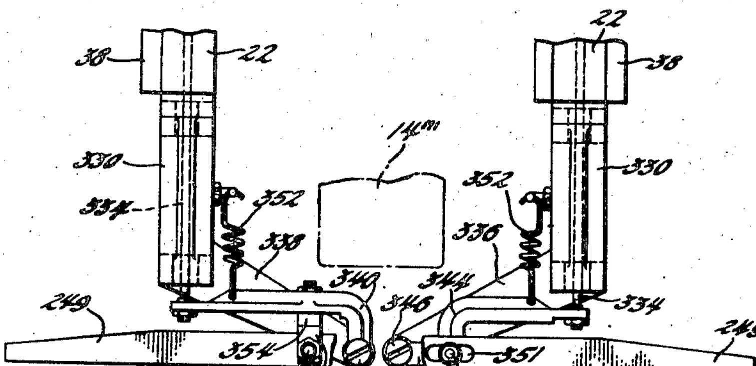

Fig. 19

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BALANCING MACHINE

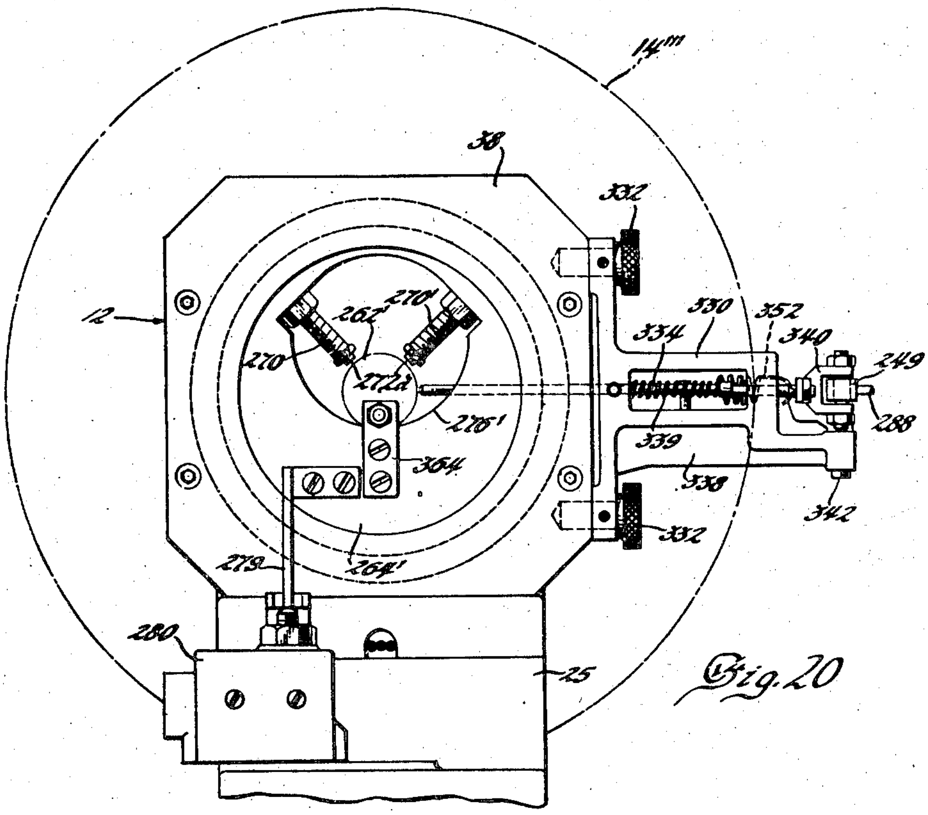

Fig. 20

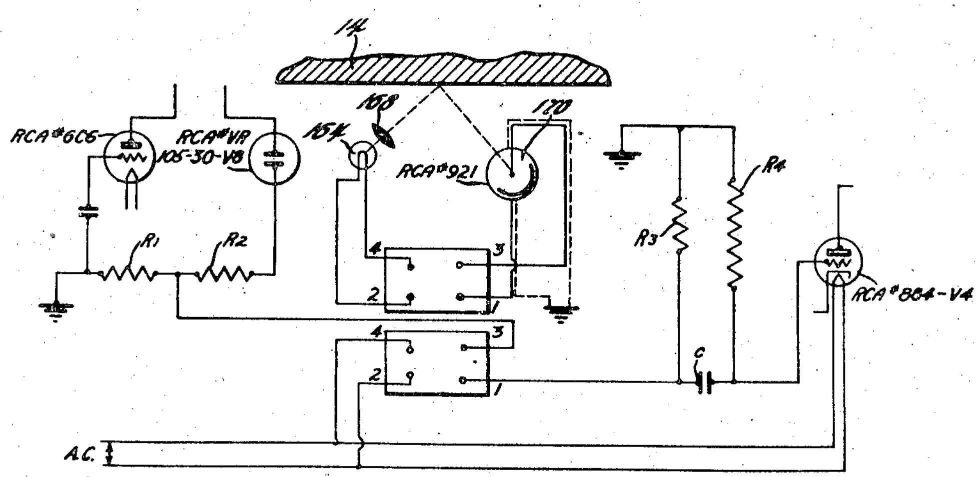

Fig. 21

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Patented Sept. 14, 1948

2,449,429

UNITED STATES PATENT OFFICE

2,449,429

BALANCING MACHINE

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Application December 8, 1943, Serial No. 513,420

10 Claims. (Cl. 77—21)

1

This invention relates to balancing machines and particularly to a machine to balance the rotors of gyroscopes.

In the novel means for balancing the rotors, a first or rough balance is made to correct for the greater part of the unbalance and a second or finish balance is then given to the rotor to correct any small amount of unbalance remaining after the completion of the rough balance. The out-of-balance of the rotors is determined while they are freely rotating in the machine and in the rough balancing operation (at a speed of about 1800 R. P. M.) experience has taught that it is inadvisable to attempt to correct for all of the unbalance. A second or finish unbalance operation (at a speed of about 5,000 R. P. M.) is necessary to obtain the fineness and accuracy of balance desired for the rotor. For the rough balance the shaft of the rotor operates in ball bearings which rest freely on a curved track in a pendulum suspension member. For the finish balance the rotor shaft is mounted in plain bearings made of high lead bronze supported in a Neoprene suspension member.

The vibration or motion of the plain or roller bearings caused by the unbalance is communicated to a Brush DP-1 displacement, piezoelectric type pickup, and the action on the pickup is communicated to a Model 160-B RCA (Radio Corporation of America) oscillograph as the vertical input. The sweep of the light spot on the fluorescent screen of the oscillograph is controlled by a voltage impulse on the grid of the oscillator tube of the sweep circuit of the oscillograph.

One side of the rotor is blackened and has a bright spot placed thereon. A light casts a ray on the rotor side in the path of the bright spot and each time the spot passes the light, a beam of light is reflected on a light sensitive photocell which is in the circuit of the synchronizing voltage source of the oscillograph. In this way the sweep circuit of the oscillograph is timed with the unbalance signal by imposing a voltage impulse on the grid of the oscillator tube of the sweep circuit once each revolution of the rotor.

In some instances the rotor and its shaft are of such inherent shape that the piezoelectric pickup can be placed directly at the place of mounting of the suspension members. In other instances with other rotors, the place, or the node, where the unbalance must be measured does not coincide with the mountings but falls outside thereof. In these instances use is made of an indicator bar or nodal bar (see the patent to

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Van Degrift 2,293,371) which partakes of the same movement as the body to be balanced, i. e., the rotor.

Another novel feature of the invention is the supplying of a constant flow of lubricant to the plain bearings of the finish balance. A pump constantly feeds filtered lubricant because any roughness in the bearing will have an effect on the indication of the amount of unbalance.

A further novel feature of the invention is the provision in the machine of two drills to drill the rotor to remove metal to bring about true balance.

On the drawings:

Figure 1 is a front elevation of the novel balancing machine with the set-up for the finish balance.

Figure 2 is a side elevation of the machine of Figure 1.

Figure 3 is an enlarged sectional view of the central part of the machine showing the finish balance setup with the rotor in dotted outline. The view is taken on the line 3—3 of Figure 2.

Figure 4 is an enlarged detailed end view of the track taken on the line 4—4 of Figure 1.

Figure 5 is an enlarged detail view of the drills and their mounting and of the drill stop.

Figure 6 is an enlarged detailed view of the pickup and its mounting taken on the line 6—6 of Figure 1.

Figure 7 is an enlarged detailed view of the lamp and photocell taken on the line 7—7 of Figure 3.

Figure 8 is an enlarged sectional detailed view on the line 8—8 of Figure 1, showing the brake mechanism, the track section lifter and the drill stop.

Figure 9 is a detailed view substantially on the line 9—9 of Figure 8.

Figure 10 is a side elevational view of the finish balance setup of a structure using an indicator bar.

Figure 11 is a front elevation, partly in section, showing the rough balancing construction with an indicator bar from which the unbalance is measured. The view is taken on the line 11—11 of Figure 13.

Figure 11*a* is a detailed view on the line 11*a*—11*a* of Figure 11, showing the manner of removably mounting the indicator bar in Figure 11.

Figure 12 is a view similar to Figure 3, but showing a different type and shape of rotor.

Figure 13 is a side view of Figure 11 taken on the line 13—13 of Figure 11.

Figure 14 is a view similar to Figures 3 and 11, but showing a different type and shape of rotor and taken on the line 14—14 of Figure 10.

Figure 15 is a plan view of the indicator bar and its mounting of Figure 10, taken on the line 15—15 of Figure 10.

Figures 16 and 17 are detailed sectional views on the lines 16—16 and 17—17 of Figure 15.

Figure 18 is a front elevational view, with parts shown in section, of the rough balance setup for a different type of rotor.

Figure 19 is a plan view of the indicator bar of Figure 18 and its mounting, parts being broken away clearer to illustrate the construction.

Figure 20 is a side view on the line 20—20 of the structure of Figure 18.

Figure 21 shows so much of the wiring diagram of the oscillograph as it differs from the conventional RCA oscillograph diagram.

In Figure 1 the numeral 2 indicates the balancing machine as a whole. The machine has a base 4 and a sub-base 6 rigidly secured together. The sub-base 6 has a smooth level machined surface 8, the purpose of which will be later described. Equally spaced at opposite sides of the center of the machine there are mounted the suspension assemblies 10 and 12, better shown in detail in Figure 3. The rotor 14 to be balanced is mounted by its shaft 16 in the suspension members. The left hand assembly 12 (Figures 1 and 3) is rigidly mounted on the sub-base 6 while the right hand assembly 10 is slidably mounted as a unit on a track 18 (Figures 2 and 4) to enable the insertion and removal of the rotor 14 and its shaft 16.

Referring to Figure 3, the suspension assembly 12 comprises the central chucking ring 20 supported in the outer adapter plate 22, the lower end 24 of which is positioned on and rigidly secured to the adapter support 25 which in turn is rigidly secured to the sub-base 6. The chucking ring has an eccentric opening 26 in which there is positioned the suspension member 28 which is used for the finish balance only. This suspension member comprises an outer ring 30, an inner ring 32 and a washer-shaped filling 34 of synthetic rubber, such as "Neoprene," therebetween. The "Neoprene" is vulcanized to both rings. When the rotor 14 is in position in the machine, the weight of the rotor will compress the "Neoprene" somewhat to cause a slight sag in the "Neoprene." A dowel pin 36 enters an opening in the chucking ring and a recess in the outer ring 30 of the suspension member to position the suspension member and to prevent its rotation. The opening 26 is sufficiently large to enable the insertion of the suspension member 28 and its positioning over the pin 36. To hold the suspension member laterally, an outer cover plate 38 and an inner stator support 40 are removably secured to the adapter plate 22. The stator support has rotatably mounted thereon a circular dial or index 42 graduated in 360°. To the top of the adapter plate a pointer or index finger 44 is secured. The pointer 44 extends over the dial and closely adjacent the side face of the outer part of the rotor.

At the center of the suspension member 28 a bearing housing 46 is rigidly secured, and in the housing 46 a plain bearing 48 for the shaft 16 of the rotor is positioned. An inner oil retainer 50 and an outer bearing cap 52 are secured to the bearing housing 46. The cap 52 has an axial oil inlet opening in which the oil inlet tube 54 is mounted and the bearing housing 46 has an opening in which the oil outlet tube 56 is secured. The inlet tube 54 and outlet tube 56 are connected by suitable oil resistant flexible tubing 58 and 60 to oil inlet and oil outlet fittings 62 and 64 in an oil header 66 rigidly mounted on the adapter support 25.

The suspension assembly 10 is substantially the same as the suspension assembly 12 except that it is not rigidly mounted on the sub-base 6 but is shiftable along the track 18. An adapter support 68 is rigidly secured to the adapter plate 22' and this support has an extension 70 extending over the track 18 and serving as a mounting for the right hand oil header 66'. The lower part of the support 68 is shaped as at 71 (Figure 4) to conform to the dovetail shape of the track 18 and a gib 72 is placed between the dovetail track 18 and the shaped lower part 71 to take up play. Suitable oil inlet and outlet connections 74 and 76 (see Figures 1 and 4) are secured to the header 66' and pass through an opening 78 in the track and a slot 80 in the sub-base. The extension 70 has a cover plate 82 secured thereto to protect the duck ways 84 which are formed of "Bakelite" or material treated therewith and which are secured to the track 18.

A handle 86 at the front of the machine operates a mechanism (not shown) to lock the support 68 to the track 18. The handle is shown in the locked position of the mechanism in Figures 1 and 3. By swinging the handle counterclockwise the mechanism is released, thereby enabling the adapter support 68 and the parts secured thereto to be shifted to the right on the track 18.

The adapter plate 22' has a stator support 40' secured to the inside thereof. A stator 88 is secured to the stator support 40' by the bolts 90 and a stator 92 is secured to the stator support 40 by similar bolts 90. The center of the rotor 14 has recesses at both sides which enable the stators to extend part-way into the rotor but out of contact therewith. Wires 94 from a source of electric energy (in this instance a variable frequency unit) lead to the stators 88 and 92 to energize the same and cause the rotor 14 and its shaft 16 to turn in the bearings 48.

The base 4 houses a lubricating system to deliver oil to the headers 66 and 66'. An oil reservoir 96, having a filler spout 98, a vent 100 and a drain 102, is mounted in one corner of the base 4. The reservoir 96 has an outlet pipe 104 having a gooseneck or return bent upper end 105 which delivers oil to a pump 106 driven by an electric motor 108. The pump has an outlet pipe 110 which delivers the oil into a pressure relief bypass valve 112. The bypass has an adjusting screw 113 to regulate the flow of oil. From the bypass 112 one pipe 114 returns to the reservoir 96 while another outlet 116 delivers oil to the top of a filter 118. The oil passes through the filtering material in the filter and leaves the filter at the bottom through the T connection 120. From the connection 120 the oil passes through the oil resistant flexible tubing 122 to the oil headers 66 and 66'. From the oil headers the oil passes to the inlet pipes 54, into the bearing caps 52, then between the journals of the shaft 16 and the bearings 48 and into the oil retainers 50. The oil then passes through an opening 124 in each bearing housing 48 and into the outlet pipes 56 and then through the headers 66 and 66' into the oil resistant return flexible tubes 126. From the tubes 126 the oil returns through the pipe 128 to the reservoir 96. The pump 106, bypass 112 and filter have a resistance such as to make an oil pressure of four or five pounds at the bearings 48.

The pressure is just sufficient to keep a slow flow of oil passing through the oiling system.

The oiling or lubricating system is used in connection with the finish balance only and its purpose is to obtain a free and easy rotation of the rotor during the balancing operation. Any roughness in the bearing, or any particle of foreign matter, will cause a jiggling action and prevent a smooth curve from being obtained on the oscillograph screen.

The out-of-balance movement of the rotor 14 and its shaft 16 are communicated to two Brush DP-1 displacement piezoelectric type pickups 130 mounted on the adapter plates 22 and 22'. The mounting is best shown in Figure 6. Suitable electric connections (not shown) pass through an opening 131 to transmit the electric charge developed at the surfaces of crystal to the oscillograph. A detailed description of the inside of the pickup is not given for the reason that it forms no part of the invention and the pickup is purchased commercially.

The pickup support is indicated at 132. This support comprises base member 134 and the two steel tubes 136 secured thereto. Suitable long bolts, the knurled heads of which are indicated at 138, pass through the steel tubes 136 and are screwthreaded into the adapter plates 22 or 22'.

The "Neoprene" 34 has an opening 140 therein and a needle-like probe 142 extends through the opening 140 and through a mating opening (not shown) in the adapter plates 22 and 22'. The probe 142 has a point which is pressed against the inner ring 32 of the suspension member 28. A pickup probe guard 144 surrounds the probe and has its smaller end extending into the opening in the adapter plate 22 or 22'. A clamp for the probe guard is indicated at 146, and 148 indicates the pickup housing. A lock ring 150 and a pickup adapter 152 complete the pickup. A thumb screw 154 screwed into the adapter 152 holds the pickup on the pickup support 132.

In the structure of the finish balance of Figures 1-4, inclusive, and 6, the pickups are able to take the unbalance directly from the bearings in the adapter plates. The inherent distribution of mass of the rotor indicated in Figure 3 permits this, but with different shaped rotors the pickups cannot be mounted at the adapter plates because it is impossible to pick up the unbalance at the bearings.

In order to assure that the wave on the oscillograph screen always will start at 0° on the screen scale, the triggering structure of Figures 7 and 21 is provided. The adapter support 68 at the right side has a housing 156 at its upper part and this housing is covered by a cover 158. The housing 156 has one side open at 160 and this opening 160 mates with an opening 162 in the lower part of the adapter plate 22'. The rotor in its rotation passes in front of the openings 162 and 160 and has a painted or bright spot thereon which passes the openings once each revolution. In the housing there is mounted a small electric light bulb 164. This bulb 164 is mounted in a tube 166 which has a lens 168 mounted in the end thereof. The beam of light is focused on the side of the rotor by adjusting the position of the tube 166. The beam will fall on the rotor side in the path of the bright spot. The reflected beam of light from the bright spot strikes a light sensitive cell 170 mounted in the housing 156. The current produced by the light falling on the cell 170 is transmitted by suitable wires (not shown) to the circuit of the oscillograph.

The oscillograph 172 (Model 160-B, five-inch RCA) is rigidly mounted at the back center of the machine on a box-like support 174 secured to the base 4. The screen of the oscillograph is indicated at 176.

When the place and amount of unbalance are determined, drills 178 are provided to remove the necessary amount of metal. The drills are driven by electric motors 180 and the drills and motors are mounted on supports 182 secured to hinge blocks 183 pivoted between the ears 184 of brackets 186 rigidly secured by bolts and nuts 188 to a shelf 190 at the rear of the sub-base 6. Handles 191 operate a conventional rack and pinion mechanism to move the drills to and away from the rotor 14. Because the frame 182 of the drills is pivoted, it is possible to swing the drills to and away from the rotor.

Immediately behind the rotor 14 and between the points of the drills 178, a drill stop 192 is pivoted at 194 in a bracket 195. The pivotal axis at 194 is coincident with the pivotal axis of the brackets 182. This drill stop is generally H-shaped and is pivoted at the two lower arms of the H while the two upper arms are capable of straddling the rotor. The arms of the drill stop are spaced sufficiently wide to take care of the thickest or widest rotor, but to accommodate the stop to a narrower rotor, filler blocks are secured at the insides of the arms of the H, openings 195' being provided to secure the blocks in place. These filler blocks are of sufficient width to enable a rotor to be snugly received between them. When the drill stops are in operative position the arms thereof back the rotor in line with the drills to enable the drills to remove an amount of metal equivalent to the unbalance.

The drills 178 are graduated to tell the operator how far to operate them to remove a given amount of metal.

The brackets 182 for the drills 178 each have extension fingers 193 which engage the drill stop 192 to move it upwardly on its pivotal axis 194 to cause the arms thereof to be positioned on opposite sides of the rotor. A spring 196, having its ends secured to the drill stop and to the mounting bracket 186 for the drill stop, pulls the drill stop away from the machine or to inactive position when the drills are moved to inactive position.

A switch 198 is mounted in the rear of the machine. This switch has an operating arm 199 in the path of the drill stop 192 and when the drill support brackets 182 are moved to the position shown in Figure 1, they move therewith the drill stop 192 which strikes the arm 199 to move the switch to the off position to cut off the current from the stators 88 and 92. In this way the electric power is prevented from energizing the stators and driving the rotor when the drills are operating.

Referring to Figure 8, brake blocks or shoes 200 covered with hard felt 202 are provided to stop the rotor 14 after the out-of-balance has been determined. The shoes are pivoted at 203 to brackets 204 rigidly mounted on the upper end of rods 206 which extend through openings in the sub-base 6. The brackets 204 normally rest on the machined surface 8. The rods 206 are pivoted at 208 to the ends of a brake beam 210 which has pivoted at its center a brake rod 212, the lower end of which is pivotally connected at 214 to a treadle or foot pedal 216 pivotally mounted at 218 to a bracket 220 secured to the base 4 (Figure 2). Suitable springs 222, 224, and 226 are applied to the brake operating mechanism to retain the brake blocks in the position shown in Figure 8. To operate the brakes the operator presses the foot pedal 216.

The track section 228 immediately under the rotor 14 is a separate section movable upwardly and downwardly by a rod 230 secured thereto. The track section 228 has the duck ways 84', continuations of the ways 84 of the main track 18. A compression spring 231 around the rod 230 always urges the track section 228 downwardly. The lower end of the rod 230 is pivotally secured at 233 to the end of a lever 232, pivoted at 229 to a bracket 235 secured to the sub-base 6. The handle of the lever 232 extends outwardly of the sub-base through an opening in the sub-base and has a short locking lever 234 pivoted thereto. The lever 234 has an integral downwardly extending hook 236 adapted to engage under a latch 238 pivoted at 240 to the sub-base 6. Two latch adjusting blocks 242 and 244 are secured to the sub-base 6 and adjusting screws 246 are screwed into the blocks. Nuts 248 retain the screws 246 in adjusted position. The purpose of the fine adjustment made possible by the structure of Figure 8 is to enable the operator to adjust the position of the movable track section so that the shaft of a rotor carried by it is in very accurate alignment with the bearings 48 in the suspensions 30.

The operation of the structure of sheets 1—6 is as follows: The operator will first move the handle 86 to release the movable adapter support 68. The support 68 and connected mechanism is then moved on the track 18 toward the end of the machine. A rotor is now placed on the duck ways 84 and the rotor is then slid on to the ways 84' which at this time are in their lower position in alignment with ways 84. Ways 84' are now raised by swinging lever 232 engaging hook 236 with catch 238. The rotor is thereby raised to a position in which its shaft is in alignment with the bearings 48 in the suspension members 28. The rotor is now slid on the ways 84' to engage its shaft 16 with the bearing 48 in the stationary suspension members 28 as shown at the left of Figure 3. The shiftable adapter support 68 and its adapter plate 22' are now shifted toward the rotor until the suspension member and its bearing 48 are properly positioned on the shaft of the rotor. The handle 86 is now moved to locked position and the hook 236 released from the catch 238 to enable the movable track section to drop away from the rotor 14. The drills 178 and the drill stop 192 are away from the rotor. The electric current is now turned on to energize the stators which will cause the rotor to rotate. When the desired degree of speed has been reached, the power is shut off and the rotor allowed to run freely, and during this free rotation the unbalance is noted. The wobbling or the vibration of the rotor due to unbalance will compress the Neoprene and also move the probe 142 to affect the pickup 130. The electric charges produced in the pickup will be recorded as vertical displacements in the curve depicted on the screen of the oscillograph. Each time the bright spot on the rotor passes the light 164, the cell 170 will be affected and the produced electric current transmitted to the circuit of the oscillograph to cause the spot of light from the cathode tube to be started at 0° on the oscillograph scale and traverse the scale once. The graph on the screen will have the shape of a sine curve and the vertical distance between peaks of the curve will indicate the amount of unbalance and the position on the scale of the upper peak of the curve will indicate the place of unbalance. The rotor is now stopped by the brakes.

After the amount and place of unbalance are determined, the operator presses the foot pedal 216 to stop the rotor. The rotor is then removed and a new one inserted.

The dial 42 and rotor 14 are now relatively oriented so that the 0° mark on the dial corresponds with the bright spot on the rotor. By now observing the number of degrees on the dial corresponding to the degrees on the oscillograph corresponding to the upper peak of the sine curve, the place of unbalance on the rotor is indicated. This place is marked. The drills and drill stop are now swung into place and the motors 180 operated to turn the drills. By moving the handle (or handles) 191, the drill can be moved to the rotor to cause the proper amount of metal to be removed.

Figures 11 and 13 show the rough balancing setup and operation corresponding to the finish balance setup of Figures 1–9 inclusive. As much of the structure of Figures 1–9 inclusive is omitted which would be duplicated for the rough balancing operation and the structure shown is that which is different from Figures 1–9, inclusive.

In this rough balancing operation, the pickup points or places do not coincide with the bearings and it is necessary to use an auxiliary device such as an indicator bar or nodal bar 249 to enable the pickups to register the degree of unbalance. The probes 142' are applied similarly as the probes 142 are applied in connection with the finish balancing operation, except that they are attached at their outer ends to the indicator bar. A yoke 250 is secured to one probe and two pointed pins 252 are screwthreaded into the arms of the yoke and are pivoted in recesses in the bar 249. The other probe at the other bearing of the rotor is secured to a member 253 having a knife edge 251 which rests against the inside of a wear band 255 which surrounds the bar. A flat spring 257, having its outer end upwardly curved to bear against the outer side of the bar and press it against the knife edge, is secured to the bottom of the knife edge member. In this way one end of the bar is removably secured to permit its being moved so that the movable assembly 10 can be shifted to remove a rotor and replace it with another. A spring 260 constantly urges the probe 142' against the bearing 262 of the rotor.

The antifriction ball or roller bearings 262 used in the rough balance setup are allowed to yeld in the horizontal plane only, and for this rough balancing operation the suspension members or suspensions 28 are removed from the suspension assemblies 10 and 12 and the rough balance or pendulum suspension 264 substituted therefor. This rough balance suspension 264 comprises a ring 266 which fits in a centralizing ring 268 which in turn fits snugly in the eccentric openings 26 of the adapter plates 22 or 22'. Suitable screws 270 are provided to prevent the rotor contacting the stator when the rotor is rotating. Sufficient clearance is allowed at 272 between the screw ends and the bearing to enable the wobbling due to out-of-balance to be communicated to the probes 142'. The ring 266 has a bearing retainer 274 secured thereto, and this retainer has an arcuate track 276 on which the bearing 262 rests. The retainer is also provided with a stop plate 277 to serve as an abutment for the bearing when the rotor is placed in position. A switch actuator finger or bracket 279 is secured to the bearing retainer and when the rough balancing setup is in place the actuator 279 contacts the button 278 of the limit switch 280 which controls a double throw contactor for supplying either the high frequency or low frequency power to the stator. Figure 11 shows the rough balance setup which requires 110-volt, 60-cycle, 3-phase power to the stator to drive the rotor at the approximate rough balance speed of 1750 R. P. M. When the switch 280 is actuated by the finger 279, the power to the oil pump motor and to the frequency changer drive motor is cut out.

Because the points at which the out-of-balance is to be taken by the pickups 130 do not coincide with the bearing supports in the adapter plates 22 and 22', it is necessary to determine two new places or points at which to apply the pickups: If we take a rotor known to be in perfect balance, apply an unbalanced weight in the plane of one of its lateral faces, then rotate the rotor in the balancing structure of Figure 10 or Figures 11 and 13 and later allow the rotor to run freely with the power shut off from the stators, it will be found that the indicator bar will have a place where there is no vibration, that is, a node, in a plane parallel to the rotor face and spaced from the other side of the rotor. If the procedure is repeated with the weight transferred to the other face of the rotor, a second node will be found in a plane spaced from the rotor side which does not have the weight applied thereto. The out-of-balance of the rotor in the rough balancing setup is taken at these nodal points which are suitably marked on the indicator bar.

The pickup 130 of Figure 10 is mounted on a pickup support 282 which has a hinged top 284 held in place by a pivoted eye bolt and knurled nut 286. The pickup has a probe 288 adapted to contact the nodal bar 249 at the nodal points. The support has the weighted bottom 209 (see Figure 10) which rests flatwise on the machined surface 8 and is manually movable to adjust the support to the desired position so that the probe 288 will be at the nodal point which has previously been determined and marked on the nodal bar.

Figure 12 is a view similar to Figure 3 and shows the finish balance setup for a rotor 41, which is different from the rotor 14 of the Figures 1–8, inclusive. In this species but one stator 92a is used. The stator support at the right is replaced by the plate 292 and the stator support 40a at the left is differently shaped to accommodate it to the length of the rotor shaft 16a. The rotatable annular index or dial 42' is secured to the stator support adjacent the rotor and the pointers 44a and 44b are shaped slightly differently. The oiling system, the installation of the pickups 130, and the rest of the structure is the same as shown in Figures 1–3 and 6.

Figure 14 is also a view similar to Figure 3, and shows the finish balance setup for a still different type of rotor 14''. In this species, as in Figure 12, but one stator 92b is used, and the stator support 40b is differently shaped to accommodate it to the rotor and the rotor shaft. The bearing 48a is also differently shaped to accommodate it to the shaft 16b. The main difference between the showing of Figure 14 and its related Figures 15—17 over Figures 3 and 6 is in the application of a nodal bar 249. Each adapter support 22 or 22' has a bracket 300 secured thereto by suitable clamp screws 301 (see Figure 10) and on the ends of these brackets there are rigidly mounted the extensions 302 and 303. Each extension has pivoted thereto at 304 a lever 306 or 307 and the nodal bar 249 is mounted at the free ends of these levers. The mounting for the nodal bar at the right hand lever 306 is shown in detail in Figure 17. The lever 306 has a reduced end 308 flat on the side toward the nodal bar 249. A spring 310 is pivoted at its ends to the nodal bar by means of the screws 312. This spring 310 has a loop 314 at its end adapted to be removably engaged with the end 308 of the lever 306. A roller 318 is mounted in the nodal bar, and this roller bears against the flat face of the lever 306. By swinging the spring 310 on its pivots to the left (Figure 15) the adapter support 22' is disengaged from the nodal bar and can be moved to enable the withdrawal of the balanced rotor and replacement by an unbalanced one.

A probe 334 passes through a bore in each bracket, and a coil spring 339 surrounds each probe and urges it against the inner race of the Neoprene suspension. Springs 352 constantly urge the levers 306 and 307 against the ends of the probes.

The support for the nodal bar from the lever 307 is shown in detail in Figure 16. A fork or yoke 320 has a shank 322 journaled in the lever 307. The nodal bar is received in the fork of the yoke 320 and a pin 324 passes through the tines of the fork and through the nodal bar to form a pivotal connection. When the loop 314 is freed from the end 308, the nodal bar 249 can be swung on its pivot formed by the shank 322 in the lever 307.

The linkage for the nodal bar shown in Figure 15 is an amplitude increasing linkage better to enable the nodal bar to communicate to the pickup 130 the small amount of out-of-balance.

Figures 18, 19 and 20 show a rough balance setup and unique nodal bar mounting for a still different type of rotor 14''' using but one stator 92. If a nodal bar mounting such as shown in Figures 10 and 11 were used, a very long nodal bar would be necessary because the nodal points occur at much wider spaced places. To decrease the length of the nodal bar, an amplitude decreasing linkage as shown is used. Brackets 330 are secured to the adapter plates 22 and 22' by means of the screws 332. Each bracket has a bore to enable the passage of the probe 334, and also has secured thereto an inwardly directed arm 336 or 338. A spring 339 is positioned around each probe 334 and constantly urges the probe away from the bearing 262'. An angled lever 340 is pivoted at its end at 342 to the end of the arm 338 and an angled lever 344 is pivoted at its end at 346 to the end of the arm 336. The lever 344 is somewhat zig-zag shaped and has a part 348 which extends under and parallels the indicator bar 249. A pivot pin 350 enters a slot 351 in the indicator bar. The ends of the probes 334 act on the free ends of the levers 340 and 344, and tension coil springs 352, secured at their ends to the levers 340 and 344 and brackets 330, always maintain the lever ends in contact with the probes 334 and the probe ends in contact with the bearing. A support 354 is journally mounted in the lever 340 and a fork 356 on the end of the support receives the nodal bar 249 therebetween. The nodal bar 249 is supported at opposite sides by pivot pins 358 having points fitting in corresponding indentations in the bar. Compare Figures 11 and 13.

Referring to Figure 20, there is shown in side view the rough balance setup for the rotor 14''' having a smaller bearing 262'. The suspension assembly 264' is shaped differently but has the inclined or arcuate track 276' and there is secured to the assembly 264' the metal strip 364 to serve as an abutment for the end of the rotor shaft and the bearing. Screws 270' are provided to prevent the rotor 14''' contacting the stator when the power is on. Clearance as shown at 272d is allowed between the ends of the screws 270' and the bearing 262' to enable the rotor 14''' to run freely immediately after the power is shut off the stator in order that the unbalance can properly be indicated to the pickup by the probes 334 and the indicator or nodal bar 249.

Figure 21 shows only so much of the oscillograph circuit as is different from the conventional circuit of the RCA No. 160B oscillograph.

The operation of the phototube synchronizer circuit is as follows: The purpose of this circuit is to lock the sweep of the oscillograph in phase with the rotation of the part being balanced. In order to do this, a voltage must be impressed on the grid of the RCA–884–V4 tube of the oscillograph at the proper time. This is accomplished in the following manner:

A bright, light-reflecting spot is put on the part to be balanced. This reflecting surface is used to reflect the light ray from a source 164 through a lens 168 to a phototube 170 each time the spot passes the light ray as the piece is being rotated in the machine. Thus, by the nature of the phototube 170, an implse of current is permitted to flow each time the light is received. This impulse of current also results in a voltage change in the circuit. The phototube circuit is coupled to the 884–V4 tube by condenser C. Thus, required voltage change is impressed on the grid of the 884–V4 tube to synchronize the sweep to the rotation of the part.

The voltage for the phototube circuit is taken from the potentiometer circuit, consisting of resistors R_1 and R_2. The phototube circuit consists of the phototube, resistance R_3, condenser C, and resistance R_4 and is connected to the potentiometer circuit by double plugs 1, 2, 3, 4. Resistance R_3 is the load resistor which determines how great a voltage change will be effected by a change in illumination of the phototube. The condenser C couples the circuit to the 884–V4 tube. Resistance R_4 is the leak resistance that permits the current to drain from the grid at a higher rate than it does through the resistance R_3.

We claim:

1. In a machine for balancing rotors two upright mounting suspensions adapted to receive the bearings of the shaft of the rotor, one of said suspensions being movable to enable the insertion and removal of the rotor, a track on the machine to receive the rotor preparatory to its insertion in the suspensions, a part of said track under the mounted rotor being movable to and from the rotor and being capable of being aligned with the remainder of the track, means to cause the rotor to turn in its bearings in the suspensions, the mounting of the rotor in the suspensions permitting the rotor and its shaft to have a limited amount of bodily movement produced by the unbalance in the rotor, and means including movable probes mounted on the suspensions adapted to indicate the amount of movement due to unbalance.

2. In a balancing machine, the combination of a pair of spaced supports adapted to receive the part to be balanced and permit rotation thereof, means at opposite ends of said part for removing material therefrom, a shiftable mounting for each of said means to permit it to be moved into and out of operative position, means for straddling the part and backing it up while material is being removed therefrom, a shiftable mounting for said last-named means to permit it to be moved into and out of operative position, and means for interconnecting the shiftable mounting for said first-named means and the shiftable mounting for said backing up means to cause said backing up means to move to operative position when said material removing means is moved to operative position.

3. In a balancing machine the combination of a pair of spaced supports adapted to receive the part to be balanced and permit rotation thereof, means at the opposite ends of said part for removing material therefrom, a shiftable mounting for said means to permit it to be moved into and out of operative position, means for straddling the part and backing it up while material is being removed therefrom, a shiftable mounting for said last-named means to permit it to be moved into and out of operative position, and means for interconnecting said shiftable mountings to cause said backing-up means to move to operative position when said material removing means is moved to operative position, and means actuated by one of said shiftable mountings for disconnecting the drive for the part when the said means is moved to operative position.

4. In a balancing machine the combination of a support, a bearing fixed to the support adapted to receive one of the journals of the body to be balanced, an assembly mounted on said support for movement toward and from said fixed bearing, a bearing carried by said assembly in alignment with said fixed bearing and adapted to receive the other journal of said body, said support being provided with a fixed rest for said body adjacent one of said bearings, a vertically movable rest mounted on said support between said bearings, said movable rest being normally aligned with the fixed rest, and means for raising said movable rest to align the journals of the body with said bearings to permit their insertion in said bearings.

5. In a balancing machine, a support having an arcuate supporting surface, a cylindrical bearing having limited rolling engagement with said surface, said bearing being adapted to receive within it a journal of a body to be balanced, means for rotating the body whereby in case of unbalance therein said bearing rolls back and forth on said surface, and means responsive to the movement of said bearing for indicating the rolling movement of said bearing in response to unbalance.

6. In a balancing machine, a pair of aligned arcuate supporting surfaces, a pair of cylindrical bearings each having rolling engagement with one of said surfaces, means for limiting rolling movement of said bearings on said surfaces, each of said bearings being adapted to receive within it a journal of a body to be balanced, means for rotating the body whereby in case of unbalance therein said bearings roll back and forth on said surfaces, and means responsive to the movement of one of said bearings for indicating the amount of rolling movement of said bearing in response to unbalance.

7. In a balancing machine, a support having an arcuate supporting surface, a cylindrical bearing of smaller radius than said surface, said bearing

being in rolling engagement with said surface and being adapted to receive within it a journal carried by the body to be balanced, means for rotating the body whereby in case of unbalance in said body said bearing rolls back and forth on said surface thereby affording an indication of unbalance, and means responsive to the movement of said bearing for indicating the amount of rolling movement of said bearing in response to unbalance.

8. In a balancing machine, the combination of a pair of spaced supports having coaxial arcuate supporting surfaces, aligned antifriction bearings having cylindrical outer surfaces of smaller radius of curvature than said arcuate surfaces, said bearings each being in rolling engagement with one of said arcuate surfaces and being adapted to receive the journals of the body to be balanced, means for rotating the body whereby, in case of unbalance in said body, said bearings will roll back and forth on said arcuate surfaces thereby affording an indication of unbalance, and means responsive to the rolling movement of one of said bearings for indicating the amount of rolling movement of said one bearing in response to unbalance.

9. In a balancing machine, a support having an arcuate supporting surface, an antifriction bearing having a cylindrical outer surface of smaller radius of curvature than said arcuate surface, said bearing being in rolling engagement with said arcuate surface and being adapted to receive a journal of the body to be balanced, means for movably supporting the other journal of said body, means for rotating the body whereby in case of unbalance in said body said bearing rolls back and forth on said arcuate surface, and means responsive to the rolling movement of said bearing for indicating the amount of rolling movement of said bearing in response to unbalance.

10. In a balancing machine, a support having an arcuate supporting surface, an antifriction bearing having a cylindrical outer surface of smaller radius of curvature than said arcuate surface, said bearing being in rolling engagement with said arcuate surface and being adapted to receive a journal of the body to be balanced, means for movably supporting the other journal of said body, means for rotating the body whereby in case of unbalance in said body said bearing rolls back and forth on said arcuate surface, means engaging said bearing and responsive to its rolling movement for indicating the amount of rolling movement of said bearing in response to unbalance, and stops on said support spaced from said bearing and adapted to limit its rolling movement.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
194,004	Scofield	Aug. 7, 1877
1,009,323	Lincoln et al.	Nov. 21, 1911
1,032,439	Templeton	July 16, 1912
1,095,552	Colpitts	May 5, 1914
1,132,745	Sundh	Mar. 23, 1915
1,252,695	Hopkins	Jan. 8, 1918
1,449,172	Gendreau et al.	Mar. 20, 1923
1,481,785	Akimoff	Jan. 29, 1924
1,491,523	Ekstrom	Apr. 22, 1924
1,588,205	Stephenson	June 8, 1926
1,625,259	Johnson	Apr. 19, 1927
1,651,272	Hapgood	Nov. 29, 1927
1,652,502	Saderberg	Dec. 13, 1927
1,740,762	Biquard	Dec. 24, 1929
1,839,134	Van Degrift	Dec. 29, 1931
2,037,443	Van Degrift	Apr. 14, 1936
2,043,618	Havill	June 9, 1936
2,054,267	Ohlson	Sept. 15, 1936
2,122,621	Ohly	July 5, 1938
2,123,443	Taylor	July 12, 1938
2,130,122	Dybvig	Sept. 13, 1938
2,131,602	Thearle	Sept. 27, 1938
2,167,488	Ohlson	July 25, 1939
2,180,853	Scheppmann	Nov. 21, 1939
2,186,339	Moore	Jan. 9, 1940
2,201,369	Hem	May 21, 1940
2,243,458	Esnal et al.	May 27, 1941
2,275,256	Fried	Mar. 3, 1942
2,289,074	Rushing et al.	July 7, 1942
2,289,200	Lundgren	July 7, 1942
2,293,371	Van Degrift	Aug. 18, 1942
2,327,609	Saltz	Aug. 24, 1943
2,329,654	Rouy	Sept. 14, 1943
2,329,835	Hope et al.	Sept. 21, 1943
2,344,753	Van Degrift	Mar. 21, 1944
2,382,665	Riopelle et al.	Aug. 14, 1945
2,383,588	Bousky	Aug. 28, 1945

FOREIGN PATENTS

Number	Country	Date
585,907	Germany	Oct. 12, 1933
621,821	Germany	Nov. 14, 1935