

Feb. 5, 1952

E. L. THEARLE

2,584,942

DYNAMICALLY BALANCED ROTOR

Filed April 18, 1949

4 Sheets-Sheet 1

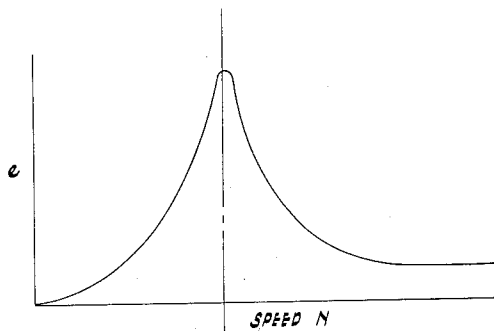


FIG. 3

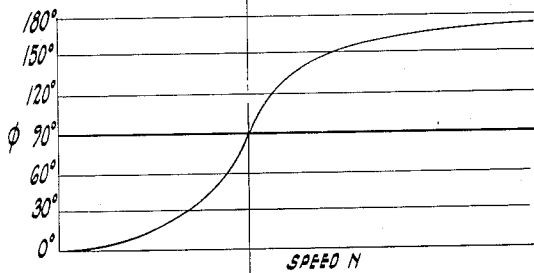


FIG. 4

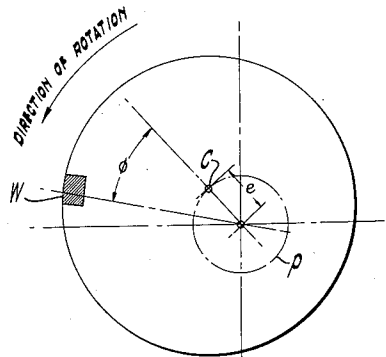


FIG. 2

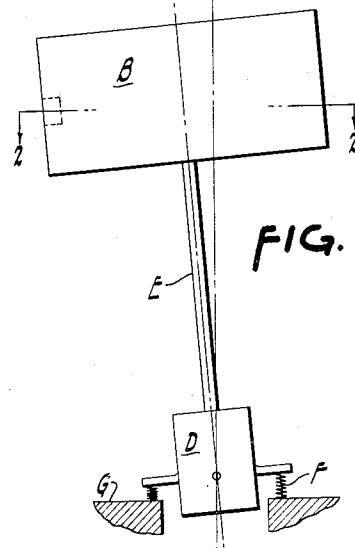


FIG. 1

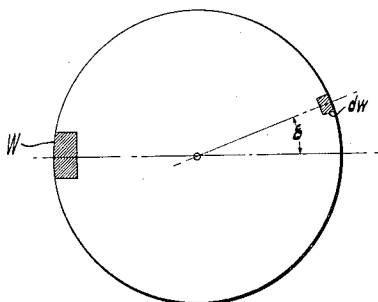


FIG. 5

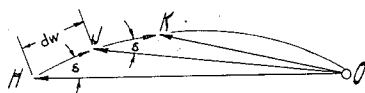


FIG. 6

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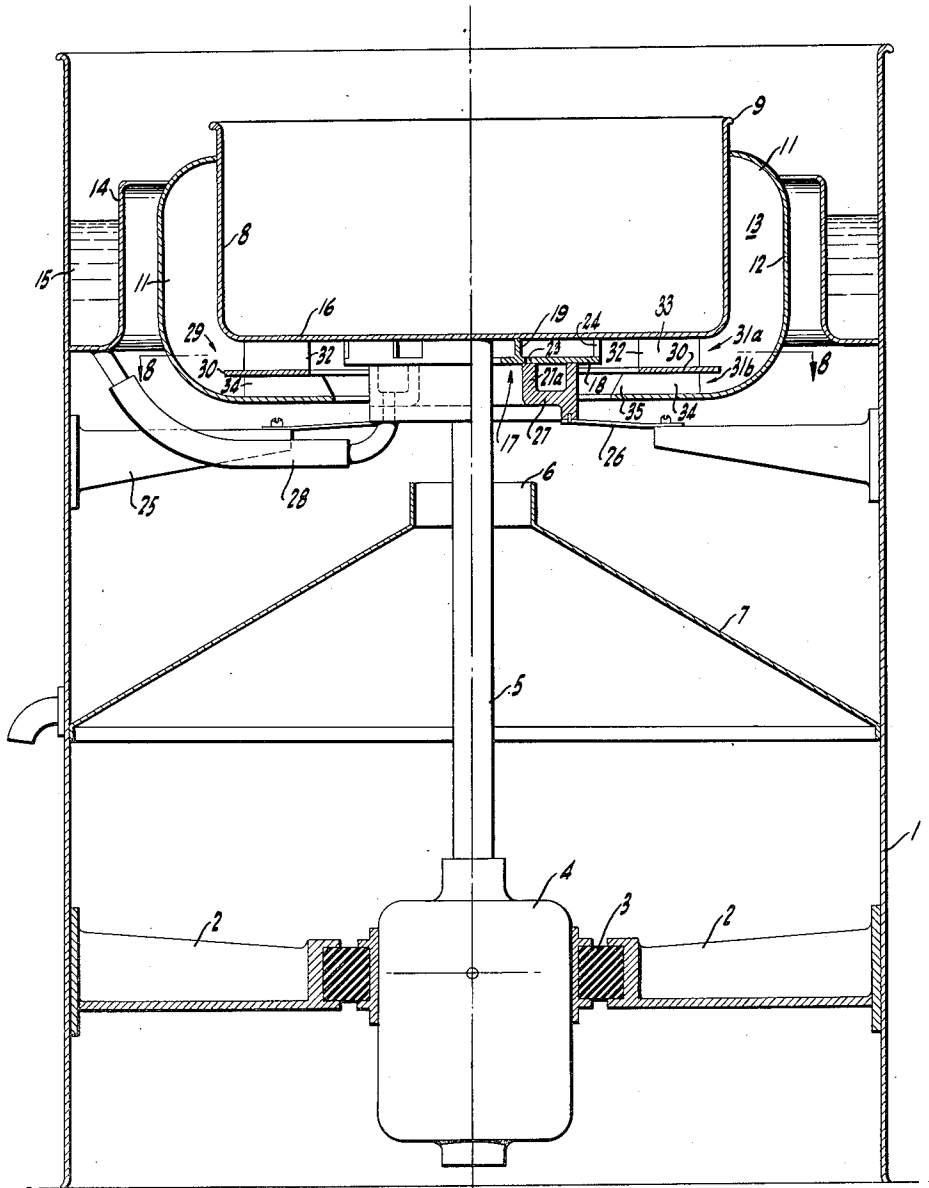
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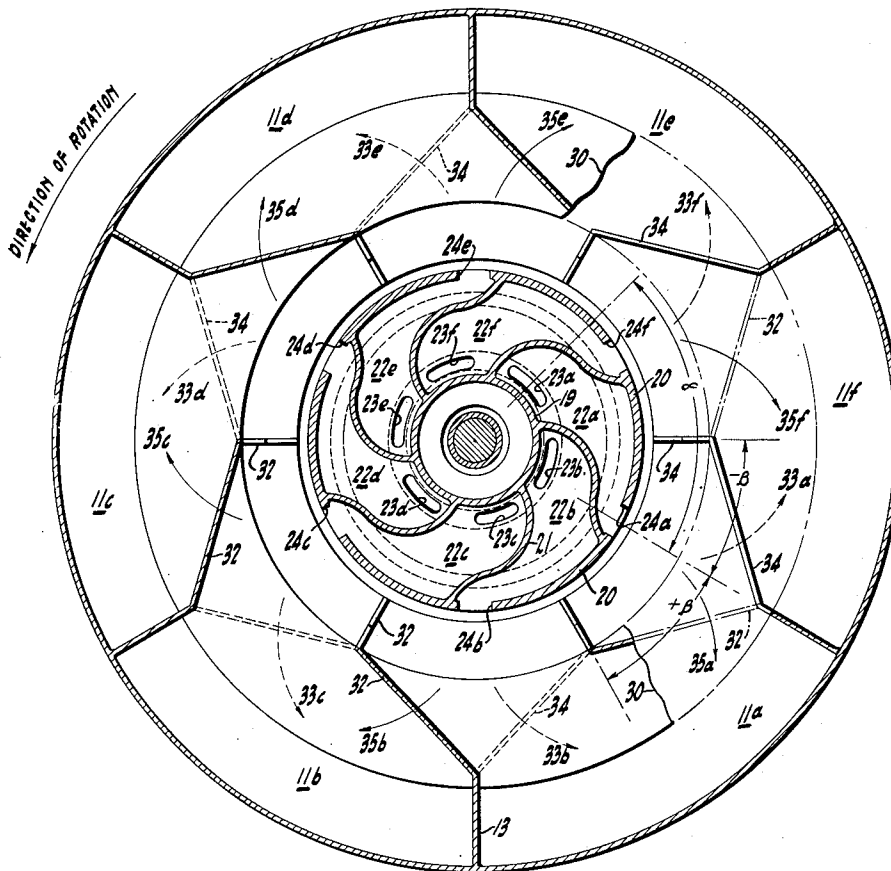


FIG. 8

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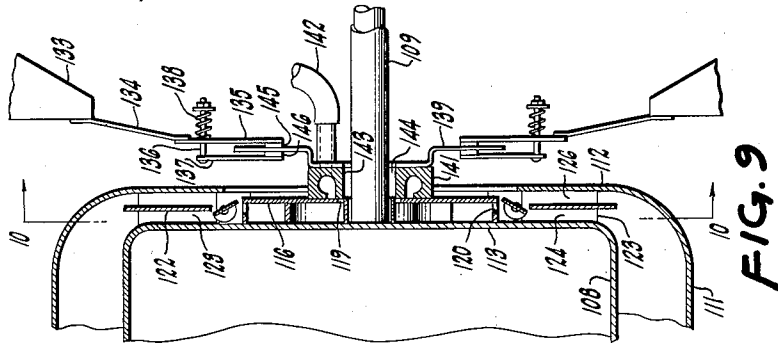


FIG. 9

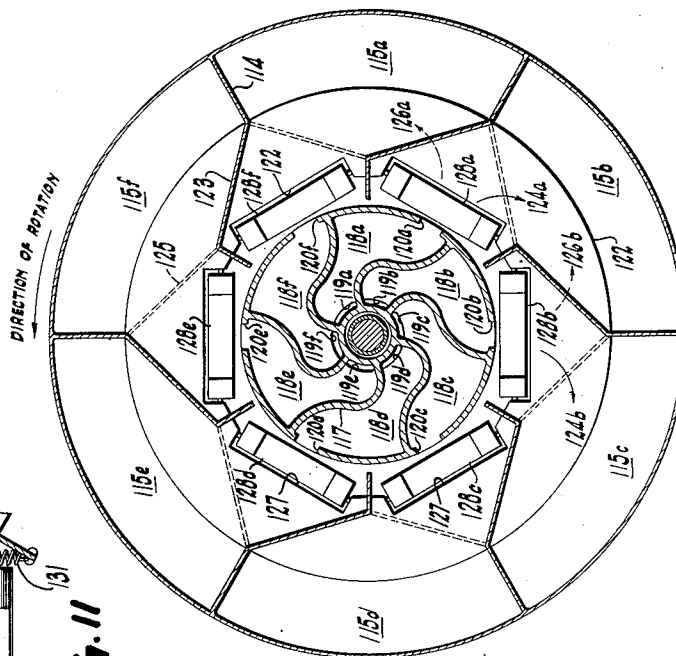


FIG. 10

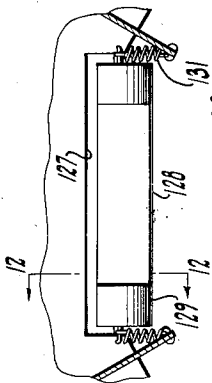


FIG. 11

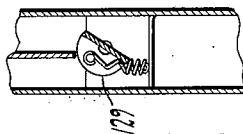


FIG. 12

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UNITED STATES PATENT OFFICE

2,584,942

DYNAMICALLY BALANCED ROTOR

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Application April 18, 1949, Serial No. 88,067

24 Claims. (Cl. 74—573)

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This invention relates in general to rotating equipment such as for example domestic centrifugal clothes extractors, and more particularly to devices of this character provided with automatic means for bringing them into and maintaining them in dynamic balance.

As is well known in the trade, many centrifugal extractors for expelling water from laundered clothes are subject to such excessive vibration when in operation that most, if not all, apartment houses preclude their installation above the ground floor. This of course results from the unequal distribution of the clothes within the extractor, a condition over which the operator has no control in the case of automatic clock-controlled washer-extractor combinations. Although various expedients have been resorted to in attempting to overcome this problem, none of them has been entirely satisfactory. Among the most successful of such expedients is the provision of peripherally spaced, longitudinally extending balancing pockets formed about the extractor tub or basket in conjunction with valve means responsive to the gyratory movement of the shaft on which the basket is mounted and which selectively delivers balancing water to one or more of the pockets lying diametrically opposite to the direction of the eccentricity of the basket. Although this to some extent aids in bringing the basket into dynamic balance, it falls considerably short of its intended purpose. For one reason, this is due to the fact that to bring about an actual dynamic balance, the balancing fluid should not be supplied to the basket at a point diametrically opposite to the direction of its eccentricity, but rather at a point diametrically opposite from the point at which the unbalancing load is concentrated.

As is known to those conversant with the behavior and mechanics of centrifugal equipment, and as presently will be more fully explained, any point on the geometric axis of a rotor, when rotating at a constant speed and under the influence of an unbalancing weight, is displaced from its spin axis and describes a circular path about its spin axis having a radius equal to its displacement or eccentricity. Contrary to what normally might be expected, the direction of this displacement or eccentricity is not in radial alignment with the unbalancing weight, but instead is angularly offset by what may be referred to as the angle of lag. Furthermore, both the eccentricity and the angle of lag vary with the speed of rotation. It will be seen therefore that to

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bring a rotor into dynamic balance, all of these factors must be taken into consideration.

In general, then, the object of this invention is the provision in combination with a rotor of a balancing device sensitive and responsive to variations in the eccentricity of the rotor and in the angle of lag of the eccentricity, for adding a balancing fluid to the rotor at a point substantially diametrically opposite the unbalancing load.

More specifically, the object of this invention is the provision in combination with a rotor provided with peripherally spaced, longitudinally extending unbalancing pockets, of an automatic distributor operating in response to variations in the eccentricity of the rotor and the angle of lag of the eccentricity, for adding balancing fluid to said pockets at a point diametrically opposite the unbalancing load.

A further object of this invention is the provision of a distributor of the character above described in combination with a centrifugal rotor designed to rotate on either a vertical or a horizontal axis.

The invention possesses other advantageous features, some of which, with the foregoing, will be set forth at length in the following description where those forms of the invention which have been selected for illustration in the drawings accompanying and forming a part of the present specification are outlined in full. In said drawings, two forms of the invention are shown, but it is to be understood that it is not limited to such forms, since the invention as set forth in the claims may be embodied in a plurality of forms.

Referring to the drawings:

Fig. 1 is a diagrammatic elevation of a free spindle rotor assembly showing its action when not in dynamic balance.

Fig. 2 is a transverse section taken on the section line 2—2 of Fig. 1.

Fig. 3 is a graph showing the relation between the speed of rotation of a rotor and its eccentricity resulting from an out-of-balance condition.

Fig. 4 is a graph showing the relation between the speed of rotation of a rotor and the angle of lag of its eccentricity resulting from an out-of-balance condition.

Fig. 5 is a diagrammatic illustration of an unbalanced rotor to be hereinafter used in conjunction with Fig. 6 to illustrate the effectiveness and efficiency obtained in applying a counterbalancing weight progressively at different points on the rotor.

Fig. 6 is a vector diagram illustrating the progressively incremental balancing of a rotor.

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Fig. 7 is a mid vertical section of a clothes extractor embodying the objects of my invention and arranged to rotate on a vertical axis.

Fig. 8 is a horizontal section taken on the section line 8—8 of Fig. 7.

Fig. 9 is a fragmentary longitudinal section similar to the section illustrated in Fig. 7 but wherein the objects of my invention have been embodied in a rotor arranged to rotate on a horizontal axis rather than on a vertical axis.

Fig. 10 is a section taken on the section line 10—10 of Fig. 9.

Fig. 11 is an enlarged detail of the deflecting vanes and associated structures forming a part of the device shown in Figs. 9 and 10.

Fig. 12 is a section taken on the section line 12—12 of Fig. 11, but showing the deflecting louvers in the position assumed thereby when the rotor is rotating at speeds above the transition speed.

Since as above indicated the construction and operation of the balancing mechanisms incorporated in the devices shown in Figs. 7 to 12 inclusive depend upon the mechanics and behavior of a free spindle rotor operating at speeds at which centrifugal force becomes a factor, a more detailed consideration thereof should be helpful in gaining an appreciation of the construction and function of these devices. For this purpose, reference is had to Figs. 1 to 6 inclusive.

The free spindle rotor assembly illustrated in Figs. 1 and 2 includes by way of example an extractor basket or tub B of conventional form mounted on the upper end of a substantially rigid shaft E. The lower end of this shaft is fixed to or serves as the shaft of a motor D resiliently or flexibly mounted through springs F on a frame or base G. In effect, then, the shaft E has a universal connection with the frame G and consequently the shaft and its basket are free to gyrate about the fixed reference axis or axis of rotation O, and may be considered as a free spindle system.

If the basket B is in dynamic balance and rotating at a constant speed, the geometric center C of the basket will coincide with the spin axis or axis of rotation O, and as a consequence the system will be free of vibration. If, however, it be assumed that the basket B is not in dynamic balance due to an unbalance weight W, the geometric center C of the basket will be deflected a distance e , from the axis of rotation, and describe a circular path p of radius e . From an inspection of Fig. 2 it will be seen that contrary to popular conception, the direction of this deflection, or eccentricity e does not coincide with the direction of the unbalance weight W, but instead lags behind it by an angle ϕ , this angle being hereinafter referred to as the "angle of lag." As shown in Figs. 3 and 4, the eccentricity e , and the angle of lag ϕ , vary with the speed of rotation N of the rotor. These relations can be demonstrated experimentally or analytically and are well known to the art as is evidenced by the following publication: "A new type of dynamic balancing machine," by E. L. Thearle, A. S. M. E. Trans., vol. 54, pp. 131-141, 1932, A. P. M. section. Also as set forth by the same author in his article entitled "The rotating disk," appearing in the November 1924 issue of Mechanical Engineering, the amount of dampening in the system and the angular acceleration of the rotor have some influence on the shapes or proportions of the graphs shown in Figs. 3 and 4.

By reference to Fig. 3 it will be seen that the

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eccentricity, e , or radius of whirl of an unbalanced rotor, increases with speed and reaches a maximum at about the critical, or resonant speed of the system. Above this speed it then decreases and approaches the eccentricity of the center of gravity of the basket and its unbalance load. As shown in Fig. 4, the angle of lag, ϕ , is zero at zero speed, increases with speed to a value of 90° at the critical speed, and approaches 180° at infinite speed.

From these considerations it is apparent that a satisfactory automatic balancing device must:

1. Be operative at speeds below, at, and above its critical speed.

2. Be sensitive and responsive to the amount of eccentricity and perform the amount of unbalance so as immediately to bring the system into dynamic balance and maintain it in such balance.

3. Be sensitive and responsive to variations in the angle of lag so as to be operative below, at, and above the critical speed of the system.

Superficially it may be thought that, in order to meet these requirements, an automatic balancer should operate to add each increment of balancing weight at a point exactly diametrically opposite the unbalancing weight. This, however, is not the case, as will become apparent from a consideration of Fig. 5. In this figure, W represents the unbalance in the system and since unbalance has direction as well as magnitude it can be represented by the vector O—H indicated in Fig. 6. Now assume that the balancing device, during any small interval of time, adds an increment of corrective weight, dw , not at a point diametrically opposite the unbalance, but at an angle δ (angle of error) from this point, this increment of correction dw , being indicated as the vector H—J in Fig. 6. The next increment of correction, vector J—K, will then be added at an angle of error δ from the vector O—J to compensate for the resultant of the initial unbalance W and the first increment of correction H—J. From this it can be seen that a balanced condition will always be approached along a logarithmic spiral if the angle of error δ is less than 90° as illustrated in Fig. 6. Therefore, the effectiveness of an automatic balancer meeting the conditions above set forth is 100% so long as the mean angle of error, δ is less than 90° .

To determine the efficiency of such a balancer as distinguished from its effectiveness, reference is had to Fig. 6 from which it will be seen that:

$$dW = dw \cos \delta$$

Assuming a constant angle of error, or using δ in the sense of a mean angle of error, Equation 1 integrates into:

$$W = w \cos \delta$$

If W = the original unbalance, in pound inches, then w = the required balance-correction in pound inches and if the efficiency of the balancer be defined as W/w , then Equation 2 shows that:

$$\text{Efficiency} = \cos \delta$$

Thus, for example, if the mean angle of error is 30° , and the correction is added at the same radius as the initial unbalance, each pound of corrective fluid will perfectly balance 0.866 pound of initial unbalance. This difference is due to the distribution or location of the corrective balance weight.

The fact that the "efficiency" of such a balancer is less than 100% does not detract from its value, for it is nevertheless 100% effective.

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Automatic dynamic balancers operating in accordance with the above principles have been embodied by way of example in the two forms of centrifugal extractors diagrammatically illustrated in Figs. 7 to 12 inclusive. Both of these modifications include a free spindle type of extractor basket provided with longitudinally extending, peripherally spaced balancing pockets; a segmented distributing disk for selectively slinging balancing fluid to conduits communicating with the balancing pockets, and an automatic valve operative in response to the displacement of the basket for selectively delivering balancing fluid from a source of such fluid to one or more of the segments of the distributing disk.

The modification shown in Figs. 7 and 8 is designed to rotate on a vertical axis and in this modification gravity is utilized for making the balancer sensitive and selectively responsive to variations in the speed of rotation of the basket.

In the modification illustrated in Figs. 9, 10, 11 and 12 and designed to operate on a horizontal axis, centrifugal force is utilized for making the balancer sensitive and selectively responsive to variations in the speed of rotation of the basket.

The extractor illustrated in Figs. 7 and 8 includes a shell or casing 1 provided at its lower end with a plurality of inwardly extending brackets 2. Mounted on the inner ends of these brackets through the medium of rubber blocks 3 is a motor 4 including a vertical shaft 5 extending upwardly through a relatively large central opening 3 formed in the casing bottom 7. Fixed to the upper end of the shaft is an extractor tub or basket 8 terminating at its upper peripheral edge in an outwardly and downwardly turned lip 9. Formed integral with the basket 8 about its outer periphery are a series or plurality of balancing pockets 11a through 11f formed by a common circular wall 12 coaxial with the basket 8 and by radial partitions 13 extending between the basket 8 and the circular wall 12. Surrounding the wall 12 and formed integral with the shell or casing 1 is an annular trough or reservoir 14 for the accommodation of a supply of water 15 or other balancing fluid.

Mounted or formed on the bottom 16 of the basket 8 is a balancing fluid distributing disk or slinger generally designated by the reference numeral 17, and defined by an annular bottom plate 18 and by peripherally spaced circular walls 19 and 20. Extending between the bottom 18 of the distributing disk and the bottom 16 of the basket, which serves as the upper wall of the disk, is a plurality of symmetrically and spirally disposed webs or vanes 21 dividing the disk into a plurality of generally spiral fluid channels 22a through 22f, angularly offset in a direction opposite to the direction of rotation of the basket as indicated in Fig. 8. Formed at the inner ends of the respective channels 22a through 22f are inlet ports 23a through 23f, and formed on the outer ends of each of these channels are fluid outlet ports 24a through 24f respectively. From an inspection of Fig. 8 it will be seen that the outlet ports of each of these channels is angularly offset in a direction opposite to the direction of rotation of the basket with respect to its inlet port, that each of the outlet ports are in radial alignment with one of the partitions 13 and that its associated inlet port is slightly radially offset with respect to the next counter-clockwise succeeding partition 13.

Fastened to the side walls of the shell 1 and extending inwardly thereof are brackets 25 and secured to the inner end of each of these brackets is

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a spring finger 26. Fastened to the inner ends of these spring fingers is a channel supply ring 27, arranged to have sealing engagement with the bottom 18 of the distributor 17 and to form an automatic valve therewith. Due to this method of mounting the supply ring 27, it is fixed against rotary and radial motion but free to nod in response to any gyratory movement of the basket resulting from its out-of-balance. Connecting the trough or reservoir 14 with the ring 27 is a hose 28 of sufficient length and flexibility to permit the free tilting movement of the ring 27.

It is important to note from an inspection of Fig. 7 that the inner wall 27a of the ring 27 is formed on a radius approximately equal to the inner radius of the ports 23a through 23f, is of a thickness somewhat greater than the width of these ports, and that consequently when the system is static or in dynamic balance all of the ports 23a through 23f will be closed by this wall of the channel. Under these conditions there will be no communication between the supply ring 27 and the distributing disk and slinger 17. If, however, the basket is displaced to the right as viewed in Figs. 7 and 8 under the influence of an unbalancing load, the distributing disk being fixed to the basket will also move to the right thereby bringing one or more of its inlet ports into registration with the supply ring and thereby permitting the flow of balancing fluid from the reservoir 14 through the hose section 28 and through the ring 27 into one or more of the corresponding segments of the distributing disk 17.

Although the upper ends of the balancing pockets 11 are closed by a continuation of the common annular wall 12, their lower ends are provided with ports 29 on substantially the level of the distributing disk 17 and with the supply ring 27. Disposed between the basket bottom 16 and the lower horizontal ends of the circular wall 12 is a transverse annular plate 30 dividing the ports 29 into upper and lower port sections 31a and 31b. Extending between the bottom 16 of the basket and the plate 30 are vertical baffles 32 forming an extension of the radial partitions 13 and angularly offset in the direction of rotation of the basket 8. The bottom 16 of the basket, the plate 30 and each adjacent pair of the baffles 32 therefore define a series of angularly offset conduits 33a through 33f communicating at their outer ends with the upper port sectors 31a of the balancing pocket ports 29 and terminating at their inner ends in open sectors subtending and in angular alignment respectively with the outlet ports 24a to 24f of the distributing disk 17 but radially spaced therefrom. Similarly disposed between the plate 30 and the lower end of the wall 12 are vertically disposed baffles 34 forming a continuation of the partitions 13 but angularly offset in a direction opposite to the direction of rotation of the basket 8. Each pair of adjacent baffles 34, together with the plate 30 and the bottom portion of the wall 12, define a series of conduits 35a through 35f communicating at their outer ends respectively with one of the lower port sectors 31b of the pockets 11 and terminating at their inner ends in open sectors lying adjacent to but below the distributing disk 17 and in angular alignment with one of the outlet ports 24 thereof. Water entering one of the inlet ports 23 therefore travels spirally in a clockwise direction through one of the channels 22, passes outwardly through the corresponding outlet port 24, and then depending upon the

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speed of rotation of the basket, passes to one or the other of the balancing pockets formed on either side of that particular radial wall 13 lying in substantial angular alignment with the outlet port 24 under consideration. If the basket is rotating at low speeds, the water on leaving the ports 24 will be subjected to the action of gravity for a sufficient length of time to cause it to drop into one of the lower radially aligned conduits 35. At high speeds the water enters the balancing pocket 11 through one of the upper channels. Depending then on the speed of rotation, the water can be given either a positive or negative lag relative to the corresponding outlet port 24.

Now assume that at some instant under consideration the basket 8 due to an unbalance weight as viewed in Fig. 8, has been displaced to the right and that consequently balancing water is entering the port 23a of the distributing disk and being slung radially therefrom through its discharge port 24a. Depending upon the speed of rotation of the basket, the water leaving the discharge port will pass through the conduit 35a into the pocket 11a or through the conduit 33a into the next succeeding pocket 11f in the direction of rotation of the basket. In connection with the following description of the operation of this device it should be noted that the term "transition speed" is used to denote that speed at which the centrifugal force at which the balancing water is slung outwardly from the distributing disk is sufficient to overcome the action of gravity in the first modification and in the second modification the speed at which the centrifugal force becomes effective to rotate the deflecting louvers against the action of their biasing springs. If the basket is rotating at a speed below the transition speed it will take the former path for there is then sufficient time for gravity to draw it into the lower conduit. In on the other hand the basket is traveling at a speed above the transition speed, the water will be slung into the upper conduit before gravity has had sufficient time to deflect it downwardly into the lower conduit. At the transition speed the water may of course be split between the two conduits. It will therefore be seen that regardless of the speed of rotation, the balancing water in passing through the distributing disk is deflected in a direction opposite to the direction of rotation of the basket through the angle subtending the inlet and discharge ports of distributing disk channels 22 and which may be referred to as the distributing disk angle α . Independently of this deflection, and superposed thereon selectively in response to the speed of rotation of the basket is an additional angle of lag β to which the balancing water is subjected in passing from the distributing disk into the balancing pockets 11. As above indicated, this latter deflection may be either positive, that is additive to α at speeds below the transition speed to correct for the low angle of lag of the eccentricity at low speeds or it can be negative when the basket is rotating at speeds above the transition speed to correct for the greater angle of lag of the eccentricity occurring at these speeds. It should here be noted that the inner diameter of the horizontal portion of the pocket wall 12 serving as the bottom of the lower conduits 33, can be so chosen that the balancer becomes effective only above a selected speed of rotation of the basket. Also the inner diameter of the plate 30 determines the transitional speed at which the balancing water is slung through the upper conduits to the bal-

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ancing pockets rather than through the lower conduits.

The relations existing between the various angles above referred to are as follows:

(Above the transition speed)

$$\phi + \alpha - \beta + \delta = 180^\circ$$

(Below the transition speed)

$$\phi + \alpha + \beta + \delta = 180^\circ$$

In the balancer illustrated in Figs. 7 and 8 and below the transition speed

$$\alpha = 75^\circ, \text{ and } +\beta = +30^\circ$$

Substituting the values in Equation 5 gives

$$\phi + 75^\circ + 30^\circ + \delta = 180^\circ$$

or

$$\phi + \delta = 75^\circ$$

Thus the angle of error, δ , is zero when the angle of lag of the eccentricity, ϕ is 75° and this occurs when the basket is rotating somewhat below its critical speed.

Above the transition speed:

$$\alpha = 75^\circ, \text{ and } -\beta = -30^\circ$$

Substituting these values in Equation 4 gives

$$\phi + 75^\circ - 30^\circ + \delta = 180^\circ$$

or

$$\phi + \delta = 135^\circ$$

Here the angle of error is zero when the angle of lag of the eccentricity is 135° and this occurs when the basket is rotating at a speed somewhat above its critical speed. With this particular design, the "effectiveness" will always be 100% and since the angle of error will always be less than 45° , the "efficiency" will always be greater than 70%.

Although the balancer above described has been shown as provided with six balancing pockets any number greater than two are operative. It should also be noted that it is not necessary as shown in Fig. 8, that the change in the angle of lag to which the balancing fluid is subjected (2β) be equal to the angle subtended by each of the balancing pockets (here 60°). This angle, 2β may be that subtended by any desired number of balancing pockets.

Since, as shown by Fig. 4, the total range of the angle of lag of the eccentricity, ϕ , is 180° , this device permits the designer to choose arbitrarily:

- (1) A minimum rotative speed at which the device becomes operative.
- (2) A low speed range, below the critical speed, over which the angle of error is always less than 45° .
- (3) A high speed range, above the critical speed, over which the angle of error is always less than 45° .
- (4) The transition speed between these two ranges.

Obviously, if the added complication were justified, three or more conduits entering the balancing pockets could be used, thereby giving further freedom to the designer.

The modification shown in Figs. 9, 10, 11 and 12 is essentially the same as that above described and differs from it only in that instead of using gravity to divert the balancing fluid into one of the two conduits leading to each of the balancing pockets, spring biased deflecting vanes responsive to a selected centrifugal force are resorted to and also a floating, self-centering supply ring.

Both of these changes are required for the reason that this modification is designed to rotate on a horizontal axis rather than a vertical axis.

In this modification the rotor or basket 108 is fixed to the outer end of a free spindle shaft 109 in accordance with conventional construction. Surrounding the basket is a shell 111 sealed at its outer end to the basket and forming at its inner end, an annular end wall 112 spaced from the head 113 of the basket. Disposed between the basket 108 and the shell 111 are a number of longitudinally extending partitions 114 serving to define an equal number of balancing pockets 115a to 115f. Mounted on the basket head 113 and forming an integral part thereof is a distributing disk 116 divided by spiral vanes 117 into spiral channels 118a to 118f. These channels are provided with inlet ports 119a to 119f respectively at their inner ends and at their outer ends with corresponding discharge ports 120a to 120f. Disposed between the basket head 113 and the end wall 112 is an annular plate or ring 122. Extending between the basket head 113 and the ring 122 are baffles 123 defining a series of angularly offset conduits 124a to 124f communicating at their outer ends respectively with the balancing pockets 115a to 115f and at their inner ends respectively subtending the discharge ports 120a to 120f. Extending between the ring 122 and the wall 112 are a series of angularly offset baffles 125 defining a series of conduits 126a to 126f, respectively communicating at their outer ends with the balancing pockets 115f to 115a and terminating at their inner ends in open sectors respectively subtending the distributing disk discharge ports 120a to 120f. It should here be noted that the ring 122 is in substantial longitudinal alignment with the discharge ports 120. The structure so far described is identical with the structure illustrated in Figs. 7 and 8 with the single exception that it is designed to rotate on a horizontal axis rather than on a vertical axis.

Journalled on the ring 122 for rotation in rectangular recesses 127 formed therein directly opposite each of the discharge ports 120 are deflecting louvers 128a to 128f. Each of these louvers is provided at each end thereof with an outwardly extending weight 129 and with a biasing spring 131 normally holding their louvers in the position shown in Fig. 9 at basket speeds below the transition speed. In this position of the louvers water slung from the discharge ports of the distributing disk passes into the balancing pockets through the outer conduits 124. At speeds above the transition speed the centrifugal force acting on the weights 129 is sufficient to force the louvers 128 against the biasing action of their associated springs to the position shown in Fig. 12. In this position balancing fluid slung from the distributing disk is deflected to the right as shown in Fig. 12 and therefore passes into the balancing pockets through the inner series of conduits 126. Here then an additional angle of lag β is given to the balancing fluid under the influence of centrifugal force rather than under the influence of gravity as in the first modification described.

Mounted on brackets 133 extending inwardly from the basket frame are spring fingers 134 and supported by these fingers is a ring 135. Mounted on this ring by pins 136 extending there-through is a clamping ring 137, this ring being biased toward the ring 135 by springs 138. Clamped between the two rings 135 and 137 is

supply ring carrier 139 and fixed thereto is a balancing fluid supply ring 141 communicating through a hose 142 with a suitable source of balancing fluid. As in the modifications previously described the inner wall 143 is arranged normally to close the inlet ports 119 of the distributing disk. As a result of this construction the supply ring 141 is restrained against rotation, and is free to nod with the basket in sealing engagement therewith as in the case of the first modification and in addition to this is self-centering. When the extractor is first started rotating the eccentricity of rotation increases, due to unbalance. If the supply ring 141 does not happen to be centered relative to the neutral position of the shaft, the eccentricity of rotation will increase until it equals the radial clearance 144 between the shaft 109 and the supply ring 141. The "high side" of the shaft will then strike the supply ring, sliding it and the carrier ring 139 between the friction shoes 145 and 146 respectively mounted on the rings 135 and 137, in such a direction as to tend to center the supply ring. As the balancer becomes operative it decreases the eccentricity of rotation until it is less than the radial clearance 144 and the shaft 109 no longer touches the supply ring 141. This then leaves the supply ring in the desired centered position relative to the neutral position of the shaft. By resorting to this expedient, compensation is made for the particular neutral position of the shaft which of course depends upon the load to which the basket happens to be subjected.

In so far as the balancing function of this modification is concerned, its operation is identical to the operation of the modification illustrated in Figs. 7 and 8.

In both modifications the balancing fluid in passing through the distributing disk is deflected in a direction opposite to the direction of rotation of the basket through the "angle of distribution α " of the distributing disk. In addition to this, the balancing fluid slung from the distributing disk can be given a further angle of lag β either plus or minus depending upon whether the basket is rotating below or above its transition speed.

For convenience of definition the terms "radius of eccentricity" and "radius of unbalance" are used in several of the claims. By "radius of eccentricity" is meant that radius drawn from the fixed reference axis (i. e., the axis "O" in the drawings) through the axis of the rotor (i. e., the axis "C" in the drawings.) By "radius of unbalance" is meant that radius drawn from the fixed reference axis through the center of gravity of the unbalancing weight. Also, as used herein, the term "light side," as applied to an unbalanced rotor, is meant that portion of the rotor which is located more than 90° from the center of gravity of the unbalancing weight. Correspondingly, the "heavy side" is that portion which is less than 90° from the center of gravity of the unbalancing weight.

The functions of the extractors in which my automatic balancer has been embodied, as above described, need no explanation. As extractors per se they operate in accordance with principles well known in the industry.

I claim:

1. An automatically balancing rotor comprising: a frame; a shaft mounted on said frame for gyration about a reference axis; a rotor fixed to said shaft coaxially and for rotation there-

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with; fluid receiving balancing pockets formed on the periphery of said rotor; a fluid distributor mounted on said rotor for coaxial rotation therewith; said distributor being symmetrically divided by spiral vanes into spiral sections angularly offset from their inner to their outer ends, each of said sections being provided on its inner end with an inlet port and on its outer end with a discharge port angularly offset with respect to said inlet port; conduits mounted on said rotor with their inner ends lying adjacent to and in substantial angular alignment with said discharge ports and with their outer ends in communication with said pockets; and automatic valve means associated with said rotor and responsive to the eccentricity of said rotor for selectively delivering balancing fluid to one of said distributor sections.

2. An automatically balancing rotor comprising: a frame; a shaft mounted on said frame for gyration about a reference axis; a rotor fixed to said shaft coaxially and for rotation therewith; fluid receiving balancing pockets formed on the periphery of said rotor; a fluid distributor mounted on said rotor for coaxial rotation therewith; said distributor being symmetrically divided by spiral vanes into spiral sections angularly offset from their inner to their outer ends, each of said sections being provided on its inner end with an inlet port and on its outer end with a discharge port angularly offset with respect to said inlet port; conduits mounted on said rotor with their inner ends lying adjacent to and in substantial angular alignment with said discharge ports and with their outer ends in communication with said pockets; and automatic valve means associated with said rotor and responsive to the eccentricity of said rotor for selectively delivering balancing fluid to one of said distributor sections.

3. An automatically balancing rotor comprising: a frame; a shaft mounted on said frame for gyration about a fixed reference axis; a rotor fixed to said shaft coaxially and for rotation therewith; fluid receiving balancing pockets formed on the periphery of said rotor; a sectionalized fluid distributor formed on said rotor, each of the sections thereof being provided with an inlet port and a discharge port angularly offset with respect to said inlet port of said rotor; conduits mounted on said rotor, said conduits communicating at their outer ends with said balancing pockets and terminating at their inner ends in intake openings spaced from but in angular alignment with said discharge ports so as to receive balancing fluid slung therefrom; and an automatic valve associated with said rotor for selectively delivering balancing fluid to one of the sections of said distributor in response to the radial movement of said shaft.

4. An automatically balancing rotor comprising: a frame; a shaft mounted on said frame for gyration about a fixed reference axis; a rotor fixed to said shaft coaxially and for rotation therewith; fluid receiving balancing pockets formed on the periphery of said rotor; a sectionalized fluid distributor formed on said rotor, each of the sections thereof being provided with an inlet port and a discharge port angularly offset with respect to said inlet port; conduits mounted on said rotor, said conduits communicating at their outer ends with said balancing pockets and terminating at their inner ends in intake openings spaced from but in angular alignment with said discharge ports so as to re-

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ceive balancing fluid slung therefrom; and an automatic valve associated with said rotor for selectively delivering balancing fluid to one of the sections of said distributor in response to the radial movement of said shaft.

5. A centrifugal extractor comprising: a frame; a shaft mounted on said frame for gyration about a fixed reference axis; an extractor basket fixed to said shaft coaxially and for rotation therewith; fluid receiving balancing pockets formed on the periphery of said basket; a sectionalized fluid distributor formed on said basket, each of the sections thereof being provided with an inlet port and a discharge port angularly offset with respect to said inlet port; conduits mounted on said basket, said conduits communicating at their outer ends with said balancing pockets and terminating at their inner ends at a point spaced from but in angular alignment with said discharge ports so as to receive balancing fluid slung therefrom; and an automatic valve associated with said distributor for selectively delivering balancing fluid to one of the sections of said distributor in response to the radial movement of said shaft.

6. An automatically balancing rotor comprising: a frame; a shaft mounted on said frame for gyration about a fixed reference axis; a rotor fixed to said shaft coaxially and for rotation therewith; a series of fluid receiving balancing pockets formed on the periphery of said rotor; a fluid distributor mounted on said rotor for coaxial rotation therewith, said distributor being divided by vanes into symmetrical sections, each of said sections being provided on its inner end with an inlet port and on its outer end with a discharge port angularly offset with respect to said inlet port; a series of pairs of longitudinally adjacent conduits mounted on said rotor, the inner ends of each pair of conduits subtending one of the discharge ports of said distributor and the outer ends thereof communicating respectively with different members of said series of balancing pockets; an automatic valve associated with said rotor for selectively delivering balancing fluid to one of said distributor sections in response to gyration of said rotor; and means for diverting balancing fluid slung from said discharge ports to either one or the other of a pair of said conduits selectively in response to the speed of rotation of said rotor.

7. An automatically balancing rotor comprising: a frame; a shaft mounted on said frame for gyration about a fixed reference axis; a rotor fixed to said shaft coaxially and for rotation therewith; a series of fluid receiving balancing pockets formed on the periphery of said rotor; a fluid distributor mounted on said rotor for coaxial rotation therewith, said distributor being divided by vanes into symmetrical sections, each of said sections being provided on its inner end with an inlet port and on its outer end with a discharge port angularly offset with respect to said inlet port; a series of pairs of longitudinally adjacent conduits mounted on said rotor, the inner ends of each pair of conduits subtending one of the discharge ports of said distributor and the outer ends thereof communicating respectively with different members of said series of balancing pockets; an automatic valve associated with said rotor for selectively delivering balancing fluid to one of said distributor sections in response to gyration of said rotor; and means for diverting balancing fluid slung from said discharge ports to either one or the other of a pair

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of said conduits selectively in response to the speed of rotation of said rotor.

8. An automatically self-balancing rotor comprising: a frame; a shaft mounted on said frame for gyration about a vertical reference axis; a rotor fixed to one end of said shaft coaxially and for rotation therewith; fluid receiving balancing pockets formed on the periphery of said rotor; a fluid distributor mounted on said rotor for coaxial rotation therewith, said distributor being divided into symmetrical sections spiraling outwardly; a series of pairs of upper and lower conduits mounted on said rotor for rotation therewith, the inner ends of each pair of conduits being adjacent to and in substantial angular alignment with one of said discharge ports, the outer ends of the conduits forming each pair of conduits being in communication with different and peripherally spaced balancing pockets, and the lower walls of said lower conduits extending inwardly beyond the lower wall of said upper conduits; and automatic valve means mounted on said rotor and responsive to the eccentricity of said rotor for selectively delivering balancing fluid to one of said distributor sections.

9. An automatically self-balancing rotor comprising: a frame; a shaft mounted on said frame for gyration about a vertical reference axis; a rotor fixed to one end of said shaft coaxially and for rotation therewith; fluid receiving balancing pockets formed on the periphery of said rotor; a fluid distributor mounted on said rotor for coaxial rotation therewith, said distributor being divided into symmetrical sections spiraling outwardly in a direction opposite to the direction of rotation of said rotor; a series of pairs of upper and lower conduits mounted on said rotor for rotation therewith, the inner ends of each pair of conduits being adjacent to and in substantial angular alignment with one of said discharge ports, the outer ends of the conduits forming each pair of conduits being in communication with different and peripherally spaced balancing pockets, and the lower walls of said lower conduits extending inwardly beyond the lower wall of said upper conduits; and automatic valve means mounted on said rotor and responsive to the eccentricity of said rotor for selectively delivering balancing fluid to one of said distributor sections.

10. An automatically self-balancing rotor comprising: a frame; a shaft mounted on said frame for gyration about a reference axis; a rotor fixed to said shaft coaxially and for rotation therewith; fluid receiving balancing pockets formed on the periphery of said rotor; a fluid distributor mounted on said rotor for coaxial rotation therewith, said distributor being divided into channels spiraling outwardly, and each of said channels being provided at its inner end with a fluid inlet port and at its outer end with a discharge port; a louver pivoted on said rotor adjacent to and in radial alignment with each of said discharge ports, said louvers being weighted and spring-biased so as to assume a predetermined deflected position at rotor speeds below a selected speed and to assume a different deflecting position under the influence of centrifugal force operating on the louver weights at speeds above said selected speed; a series of pairs of longitudinally adjacent conduits mounted on said rotor having inner ends in radial alignment with said louvers and outer ends communicating respectively with different peripherally spaced balancing pockets; and an automatic valve mounted on said rotor and responsive to the eccentricity of said rotor

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for selectively delivering balancing fluid to one of said distributor channels.

11. An automatically self-balancing rotor comprising: a frame; a shaft mounted on said frame for gyration about a reference axis; a rotor fixed to said shaft coaxially and for rotation therewith; a balancing fluid distributing disk fixed to said rotor coaxially therewith, said disk being formed with a series of radially extending fluid channels each having an intake port at its inner end and a discharge port at its outer end; a balancing fluid supply ring disposed in sealing engagement with said distributing disk; means for holding said supply ring coaxial with said reference axis and against rotation, but permitting it to nod in response to the gyration of said rotor, said supply ring serving to close all of the inlet ports of said distributing disk when said rotor is coaxial with said reference axis and to open one or more of said inlet ports in response to the gyration of said rotor; a series of longitudinally extending, peripherally spaced fluid receiving, balancing pockets formed on the periphery of said rotor; and a series of pairs of conduits formed on said rotor substantially in the plane of said distributing disk, each pair of conduits having inner ends disposed adjacent one of the discharge ports of said distributing disk for the reception of balancing fluid therefrom, and outer ends communicating respectively with different and peripherally spaced members of said series of balancing pockets.

12. An automatic, self-balancing rotor comprising: a frame; a shaft mounted on said frame for gyration about a reference axis; a rotor fixed to said shaft coaxially and for a rotation therewith; a balancing fluid distributing disk fixed to said rotor coaxially therewith, said disk being formed with a series of radially extending fluid channels each having an intake port at its inner end and a discharge port at its outer end angularly offset from its associated inlet port; a balancing fluid supply ring mounted on said frame in sealing engagement with said distributing disk and for radial movement in response to the gyration of said shaft, said supply ring serving to close all of the inlet ports of said distributing disk when said rotor is coaxial with said reference axis and to open at least one of said inlet ports in response to the gyration of said rotor; means for dampening the radial movement of said supply ring; a series of longitudinally extending, peripherally spaced fluid receiving balancing pockets formed on the periphery of said rotor; and a series of pairs of conduits formed on said rotor substantially in the plane of said distributing disk, each pair of conduits having inner ends disposed adjacent one of the discharge ports of said distributing disk for the selective reception of balancing fluid therefrom, and outer ends communicating respectively with different and selected members of said series of balancing pockets.

13. A centrifugal machine comprising: a frame; a shaft mounted on said frame for gyration about a fixed reference axis; a rotor fixed to said shaft coaxially and for rotation therewith; fluid receiving balancing pockets formed on the periphery of said rotor; a sectionalized fluid distributor formed on said rotor, each of the sections thereof being provided with an inlet port and a discharge port angularly offset with respect to said inlet port; a balancing fluid supply ring disposed in sealing engagement with said fluid distributor; means for holding said supply ring

coaxial with said reference axis and against rotation; conduits mounted on said rotor, said conduits communicating at their outer ends with said balancing pockets and terminating at their inner ends in openings subtending each of said discharge ports but radially spaced therefrom.

14. In a dynamically balanced machine of the character described comprising a rotor mounted for rotation about its axis and for gyration about a fixed reference axis in response to an unbalancing weight, and balancing means therefor including fluid supply means and fluid receiving means for receiving from said supply means a balancing fluid to counterbalance the unbalancing weight, the improvement which comprises means responsive to and operated by the speed of the rotor for channelling the supply of balancing fluid passing from said supply means to said receiving means in accordance with the angle of lag between the radius of eccentricity and the radius of unbalance, to add balancing fluid at speeds above the critical speed to a sector of said receiving means located not less than 90° from the radius of unbalance.

15. In a dynamically balanced machine of the character described comprising a rotor mounted for rotation about its axis and for gyration about a fixed reference axis in response to an unbalancing weight, and balancing means including automatic valving means operated by eccentricity of the rotor to provide a supply of balancing fluid to a distributing member, and balancing compartments arranged about the rotor axis to receive balancing fluid from said distributing member to counterbalance the unbalancing weight, the improvement which comprises a selective distributing member capable of channelling balancing fluid to said compartments and operated by and in response to the speed of the rotor to select a compartment to receive the balancing fluid so as to add the fluid at a point not less than 90° from the radius of unbalance.

16. In a rotating system of the character described, including a rotor mounted for rotation about its own axis and for gyration about a fixed reference axis coinciding with the rotor axis when the rotor is dynamically balanced, said system having the characteristic of gyrating with the heavy side out at speeds below the critical speed and with the light side out at speeds above the critical speed of the system, the improvement which comprises automatic balancing means controlled and operated by eccentricity and speed of the rotor for maintaining a supply of balancing fluid on the light side of the rotor over a wide range of speeds including speeds above the critical speed.

17. In a rotating system of the character described, including a rotor mounted for rotation about its own axis and for gyration about a fixed reference axis coinciding with the rotor axis when the rotor is dynamically balanced, said system having the characteristic of gyrating with the heavy side out at speeds below the critical speed and with the light side out at speeds above the critical speed of the system, the improvement which comprises automatic balancing means including valve means automatically operated in response to eccentricity of the rotor to provide a supply of balancing fluid, and fluid distributing means controlled and operated by the speed of the rotor for maintaining a supply of balancing fluid on the light side of the rotor over a wide range of speeds,

including speeds above the critical speed of the system.

18. In a rotating system of the character described, including a rotor mounted for rotation about its own axis and for gyration about a fixed reference axis coinciding with the rotor axis when the rotor is dynamically balanced, said system having the characteristic of gyrating with the heavy side out at speeds below the critical speed and with the light side out at speeds above the critical speed of the system, the improvement which comprises automatic balancing means including balancing compartments arranged about the rotor axis to receive balancing fluid, valve means automatically operated in response to eccentricity of the rotor to provide a supply of balancing fluid for said compartments and fluid distributing means controlled by the speed of the rotor for distributing balancing fluid to one or more of said compartments on the light side of the rotor over a wide range of speeds, including speeds above the critical speed of the system, said distributing means comprising upper and lower channels communicating with different balancing compartments, said upper channels receiving balancing fluid at relatively high rotor speeds and said lower channel receiving balancing fluid at relatively low rotor speeds.

19. In a rotating system of the character described, including a rotor mounted for rotation about its own axis and for gyration about a fixed reference axis coinciding with the rotor axis when the rotor is dynamically balanced, said system having the characteristic of gyrating with the heavy side out at speeds below the critical speed and with the light side out at speeds above the critical speed of the system, the improvement which comprises automatic balancing means including balancing compartments arranged about the rotor axis to receive balancing fluid, valve means automatically operated in response to eccentricity of the rotor to provide a supply of balancing fluid for said compartments and fluid distributing means controlled by the speed of the rotor for maintaining a supply of balancing fluid on the light side of the rotor over a wide range of speeds including speeds above the critical speed of the system, said distributing means comprising centrifugally operated valves arranged to channel balancing fluid to one or another of said compartments according to the speed of the rotor and the centrifugal force exerted thereby upon the valves.

20. In an automatically balancing rotating system of the type comprising a rotor mounted to rotate about its own axis and to gyrate about a fixed reference axis in response to an unbalancing weight, balancing means arranged about the rotor axis to receive balancing fluid, and distributing means for selectively distributing balancing fluid to said balancing means to correct a condition of unbalance, the improvement which comprises automatic valving means for admitting balancing fluid from a source thereof to said distributing means, said automatic valving means comprising a valve member non-rotatably fixed to the frame of the machine and a co-operable valve member fixed to the rotor for rotation therewith, said valve members being automatically operated in response to deflection of the rotor to open when the rotor is deflected and to close when the rotor is dynamically balanced.

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21. An automatically balancing rotating system comprising a rotor mounted to rotate about its own axis and to gyrate about a fixed reference axis, balancing compartments arranged about the rotor axis to receive balancing fluid, and valve and distributor means for supplying balancing fluid to said compartments, said valve and distributor means comprising a non-rotatable valve member fixed to the frame of the machine and having an annular passage defined by side walls and a rotatable valve and distributor member fixed to the rotor for rotation therewith, said rotatable member comprising a plurality of channels each communicating with a selected compartment, said rotatable member also comprising a bottom closure in sealing engagement with the walls of said annular passage, said bottom closure being formed with a hole for each channel which is closed by a wall of said annular passage when the rotor is balanced, one or more of said holes being uncovered and communicated with said annular passage when the rotor is deflected.

22. An automatically balancing machine of the character described, comprising a rotor mounted for rotation about its axis and for gyration about a fixed reference axis in response to an unbalancing weight, fluid receiving means arranged to receive balancing fluid to counterbalance said unbalancing weight, fluid supply means operated by eccentricity of the rotor for supplying balancing fluid to said fluid receiving means and alternate channelling means including a first set of channels arranged to channel fluid from said supply to said receiving means and a second set of channels arranged to channel fluid from said supply means to said receiving means, said first set being so arranged as to channel fluid at speeds below critical speed to a sector of said receiving means opposite the deflected side of the rotor and opposite the heavy side of the rotor and said second set being so arranged as to channel fluid at speeds above critical speed to a sector of said fluid receiving means on the deflected side of the rotor and opposite the heavy side of the rotor.

23. An automatically balancing machine of the character described, comprising a rotor mounted for rotation about its axis and for gyration about a fixed reference axis in response to an unbalancing weight, fluid receiving means arranged to receive balancing fluid to counterbalance said unbalancing weight, fluid supply means operated by eccentricity of the rotor for supplying balancing

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fluid to said fluid receiving means and centrifugally operated channelling means for selectively channelling balancing fluid, said channelling means comprising: a first set of channels each having an inlet communicating with said fluid supply means and an outlet communicating with a sector of said fluid receiving means; said channelling means also comprising a second set of channels each having an inlet in registry with the inlet of one of said first set of channels and an outlet communicating with a different sector of said fluid receiving means; and means operated automatically by centrifugal force for directing fluid from said supply means to said first set of channels at speeds below critical speed and to said second set of channels at speeds above the critical speed; the outlet ends of said first and second sets of channels being angularly displaced such that fluid will be delivered by the first set opposite the deflected side and the heavy side of the rotor, and such that fluid will be delivered by the second set to the deflected side and opposite the heavy side of the rotor.

24. An automatically balancing machine comprising a rotor mounted for rotation about its axis and for gyration about a fixed reference axis in response to a condition of unbalance, fluid supply means responsive to and operated by eccentricity of the rotor for supplying a balancing fluid to correct said condition of unbalance, fluid receiving means arranged about said axis of rotation to receive said fluid, and channelling means for receiving said fluid from said supply means and channelling it to said receiving means, said channelling means being responsive to and operated by centrifugal force created by rotation at speeds above the critical speed so as to channel fluid to a sector of said receiving means more than 90° from the radius of unbalance.

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