Aug. 28, 1945. S. BOUSKY 2,383,588

BALANCING MACHINE

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Fig. 1.

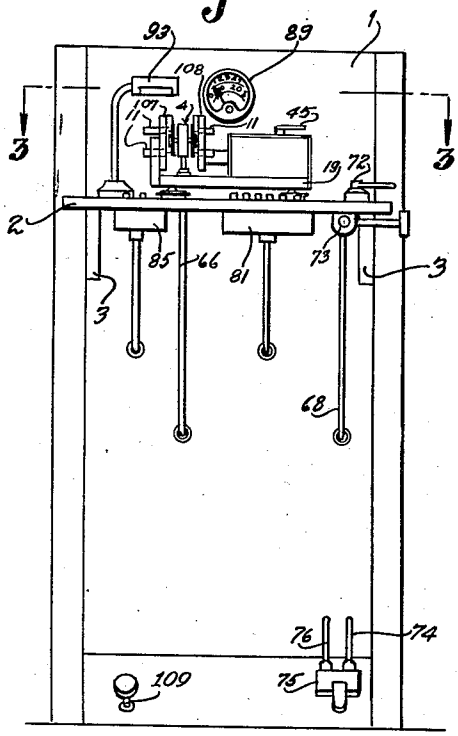


Fig. 2.

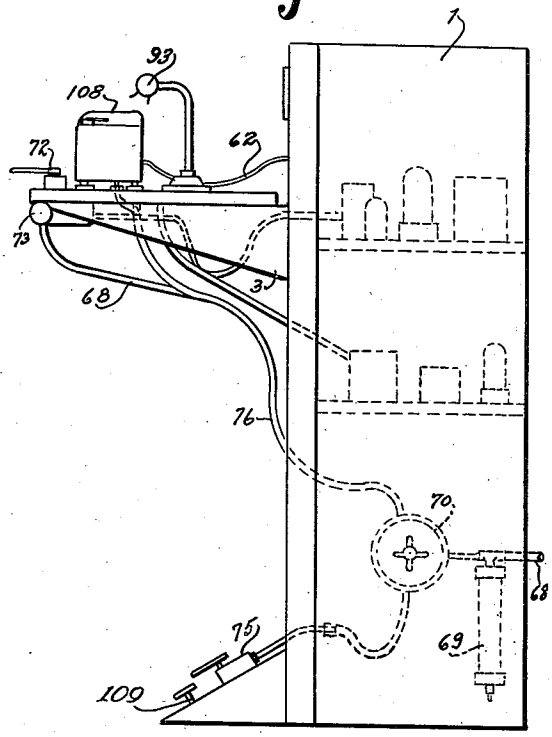
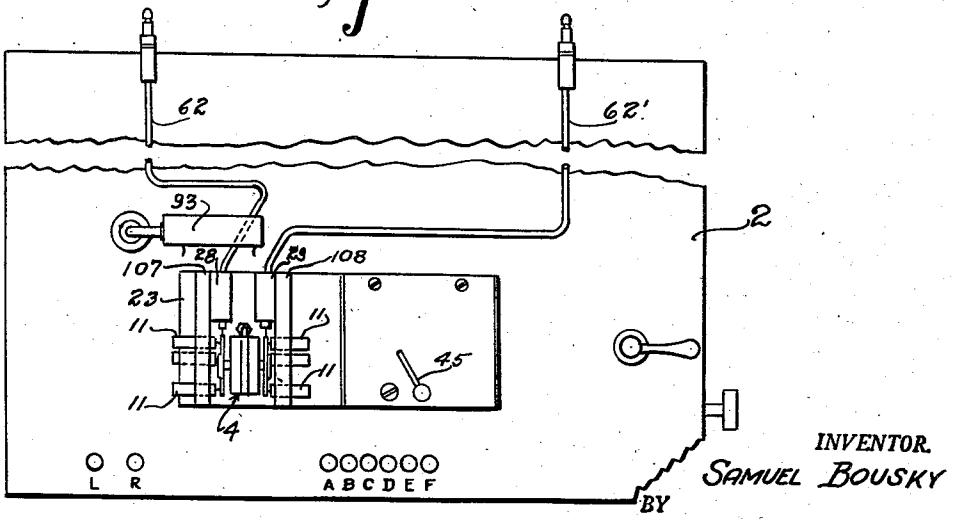


Fig. 3.



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Fig. 4.

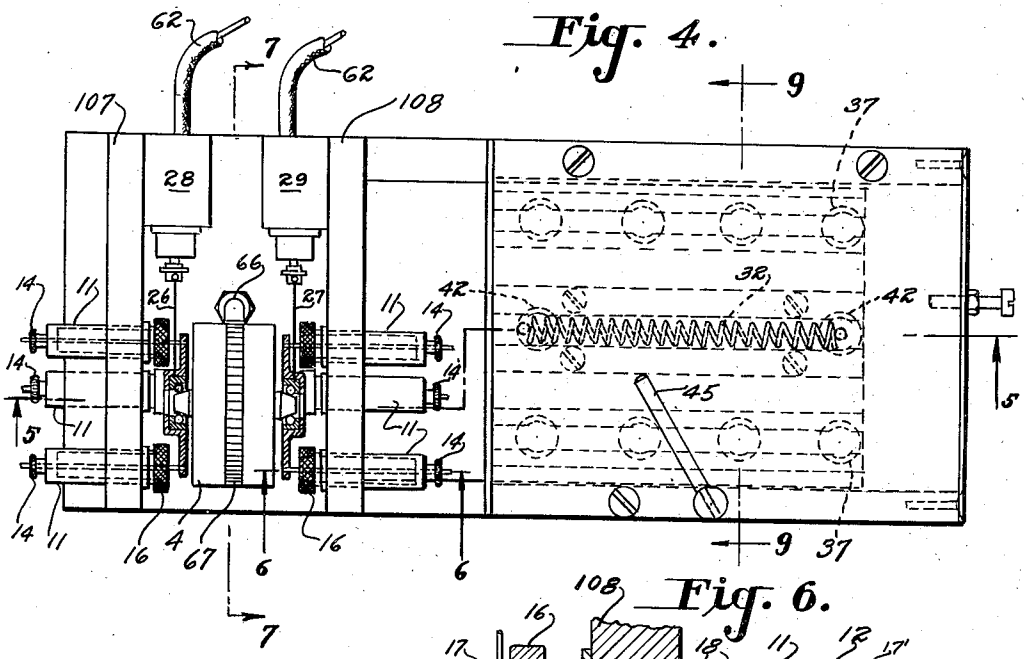


Fig. 6.

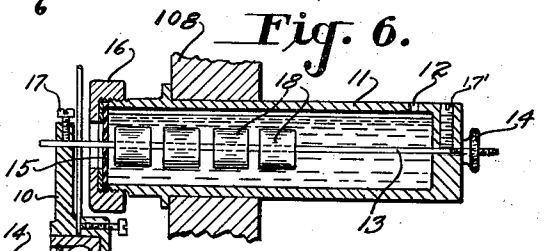
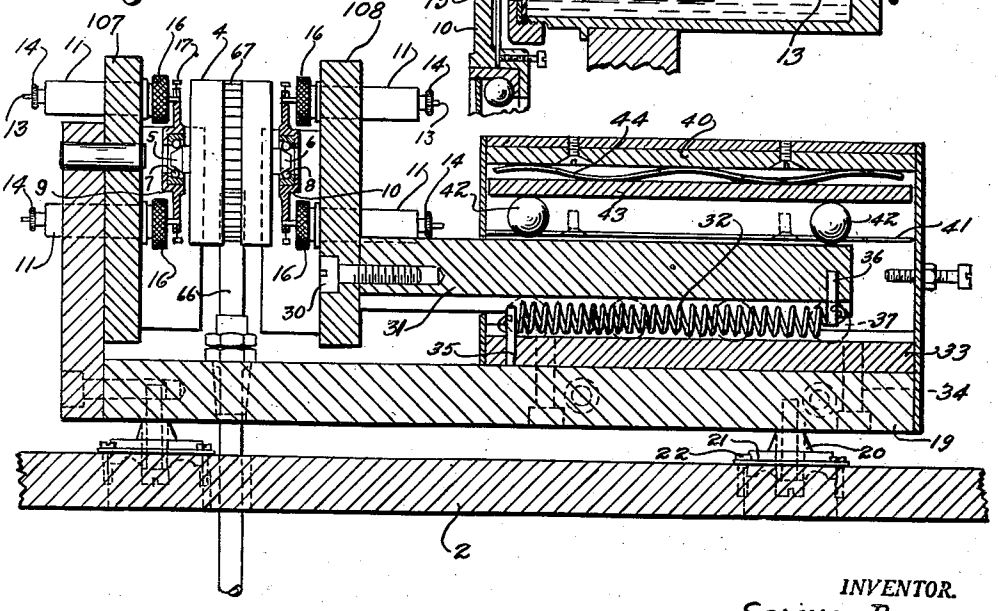


Fig. 5.



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Fig. 7.

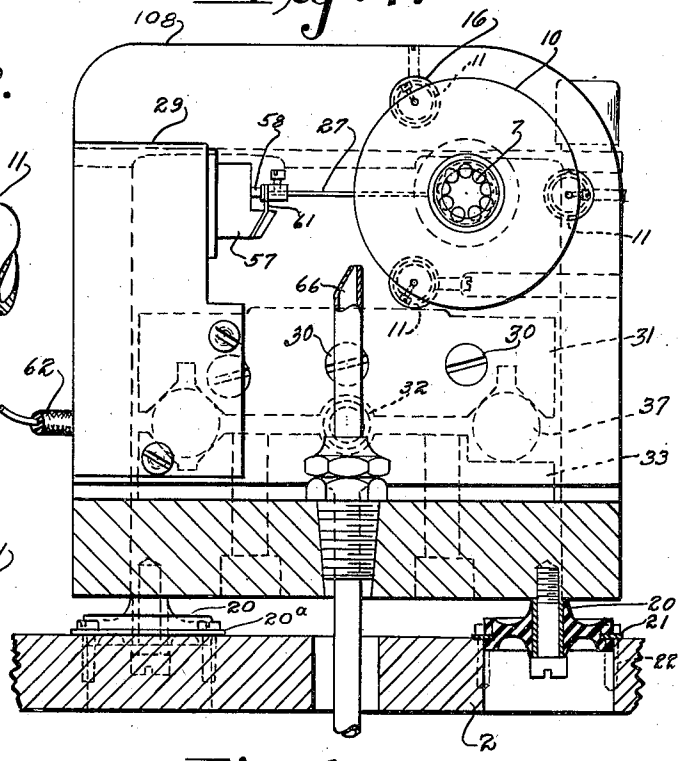


Fig. 12.

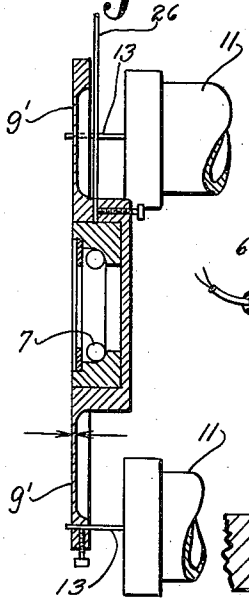


Fig. 8.

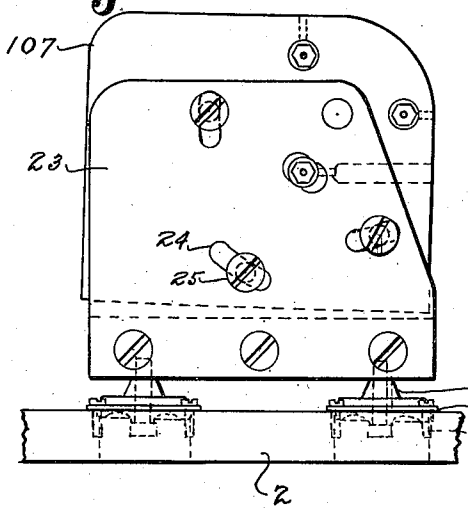
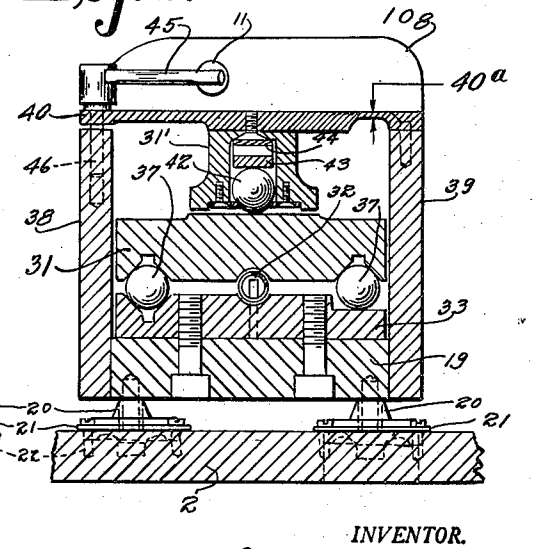


Fig. 9.



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Fig. 10.

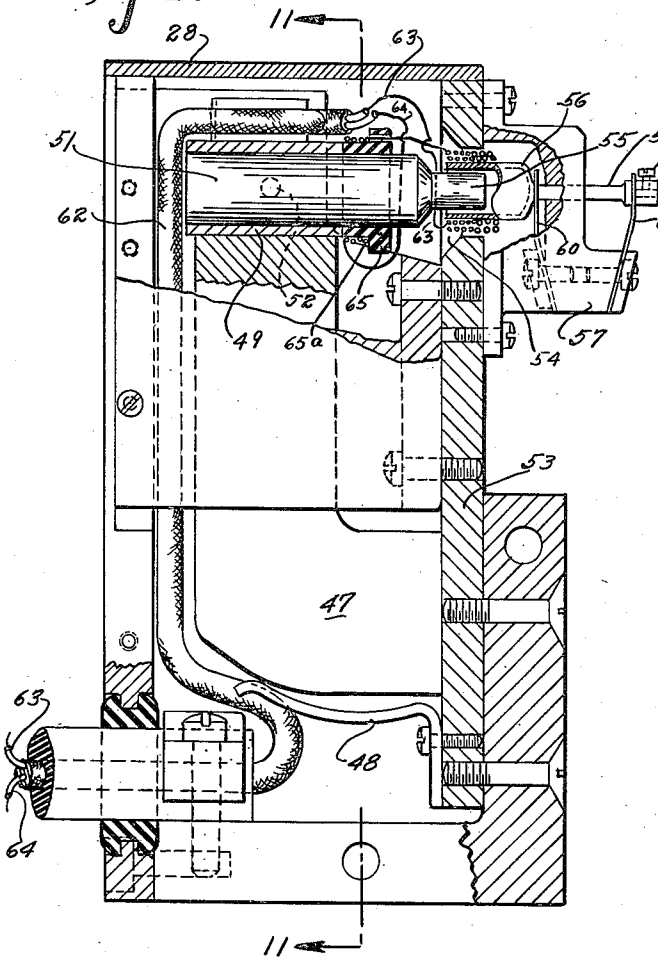


Fig. 11.

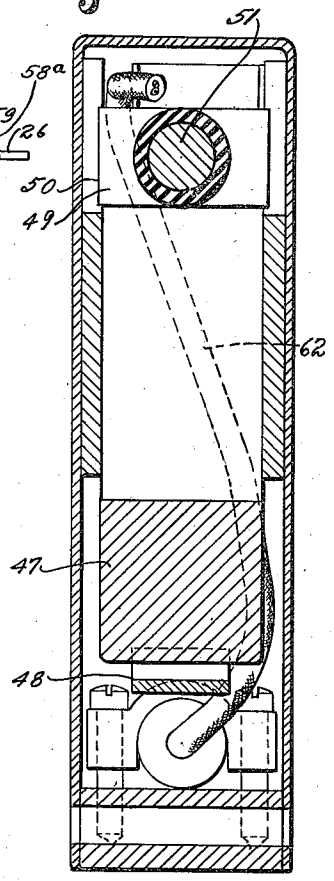
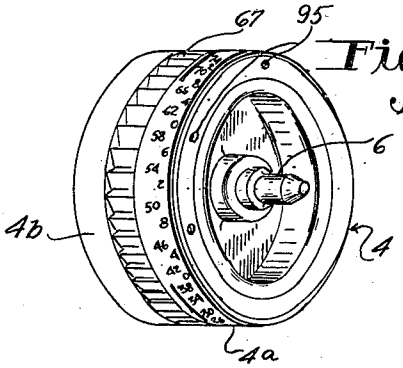


Fig. 15.



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BALANCING MACHINE

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Fig. 13.

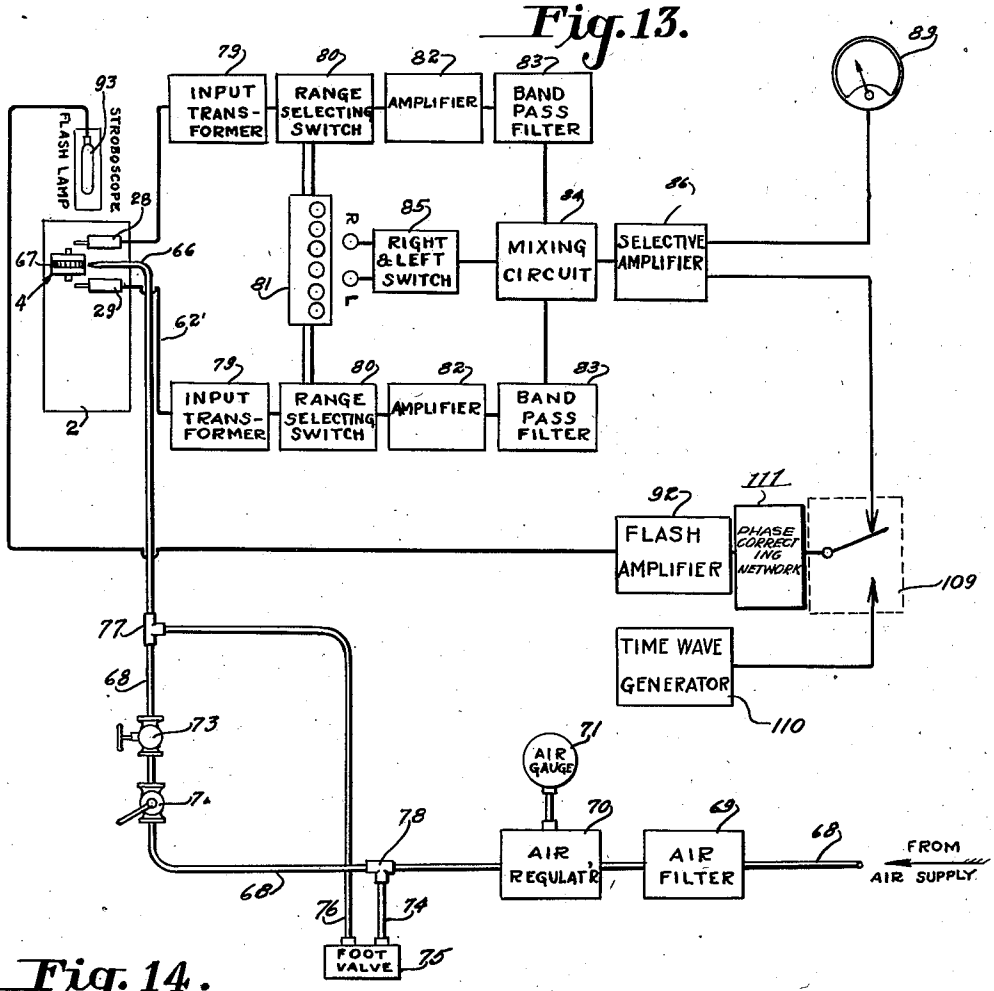
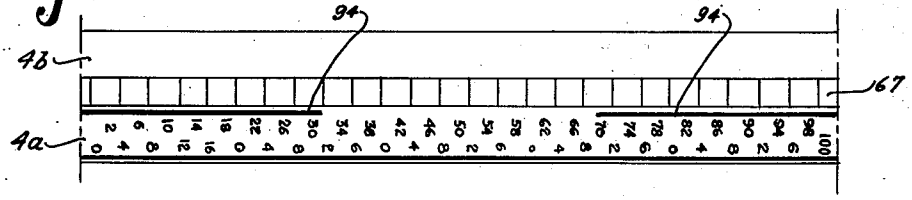


Fig. 14.



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BALANCING MACHINE

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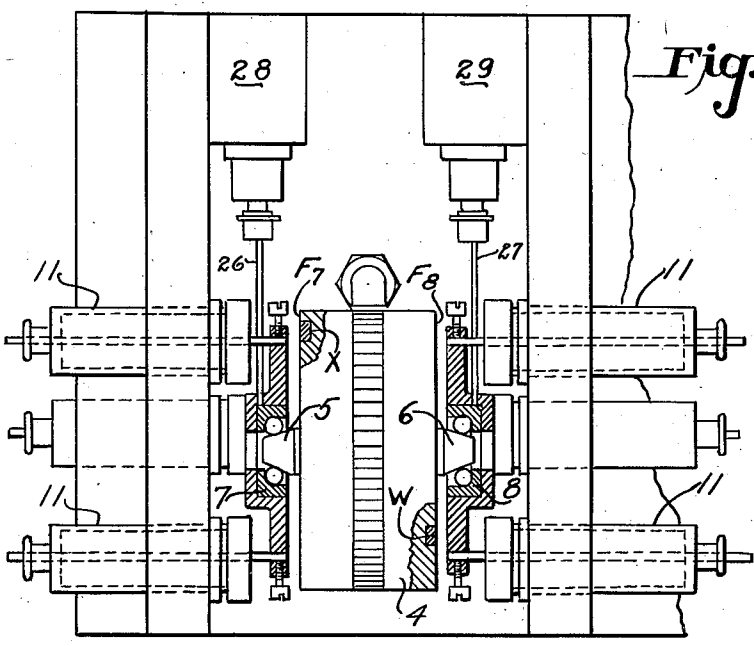
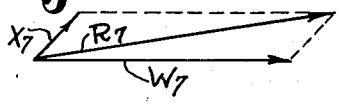


Fig. 16.

Fig. 17.



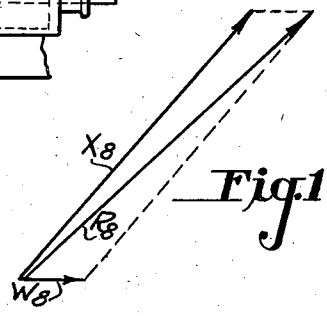
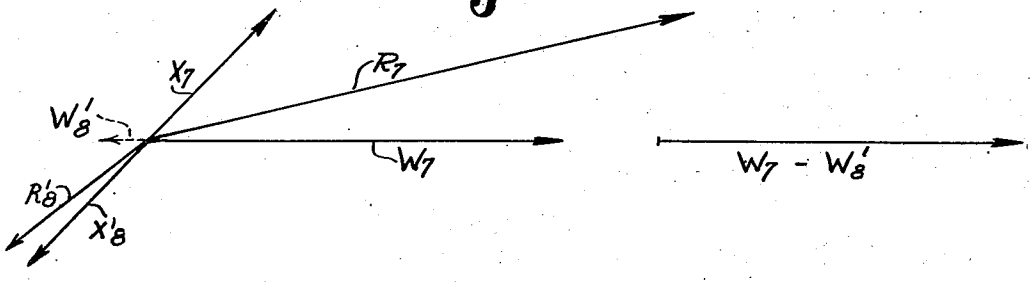


Fig. 18.

Fig. 19.



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Patented Aug. 28, 1945

2,383,588

UNITED STATES PATENT OFFICE

2,383,588

BALANCING MACHINE

Samuel Bousky, Shaker Heights, Ohio, assignor to Jack & Heintz, Inc., Bedford, Ohio, a corporation of Ohio

Application November 20, 1942, Serial No. 466,265

6 Claims. (Cl. 73—66)

This invention relates in general to balancing machines, or in other words to improvements in devices for determining and indicating the amount and location of dynamic unbalance or state of dynamic balance of high speed rotating masses such as gyro rotors, armatures and the like.

One of the primary objects of the invention is to provide a testing device that will properly and accurately simulate the conditions of actual operation that will permit unbalance determinations of the rotor that would actually occur under actual operation thereof.

A further object of the invention is to provide in such a testing device, a rotor bearing suspension and electrical pick-up assembly whereby the rotor bearings will lie in parallel planes and will be resiliently suspended so as to be substantially free to move in all directions within a plane at right angles to that of the rotor so that, under the influence of unbalance forces, motion of the bearings is effected to drive the pick-up units to generate electrical voltages which are proportional to the movements of the bearings.

A further object of the invention is to provide in such a testing device improved electronic circuits to properly amplify the minute pick-up voltages, select the proper components and mix them in the proper phase and magnitude relationships.

A further object of the invention is to provide in such a testing device means whereby the position of unbalance is indicated separately on both sides of the rotor by a stroboscopic lamp which flashes directly thereon.

A further object of this invention is to provide an electrical pick-up assembly and associated electronic amplifier and filter circuits of such extreme sensitivity as to permit unbalance determinations of a degree hitherto unattainable.

With the foregoing and other objects in view the invention resides in the combination of parts and in the details of construction hereinafter set forth in the following specification and appended claims, certain embodiments thereof being illustrated in the accompanying drawings, in which:

Figure 1 is a view in front elevation of the device showing the rotor suspension assembly and the cabinet for the electrical and pneumatic operating system;

Figure 2 is a view in side elevation of the device shown in Figure 1;

Figure 3 is a view in section taken along line 3—3 of Figure 1 partly broken away showing the rotor suspension assembly in top plan;

Figure 4 is an enlarged view of the rotor suspension assembly showing in dotted lines the slidable support and latching device for the movable suspension member;

Figure 5 is a view in section taken along line 5—5 of Figure 4 showing the rotor suspension device and the slidable support and latching device for the movable suspension member;

Figure 6 is a view in section taken along line 6—6 of Figure 4 showing in section one of the suspension wires for the rotor bearing disc and the damping means for the suspension wire;

Figure 7 is an enlarged view in section taken along line 7—7 of Figure 4 showing in side elevation one of the rotor bearing discs and its suspension as well as a pick-up unit and rotor driving air jet;

Figure 8 is a view in end elevation of the stationary support for one of the rotor bearing plates;

Figure 9 is a view in section taken along line 9—9 of Figure 4 showing the slidable support for the other bearing plate and the means for locking the same in place;

Figure 10 is an enlarged view in vertical section taken through one of the pick-up assemblies;

Figure 11 is a view in section taken along line 11—11 of Figure 10;

Figure 12 is a view in vertical section taken through a modified form of bearing plate and its support;

Figure 13 is a schematic illustration including the rotor and the pick-ups and the electrical and pneumatic system of the testing device;

Figure 14 is a schematic illustration of the gyro wheel rim and buckets showing the numeral indicia on one side of the rim and the lines on the same for indicating purposes;

Figure 15 is a view in perspective of the gyro rotor with indicia on its rim and with lightening drill holes made in the side wall after the balancing testing operation;

Figure 16 is a partial view of the suspended rotor similar to that shown in Figure 4 with theoretical rotor unbalance displacements for purposes of explanation of forces involved in the operation of the device;

Figure 17 is a diagram of the voltages induced in one pick-up due to the forces in one bearing;

Figure 18 is a diagram of the voltages induced in the other pick-up due to the forces in the other bearing; and

Figure 19 is a diagram representing the mixing of the voltages induced in the two electrical pick-ups.

Referring more particularly to the drawings, the testing device generally comprises a cabinet 1 for housing the electrical and pneumatic equipment and a table 2 connected thereto by supports 3 for supporting the gyro rotor suspension, the dynamic pick-ups, stroboscopic lamp, electric switches and indicating meter.

The gyro rotor 4 under test is supported for horizontal rotation with its pivots 5 and 6 engaging ball bearing assemblies 7 and 8 carried by plates 9 and 10 that are resiliently suspended and adjustable to lie in parallel vertical planes. These plates are suspended so as to be free to move in all directions within a plane at right angles to the axis of rotation of the gyro rotor 4 about its pivots 5 and 6. In order to accomplish this there is provided a fixed preferably non-magnetic support 107 and a slidably adjustable preferably non-magnetic support 108. To each of these supports are secured preferably three equidistantly spaced assemblies such as shown in detail in Figure 6 which consists of a fluid filled cylinder 11 with a small breather 12. Through the cylinder extends a fine strong wire 13 screw threaded at one end to receive an adjusting nut 14. The other end of the cylinder is sealed by a flexible diaphragm 15 held in place by a knurled cap 16 through which the wire extends to engage an aperture in the bearing plate 10 near its periphery and is held in place in bearing plate 10 by a screw 17. A screw 17' anchors the wire in cylinder 11. The wire 13 carries a suitable number of beads 18 which preferably have roughened surfaces. Although the wires are taut the effect of this arrangement is that while it is sufficiently resilient to permit substantially free movement of bearing plate 10 such movements are damped without materially affecting the natural period of suspension.

As a means of providing further flexibility of suspension the bearing plate of Figures 1, 3, 4 and 5 may be modified, as shown in Figure 12, to include the same hub portion but a diaphragm portion 9' sufficiently thin to afford a suitable degree of flexibility.

In order to safeguard against errors due to extraneous vibration the suspension assembly is supported on table 2 in the following manner. A stationary base member 19 is secured to resilient shock absorbing web 20 carrying a metal plate 21 and secured to the table 2 by bolts 22 for resilient suspension. To this base is secured an end member 23 provided with arcuate slots such as 24 with adjustment studs 25 to permit limited rotational adjustment of support 107 and consequently the bearing plate 9. The purpose of this adjustment feature is to insure absolute mechanical phase alignment of the pick-up assemblies.

In order to test various rotors it is obviously necessary that one of the suspension supports be movable. For this reason support 108 is secured by bolts 30 to a low friction ball bearing slide 31. This slide is held forward by a spring 32 which applies a uniform force of proper extent for the various rotors to be tested and provision is made for locking this slide during the rotor testing operation in such a manner as not to disturb the thrust load. This is accomplished by securing a plate 33 by bolts 34 to base 19. One end of tension spring 32 is secured by a pin 35 to plate 33. The other end of spring 32 is secured by a pin 36 to the slide 31 which in its sliding movement moves on ball bearings 37 between the slide and the base. With the rotor in position with its pivot 5 in engagement with its bearing 7, the slide is allowed to be moved home under the influence of spring 32 until pivot 6 is engaged by its bearing 8. As a means for locking the slide in such adjusted position there is provided a slide cage comprising walls 38 and 39, a top plate 40, and a retainer plate 41 with holes therein sufficiently large to allow a portion of the balls 42 to protrude downwardly therethrough, as shown in Figure 5. Intermediate the balls 42 and the top plate 40 is a floating plate 43 downwardly urged resiliently by a leaf spring 44. Thus when spring 32 has urged the support 108 and the bearing plate 10 home a handle 45 is manually turned which through its connection with a screw bolt 46 brings about a tightening of the adjustable relationship between the top plate 40 and the wall 38 through which the bolt passes. This, through the flexibility of top plate 40 in the portion shown at 40a, resiliently locks the slide 31 in abutment with the cage 31' as the balls 42 recede into the cage.

The electrical pick-up units 28 and 29 are arranged to be driven by each of the bearing support plates 9 and 10, respectively, by reason of the connecting wires 26 and 27. Each of these pick-up units is identical in construction and purpose and one of these, which for the purpose of reference will be called unit 28, is shown in detail in Figures 10 and 11, and in which the housing is indicated at 28. In this housing is releasably inserted a permanent magnet 47 which is held in place by a spring clip 48. Resting on top of the magnet is a magnetizable block 49 inserted in the guideway 50 of the casing. Inside of the block is a round magnetizable core 51 that may be adjustable longitudinally and locked in adjusted position by a set screw 52. The metal plate 53 abutting the magnet 47 is provided with a gap opening 54 to receive the reduced end 55 of the core 51 and the coil bobbin 56 mounted for horizontal movement within the gap 54 and about the core 55. This mount consists of a bracket 57 secured to the plate 53 to resiliently support a bobbin arm 58 which has a chuck 58a to receive wire 26 and a set screw 59 to secure the wire in place. Vibrations of the rotor as transmitted from bearing plate 9 through wire 26 will cause a reciprocation of arm 58 in its bearing bracket 57. This motion is restricted to substantially a reciprocatory one by means of two opposed leaf springs 60 and 61 secured to the bearing bracket 57 and secured at spaced points to the bobbin arm 58. The insulated cable 62 leading from the housing 28 into the cabinet and the electric system encloses two spaced insulated wires 63 and 64. As viewed in Figure 10 wire 63 connects to one end of pick-up coil wound on bobbin 56. The other end of this coil connects to neutralizing coil 65a. Wire 64 then connects to the other end of neutralizing coil 65a electrically. Coil 65a and the pick-up coil on bobbin 56 are connected so as to be bucking for cancelling out the effects of any voltages induced by the action of stray varying magnetic fields.

The resultant construction is the formation of two bucking coils in series wherein the coil about the insulator 65 plays no direct part as to generation of electromotive force due to the motion of the bobbin 56. However, as stated before, the plate 53, being in contact with permanent mag-

net 47, is magnetized and the reciprocatory movement of bobbin 56 and its coil break through lines of force so as to generate electrical voltages in response to and proportional to the minute motions of the rotor bearings due to their state of unbalance during rotation.

The gyro rotor is preferably driven pneumatically by an air jet 66 expelling air under pressure against the rotor buckets 67. Two valve systems are incorporated in the instrument, one operated by foot for bringing the rotor up to speed rapidly and another operated by hand providing a needle valve adjustment for maintaining the desired speed of gyro rotor rotation during test. As shown schematically in Figure 13, air under pressure is drawn in through pipe 68 from a suitable source of air supply. The air is then drawn through an air filter 69 and air regulator 70 provided with an air gauge 71 and through pipe 68 past a hand shut-off valve 72 and adjustable needle valve 73 to the air jet 66. A by-pass for the air is provided through junction pipe 74 leading through a foot valve 75 and a pipe 76 by-passing the hand valves and joining pipe 68 at 77. In operation the foot valve is operated to direct the air from pipe 68 at junction 78 through pipes 74 and 76 at gauge pressure to the air jet. When the rotor has gained the approximate desired speed the foot valve is released and shut-off valve 72 and needle valve 73 adjusted to meter and maintain the necessary pressure air flow to obtain the desired speed of rotor rotation.

As stated before, the minute pick-up voltages generated in the pick-up units must be amplified and their proper components selected and mixed in proper phase and magnitude relationships. Figure 13 also shows diagrammatically the arrangement and purpose of the electronic circuits employed in the balancing machine. Voltages are generated in the two identical pick-up units 28 and 29 which are proportional to the unbalance movements of the right and left sides of the rotor. These electrical voltages are very minute and in magnitude they may be measured in the order of a few millionths of a volt. These voltages are then separately increased in magnitude by two identical electrical channels consisting of units 79, 80, 82 and 83. The input transformer 79 serves mainly as a voltage step-up device from the low impedance pick-up unit to the higher impedance range selecting switch 80. The range selecting switches are mechanically interconnected so that both electrical channels are simultaneously switched when any one of the switch buttons on board 81 are operated. The amplifiers 82 serve only to amplify the electrical voltages. The band pass filter 83 selects only the electrical component due to the unbalance movement of the rotor under test and rejects all other extraneous voltages such as those produced by ball bearing noises and other vibrations. In addition this band pass filter is preferably one that has low phase shift characteristics in the pass band. After such amplification and filtering the two voltages are mixed in the proper amplitude and phase so that the unbalance may be referred to one side of the rotor at a time. The theory and practice involved in this procedure is as follows:

Consider an unbalance mass occurring only on the right side of the rotor. Voltages will be generated in both pick-ups 28 and 29 due to this unbalance mass when the rotor is rotated. Consider in addition another unbalance mass on the left side of the rotor but in a different phase relationship with that which occurs on the right side. The voltages generated in the two pick-ups due to the left unbalance mass will then produce a masking effect on the location of the right mass.

For purposes of graphic illustration, reference will be had to Figures 16 to 19, inclusive, and in connection with Figure 16, it will be assumed that there exists an unbalance mass X on face F7 of rotor 4 and an unbalance mass W on rotor face F8. It should be borne in mind that in the present invention the resilient rotor suspension means and the speed of rotation of the rotor are so chosen that the latter is considerably greater than the natural period of suspension. Such being the case, the presence of weight X on face F7 on the left side of the rotor will produce a greater vibration on bearing 8 at the right side than on bearing 7 on the left side.

Referring to Figures 17, 18 and 19, let W7 indicate the instantaneous unbalance displacement of bearing 7 due only to the unbalance mass W on rotor face F8. Similarly, let X8 indicate an instantaneous unbalance displacement at bearing 8 due to mass X on face F7. The resultant displacement R7 at bearing 7 will be the total effect of X7 and W7 of masses X and W. Similarly, the resultant displacement at bearing 8 is vectorially developed as R8 as being the total of X8 and W8.

Disregard for the time being the phase difference between the displacement and its electromagnetically generated voltage and consider R7 and R8 to also represent the voltages in pick-ups 28 and 29. Electrically speaking, if as shown in Figure 19 a small portion of R8, namely R'8, be added to R7 at 180° phase reversal of R8 and of such magnitude that component X'8 is exactly equal to X7 but 180° different in phase, then the resultant of this addition will be W7 minus W8, a quantity that depends only upon mass W and which is representative of it both in magnitude and phase. The proper ratio X8/X'8 is a function only of the linear dimensions of the rotor and the bearing spacings and is therefore a constant for a given type of rotor.

Thus it is seen that by mixing the voltages in the two channels with proper regard to magnitude and phase, a resultant voltage is attained which is representative of unbalance on only one side of the rotor. By electrically reversing this mixing method relative to the two channels, the unbalance on the other side of the rotor can be indicated.

In this manner there is simulated the condition of using two pivots simultaneously without the need of the mechanical structure of two fixed pivots. This is obtained by operation above resonance wherein the unbalance mass on one side must be 180° out of phase with the displacement on that side. The particular suspension provides the necessary axial rigidity as well as the necessary freedom of movement in any direction within the plane at right angles to the axis of suspension of the rotor to accomplish the above described phenomenon.

Such a voltage is then fed to the selective amplifier 86 which further rejects extraneous and interfering voltages. At this point a meter 89 is arranged to indicate the magnitude of the unbalance force directly in micro-ounce-inches, or in terms of millionths of an ounce-inch. The voltage from the selective amplifier 86 is used to locate the position of the unbalance mass. By

means of a foot-operated switch 109 the output voltage from amplifier 86 is fed into flash amplifier 92 where it is amplified and its wave shape is changed so as to present an extremely sharp wave front for flashing the stroboscopic lamp 93. In this manner the stroboscopic lamp is flashed momentarily and once for each revolution of the rotor. The flash lamp is on for such a short interval that it appears to stop the rotation of the rotor and indicates by this means the position at which the unbalance mass occurs. This rotation can be readily identified by the indicia appearing on the wheel as illustrated in Figures 14 and 15. When the foot switch 109 is operated to its other position a voltage from the time wave generator 110 is fed into the flash amplifier 92 and thus operates the stroboscopic flash lamp 93. The speed of the rotor when rotating is determined by this means since the indicia 4a on the rotor will appear to be stationary or rotate slowly when the rotor is rotated at substantially the same rate as the voltage generated by the generator 110.

As previously explained, in the operation of the testing device, the rotor pivots are thoroughly cleaned, the table slide 31 is held with one hand while rotor 4, with its printed numbers on one side 4a, is placed between the bearings 7 and 8 with the other and the slide is released leaving spring 32 free to move the same home, after which it is locked in place by lever 45. The hand operated valve 73 is turned on after which the foot operated valve 75 is depressed to by-pass the air flow for quickly bringing the rotor up to the desired speed of rotation. The foot operated switch 109 is then operated to cause the stroboscopic flash lamp 93 to flash at the rate of 12,000 times per minute. In about five to ten seconds the rotor attains a speed of rotation of 12,000 revolutions per minute. At this point the foot operated air valve 75 is released and fine control of rotor speed is obtained by operation of the hand operated needle valve 73. With the rotor at such speed the magnitude of the unbalance of the rotor is read directly on the meter 89, with the aid of a six push button range selecting switch 81 arranged conveniently at the front of table 2. Readings may be taken either in micro-ounce-inch units or by means of some suitable convenient series of numbers on the meter dial 89.

With the rotor at speed an indication of the position of unbalance of the rotor is obtained by releasing the foot switch 109 and observing the stroboscopic position of the rotor. The printed number on the rotor rim which is thus stroboscopically illuminated is the point of unbalance and the point at which the rotor is to be drilled, to lessen the weight, to effect a perfect balance. Such a drilled point is shown at 95 opposite the printed number 94 on the rim 4a of the rotor, shown in perspective in Figure 15.

There are actually many phase changes in the balancing machine that are taken into consideration in the construction of the machine. The rotor suspension and the operation of the rotor are such that there is an 180° phase difference between the position of the unbalance mass and the displacement in two electrical planes. There is also a small mechanical phase shift due to the damping on the resilient support. Since the voltage generated in the pick-ups is by means of a moving coil, this voltage is proportional to velocity and therefore differs in phase by 90° with the movement of the coil. There are several places in the amplifiers and in the mixing circuit where small electrical phase shifts occur and also several points where 180° phase reversals occur. Actually there preferably is a phase correcting network that may be included as a part of a flash amplifier 92 but preferably in the form of a phase network 111 separate from but in circuit with the flash amplifier. Correction for all of the above mentioned phase shifts may be taken care of in this one phase correcting network having a variable adjustment to serve as a calibrating means so that the proper indicia on the rotor may be illuminated at the proper point.

The method of operating the rotor at a speed greater than the natural period of resilient support is an advantage in that it permits unbalance testing at extremely high speeds while permitting sufficient resilience in the support for appreciable amplitude of displacements to accomplish sensitivity. Morever, the displacements of the supports are directly proportional only to the unbalance torque and inversely proportional to the total mass of the rotor except as slightly affected by the damping means provided on the resilient support whereas operation below resonance would make the displacement directly proportional to the unbalance torque times the square of the speed of rotation and inversely proportional to the spring constant. It also provides an effective dynamic gyrating system which gives the effect of two pivots acting simultaneously.

In the right-and-left switch are two buttons marked "L" and "R." If the "L" button was depressed during the above test the data applies to the left side of the rotor. While maintaining rotor speed the "R" button is then depressed and magnitude and position readings of rotor unbalance are taken for the right side.

For balancing, the table air valve 73 is shut off, the rotor stopped and removed from the test stand and placed on a suitable drill press. The rotor is drilled on each side at the position indicated and to a depth corresponding to the amount of unbalance. After drilling, the above procedure is repeated again or as many times as necessary to effect the proper balance.

I claim:

1. In a testing device for rotors, controllable means for rotating the rotor to be tested, separate bearing assemblies each including a plate and anti-friction bearings carried therein for receiving and supporting each end of the axle of the rotor, separate supporting standards on either side of said rotor, separate cantilever suspension means for suspending each of said plates including a plurality of cantilever members disposed at right angles to said plate and connected at their inner ends to said plate and at their outer ends to said adjacent standard with radial clearance in the latter for the main body of the cantilever members for maintaining said bearing assemblies substantially parallel to each other so as to permit movement of said cantilever members in said standards and movement of each bearing assembly independently of movement of the other cantilever member and bearing assembly in any direction within the planes at right angles to the axis of rotation of the rotor, separate means connected to each of said bearing suspension means adapted to be driven thereby in planes at right angles to the axis of the rotor in response to a state of unbalance thereof for setting up electrical voltages in response to movements of each of said bearing suspension plates and means for amplifying said voltages and for indicating the amount of unbalance of said rotor and means

controlled by said voltages for indicating the location of unbalance of the rotor.

2. In a testing device for rotors, controllable means for rotating the rotor to be tested, separate bearing assemblies each including a plate and anti-friction bearings carried therein for receiving and supporting each end of the axle of said rotor, separate supporting standards on either side of said rotor, separate cantilever suspension means for suspending each of said plates including a plurality of wire-like cantilever members disposed at right angles to said plate and connected at their inner ends to said plate and at their outer ends to said adjacent standard with radial clearance in the latter for the main body of the cantilever members for maintaining said bearing assemblies substantially parallel to each other and so as to permit movement of said cantilever members in said standards and movement of each bearing assembly in any direction within the planes at right angles to the axis of rotation of the rotor and independently of any movement of the other cantilever members and other bearing assembly, separate electro-dynamic pick-up units connected to each of said bearing suspension means and adapted to be driven thereby in response to a state of unbalance of said rotor and set up electrical voltages in response to resulting movements of each of said bearing suspension means, means for amplifying said voltages, a meter connected to said amplifying means for indicating the amount of unbalance of said rotor, said rotor having indicia on its rim, means for indicating the angular position of unbalance of said rotor on said rotor including a stroboscopic lamp mounted adjacent the rim of said rotor and means responsive to the voltages set up in said pick-up units for flashing said lamp for instantaneously illuminating said indicia.

3. In a testing device for rotors, controllable means for a source of fluid pressure adapted for rotating the rotor to be tested, separate bearing assemblies each including a plate and anti-friction bearings carried therein for receiving and supporting each end of the axle of said rotor, separate supporting standards on either side of said rotor, said standards each carrying a plurality of concentrically arranged cylindrical members extending outwardly at right angles to said standard, separate cantilever suspension means for suspending each of said plates including a plurality of wire-like cantilever members connected at their inner ends to said plate and extending with radial clearance in said cylindrical members and fixedly connected to the outer ends thereof to be relatively taut for maintaining said bearing assemblies parallel to each other so as to permit movement of said cantilever members in said standards and movement of each bearing assembly in any direction within the planes at right angles to the axis of rotation of the rotor and independently of any movement of the other cantilever members and other bearing assembly, separate electro-dynamic pick-up units connected to each of said bearing suspension means and adapted to be driven thereby in angles to the axis of the rotor responsive to a state of unbalance of said rotor, means for proportionately amplifying said voltages, a meter connected to said amplifying means for indicating the amount of unbalance of said rotor, said rotor having indicia on its rim, means for indicating the angular position of unbalance of said rotor on said rotor including a stroboscopic lamp mounted adjacent the rim of said rotor and control means responsive to the voltages set up in said pick-up units for flashing said lamp for instantaneously illuminating said indicia.

4. In a testing device for rotors, controllable means for a source of fluid pressure adapted for rotating the rotor to be tested, separate bearing assemblies each including a plate and anti-friction bearings carried therein for receiving and supporting each end of the axle of said rotor, separate supporting standards on either side of said rotor, said standards each carrying a plurality of concentrically arranged cylindrical members extending outwardly at right angles to said standard, separate cantilever suspension means for suspending each of said plates including a plurality of wire-like cantilever members connected at their inner ends to said plate and extending with radial clearance in said cylindrical members and fixedly connected to the outer ends thereof to be relatively taut for maintaining said bearing assemblies parallel to each other so as to permit movement of said cantilever members in said standards and movement of each bearing assembly in any direction within the planes at right angles to the axis of rotation of the rotor and independently of any movement of the other cantilever members and other bearing assembly, means for damping the radial movements of said cantilever members in said cylindrical members and consequently the radial movements of said bearing assembly supporting plates, separate electro-dynamic pick-up units connected to each of said bearing suspension means and adapted to be driven thereby in angles to the axis of the rotor responsive to a state of unbalance of said rotor, means for proportionately amplifying said voltages, a meter connected to said amplifying means for indicating the amount of unbalance of said rotor, said rotor having indicia on its rim, means for indicating the angular position of unbalance of said rotor on said rotor including a stroboscopic lamp mounted adjacent the rim of said rotor and control means responsive to the voltages set up in said pick-up units for flashing said lamp for instantaneously illuminating said indicia.

5. In a testing device for rotors, controllable means for rotating the rotor to be tested, separate bearing assemblies each including a plate and anti-friction bearings carried therein for receiving and supporting each end of the axle of said rotor, separate supporting standards on either side of said rotor, said standards each carrying a plurality of concentrically arranged cylindrical members extending outwardly at right angles to said standard, separate cantilever suspension means for suspending each of said plates including a plurality of wire-like cantilever members connected at their inner ends to said plate and extending with radial clearance in said cylindrical members and fixedly connected to the outer ends thereof to be relatively taut for maintaining said bearing assemblies parallel to each other so as to permit movement of said cantilever members in said standards and movement of each bearing assembly in any direction within the planes at right angles to the axis of rotation of the rotor and independently of any movement of the other cantilever members and other bearing assembly, means including fluid carried by said cylindrical members and beads carried by said cantilever members to be immersed in said fluid for damping the radial movements of said cantilever members in said cylindrical members and consequently the radial movements of said bearing assembly plates for supporting said rotor, sep-

arate electro-dynamic pick-up units connected to each of said bearing suspension means and adapted to be driven thereby in angles to the axis of the rotor responsive to a state of unbalance of said rotor, means for proportionately amplifying said voltages, a meter connected to said amplifying means for indicating the amount of unbalance of said rotor, said rotor having indicia on its rim, means for indicating the angular position of unbalance of said rotor on said rotor including a stroboscopic lamp mounted adjacent the rim of said rotor and control means responsive to the voltages set up in said pick-up units for flashing said lamp for instantaneously illuminating said indicia.

6. In a testing device for rotors, controllable means for rotating the rotor to be tested, separate bearing assemblies each including a plate and anti-friction bearings carried therein for receiving and supporting each end of the axle of said rotor, separate supporting standards on either side of said rotor, said standards each carrying a plurality of concentrically arranged cylindrical members extending outwardly at right angles to said standard, separate cantilever suspension means for suspending each of said plates including a plurality of wire-like cantilever members connected at their inner ends to said plate and extending with radial clearance in said cylindrical members and fixedly connected to the outer ends thereof to be relatively taut for maintaining said bearing assemblies parallel to each other so as to permit movement of said cantilever members in said standards and movement of each bearing assembly in any direction within the planes at right angles to the axis of rotation of the rotor and independently of any movement of the other cantilever members and other bearing assembly, each of said cylindrical members having its inner end provided with a flexible diaphragm through which one of said cantilever members extends, each of said cylindrical members being filled with fluid and each of said cantilever members having beads immersed in said fluid for damping the radial movements of said cantilever members and consequently the radial movements of said bearing assembly plates for supporting said rotor, separate electro-dynamic pick-up units connected to each of said bearing suspension means and adapted to be driven thereby in angles to the axis of the rotor responsive to a state of unbalance of said rotor, means for proportionately amplifying said voltages, a meter connected to said amplifying means for indicating the amount of unbalance of said rotor, said rotor having indicia on its rim, means for indicating the angular position of unbalance of said rotor on said rotor including a stroboscopic lamp mounted adjacent the rim of said rotor and control means responsive to the voltages set up in said pick-up units for flashing said lamp for instantaneously illuminating said indicia.

SAMUEL BOUSKY.