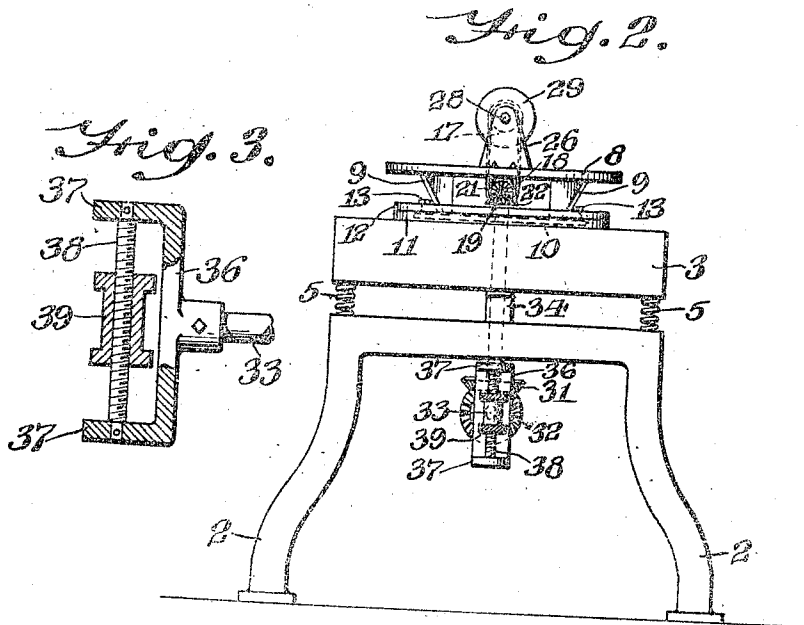
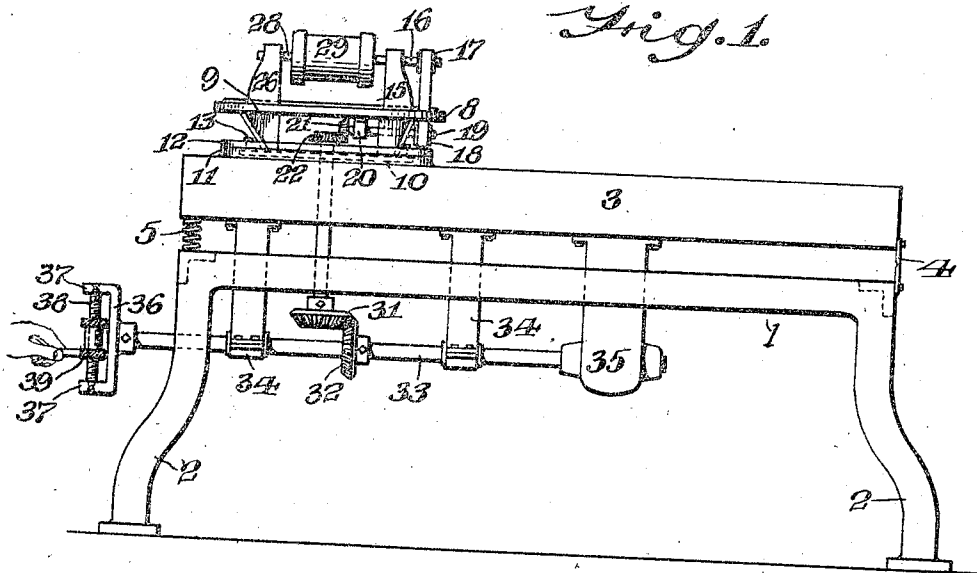


N. W. AKIMOFF.
BALANCING MACHINE.

APPLICATION FILED DEC. 18, 1916. RENEWED JULY 6, 1918.

1,296,610.

Patented Mar. 11, 1919.
2 SHEETS—SHEET 1.



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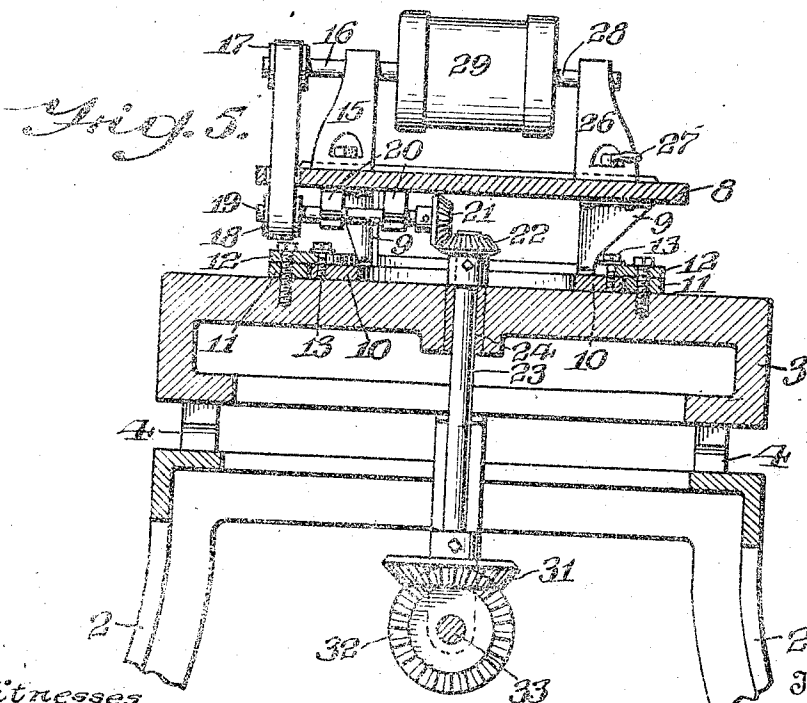
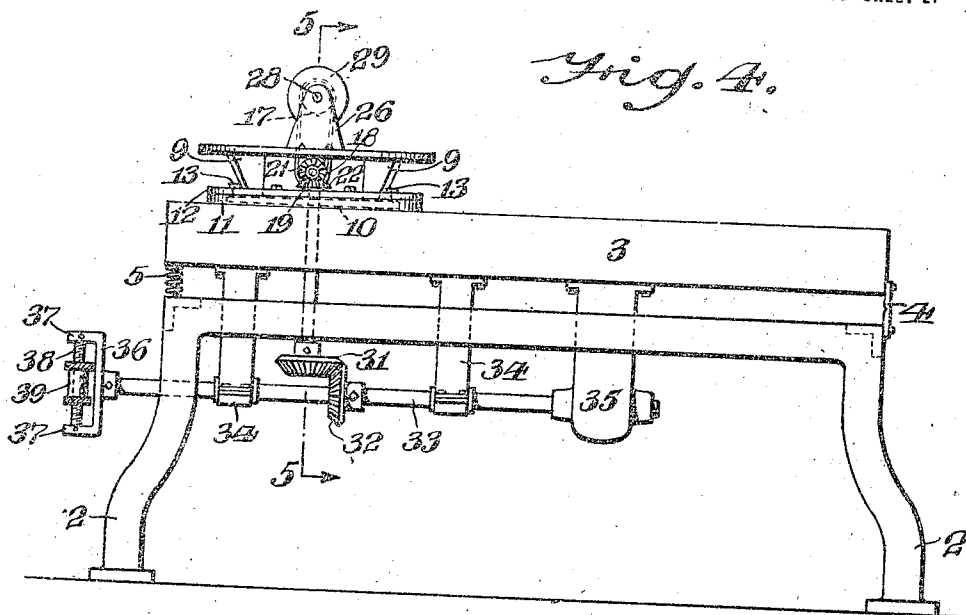
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Witnesses
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UNITED STATES PATENT OFFICE.

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BALANCING-MACHINE.

1,296,610.

Specification of Letters Patent.

Patented Mar. 11, 1919.

Application filed December 18, 1916, Serial No. 137,564. Renewed July 6, 1918. Serial No. 243,702.

To all whom it may concern:

Be it known that I, NICHOLAS W. AKIMOFF, a subject of the Czar of Russia, residing at Philadelphia, in the county of Philadelphia and State of Pennsylvania, have invented certain new and useful Improvements in Balancing-Machines, of which the following is a specification.

The science of rigid dynamics contemplates various modes of constraints under which the motion of bodies takes place, and the character of the constraints determines the number and characteristics of the so-called "degrees of freedom" of the body. Thus, a bead on a wire can only move in one manner, as also can the pendulum of a clock, wherefore the bead and the pendulum are said to each possess but one degree of freedom. An insect upon a level surface, a ship navigating upon the ocean, and a body mounted to revolve upon a shaft supported by yielding bearings, are all said to possess two degrees of freedom, while on the other hand, the chassis of an automobile supported by resilient tires has as many as six degrees of freedom.

Now a body can oscillate in just as many different and entirely independent manners as it possesses degrees of freedom, wherefore, a body having two degrees of freedom is capable of vibrating in two absolutely independent manners, with two entirely distinct periods of vibration. This coexistence of a plurality of different oscillation consequently positively precludes the possibility of constructing a dynamic balancing machine upon the basis of any principle except that limited to vibrate in but one degree. In this case, and this case alone, one is concerned with the effect of unbalance manifested in but one way, thereby avoiding all confusion or ambiguity in reading or interpreting the observations of the oscillations of an unbalanced body. (For an explanation of the meaning of the "dynamic" and "static" balance of rotatable bodies, see copending applications Serial Nos. 32,296 and 114,986.)

Indeed, it has often been proved in actual practice, that, while a body balanced in a one-degree machine actually remains in balance when rotated in any other machine, a body placed in apparent balance on a two-degree machine invariably manifests very

poor balance upon the present one-degree type of machine, until finally corrected for balance on the latter, after which it of course shows perfect balance on the former or any other machine, regardless of the number of the degrees of freedom that the latter may possess. The very essence of a two-degree machine is based upon the discovery of a certain phase difference, between the periods of the two forms of vibration, which feature is a very elusive characteristic, in view of the above mentioned coexistence of two distinctly individual modes of oscillation.

A machine of but one degree of freedom is the only one that contemplates absolutely no elements of the nature of any phase difference. In this type of machine all unbalance is forced to make itself evident in one manner only, which makes it easy both to observe the effect and to estimate the extent thereof. Consequently, such a principle is the only logical one that can be conceived of for satisfying the exacting demands of commercial requirements, and actual experience with apparatus of this kind, constructed to meet many different requirements has invariably confirmed the obvious correctness of this principle. Specifically, the present machine consists not only of a correcting weight, or equivalent balancing body, of means for indicating vibrations, and of means whereby the testing and balancing bodies are run in synchronism, but of an oscillator having one degree of freedom only, especially constructed to positively manifest in a most rigid manner the presence or absence of both static and dynamic unbalance.

The embodiment in a machine of such a principle in its broad sense permits of innumerable different arrangements or constructions, and it should not be considered that the following description of one form of mechanism implies the limitation of the said principle and its adaptation to only this narrow interpretation, but on the contrary simply shows in a concrete manner one way in which perfect results in the balancing of rotatable bodies can be accomplished. The complete illustration of this form of the machine comprises Figure 1, which is a front elevation of the device set for dynamic balancing; Fig. 2, is an end elevation of the same; Fig. 3, is a detail view of a balancing member; Fig. 4 is a front elevation of the

device set for static balancing; and Fig. 5 is a section on the line 5—5 of Fig. 4.

The object of the invention, as reduced to practice in the specific manner hereby disclosed, is to provide a mechanism operative to perfectly balance a rotatable body statically while revolving; to indicate the degree of lack of balance inherent within said body, and the location and amount of material necessary to be removed therefrom, or added thereto; to provide a mechanism capable of being quickly and easily transformed into a machine operative to perfectly balance a rotatable body dynamically while revolving; to provide a dynamic balancing machine operative to indicate the degree of such balance, and the location and amount of material necessary to be removed therefrom, or added thereto; to provide in such a universal machine a balancing unit comprising a radially movable weight, operative to revolve in synchronism with the body being tested, adjustable into different angular positions with respect to said body, rotatable upon an axis parallel with the axis of said body when arranged for dynamic balancing and upon an axis in a plane perpendicular to the axis of said body when arranged for static balancing, and vibratable upon and with an oscillator forming a common support both for said unit and said body; and to provide further details of construction and operation as hereinafter described.

Referring to the drawings, a supporting frame 1, having legs 2, is provided for the oscillator 3, which is secured to but spaced from the former by a suitable hinge or pivotal member 4 at one end, while positioned between the opposite adjacent ends of the said frame and oscillatory members are compression springs 5 preferably having a predetermined and common natural period of vibration under a given load.

Upon the said oscillator is rotatably mounted a table 8, supported by legs 9 above and forming an integral part of a rim 10, the outer peripheral edge of which is movable circumferentially within a ring 11 firmly secured to the oscillator and prevented from vertical movement with respect thereto by an overhanging flange 12, bolts 13 also being provided in said rim for securing said table in a given angular position. To bring the said table and supporting members into a given position with respect to said oscillator, graduations may be provided on the flange 12, or in any other well known manner.

To the upper surface of the table 8 is secured a head stock 15, through which extends a shaft 16, carrying a pulley 17, a belt or chain connecting said pulley to a second pulley 18 carried by a shaft 19, in turn supported by hangers 20 from the under side of the said table, to the inner end of the

shaft 19 there being secured a bevel gear 21, meshing with a similar gear 22, carried by a shaft 23 journaled in bearings 24, which extend upwardly through the said oscillator.

Also carried by the table 8 and adjustably mounted thereon is a tail stock 26, removably secured in a given position by a clamp 27 and forming a bearing for the end 28 of shaft 16, while between said head and tail stocks upon said shaft a body 29, which is being tested, motion being imparted to said body through the shafts, belt, and bevel gears above described, the lower end of the shaft 23 being provided with a bevel gear 31, meshing with a gear 32 fixed to a shaft 33.

Said shaft 33 is supported by hangers 34 from the under side of the oscillator 3, and is driven by a motor 35, while upon one end is secured a yoke 36, between the parallel arms 37 of which extends a threaded rod 38, carrying in threaded engagement therewith a spool 39, preferably knurled at its end portions. By virtue of the relations of the gears extending between the motor and the revoluble support for the body being tested, the yoke 36 revolves in absolute synchronism with the said body, whether they rotate in one direction or the other.

When operating this device as a static balancing machine, the table is rotated into a position in which the axis of the body is perpendicular to the plane of vibration of the oscillator, as shown in Figs. 4 and 5. This is generally done before proceeding to dynamically balance a given body, and if the latter lacks perfect static balance, when rotated on this machine the oscillator vibrates with the spool or weight in a central position on the yoke 36. While continuing to rotate in exact synchronism with the body, the weight is shifted upon the threaded bar toward one end of the yoke.

If with a definite displacement this corrects the unbalanced condition of the said body the vibration of the oscillator ceases, a quantity of material is taken from, or added to, the body as indicated by the degree of displacement of the said weight and the angular position of the said yoke with respect to the body. However, if the unbalance is not overcome completely, the machine is stopped and the angular position of the yoke altered, or this may be accomplished while still rotating by the use of an azimuth changing mechanism such as that described in copending application, Serial No. 110,275. A readjustment of the said weight is again made until a position is found at which all vibration ceases, after which material is removed or added as above mentioned.

In the operation of this device as a machine for determining the dynamic balance of a rotatable body, the latter is arranged as shown in Figs. 1 and 2, essentially with

its axis of rotation lying in a plane coincident with the plane of vibration of the oscillator. The spool 39 is placed first in a central position, and with the yoke having a given angular relation with respect to the said body, and if upon starting up the mechanism the oscillator vibrates, the said spool is moved toward one of the yoke arms by means of frictionally engaging the knurled portions of the former.

This shifting of the spool, or balancing weight, may counterbalance a "heavy" point in the body and thereby cause the oscillator to stop vibrating, such movement on its part being directly caused by a "heavy" point on the said body, or an equivalent in the form of a "light" point on the side diametrically opposite thereto. However, if such movement of the weight does not neutralize the said unbalanced condition, or if it only partially does so, the angular relation of the said yoke with respect to the said body may be changed, by stopping the mechanism, or by providing such an azimuth changing device as above referred to, after which the same procedure is reenacted until the unbalanced condition is completely neutralized, when the machine is brought to a stop and a portion of the body filed or drilled therefrom to the extent, and in the position, indicated respectively by the displacement from center, and angular relation, of the said weight and yoke with respect thereto.

Having thus described my invention, what I claim and desire to protect by Letters Patent of the United States is:—

1. A balancing machine, comprising an oscillator limited to one degree of freedom, a rotatable support for the body to be tested carried by said oscillator, and means also carried by said oscillator and rotatably associated with the said support, and operative to test the dynamic or static balance of a body thereupon.

2. A combined static and dynamic balancing machine, comprising an oscillator, a rotatable support mounted thereon and adapted to receive a body to be tested, means to impose upon said oscillator a forced vibration of any desired frequency and amplitude, and means to move said support and said first means in synchronism.

3. A combined static and dynamic balancing machine, comprising an oscillator, a rotatable support mounted thereon and adapted to receive a body to be tested, means to impose upon said oscillator a forced vibration of any desired frequency and amplitude, means to shift the axis of rotation of said support at an angle to and parallel with the axis of oscillation of said first means, and means to move said support and said first means in synchronism.

4. A dynamic and static balancing machine, comprising an oscillatory base, a turn-

table carried thereby, and a rotatable support carried by said turntable and adapted to receive a body to be tested.

5. A dynamic and static balancing machine, comprising an oscillatory base, a turntable carried thereby, a rotatable support carried by said turntable and adapted to receive a body to be tested, a weight, means whereby said weight is revolubly carried by said base, and means operative to drive said support and said weight-carrying means in synchronism.

6. A dynamic and static balancing machine, comprising an oscillatory base, a turntable carried thereby, a rotatable support carried by said turntable and adapted to receive a body to be tested, a weight, means whereby said weight is revolubly carried by said base and is adapted to be shifted with respect to its axis of rotation, and means to drive said support and said weight-carrying means in synchronism.

7. A dynamic and static balancing machine, comprising an oscillatory base, a turntable carried thereby, a rotatable support carried by said turntable and adapted to receive a body to be tested, a weight, means whereby said weight is revolubly carried by said base and is adapted to be shifted with respect to its axis of rotation while said support and said weight are in motion, and means to drive said support and said weight-carrying means in synchronism.

8. A dynamic and static balancing machine, comprising an oscillatory base, a turntable carried thereby, a rotatable support carried by said turntable and adapted to receive a body to be tested, a weight, means whereby said weight is revolubly carried by said base and is adapted to be shifted transversely of its axis of rotation while said support and said weight are in motion and means to drive said support and said weight-carrying means in synchronism.

9. A balancing machine, comprising an oscillator limited to one degree of freedom, a support for rotatably supporting the body to be tested and carried by said oscillator, means also carried by said oscillator, and connections whereby said means is rotated in harmony with a body upon said support, the whole being operative to test the dynamic or static balance of a body.

10. A combined dynamic and static balancing machine, comprising an oscillator, a support mounted thereon and adapted to receive a body to be tested, rotatable means to impose upon said oscillator a forced vibration of any desired frequency and amplitude, and means to rotate a body upon said support and said first means in synchronism.

11. A combined dynamic and static balancing machine, comprising an oscillator, a support mounted thereon and adapted to receive a body to be tested, means to impose

upon said oscillator a forced vibration of any desired amplitude, and means to rotate a body upon said support and to operate said first means in harmony.

12. A balancing machine, comprising an oscillatory mounting, means for rotatably supporting a body to be tested and carried by said mounting, statically adjustable means also carried by said mounting, and connections whereby said last means is moved in harmony with a body upon said first means, the whole being operative to test the balance of a body upon said first means.

13. A balancing machine, comprising an oscillatory mounting, means for rotatably supporting a body to be tested and carried by said mounting, rotatable radially adjustable means also carried by said mounting and operative to impose upon said mounting a variable forced vibration, to neutralize the vibration imposed upon said mounting by a body when unbalanced and rotating upon said support, and connections whereby said last means is made to rotate in synchronism with, and operative to test the balance of, a body upon said first means.

14. A combined dynamic and static balancing machine, comprising an oscillator, a support mounted thereon and adapted to rotatably receive a body to be tested, and rotatable means connected with and operative to impose upon said oscillator a forced vibration of any desired amplitude, and connected to rotate in synchronism with a body upon said support, to counteract unbalance of such body.

15. The method which consists in mechanically associating a dynamically unbalanced body with a body adapted to be perfectly balanced and unbalanced statically at will so that each tends to oppose the tendency of the other to vibrate if unbalanced, and so that the two may be revolved synchronously,

thus forming an unbalanced system, and then adjusting said last-named body to neutralize the unbalanced condition of said first body to balance said system.

16. The method which consists in mechanically associating a dynamically unbalanced body with a body adapted to be perfectly balanced and unbalanced at will statically by radially shifting its center of gravity, so that each tends to oppose the tendency of the other to vibrate if unbalanced, and so that the two may be revolved synchronously, thus forming an unbalanced system, and then adjusting said last-named body to neutralize the unbalanced condition of said first body to balance said system.

17. The method which consists in mechanically associating a statically unbalanced body with a body adapted to be perfectly balanced and unbalanced statically at will upon an oscillatory mounting, so that each tends to oppose the tendency of the other to vibrate if unbalanced, and so that the two may be revolved synchronously, thus forming an unbalanced system, and then adjusting said last-named body to neutralize the unbalanced condition of said first body to balance said system.

18. The method which consists in mechanically associating a statically unbalanced body with a body adapted to be perfectly balanced and unbalanced statically at will upon an oscillatory mounting, so that each tends to oppose the tendency of the other to vibrate if unbalanced, and so that the two may be revolved synchronously, thus forming an unbalanced system, and then adjusting said last-named body to neutralize the unbalanced condition of said first body to balance said system.

In testimony whereof I have affixed my signature.

NICHOLAS W. AKIMOFF.