

Jan. 9, 1940.

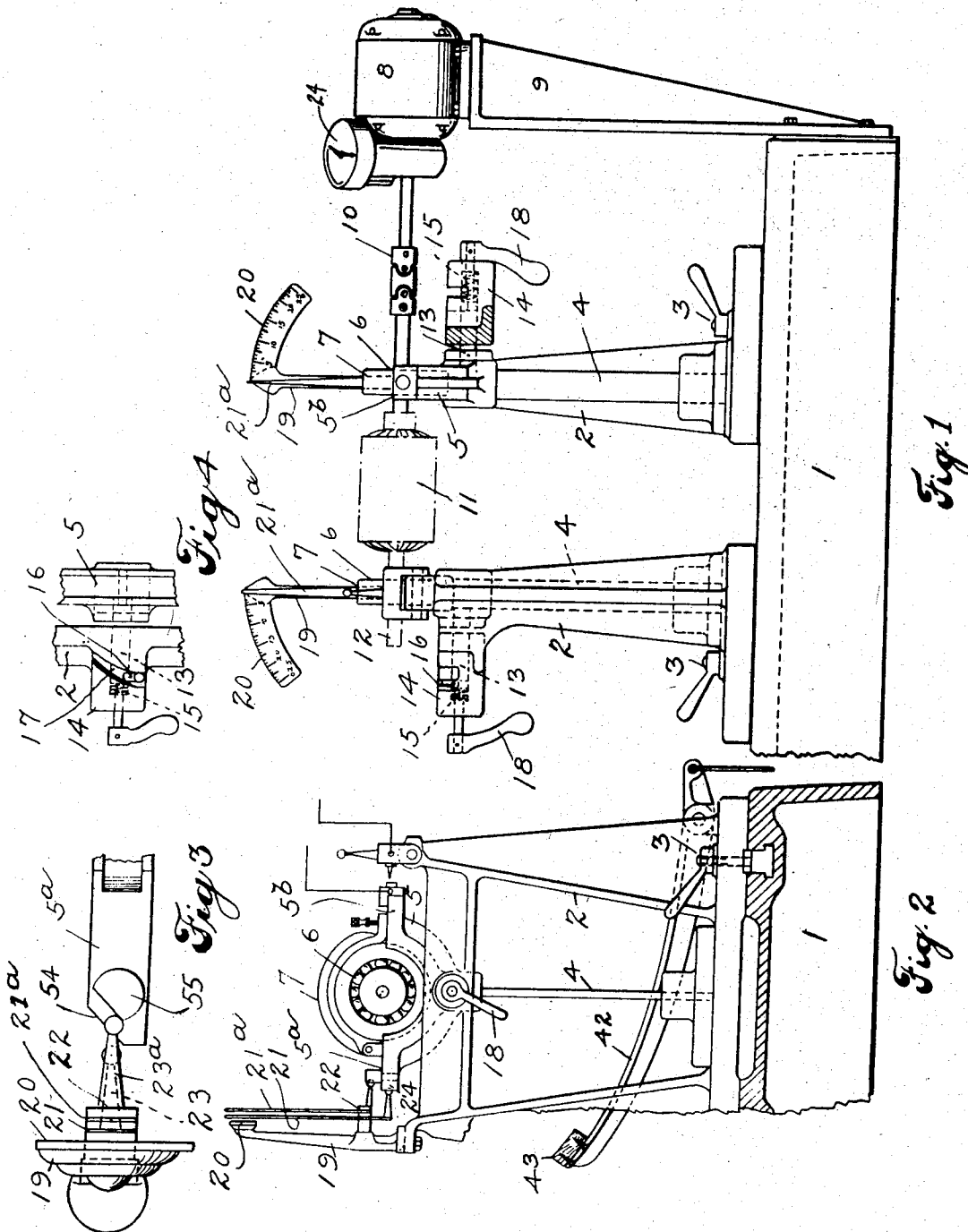
H. W. MOORE

2,186,339

DYNAMIC BALANCING APPARATUS

Original Filed Dec. 21, 1931

4 Sheets-Sheet 1



INVENTOR.

HARRY W. MOORE

BY

Henry L. Sybilis  
ATTORNEYS.

Jan. 9, 1940.

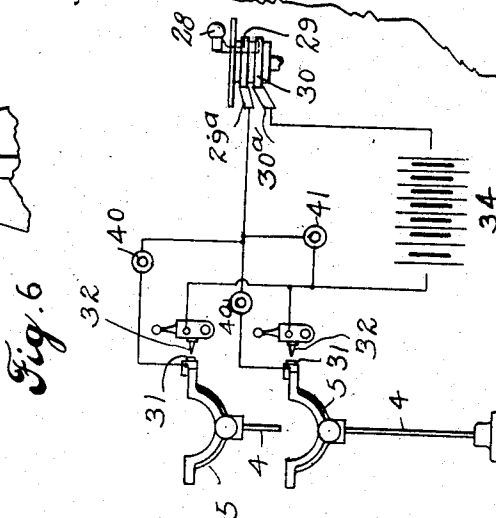
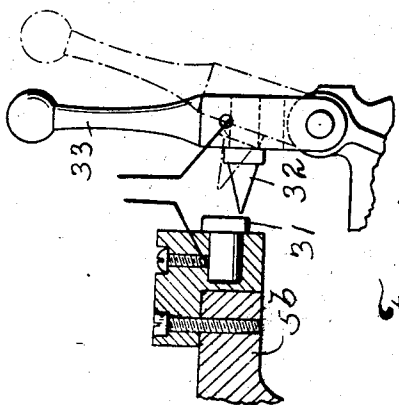
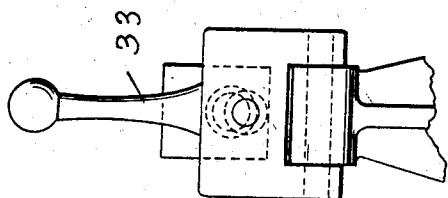
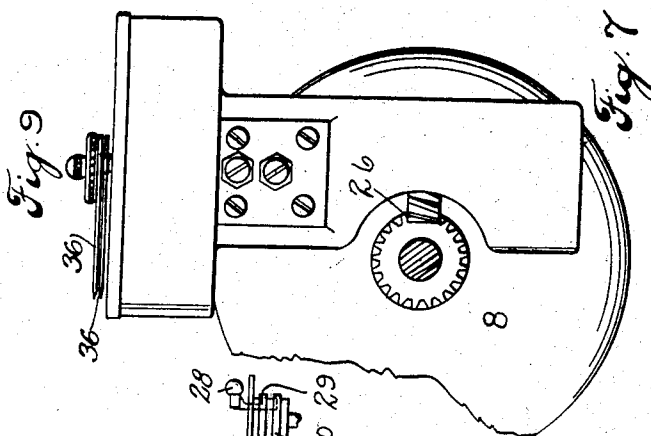
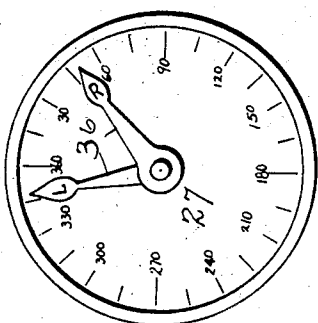
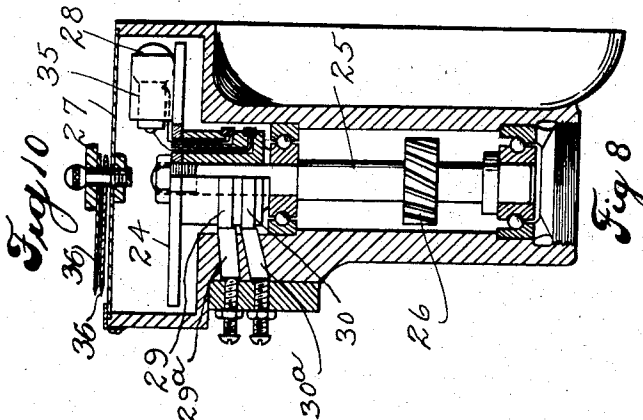
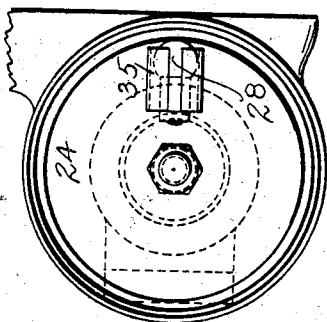
H. W. MOORE

2,186,339

DYNAMIC BALANCING APPARATUS

Original Filed Dec. 21, 1931

4 Sheets-Sheet 2



INVENTOR.

HARRY W. MOORE  
BY *Harry G. Sybing*  
ATTORNEYS.

Jan. 9, 1940.

H. W. MOORE

2,186,339

DYNAMIC BALANCING APPARATUS

Original Filed Dec. 21, 1931

4 Sheets-Sheet 3

*Fig. 12*

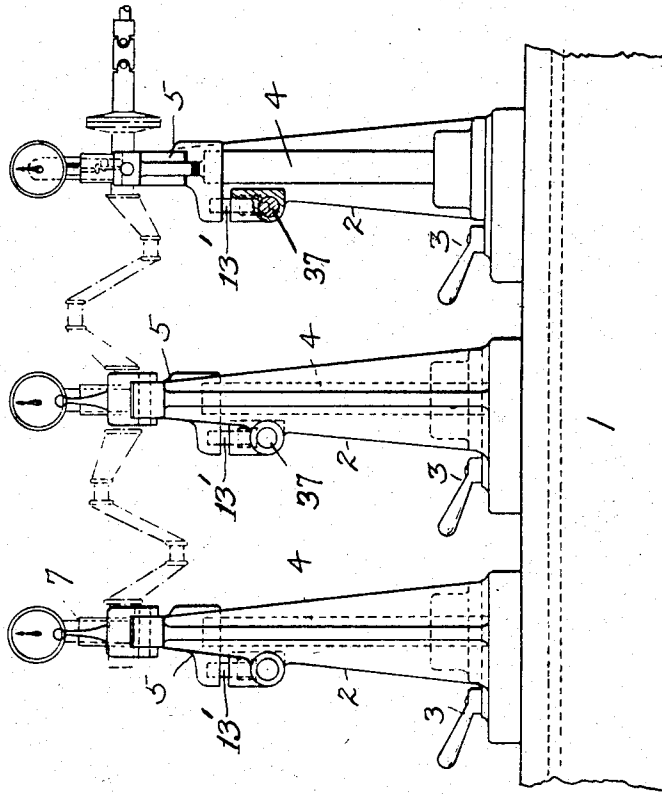
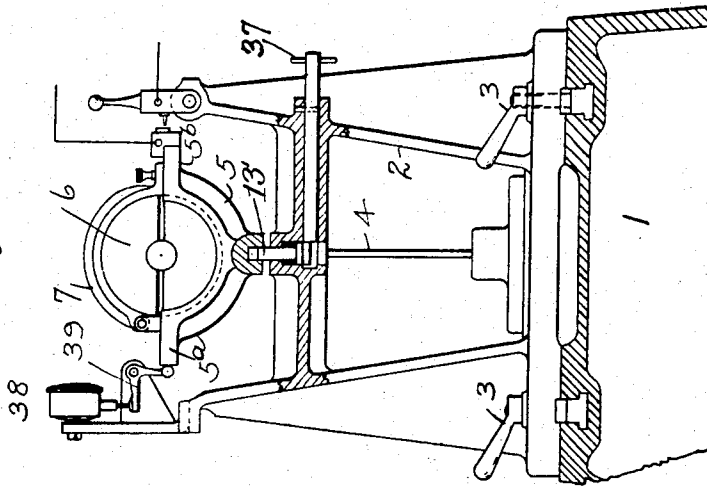


*Fig. 13*



INVENTOR.

HARRY W. MOORE

BY

*Henry G. Dybaig*  
ATTORNEYS.

Jan. 9, 1940.

H. W. MOORE

2,186,339

DYNAMIC BALANCING APPARATUS

Original Filed Dec. 21, 1931

4 Sheets-Sheet 4

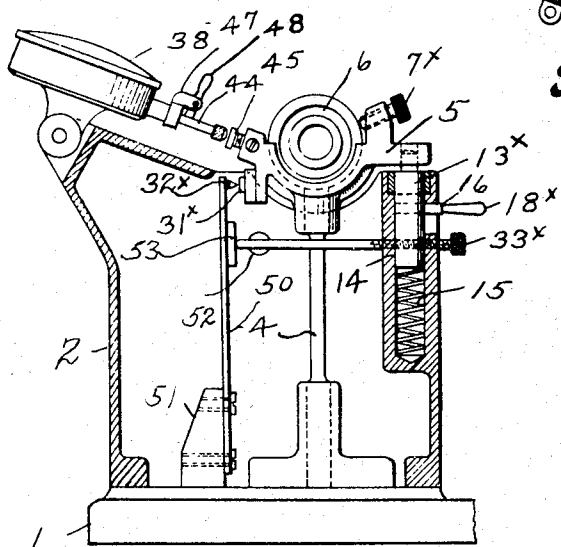
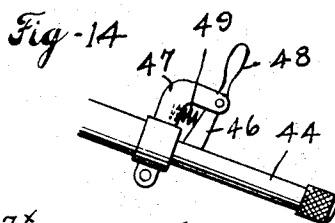
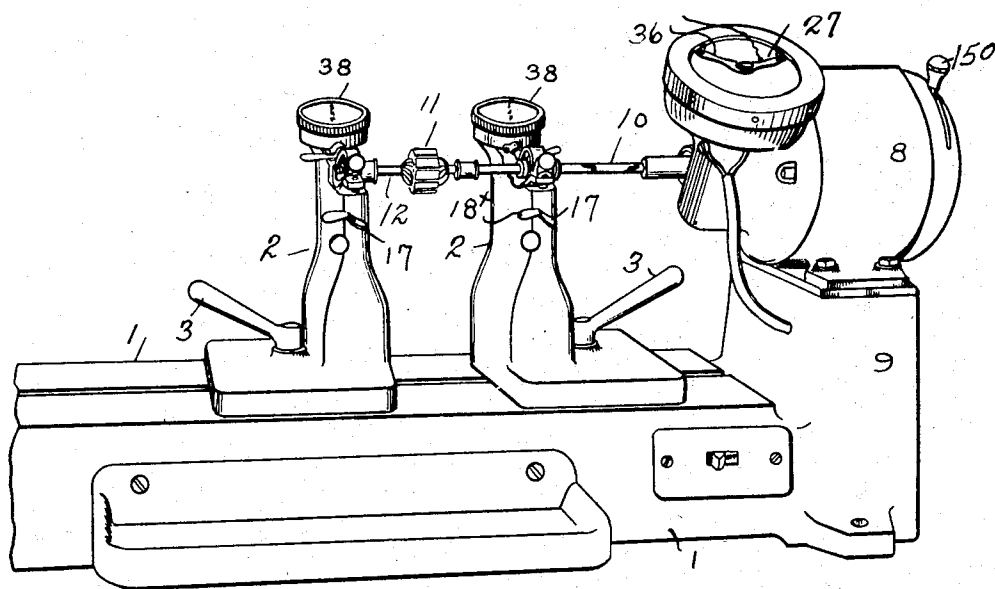


Fig.-15

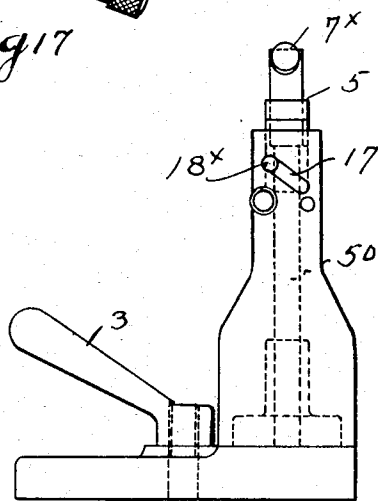


Fig.-16

INVENTOR.

HARRY W. MOORE  
BY *Henry G. Dybvig*  
ATTORNEYS.

## UNITED STATES PATENT OFFICE

2,186,339

## DYNAMIC BALANCING APPARATUS

Harry W. Moore, Dayton, Ohio

Continuation of application Serial No. 582,327,  
December 21, 1931. This application October  
5, 1936, Serial No. 104,075

4 Claims. (Cl. 73—51)

This invention relates to a dynamic balancing apparatus, and more particularly to means for rapidly ascertaining and visually indicating the location and amplitude of unbalanced areas of a rotating body.

This is a continuation of my application Serial No. 582,327, filed December 21, 1931.

A condition of unbalance in a rotating mass induces vibratory forces and reactions in the mounting of the unbalanced body which are highly objectionable and injurious to the equipment in which the body may be employed. Such vibratory reaction, however, is utilized in the present instance to operate indicating means by which the unbalanced condition is accurately and quickly defined, both as to magnitude and location.

The purpose of the present dynamic balancing apparatus is to measure and locate the magnitude of unbalance in terms of two planes which can be selected for correction, and to compensate such condition of unbalance by adding or removing material in or near these planes. To this end two indicating means are employed, one of which by measuring the range of the induced vibratory movement of the rotating mass indicates the amplitude of the unbalanced condition, the other, which is of multiple character, operates to indicate the angular position of the point of unbalance in relation to different planes of rotation.

The object of the invention is to simplify the construction as well as the means and mode of operation of dynamic balancing apparatus for rotating bodies, whereby such apparatus will not be cheapened in construction, but will be more efficient in use, automatic in its action, accurate in results, rapid in operation, easily controlled and unlikely to get out of repair.

A further object of the invention is to provide automatic means for measuring and accurately indicating the degree or amplitude of the unbalanced condition existing in a rotating body.

A further object of the invention is to provide automatic means for determining and indicating the relative radial position of the point of unbalance, and to further ascertain and indicate such radial point of unbalanced condition to different planes of rotation.

A further object of the invention is to provide an apparatus into which the body to be tested can be quickly and readily installed and removed and wherein the tests may be made rapidly by a comparatively unskilled operator.

A further object of the invention is to provide

a simple but sturdy apparatus suitable for industrial production use which will enable quantity testing to be conducted with rapidity and accuracy.

With the above primary and other incidental objects in view, as will more fully appear in the specification, the invention consists of the features of construction, the parts and combinations thereof and the mode of operation, or their equivalents, as hereinafter described and set forth in the claims.

In the accompanying drawings, wherein the preferred, but obviously not necessarily the only form of embodiment of the invention is shown, Fig. 1 is a side elevation and Fig. 2 is an end elevation of the assembled apparatus embodying the present invention.

Fig. 3 is a top plan detail view of the indicator means for measuring the amplitude of the unbalanced condition of the rotating body.

Fig. 4 is a detail plan view of the detent or locking means for the vibratory mounting which has been shown in side elevation in Fig. 1.

Figs. 5 and 6 are detail views at right angles to each other of the yielding electrical contact device which controls the signal means for indicating the radial position of the unbalanced area.

Fig. 7 is a side elevation and Fig. 8 a longitudinal sectional view of the indicator mechanism by which the radial position of the unbalanced condition is determined.

Fig. 9 is a top plan view of the indicator mechanism illustrated in Fig. 7.

Fig. 10 is a similar top plan view with the dial removed.

Fig. 11 is a diagrammatic view of the electrical circuit pertaining to the indicator mechanism illustrated in Figs. 5 to 10 inclusive.

Fig. 12 is a side elevation of a modified form of apparatus employing the multiple vibratory support which, as illustrated in the drawings, may be employed for balancing crank shafts or other devices having spaced bearing points aligned with each other.

Fig. 13 is an end elevation of the apparatus illustrated in Fig. 12 showing also modifications of the amplitude indicating means and also of the detent or locking means for the vibratory mounting.

Fig. 14 is a perspective view of a commercial embodiment of the apparatus.

Fig. 15 is a vertical sectional view through one of the supporting members or pedestals shown in Fig. 14.

Fig. 16 is a front elevation thereof.

Fig. 17 is a detail view of the indicator detent.

Referring to the drawings, 1 is the bed or base of the apparatus upon which are adjustably mounted two or more upright rigid frames 2—2 engaging in ways or grooves in the bed 1 for sliding movement toward and from each other while maintaining their parallel relation. The adjustable frames 2—2 are locked in adjusted positions by clamps 3—3. Carried by each frame 2 is a flexible standard 4 fixedly mounted upon the bottom of the frame at its lower end and free at its top for to and fro vibratory motion. Carried at the upper end of each of the vibratory standards 4 is a mounting head 5 including a self aligning anti-friction or ball bearing 6. The bearings 6 are preferably demountable, enabling bearings of different sizes to be interchanged to enable bodies of different sizes and weights to be tested. The demountable bearings 6 are held in position upon the heads 5 by clamp arms 7. The mounting head 5 is formed with oppositely extending arms 5a and 5b which cooperate with meters or gauges to measure and indicate the range and time of the vibratory action of an unbalanced rotating body carried in the bearings 6.

The body to be tested is mounted for free rotary motion in the bearings 6 of the respective heads 5, and is driven at a comparatively high rate of speed by an electric motor 8 mounted upon a pedestal 9 arising from the base or bed 1 of the apparatus. The driving motor 8 is connected with the rotary body under test by a flexible drive shaft 10, which permits unrestricted to and fro motion of the driven body upon the vibratory supporting standards 4, while maintaining rotary driving connection therewith. In Fig. 1 there is indicated by dot and dash lines a motor armature 11 mounted in the apparatus for test, the shaft 12 of which is mounted in the self aligning anti-friction bearings 6 of the respective heads 5, each of which is independently supported by a flexible standard 4, the shaft 12 being operatively connected with the driving motor 8 by the shaft 10. A detent plunger 13 is mounted in a boss or hub 14 upon each frame 2 for locking engagement with the adjacent vibratory mounting head 5 under influence of a spring 15. The detent plunger is provided with a radial stud 16 engaging in a spiral cam groove 17 which acts to retract and hold the detent plunger 13 in inoperative position upon partial rotation of the plunger by the means of the handle 18. The detents are independently operable so that the mounting head at either end of the rotary body being tested may be held immovable while the mounting head at the opposite end of the body is permitted to vibrate freely.

The rotation of an unbalanced body carried in the bearings of the mounting heads 5 induces a to and fro vibratory motion of the body upon the standards 4, the extent of which is proportionate to the degree of unbalance. To determine the maximum extent of vibratory motion resulting from rotation of the unbalanced body, there is mounted upon each frame 2 at one side of the vibratory mounting head 5 an upright arm 19 carrying a graduated indicator scale 20 with which cooperates one or more oscillatory indicator pointers 21 and 21a, pivoted at 22 to the support 19. The pointers 21 and 21a operate simultaneously under the same vibratory influence of the mounting head, but being subject to different leverage, operate through different range. One pointer is used for coarse or approxi-

mate readings and the other for more accurate indications. The lower or actuated arms of the pivoted indicators are bent laterally, 23 and 23a, at different distances from their common pivotal point 22 and hence at different levels. The lateral arms 23 and 23a terminate in spherical heads disposed in the path of vibratory movement of the head 5. The arm 5a of the head 5 is bevelled at 54 and exerts camming action upon the spherical head of the pointer arm 23. A bevelled lug 55 similarly engages and actuates the spherical head of the pointer arm 23a. The pointers are thus moved proportionately to the degree of movement of the head, but through somewhat less range due to the inclination of the cam surfaces. The pivotal connections of the pointers possess sufficient frictional resistance to maintain the pointers in the positions to which they are moved by the action of the vibratory head, each further movement of the head actuating the pointers to further degree, thus indicating the maximum deflection of the mounting head.

The contact arm 23a of the pointer 21a being of short radius, this pointer will be moved more rapidly and may be operated beyond the range of the indicator scale 20 when a marked condition of unbalance exists, at which time the pointer 21 remains effective, but such amplifying pointer is quite effectively employed when the degree of unbalance is small and as correction is applied to reduce the initially greater unbalanced condition.

While the pointers just described indicate the degree of unbalanced condition, this is not enough and the radial position of the point of unbalance must be determined. For this purpose there is employed a rotary indicator revolving in unison with the body under test and energized as the point of unbalance passes a given point.

Rotated by the motor 8 at a rate of speed coincident with that of the shaft 12 and body under test is a head 24 mounted on a shaft 25 having a gear connection 26 with the motor shaft. The head 24 and its drive shaft 25 are contained within a casing having a translucent graduated dial 27 overlying the rotary head 24. The rotary head 24 carries a small electric lamp 28, preferably of the neon gas type, which is instantly responsive to slight electrical impulses. The lamp 28 is connected to collector rings 29 and 30 upon the hub of the rotary head 24, which rings are in turn engaged by wiping brushes 29a and 30a respectively. Carried by the arm 5b of the head 5, and preferably insulated therefrom, is an electrical contact 31 connected with one of the aforementioned wiper brushes. Upon vibratory motion of the head 5, this contact 31 has operative engagement with a complementary contact 32 yieldingly mounted upon the frame 2. The contact 32 is preferably carried upon a pivoted arm 33, the pivotal connection of which possesses sufficient frictional resistance to maintain the position to which it is moved by the contact engagement of the vibratory contact 31. The second contact 32 is electrically connected through a suitable source 34 of electrical energy, with the other of the wiper brushes. At each vibratory movement of the head 5 the contact 31 impinges upon the contact 32, thereby closing the electrical circuit and momentarily energizing the signal lamp 28 upon the rotary head 24. At the same time the contact 32 is yieldingly adjusted about its pivotal connection

in proportion to the degree of maximum deflection of the vibratory supporting standard 4, whereby the signal energizing circuit is momentarily closed only at the instant of maximum deflection of the mounting head. This contact occurs, of course, only when the point of unbalance is passing a given radial point, which due to inertia, resistance of the vibratory standard 4, and momentum of the body under test or speed of rotation may not be, indeed is seldom if ever, coincident with the position of the contact 31-32. However, having signalled the passing of the unbalanced point by the intermittent closing of the circuit and resulting energization of the signal lamp, the exact location of the point of unbalance of the body may be found directly from a suitable set point on the machine. The signal lamp is enclosed within a slotted shield 35, the slot of which is radially disposed. Being rotated in unison with the body under test the relative position of the body at the moment of closing of the signal circuit is readily determined by observing the radial position of the signal lamp through the translucent dial 27 at its moment of illumination. This position is definitely defined by the radial slot of the lamp shield 35 through which the illumination is visible. By observing the angular relation of the illuminated signal light upon the graduated scale on the translucent dial 27, the radial position of the point of unbalance in the body under test is determined. Manually adjustable markers or pointers 36 may be provided upon the dial 27, which, by being adjusted to agree with the radial position at which the signal lamp is illuminated, serve to retain the indication for reference.

The use of a neon light 28 in series with a substantially noninductive and noncapacity circuit including a battery, and at least a pair of contacts, results in an indicating device that is far more sensitive and far more accurate than any of the devices used heretofore. Whenever the indicating device is connected in the secondary of a circuit, the contacts controlling the circuit being located in the primary, there is a time lag between the closing of the contacts and the energizing of the neon light in the secondary circuit. This time lag is not constant for the reason that the inductive reactance is dependent upon the frequency of the current. The contacts are closed once for each revolution. Therefore, if the body rotates at 3600 R. P. M., the resulting current is a 60 cycle current. If the body rotates at 1200, the frequency is only a 20.

From an analysis of the equation for the reactance, namely  $2\pi FL$ , it may be clearly seen that the reactance, when the body is rotated at 1200, is only one-third of the reactance when the body rotates at 3600. The same holds true if a capacity couplings were used, excepting the capacity would vary inversely as the frequency. A variable reactance in the circuit, whether it be capacity or inductive reactance, results in a variable phase displacement of the current with respect to the voltage. This in turn results in a variation in the time between the closing of the contacts in the primary circuit and the flashing of the neon light in the secondary. Consequently, the angular relation of the flashing light in a circuit where an inductance or a reactance is used is inaccurate unless correction for the variable phase change is made. This correction is dependent upon impedance of the circuit, which

varies as the rate of rotation of the body to be tested is varied.

The use of the neon light in the present circuit is duofunctional. As already described, the neon light flashes the angle of unbalance. In addition thereto, the neon light has been used to save the contacts from burning. It doesn't follow from this that the use of a neon light always prevents the burning of contacts. Neon lights used in series or in parallel with inductances or reactances may cause very serious burning of the contacts. If the neon light is placed in the secondary circuit and the contacts in the primary circuit, the two circuits being connected through a transformer, the neon light will cause practically all of the energy stored up in the inductance to be dissipated across the contacts in the primary circuit. In other words, the energy found in the inductance after the voltage drops slightly across the terminals of the neon light, cannot be further dissipated in the secondary circuit for the reason that all current ceases to flow across the contacts of the neon light. In the circuit disclosed herein, the current through the neon light stops flowing immediately upon a slight voltage drop across the terminals of the contacts. This results in a stop of the flow of the current across the contacts. Hence, the contacts in the present device seemingly last indefinitely. The contacts do not pit; do not burn; and do not char. The reason is, a slight separation of the contacts causes a decrease of voltage across the terminals of the neon light, so as to cut out the flow of current across the neon light, and thereby the flow of current across the contacts. A slight separation of the contacts will not cause an excessive amount of heat being generated so as to burn, pit or char the contacts. In the claims "minimum voltage current cut-out" has been used to express this characteristic of the neon light.

The use of the neon light having a minimum voltage current cut-out results in a more sensitive device than any that has been formerly used. Whenever a spark gap or any other type of a device for indicating the angle of unbalance is used, it is necessary to separate the contacts sufficiently to stop the flow of current in the circuit. This is usually a considerable distance. Due to the minimum voltage current cut-out characteristic of the neon light shown herein, it is only necessary to separate the contacts a very minute distance in order to interrupt the flow of the current in the circuit. A slight vibration of less than .0001 inch in amplitude may be measured.

A "pure resistance circuit," as set forth in the claims, is used to designate a circuit having substantially no inductance and no capacity, other than the inherent inductance and capacity that are always present where conductors, contacts, batteries and neon lights are used.

Any number of vibratory heads may be electrically connected with the same signal lamp indicator 28, by connecting the contacts 31 of the several heads 5 in multiple and likewise connecting the corresponding contacts 32 in multiple. By drawing the movable contact carrying lever 33 of any one or more heads beyond the range of vibratory motion of the corresponding mounting head or by immovably locking the head, such contacts may be rendered inoperative, and readings may be taken from other vibratory heads at will. By taking readings from different mounting heads separately, not only as to the

magnitude of the unbalanced condition indicated by the pointers 21 and 21a, but also the angular position of the point of unbalance, the condition of balance may be accurately determined in relation to different planes of rotation. Thus the condition of unbalance may be quickly and accurately determined in two respects, to wit, radial or angular location and amplitude.

In many structures it is desirable to determine the relative balance in a number of different planes of rotation, as for example, in extended crank shafts, such as is illustrated at 36 in Fig. 12. In such case the number of frames 2 with their corresponding indicator means and the number of vibratory standards and mounting heads carried thereby are correspondingly increased. These heads may all be operated simultaneously, and by locking one or more of the heads they may be vibrated independently and separate readings thus taken at different points throughout the length of the body being tested. As a matter of convenience the detent plungers 13' in Figs. 12 and 13 engage the vibratory heads 5 from beneath and are independently adjusted into and out of locking engagement by rotary handle stems 37 having eccentric or wrist pin connection with the detent plungers.

In Figs. 12 and 13 a standard type of gauge 38 is illustrated in lieu of the oscillatory pointers 21 and 21a. This gauge is actuated through a bell crank lever 39 by engagement with the head 5 in its vibratory motion.

The signal circuit may be provided with a series of manually operated electric switches 40, one for each vibratory head located in the corresponding shunt, the closing of which will cause the signal lamp to be energized by the corresponding head to indicate the radial position of the point of unbalance. An additional switch 41 enables the circuit to be closed to energize the signal lamp independently of the vibratory heads.

Before testing the body the maximum speed of the motor is preferably adjusted so that it is slightly higher than the resonant period of the vibratory support for the body to be tested. The speed of the motor may be adjusted by a lever 150. The motor has been designed to accelerate uniformly from stand still through the critical speed, that is, the speed at which the vibratory support resonates, to the maximum speed. As the speed advances through the critical speed the magnitude of the vibrations of the support may be amplified fifty (50) times or more, due to the resonance of the support. This amplification permits the measuring of slight unbalanced conditions.

In production the body to be tested is placed upon the vibratory supports and attached to the drive shaft. The motor circuit is then closed so as to rotate the body to be tested, accelerating the speed of rotation uniformly from stand still to maximum speed through the critical speed. As the body accelerates through critical speed, the readings are taken both as to magnitude of vibration and angle of unbalance.

Immediately upon reaching maximum speed the motor circuit is opened. To conveniently arrest the rotating body a brake arm 42 provided with a friction head 43 is brought into contact with the rotating body by a foot pedal not shown. When the body has been brought to rest, the position of unbalance of the body may be ascertained by measuring from a given point on the machine the angle of unbalance as recorded by the indicating device.

Instead of determining the position of unbalance as indicated above, this may be determined after arresting the rotation of the body by closing the switch 41, which closes the circuit to the signal lamp 28. The body may then be rotated manually until the signal light assumes the position at which it was energized while under test. A chalk mark or other mark may then be made upon the body under test opposite the contacts 31 and 32 to indicate the radial position of the body at the moment of the closing of the signal contacts. The same procedure is followed with other vibratory heads.

From the foregoing description it may readily be seen that the body may be tested while accelerating the body from stand still to maximum speed. In the past it has been necessary to take the readings while the body was decelerating. Thus, it may be seen that by the present apparatus it is possible to obtain the readings before the tester could start testing the body by devices used heretofore.

The apparatus heretofore described has been quite successfully used in practical balancing operations. However, in commercial production and distribution it is preferred to embody the invention in a simplified and compact form wherein as many parts as possible are enclosed. Such form of embodiment is illustrated in Figs. 14, 15 and 16 wherein the adjustable frames 2 are hollow and enclose the vibratory standards 4 upon which the mounting heads 5 are carried. In lieu of the clamp arm 7, the self aligning anti-friction bearings 6 are held upon the heads 5 by clamp screws 1x.

A vertically movable plunger 13x located in a guide bore 14 and actuated by a spring 15 serves to lock the vibratory heads 5 against movement. The plunger 13x is controlled by a radial stud 16 having sliding engagement in a cam slot 17, an extension of which forms a handle 18x for manually retracting the locking plunger. In this commercial form of apparatus a standard type gauge 38 is employed, the plunger or abutment 44 of which is engaged by an impact head 45 upon the vibratory head 5 at each movement thereof to correspondingly retract the gauge stem or abutment 44 as the range of vibration increases. A friction detent 46 pivoted in a mounting 47 secured to the plunger guide of the gauge 38 serves to hold the plunger in its retracted position to which it has been moved by the impact of the vibratory head. The detent has at one end a finger lever 48 which is pivoted slightly off its center line and hence has a slight eccentric or camming action against the plunger or abutment 44 under influence of a spring 49. The plunger is instantly released by rotation of the lever 48.

Also enclosed within the hollow support 2 is a yielding arm 50, secured to a fiber block 51 or other insulating body at the bottom of the frame 2, extending upwardly, and carrying at its top an electrical contact 32x coacting with a contact 31x upon the vibratory head 5 and corresponding to the contacts 31 and 32 before described. An adjusting screw stem 33x is supported in the frame 2 and in a bracket 52 within the frame, and engages a fiber or other insulating block 53 upon the yielding arm 50. By adjustment of the screw stem the arm may be flexed to move the contact 32x out of operative relation with the contact 31x, or to adjust it to such position that the contact is effected only when the head 5 vibrates beyond a predetermined range. The

construction and operation of the modified apparatus is otherwise substantially the same as before described.

Although the device has been disclosed and described as provided with means for locking the separate vibratory heads, it has been found that this is not necessary. It is merely a carry-over from the prior art. It may be desirable to lock the heads in some types of work so as to reduce vibration, etc., but it is not essential to accurate results.

Although the device has been described in connection with a neon lamp or tube, any suitable gas filled lamp or any other suitable device having a maximum voltage current cut-out characteristic may be used so as to obtain the same results.

Although the preferred modification of the device has been described, it will be understood that within the purview of this invention various changes may be made in the form, details, proportion and arrangement of parts which generally stated, consist in a device capable of carrying out the objects set forth, in the novel parts, combination of parts and mode of operation, as disclosed and defined in the appended claims.

Having thus described my invention, I claim:

1. In an apparatus for testing the dynamically unbalanced condition of a rotating body, the combination including a bed, at least a pair of oscillatable bearings arranged for horizontal movement on said bed provided with means for alternately locking the bearings against oscillation, circuit means including pairs of electrical contacts, one pair for each bearing adapted to be closed by the horizontal movement thereof, a support, means for rotating the support in synchronism with the body to be tested, and indicating means including a neon light mounted upon said support and included in said circuit to be energized by the closing of said contacts to indicate the angle of the unbalance as reflected by the vibrating bearing.

2. In a dynamic balancing apparatus for testing the unbalanced condition of a rotating body, the combination including a plurality of vibratory supports for supporting said body, said vibratory supports being arranged to move in a horizontal plane, means for alternately locking the

supports against vibration so as to permit one selected support to vibrate, circuit means including a pair of electrical contacts arranged in proximity to each of said bearings and adapted to be intermittently closed by the vibratory movement of its support, a rotary support, means for rotating said rotary support in synchronism with the rotation of the body to be tested, and indicating means including a neon light mounted upon said rotary support and rotating therewith, said neon light interconnected to the circuit being energized when the contacts are closed to indicate the angle of unbalance.

3. In a dynamic balancing apparatus for testing the unbalanced condition of a rotating body, the combination including supporting means including a pair of bearings mounted upon vibratory supports permitting a horizontal movement of the bearings arranged in spaced relation for supporting the body to be tested, means for alternately locking said bearings permitting only one bearing to vibrate, signalling means including a rotary support connected for rotation in unison with the body, a neon light mounted upon the support and rotating therewith, a plurality of operative means common to the signalling means and actuated by the vibratory movement of the body in different planes of rotation induced by its unbalanced condition, there being one operative means for each of said bearings, said locking means rendering the signalling means inoperative for the locked bearings whereby the signalling means indicates the unbalance of the rotating body as reflected by the vibrating bearing.

4. In a dynamic balancing apparatus for testing the unbalanced condition of a rotating body, the combination including a plurality of vibratory supports, circuit means including a pair of contacts arranged in proximity to one of said supports, one of the contacts being mounted for movement with the support, means pivotally mounting the other contact and providing frictional resistance therefor so that it is frictionally held in position when engaged and moved away from the support by the vibration thereof, and means for indicating the angle of unbalance adapted to be energized when the contacts are closed.

HARRY W. MOORE.