Jan. 5, 1937. J. L. TAYLOR 2,067,068

CALCULATOR

Filed Nov. 18, 1933 4 Sheets-Sheet 1

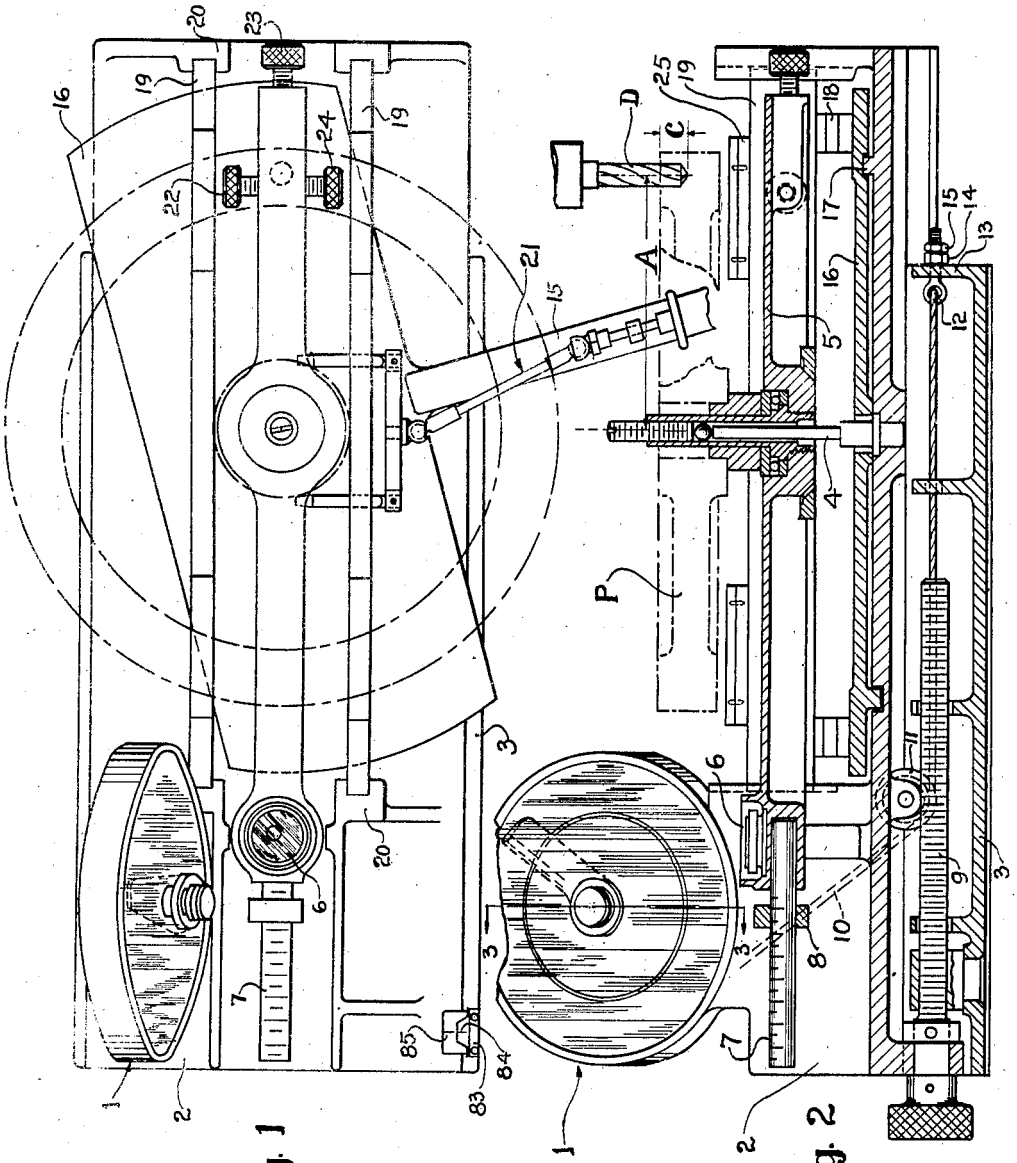

Fig. 1

Fig. 2

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CALCULATOR

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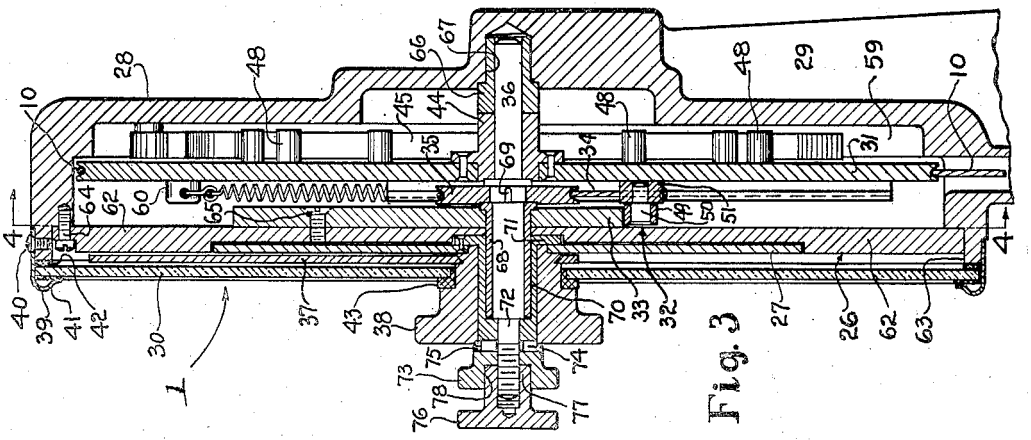

Fig. 3

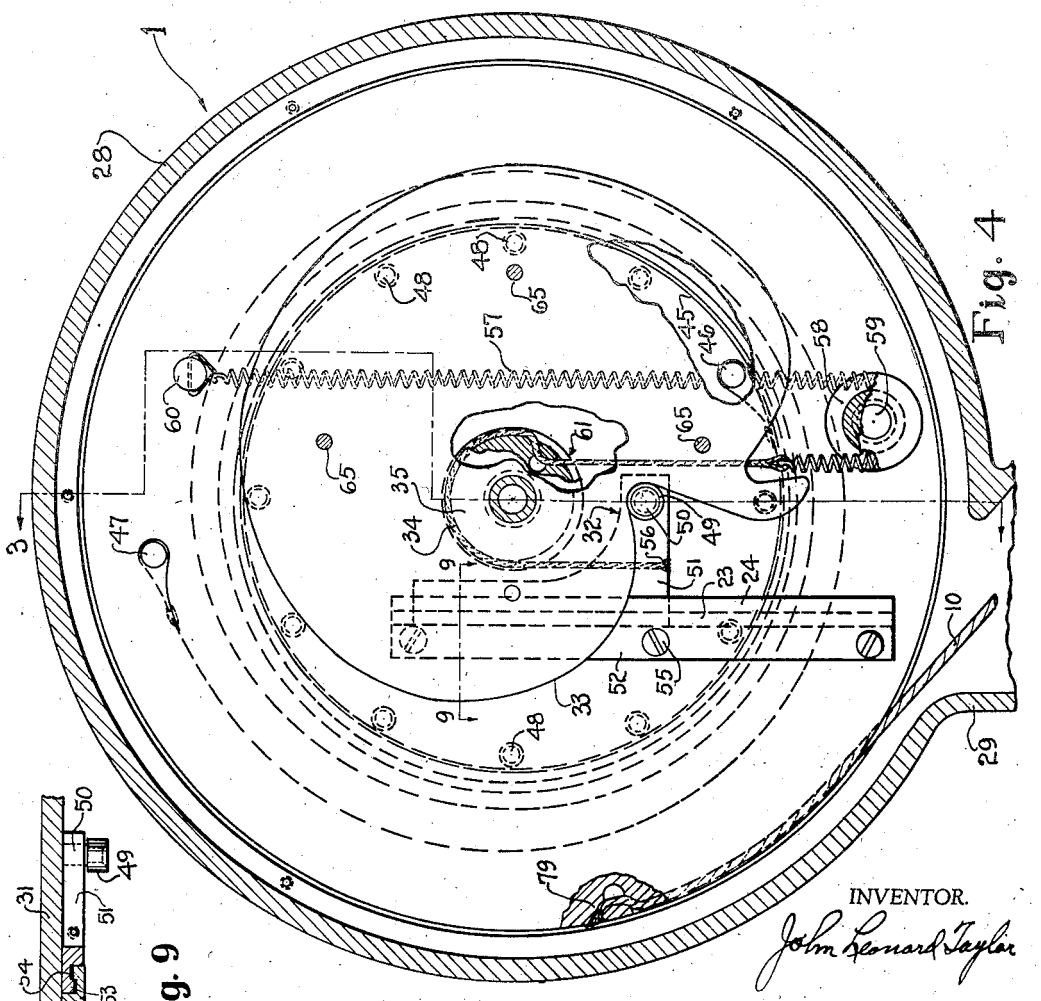

Fig. 4

Fig. 9

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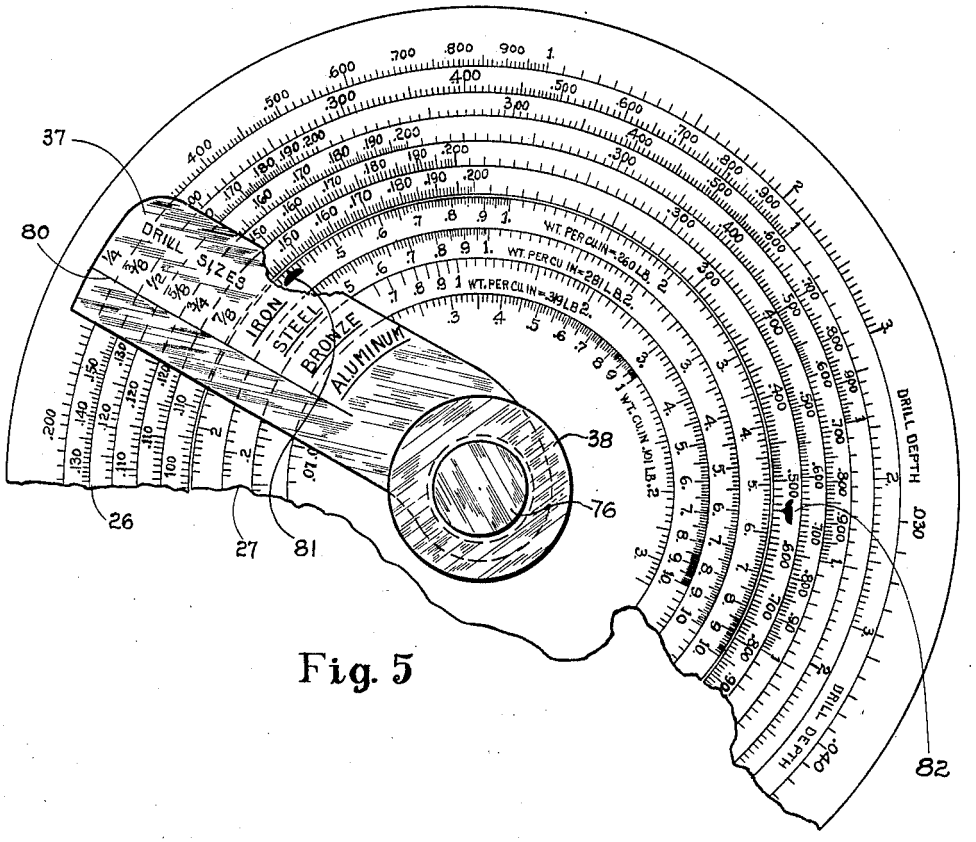
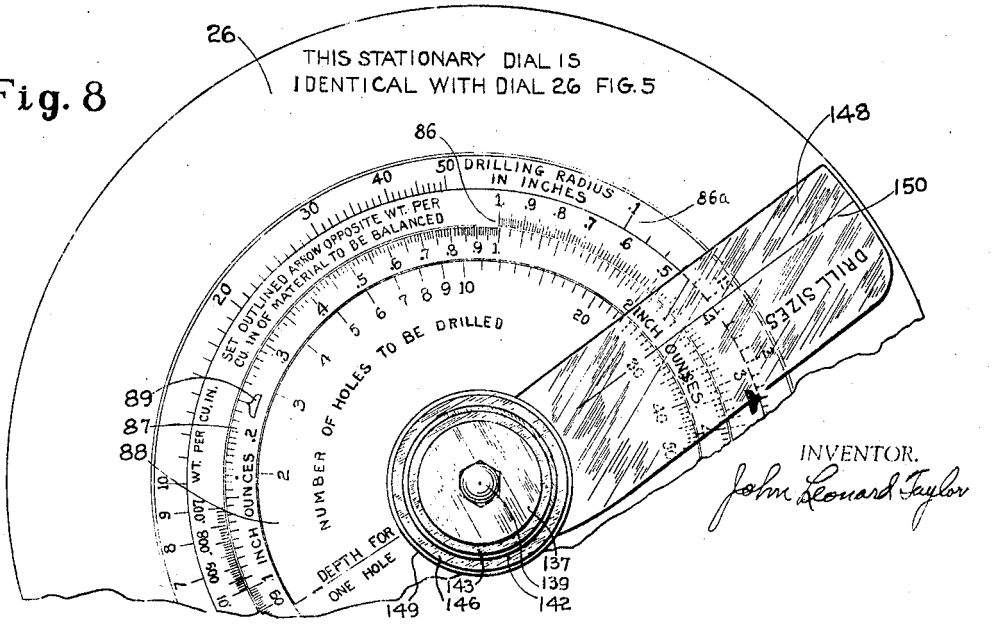


Fig. 5

Fig. 8



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CALCULATOR

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Fig. 7

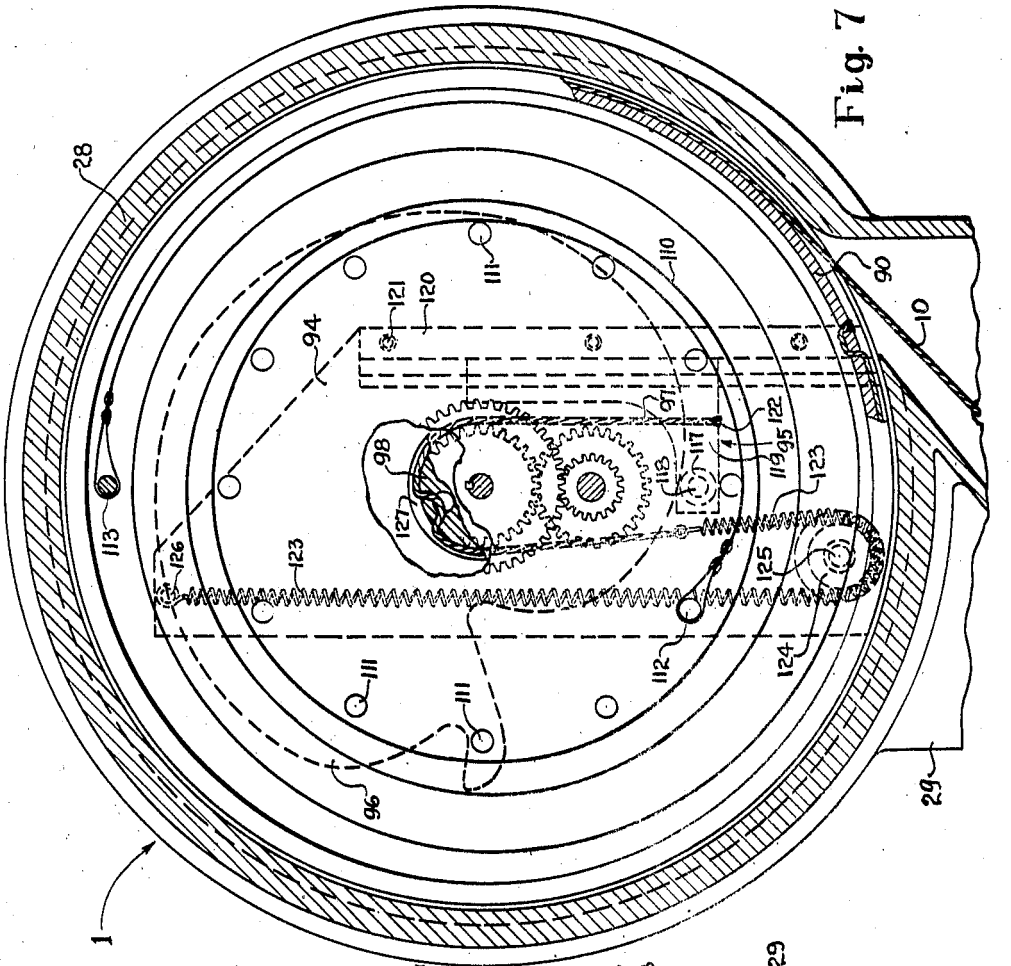
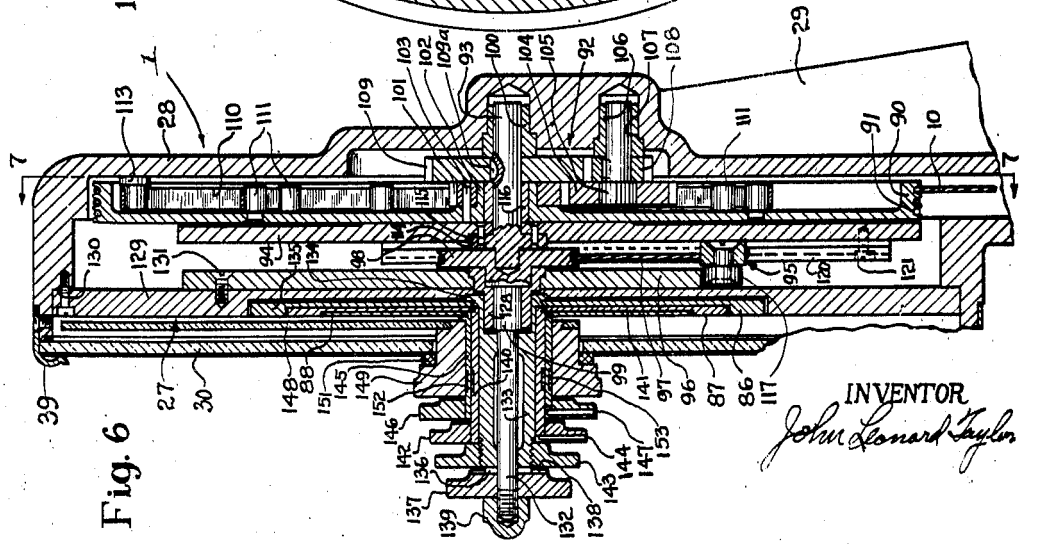


Fig. 6



INVENTOR

John Leonard Taylor

Patented Jan. 5, 1937 2,067,068

UNITED STATES PATENT OFFICE

2,067,068

CALCULATOR

John Leonard Taylor, Milwaukee, Wis.

Application November 18, 1933, Serial No. 698,595

7 Claims. (Cl. 235—61)

This invention relates to calculating devices, and an object thereof is to generally improve the construction and operation of devices of this class.

A further object is to provide a novel method of performing calculations.

A further object is to provide improved apparatus for performing such calculations.

A further object is to provide such an apparatus involving generally a plurality of relatively movable scales.

A further object is to provide such an apparatus in which movements of a machine concerning which the calculations are to be made will, at least in part, operate the apparatus to perform the calculations.

A further object is to provide a calculator particularly for use in balancing operations.

A further object is to provide a calculator which, given the moment of a force, will calculate the force necessary to produce an equivalent moment with various convenient lever arms.

A further object is to provide such a device which will express this result in terms of drill depths necessary to remove an amount of material equivalent to the weight determined.

A further object is to provide a device which will calculate drill depths necessary to remove desired amounts of material.

A further object is to provide such a device which will take into account the conical point of a drill in making such calculations.

A further object is to provide such a device which will calculate ounces of material causing a moment previously indicated in inch ounces.

Further objects and advantages will be apparent from the following specification and accompanying drawings in which:

Fig. 1 is a plan view of a typical installation of my calculating device on a balancing machine.

Fig. 2 is a vertical central sectional view of the same showing the manner of actuating the calculating mechanism.

Fig. 3 is a vertical sectional view of the calculating mechanism taken on the line 3—3 of Figs. 2 and 4.

Fig. 4 is a vertical sectional view on the line 4—4 of Fig. 3.

Fig. 5 is a front elevation of certain dials and other parts indicated in Fig. 3.

Fig. 6 is a sectional view similar to Fig. 3 showing a modified form of the device.

Fig. 7 is a sectional view on the line 7—7 of Fig. 6.

Fig. 8 is a front elevation of certain dials and other parts indicated in Fig. 7.

Fig. 9 is a detail of certain mechanism indicated in Figs. 4 and 7.

Like reference characters have been applied to the same parts throughout the drawings and specification.

Referring particularly to Figs. 1 and 2, the device is shown as it would be applied to a machine for balancing rotative parts or other parts which are required to be symmetrical, as to mass at least, about a given center, the mechanism calculating and indicating directly the amount of material to be removed to balance the piece. This particular embodiment is to be understood as illustrative merely, and it is to be understood also that nothing in this specification is to be taken in other than an exemplary sense, that other applications of the device are contemplated, and that the protection afforded by any patent into which this application may mature is not to be taken as limited by the disclosure of the description or drawings, or in fact in any manner except as defined in the annexed claims.

The calculating device itself is generically designated by numeral 1, and as shown in the figures it is fixed with the movable carriage 2 of the balancing machine in a position to be readily manipulated and read. The balancing machine itself forming the subject matter of a co-pending application to Taylor, Serial No. 645,675, filed December 5, 1932, it will not be described in the present application further than to say that a base 3 is arranged for mounting upon an ordinary drill press and carries the movable carriage 2 having a fulcrum member 4 on which is balanced a cradle member 5 arranged for tilting movement in all directions. The machine is arranged with fulcrum 4 directly under the drill spindle, the article to be balanced, or work piece P' being temporarily fixed with this cradle by appropriate means whereupon any unbalance thereof, (the piece P being fixed with its desired center of mass on the axis of the fulcrum 4) will cause tilting of the cradle 5, the direction being indicated by a universal level 6. The heavy portion of the work piece is then swung to a point opposite a beam 7, and a weight 8 is moved out to a point where the cradle is again indicated by level 6 to be in substantially perfect balance. A suitable scale then indicates from the position of the weight 8 on the beam 7 the moment of the unbalanced weight in the work piece P. The carriage 2 is now moved out by appropriate means such as a screw 9 having suitable con-

nections between base 3 and carriage 2 to a point where the drill D will reach a portion of the work piece which is suitable for the removal of material to balance the piece, this movement in the present instance, although some other movement would be utilized if the calculator were applied to some other type of machine, operating to actuate the calculator which in the present instance calculates and indicates the amount of drilling necessary, at the point arbitrarily decided upon as suitable, to destroy the moment of the unbalanced force and render the piece in exact balance. This is done by movement of one or more of a plurality of relatively movable dials, the movement thereof being effected either manually or by suitable means such as a cable or other flexible member 10 running from the interior of calculator 1 over a pulley 11 suitably journaled and supported on carriage 2. The cable is fixed, through an adjustable eye bolt 12, with an upstanding flange 13 of base 3 by means of suitable means such as lock nuts 14—14, through the manipulation of which the relation between base 3 and the internal mechanism of calculator 1 may be adjusted.

Suitable mechanism is provided for relieving fulcrum 4 of the drilling stresses and other weight when actual balancing is not being done, in the present instance a lever 15 actuating a member 16 which acts through suitable cam surfaces 17 and shims 18 to raise bar members 19, vertically slidable in guides 20, and arranged when raised to engage the work piece at either side of cradle 5 to raise the work piece, and to relieve the cradle of unnecessary stress and wear. Suitable mechanism generically designated by numeral 21 is provided to lock the cradle in level position during periods when it is not in use, and to center it accurately on fulcrum 4, and screw members or the like 22, 23, and 24 are provided in the cradle to provide for balancing it before a load is applied. Shims 25 may be interposed between bars 19 and the work piece if desirable.

The calculator itself, as shown particularly in Figs. 3, 4, and 5, comprises generally a pair of dials 26 and 27, circular in the present instance for convenience and compactness, the dials being enclosed with their operating mechanism in a housing or casing 28 supported on a bracket portion 29 and having a transparent closure 30 to permit observation of the dials while protecting them from dirt and the like. Dial 26 has a plurality of circular scales thereon corresponding respectively to different drill sizes, while dial 27 is provided with similar scales indicating in the present instance moments for different materials.

In the embodiment of these figures the dial 27 is movable and it is actuated through the following mechanism. Cable 10 in the present instance actuates a sheave 31 which carries slidably fixed therewith a cam following member generically designated by numeral 32, the follower cooperating with a cam 33 fixed relatively to casing 28. Follower 32 actuates in the present instance through a cord, cable or other flexible member 34 a sheave 35 which actuates dial 27 through a shaft 36 and appropriate connections. The contour chosen for cam 33 accordingly determines the character of movement of dial 27, which may be any type necessary to perform the desired calculations. A pointer or index 37 may be provided to assist in matching the readings of the two dials, and in the present instance it is carried by a knob 38 by which it may be moved to desired positions.

Returning now to a detailed description of the present illustrative embodiment of the invention, closure 30 is formed in the present instance of a plate of glass or the like to have some structural strength as well as transparency. It is fixed with casing 28 by means of a frame or ring 39 which fits about the front margin of the housing, and is held in place by suitable means such as screws 40 suitable gaskets 41 and 42 being interposed between the ring and glass, and the glass and housing, for obvious purposes. A gasket 43 is disposed between knob 38 and closure 30 to exclude dirt while permitting rotation of the knob and pointer.

Sheave 35 as seen in Fig. 3 is fixed with a sleeve or hub portion 44 which is journaled on above mentioned shaft 36, the shaft being supported from the housing as will presently appear. The sheave is rotated in one direction as indicated in Fig. 4 by a pull on cable 10, while it is urged in the other direction by a spiral spring 45, the spring being fixed at its inner end with a pin or the like 46 fixed with sheave 31 and suitably fixed with housing 28 at its outer end with a pin 47. The spring is in the present instance guided about a plurality of pins 48 arranged to prevent encroachment of the spring upon the region adjacent to the middle portion of sheave 31. Any other suitable means for yieldingly opposing the rotation of sheave 31 may be employed within the contemplation of the invention.

Cam follower 32 in the present instance comprises a roller 49 journaled on a pin 50 which is fixed with a member 51. Member 51 is disposed in slidable relation with sheave 31, and is so maintained by a slide member 52 as more particularly shown in Fig. 9, the members having interlocking portions 53 and 54 which prevent separation of member 51 from sheave 31 while permitting sliding movement thereof in the direction of member 52. Member 52 is fixed with the sheave by suitable means such as screws 55. Cable 34 is suitably fixed with member 51, as by introducing it into a bore in the member and fastening it in any well known manner at 56. It then extends in a direction substantially parallel to the direction of movement of member 51, and around sheave 35, being fastened at its other end to a coil spring 57, which for convenience and to secure extra length and flexibility is in the present instance passed around a pulley 58 journaled on a pin or the like 59 fixed with sheave 31, the spring thus being doubled on itself, and fastened at its end remote from cable 34 to a pin or the like 60, also fixed with sheave 31. To provide for a positive mathematically accurate drive for sheave 35, cable 34 is permanently fixed therewith at 61 by any suitable means, in the present instance the cable being sharply bent or "kinked" by passing through a pair of closely spaced holes in the periphery of the sheave. Sliding movement of the member 51 will thus cause rotation of sheave 35 relatively to sheave 31, the direction and amount thereof being determined by the contour of cam 33, the pull of spring 57 on cable 34 maintaining roller 49 continuously against the surface of the cam.

Cam 33 is stationary in the present instance, being supported by or from a plate or closure 62 fixed in housing 28 and carrying dial 26, the plate being arranged in a bore 63 in the housing and maintained therein by any suitable means such for example as screws 64. Cam 33 is fixed with plate 62 in the present instance by screws 65.

Shaft 36 is suitably journaled at one end in a

sleeve or bushing 66 which is fixed in a bore 67 in housing 28, the other end being supported in a bushing 68 which is in turn supported in aligned bores in plate 62 and cam 33. Sheave 35 is suitably fixed with shaft 36 as by means of a key 69, and dial 27 may be fixed therewith in various relations by the following means:

A bushing 70 is journaled on the exterior of sleeve 68, and is fixed with dial 27 by means of a flange 71, the bushing extending forwardly beyond the front margin of sleeve 68 and embracing a reduced portion 72 of shaft 36. For readily turning the bushing 70 a knob 73 is slidably journaled on extension 72 and connected with the bushing by suitable means such as keys 74 fixed with the bushing and engaging keyways 75 in the knob. A lock nut 76 is threaded on the extension 72 of shaft 36 and has a hub portion 77 extending in the present instance into a recess 78 in knob 73, the nut seating in the bottom of the recess when tightened, and forcing it and bushing 70 to the right as seen in Fig. 3. The bushing seats against the shoulder formed between the extension 72 and the remainder of the shaft, and is clamped therewith so as to respond accurately to movements of the mechanism. By loosening lock nut 76 dial 27 may be manually adjusted from knob 73, the dial then being locked with the shaft by tightening the nut again, for operation through the mechanism.

In order to insure a positive drive to sheave 31, cable 10 is fixed with the sheave as shown in Fig. 4, at 79, the cable being in the present instance bent sharply or kinked by passing into and out of closely spaced holes in the periphery of the sheave, and fastened at its end if desired by any suitable means. Obviously other means than cables and sheaves could be used within the contemplation of the invention to secure rotative from linear movement and it is understood that any such well known means may be resorted to without departing from the scope and spirit of the invention. Furthermore it is contemplated that actuating mechanism may be omitted under certain conditions and the dials operated entirely by hand without departing from the invention.

Pointer 37 may be rotated by knob 38, which as shown is journaled on the exterior of bushing 70. As seen in Fig. 5, the pointer in the present instance is of a substantially transparent substance, so that the scales thereunder are always entirely visible, the pointer having a hair line 80 marked thereon by means of which the scales may be readily compared and read, although of course any pointer which would permit comparison of the cooperating scales would fall within the scope of the present disclosure.

In considering the operation of the device it will be understood that, given the moment of the unbalanced weight present in the workpiece "P", and the radius on which it is found, both of which values are readily determined by the balancing machine above described, it would be possible to determine mathematically, after choosing a suitable place to drill, the weight of material which should be removed at that point to equal the moment of the unbalanced weight, and accordingly to accurately balance the piece. The unknown volume of material equivalent to this weight could then be determined by dividing this result by the weight, of a unit volume, for example a cubic inch of the material of the work piece. A convenient size of drill could then be chosen and the depth necessary to remove this volume of material could be determined by figuring the cross sectional area of the drill and dividing the volume above determined by this area. A suitable correction would have to be made for the conical or point portion of the drill, which would give a non-uniform variation to the depth determined for uniformly varying volumes up to the point where the conical portion is entirely within the work piece, after which the volume of the point would have to be added in each case to the uniformly varying depth determined for the cylindrical portion of the drill. These calculations would be time consuming, and fraught with the possibility of error, and the use of the present calculator accordingly constitutes a material advance in the art, since it positively and immediately performs these calculations and permits direct reading of the desired result, namely the depth to be drilled, without calculations on the part of the operator and without errors which would be apt to enter into such calculations.

Thus in the embodiment illustrated, it is only necessary to run the carriage 2 out to a convenient point to drill, read on the scale on dial 27 corresponding to the material of the work piece, the moment of unbalance as determined by the weight 8, and read opposite this value on the scale on dial 26 corresponding to the size of drill selected, the depth necessary for that size drill to remove the unbalanced weight. The dial 27 will have moved a distance determined by the movement of carriage 2 and the contour of cam 33, which takes into account the difference in weight required at different distances from the center to equal a given moment, and the other factors in the several calculations are accounted for in the spacing of the various scale divisions. In the embodiment shown in Fig. 5 the materials are designated on the pointer 37 over their respective scales as shown, while the drill sizes are also marked on the pointer over their respective scales.

The invention is not limited to the specific spacing or arrangement of scales herein shown, but embraces other arrangements wherein the general idea may be applicable.

For checking the accuracy of the apparatus, an index point 81 is provided on dial 27, which is arranged to register with a similar point 82 on dial 26 at such time as the fulcrum 4 is directly under the drill spindle, and as a further check, a pointer 83 Fig. 1 is fixed with base 3 and has an index 84 arranged to register with a mark 85 on a suitable portion of carriage 2. The points 81 and 82 should register at the same time as index 84 and mark 85, and once base 3 is accurately located on the drill press it is unnecessary to check with the drill spindle when it is desired to check the balancing machine, but merely to locate the carriage by points 84 and 85, and note whether 81 and 82 correspond. If there has been any wear or elongation of the cables, correction can be made by nuts 14 and 15, or by shifting dial 27 relatively to shaft 36 in the manner above explained.

Various modifications of the above structure might be made within the scope of the present invention, and as a typical example the dial shown in Fig. 8 is included. In this arrangement the outer dial is identical with dial 26 of Fig. 5, and it is accordingly designated by the same reference character. There are, however, a plurality of inner dials. Thus a dial 86 is movable from mechanism operated from movement of carriage 2 and represents density of materials. Adjacent

to this is a dial 87 which represents moments in a manner similar to dial 27 above, and may be set by hand and locked with dial 86 in any desired relation, and adjacent to dial 87 is a dial 88 which is also arranged to be set by hand.

In this embodiment the manipulation is similar to that of the arrangement just described except that the dial 87 is first adjusted so that an index point 89 is opposite the weight per unit volume of the material being balanced as represented on dial 86, the reading then being taken between the scale on the moment indicating dial 87 and one of those on dial 26. The arrangement of Fig. 8 is in general more adaptable for relatively large work pieces, and dial 88 is for use where the size or other characteristics of a piece makes desirable the drilling of several holes rather than a single one. The desired number of holes on dial 88 is set opposite the moment as read on dial 87 and the depth of any one hole is then read opposite the "1" of dial 88 on dial 26. The moment as read on dial 87 may be converted into weight by letting dial 88 represent the radius "A" of the work piece at which point it may be desired to add material, as would be required for example on the light side of a fan. Dial 86 carries a scale 86a corresponding to that on dial 87 for use when automatic operation is not desired.

In the present instance in order to give the apparatus a greater range of movement, particularly for use with relatively large work pieces, the embodiment of Fig. 8 is provided with a somewhat different arrangement of driving mechanism than that previously described. As seen in Figs. 6 and 7 the cable 10 engages a sheave 90 which is provided with a plurality of grooves 91 or otherwise arranged so that the cable may take a plurality of turns around the sheave, and thereby have a greater range of movement than would be possible with a single turn. Sheave 90 drives, through a reduction gear generically designated by numeral 92, a shaft 93 which in turn rotates a carrier plate 94 carrying a cam follower generically designated by numeral 95 cooperating with a cam 96 and operating through a cable 97 to drive a sheave 98 fixed with a shaft 99. Shaft 99 drives dial 86 through appropriate connections described below.

Returning to the specific details of construction, the whole is enclosed in a housing 28 substantially identical with the housing of Fig. 3, having a similar bracket portion 29, the housing being provided with a transparent closure or glass 30 maintained in place by a ring 39 etc., in a manner similar to the previously described structure. Sheave 90 is journaled on shaft 93 which is supported at one end in a bushing 100 fixed in a suitable bore in a portion of housing 28, and at the other end in a suitable bore in sheave 98. Reduction gear 92 comprises a gear 101 fixed on a hub portion 102 of sheave 90 by suitable means such as a pin 103 and driving a gear 104 fixed with a shaft 105 which is rotatively supported in a bushing 106 fixed in a bore 107 in housing 28. Shaft 105 has a gear 108 fixed therewith which drives a gear 109 which is fixed with above mentioned shaft 93 by appropriate means such as a key 109a. The sizes of the various gears are such in the present instance that shaft 93 is driven at a substantially slower rate than sheave 90, and accordingly a much greater travel of the carriage 2 of the machine may be had than in the previously described construction, the scales on the several dials being graduated in keeping with the different rate of travel of the carriage relatively to the dials. Obviously other ratios could be used in the gearing which would increase rather than reduce the travel of the dials if desired, such construction being better adapted for use in balancing small articles or for any purpose where an increase in the rate of the dials is desirable.

Rotation of sheave 90 is opposed by a spiral spring 110 which is coiled in the present instance about a series of pins 111 fixed with the sheave, the inner end of the spring being fastened by a pin 112 to the sheave, while the outer end is fixed with housing 28 by means of a pin 113. The spring works in a similar manner to spring 45 above described.

Shaft 93 has a flange 114 which may be fixed with carrier plate 94 by suitable means such as rivets 115, and a bushing 116 may be interposed between sheave 90 and shaft 93 if found desirable.

Follower 95 is similar to above described follower 32 comprising a roller 117 journaled on a pin 118 fixed with a member 119 which is slidably associated with carrier plate 94, a slide 120 fixed with the plate by screws or the like 121 serving to maintain the member in position. Cable 97 is passed through a suitable bore in member 119 and fastened at 122, the cable passing over sheave 98 and being connected to a spring 123 which passes around a pulley 124 journaled on a pin or the like 125 fixed with carrier plate 94, the spring then passing to a pin 126 also fixed with the plate and being fastened thereto whereby to exert a continuous pull on the cable. Cable 97, where it passes over sheave 98 is positively fixed therewith by any suitable means, in the present instance by being sharply bent for entering a pair of closely spaced holes at 127, a positive relation being thereby established between follower 118 and shaft 99, although of course other methods might be used for forming such a positive connection without departing from the present invention.

Shaft 99 is supported for rotation in a bushing 128 carried by cam 96 which is stationary and supported from a dial plate 129 which is supported in housing 28 and carries dial 26. Plate 129 is fastened therein by suitable means such as screws 130, while cam 96 is fastened in the present instance to plate 129 by screws 131. Shaft 93 as shown is separate from shaft 99 and is guided and supported in a suitable bore in sheave 98.

Shaft 99 has a forwardly extending portion 132 reduced in diameter and carrying a bushing or sleeve 133 which extends rearwardly over bushing 128, clearing the front end thereof and seating against the shoulder formed between reduced extension 132 and the remainder of shaft 99. Sleeve 133 has a flange portion 134 to which is fixed a disk 135, the peripheral offset side of which constitutes dial 86. Sleeve 133 is connected by means of a key 136 with a knob or grip member 137 slidably journaled on extension 132 of shaft 99, and provided with a keyway 138 engaging key 136. Bushing 133 and accordingly dial 86 can thus be turned by manipulating grip 137. A lock nut 139 threaded on extension 132 may be used to force grip 137 and sleeve 133 back against the above mentioned shoulder between shaft 99 and extension 132 to clamp these parts rigidly together whereupon dial 86 is positively driven from the mechanism in housing 28.

A sleeve 140 is journaled on sleeve 133, and carries on its inner end a disk 141 the peripheral

offset side of which constitutes dial 87, and on its outer end a grip or knob 142 by which the dial may be manipulated. The inner end of sleeve 140 abuts flange 134 and may be forced thereagainst by a nut 143 which is threaded on sleeve 133 and when tightened clamps the two sleeves together whereby dial 87 follows movements of dial 86. Grip 142 is fixed with sleeve 140 in any suitable manner, in the present instance by means of a pin 144 engaging a slot or the like in sleeve 140.

Dial 88 is carried by a sleeve 145 journaled on sleeve 140, sleeve 145 having fixed with its outer end a knob or grip 146 by means of which the dial may be manipulated, the knob being fixed with the sleeve by means of a pin 147 engaging a suitable slot in the sleeve. A pointer 148 is provided for matching the various scales to facilitate reading, the same being carried by a knob or grip 149 journaled on sleeve 145, the pointer being transparent in the present case and having a hair line 150 thereon (Fig. 8) for readily matching the scale divisions. A suitable gasket 151 is provided where knob 149 enters the glass or closure 30 to exclude dirt and the like.

In order to provide a certain amount of frictional resistance to the movement of certain of the members, a spring 152 seated in a suitable groove in sleeve 140 presses outwardly against the inner surface of sleeve 145, the spring being of non-circular form whereby to press at the same time inwardly against the groove in sleeve 140. The sleeve 145 is accordingly yieldingly carried by sleeve 140 and not apt to be accidentally displaced from a desired relation with sleeve 140. A similar spring 153 is seated in a groove in sleeve 145 and serves a similar purpose with relation to knob 149. Obviously other means might be employed for detaining these parts in desired positions without departing from the invention.

The mode of operation of the device will be apparent from the foregoing description, the several dials being controlled from the several grips in the manner explained in connection with Fig. 8. Thus dial 86 may be corrected in its relation with the mechanism by loosening nut 139 and turning knob 137 until the correct position is obtained. The dial may then be clamped in this relation by tightening nut 139. Dial 87 may be set in relation to dial 86 by loosening nut 143 and operating the dial manually by means of grip 142, after which the two dials may be locked together by again tightening the nut. Operation of the mechanism then turns both dials 86 and 87, and movement of dial 88 and pointer 148 may be effected by manipulation of knobs 146 and 149 respectively.

If desired the calculator may be simplified by omitting the driving mechanism and operating the dials by hand through the knobs 73, 143, etc., the correct amount of movement of the scales being determined from the scales themselves.

The scale divisions on dial 27 designated as "iron" are laid out proportionally to the logarithms of various moments, and those on dial 26 are proportional, except for a correction noted below, to the logarithms of various volumes of cast iron equivalent to weights in ounces corresponding to the moments represented on dial 27 at a lever arm or distance of one inch, and index 82 is placed at the point on dial 26 representing the logarithm of a volume of cast iron which weighs one ounce. If the moment of the unbalanced weight should be for example 5 inch-ounces, obviously one ounce would need to be removed at a lever arm of 5 inches, or five ounces at a lever arm of one inch to render the work piece in correct balance. At the point marked by index 82 one ounce is removed by drilling to the depth indicated, and if the moment of five inch-ounces on the "iron" scale is placed opposite the index it may also represent the lever arm distance, or five inches, the correct distance for balancing the piece by removing one ounce. Moments and distances may therefore both be read on this scale, and the dial accurately set by hand without resort to mechanism if desired. With the correct setting for dial 27 established in this manner, the drill depth may be read opposite the moment as in the case of the automatically operated embodiment.

Assuming a moment as obtained from the weighing apparatus to be 3 inch-ounces, and a convenient lever arm for drilling to be six inches, the material being cast iron; at a lever arm of three inches the amount to be removed would be one ounce as before, represented by the position of index 82. If a desirable lever arm is six inches, however, the amount to be removed at this distance is less than one ounce, or exactly half what it would be at the three inch distance. The weight necessary to be removed is thus inversely proportional to the distance chosen, and it is necessary to divide the amount or weight indicated on scale 26 by the ratio between the lever arm corresponding to an effective weight of one ounce, and the desired lever arm. Such calculations are readily performed on the illustrated logarithmic scales, and in the present instance the desired lever arm value of 6 would be set opposite the index 82, or one ounce position, and the moment read at 3 on the same scale on which the lever arm was read. The weight to be removed would then be found opposite the 3 on any scale on dial 26, and if the scale was identical with the "iron" scale, the weight would be .5 ounce, and this amount is indicated on any scale on dial 26, but in terms of drill depths instead of ounces. Taking any convenient drill size, however, it will be observed that the depth opposite moment 3 is not exactly half that opposite distance 6 with the above set up, but is slightly more than half. This seeming inaccuracy is caused by the distortion of the scales on dial 26 above explained to compensate for the volume of the conical portion or point of the drill, which represents a larger proportion of the total volume of the bore at the lesser depths than it does at the greater. A greater depth of drilling is therefore required to remove half a given volume than half the depth required to remove the whole volume.

Dial 27 may accordingly be set for any convenient drilling point by merely setting the lever arm represented thereby on the "iron" scale opposite index 82, and the mechanism for automatic movement thereof eliminated.

If the material being balanced is not cast iron, the lever arm is set up as before on the "iron" scale opposite index 82, but the moment is read on the appropriate scale such as "steel", "aluminum" etc., and the depth found on dial 26 as in the case of automatic operation, the setting using the 'iron" scale merely duplicating the movement of the dial which would take place automatically upon movement of the carriage of the machine in the more complicated models.

In the embodiment of Fig. 8, a similar operation is possible, the lever arm being read on scale 86a, and set opposite index 82, after which the mo-

ment is read on scale 87, the latter having first been positioned properly relatively to scale 86 for the material being operated upon.

The above being a complete disclosure of an illustrative embodiment of the invention, what is claimed as new, and desired to be secured by Letters Patent of the United States is:

1. In a calculating device the combination of a pair of concentric, circular dials, one of said dials being rotatable relatively to the other, said dials having spaced divisions thereon, the spaces being proportional to varying values to be calculated, means for moving one of said dials including a stationary cam member, a carrier member, and a relatively movable follower member carried by said carrier member, said follower member being arranged to be caused by said cam to slide on said carrier member so as to move in an orbit about the axis of said dials, and connections from said follower for rotating said rotatable dial.

2. In a calculating device the combination of a pair of concentric, circular dials, one of said dials being rotatable relatively to the other, said dials having spaced divisions thereon, the spaces being proportional to varying values to be calculated, and mechanism for driving said movable dial including a rotative driving member supported axially of said dials, a cam follower slidably supported on said driving member, and a cam fixedly supported axially of said dials and in a position to contact said cam follower, said cam being shaped to guide said follower to slide on said driving member and to move in an orbit about the axis of said dials and said driving member, and actuating connections from said follower to said movable dial and arranged to rotate said movable dial.

3. In a calculating device the combination of a casing, a pair of concentric, circular dials, one of said dials being rotatable relatively to the other, said dials having spaced divisions thereon, the spaces being proportional to varying values to be calculated, a rotative driving member supported in said casing axially of said dials, and a rotative carrier member also supported in said casing axially of said dials, speed rate changing means in said casing for driving said carrier from said driving member at a different speed from said driving member, a cam follower slidably supported on said carrier member, a cam fixedly supported in said casing axially of said dials and in a position to contact said cam follower, said cam being shaped to guide said follower in an orbit about the axis of said dials and said driving member, and actuating connections from said follower to said rotatable dial and arranged to rotate said rotatable dial when said driving member is rotated.

4. In a calculator the combination of a pair of juxtaposed concentric circular scales, a rotative shaft supporting one of said scales, and a first sheave on said shaft, driving means for said sheave including a second sheave coaxial with said first sheave and axially spaced therefrom, a slidable member supported on said second sheave, a cam fixedly supported adjacent said first sheave, follower means on said slidable member disposed to engage said cam, resilient means supported on said second sheave and operative to maintain said follower means in contact with said cam, and including a flexible member extending from said slidable member to said first sheave and engaging said first sheave.

5. In a calculator drive a rotative shaft, a first sheave on said shaft, driving means for said sheave including a carrier sheave member, and a slidable member supported thereon, means for sliding said slidable member, a cable extending from said slidable member about said sheave, and means for tensioning said cable including a second sheave journaled on said carrier sheave, adjacent an edge thereof, and a tension spring fixed to said cable, running over said second sheave, and having an end portion anchored to said carrier sheave at a point spaced from said second sheave.

6. In a calculator for actuation by movements of a balancing machine the combination of a stationary dial, and a movable dial, a rotative shaft connected to move said movable dial, and a first sheave on said shaft, driving means for said sheave including a second sheave coaxial with said first sheave, and axially spaced therefrom, a slidable member supported on said second sheave, a cam fixedly supported adjacent said first sheave, follower means on said slidable member disposed to engage said cam, resilient means supported on said second sheave and arranged to maintain said follower means in contact with said cam and including a cable connected with said slidable member and engaging said first sheave, and a cable engaged with said second sheave and leading to said balancing machine for actuating said calculator.

7. In a calculator drive a driven shaft, and a housing in which said shaft is journaled, a first sheave fixed on said shaft, a second sheave journaled on said shaft, a cam follower slidably carried by said second sheave, and arranged for sliding movement relatively thereto in a direction parallel to a radius of said sheave, a cable running off of said first sheave in a direction parallel to a radius of said first sheave and fastened to said cam follower, means for resiliently urging said first sheave in a direction to tension said cable, and a stationary cam positioned to contact said cam follower and to shift it on said second sheave for modifying the movement imparted to said first sheave by said second sheave, and means for rotating said second sheave.

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