Oct. 29, 1940. M. P. WINTHER ET AL 2,220,007

DYNAMOMETER

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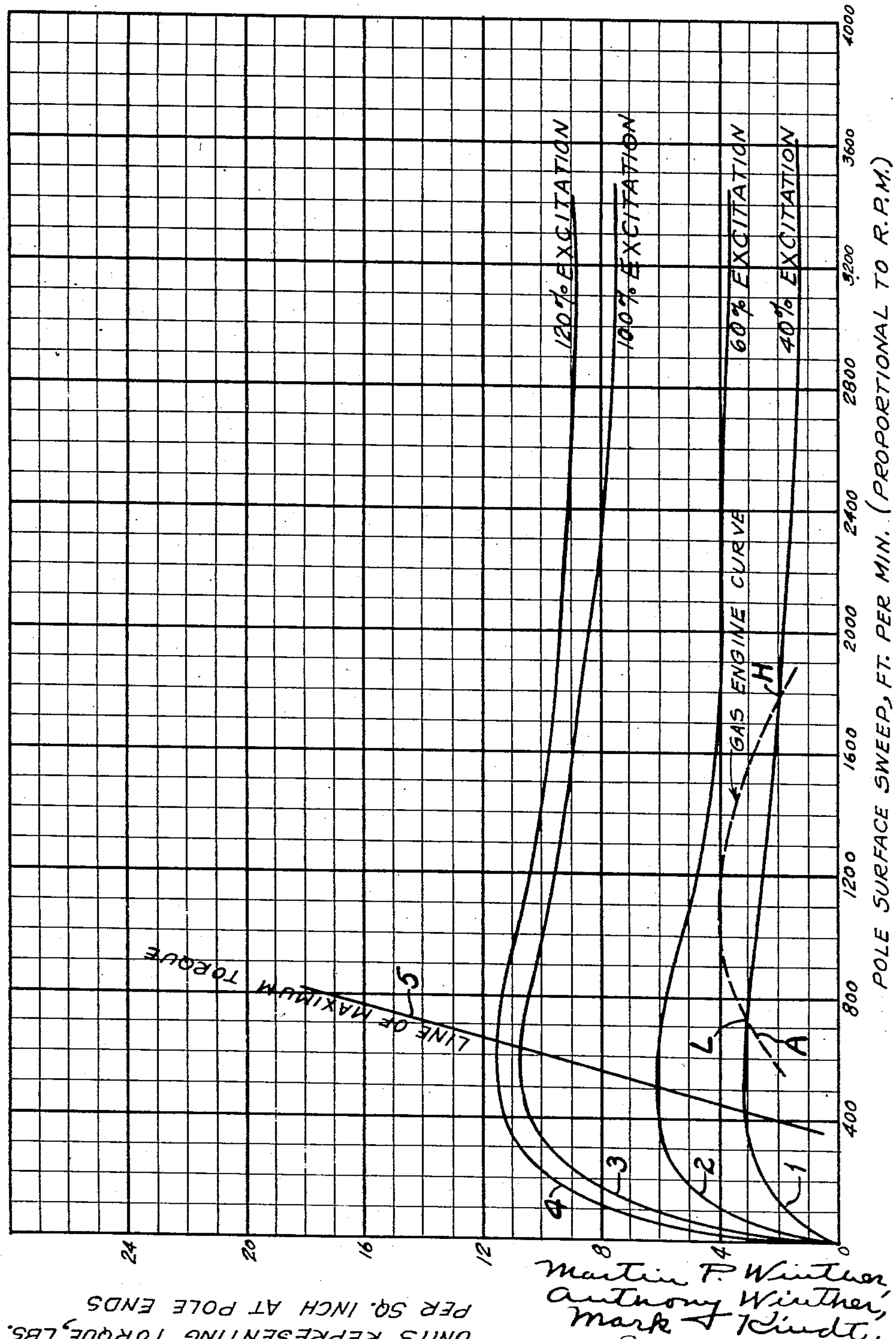
FIG. I.



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DYNAMOMETER

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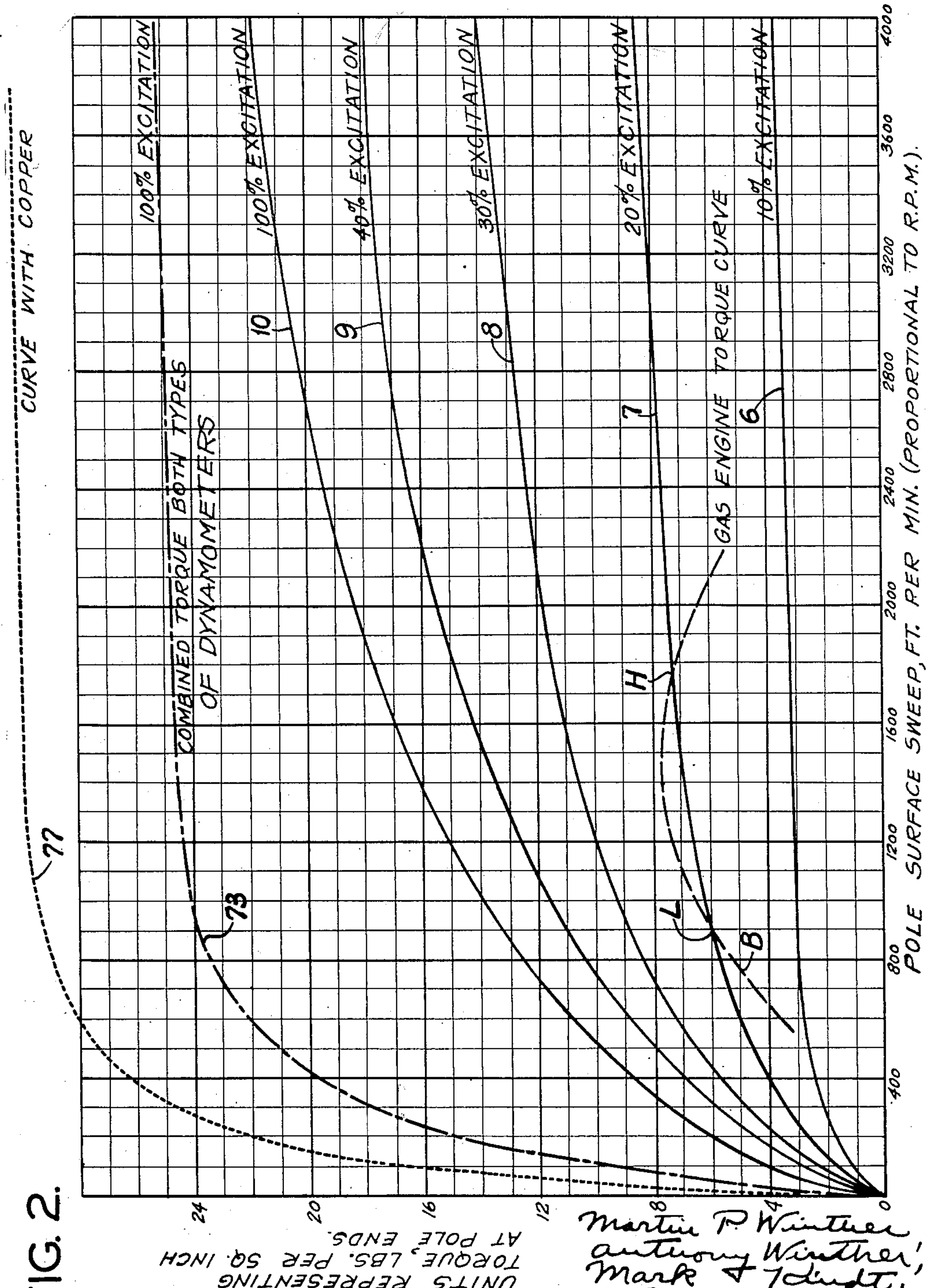

FIG. 2.

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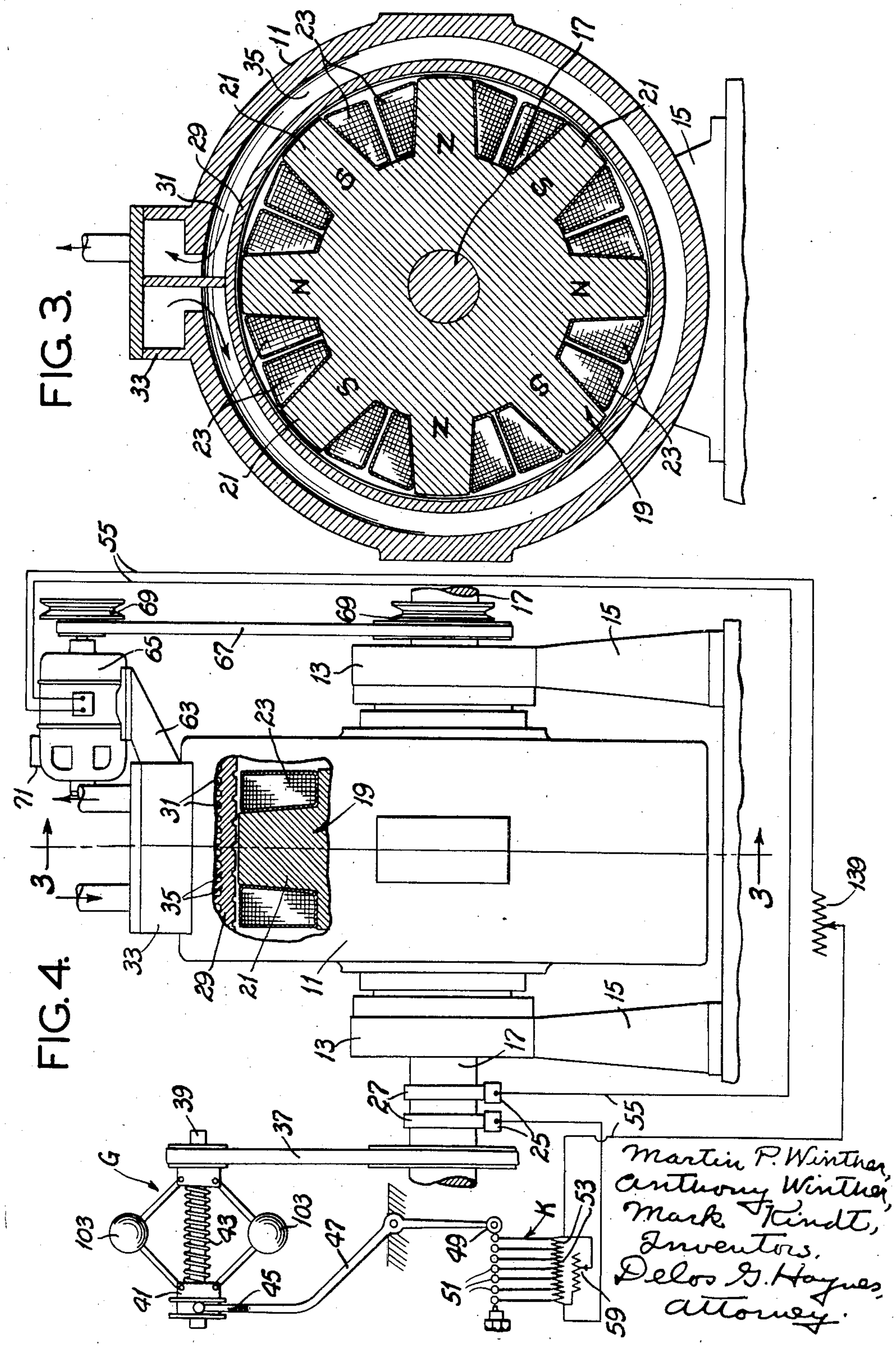

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DYNAMOMETER

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FIG. 7.

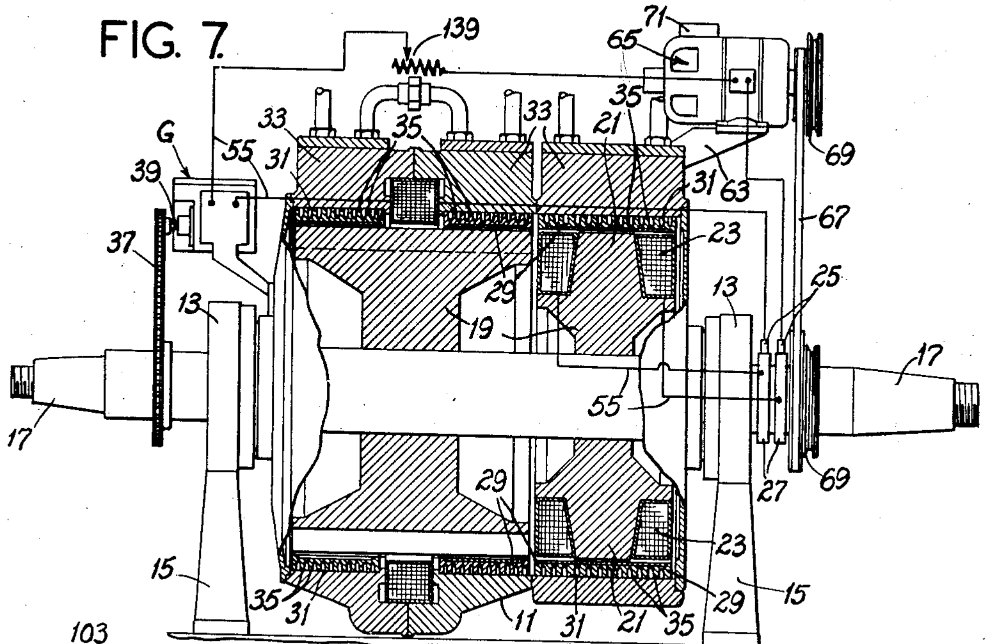
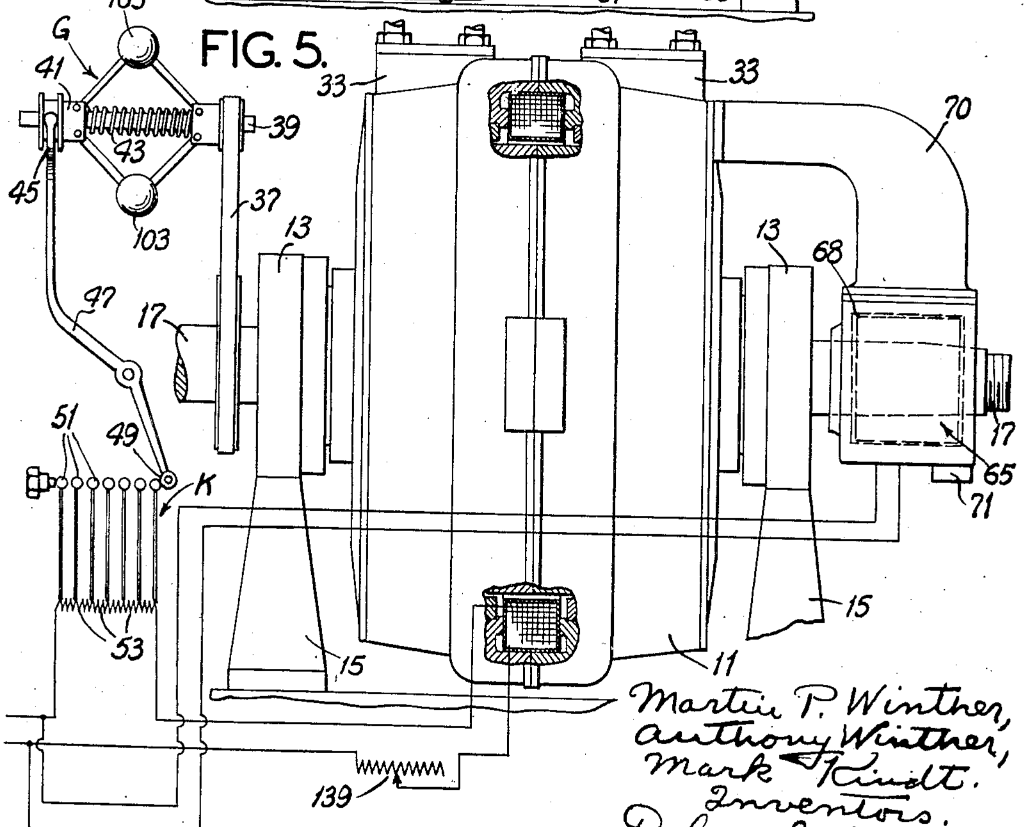


FIG. 5.



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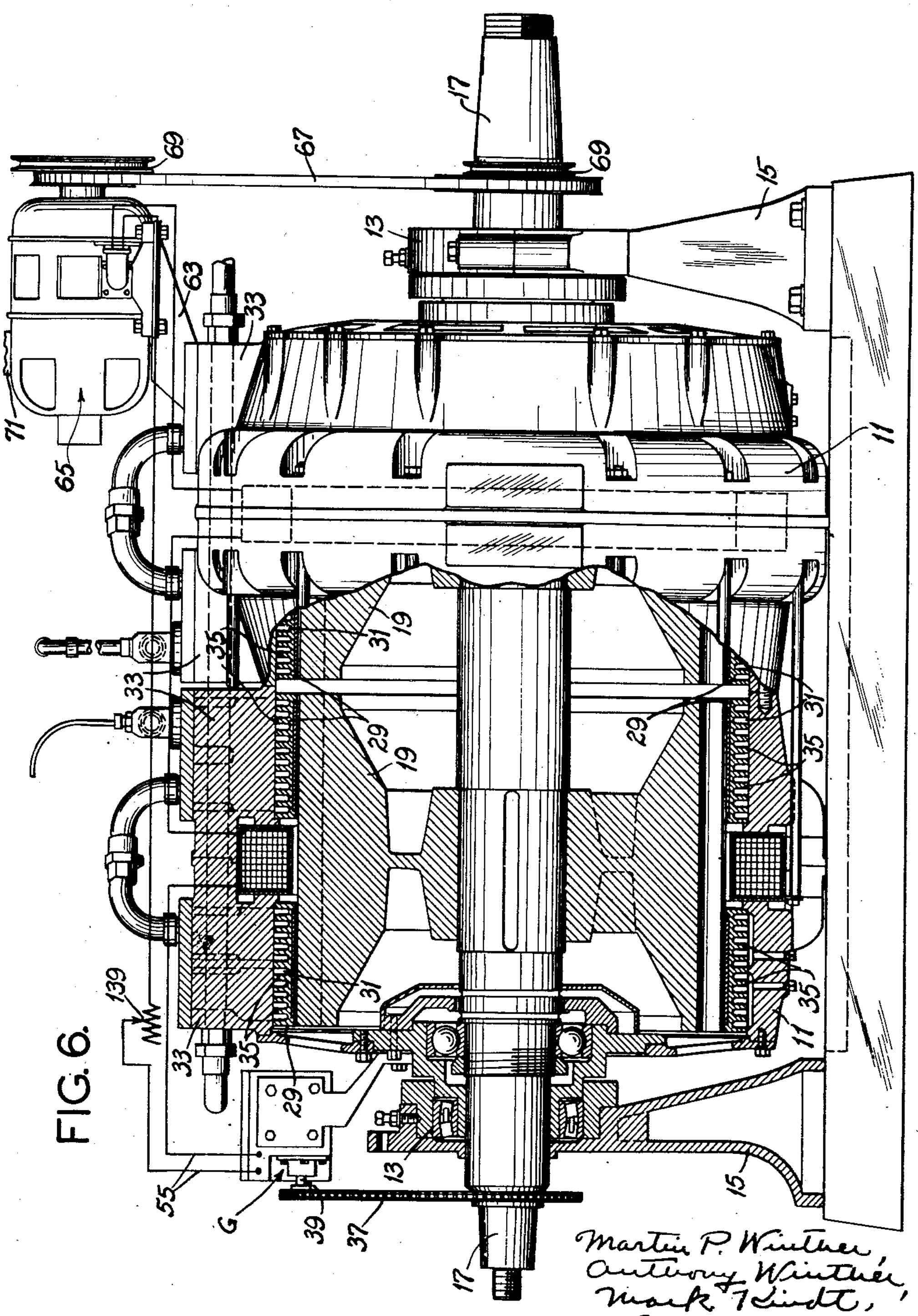

FIG. 6.

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FIG. 8.

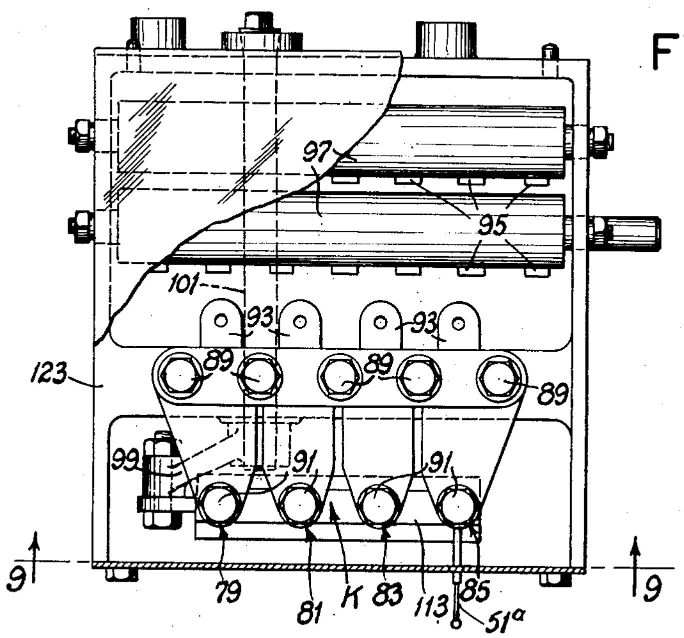
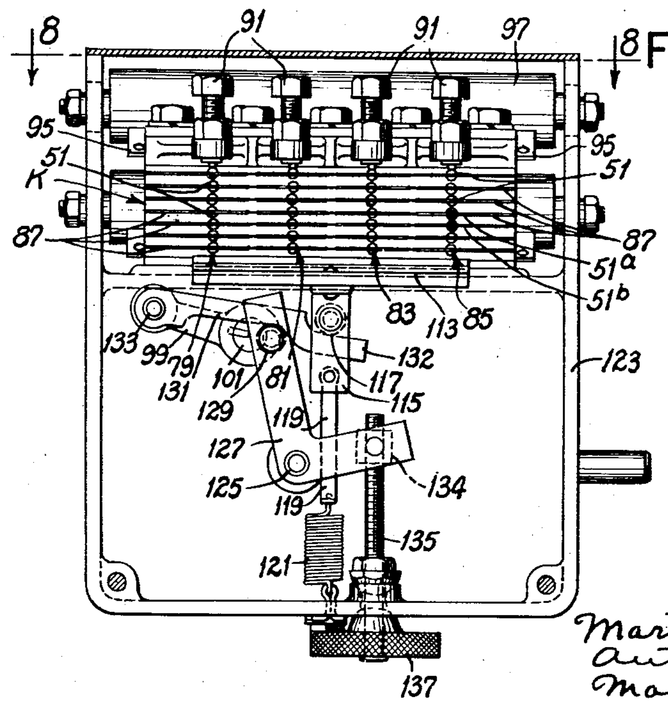


FIG. 9.



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DYNAMOMETER

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FIG. 10.

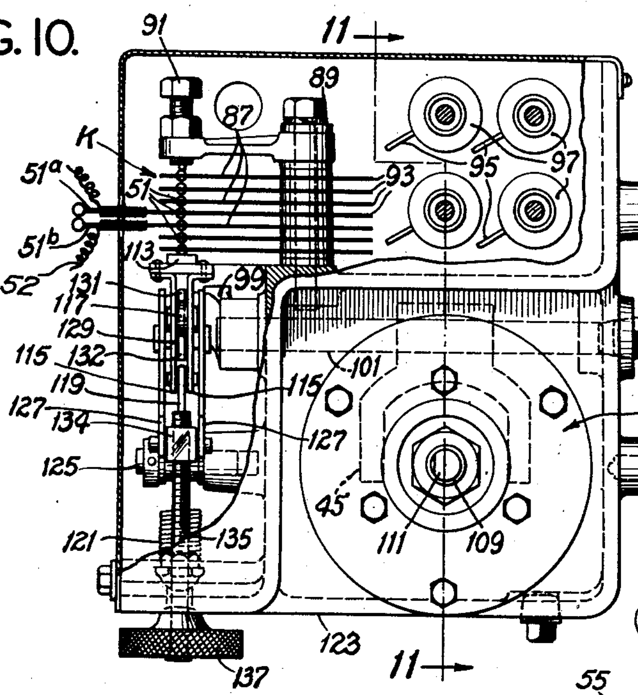


FIG. 12.

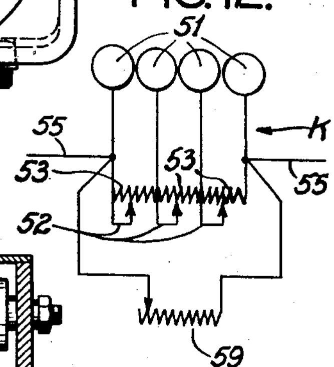
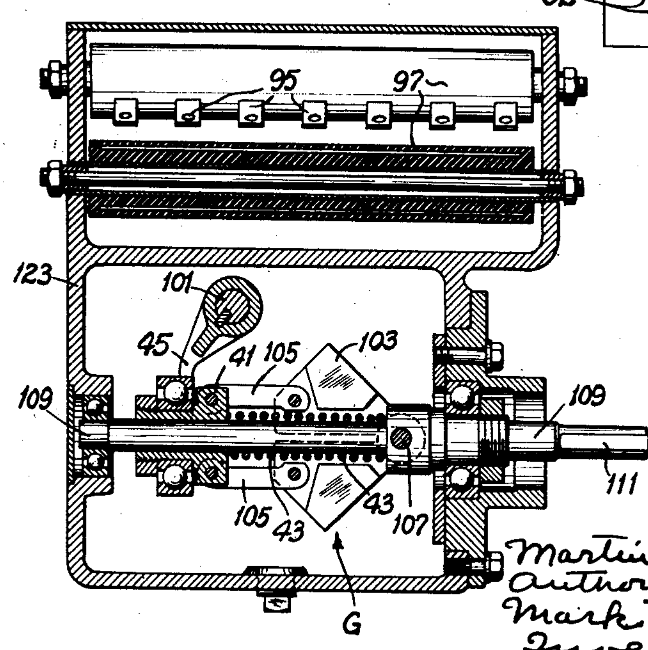


FIG. 11.



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Patented Oct. 29, 1940

2,220,007

UNITED STATES PATENT OFFICE

2,220,007

DYNAMOMETER

Martin P. Winther, Waukegan, Ill., and Anthony Winther and Mark Kindt, Kenosha, Wis., assignors to said Martin P. Winther as trustee

Application April 9, 1938, Serial No. 201,070

11 Claims. (Cl. 73—51)

This invention relates to electromagnetic apparatus, and with regard to certain more specific features, to electromagnetic apparatus constituting a dynamometer.

Among the several objects of the invention may be noted the provision of means for closely regulating and ascertaining the torque obtainable from a prime mover operating at any throttle position; the provision of apparatus of the class described wherein automatic means is included for accurate control of speed of the prime mover which drives the dynamometer; the provision of a dynamometer having an improved form of torque curve and one by means of which the prime mover functions as the source of energy for certain auxiliaries, the required torque for this purpose being accounted for by the dynamometer; the provision of means for testing the performance of a prime mover in the laboratory under the exact conditions of its operation in practice after final installation; and the provision of an improved form of resistance control, the use of which simplifies the attainment of automatic control of electromagnetic apparatus of this class in general. Other objects will be in part obvious and in part pointed out hereinafter.

The invention accordingly comprises the elements and combinations of elements, features of construction, and arrangements of parts which will be exemplified in the structures hereinafter described, and the scope of the application of which will be indicated in the following claims.

In the accompanying drawings, in which are illustrated several of various possible embodiments of the invention,

Fig. 1 is a layout of a family of exemplary torque curves for dynamometers employing separately wound, salient poles, such as shown in the United States Patent 1,977,600, of Anthony Winther, dated October 16, 1934 (reissued as 20,225, dated December 29, 1936).

Fig. 2 is a layout of a family of exemplary torque curves for dynamometers employing non-wound, toothed poles, such as shown in United States Patent 2,106,542, of Anthony Winther, dated January 25, 1938, and also certain other curves;

Fig. 3 is a diagrammatic vertical section of a salient-pole type of machine, the section being taken on line 3—3 of Fig. 4;

Fig. 4 is a diagrammatic side elevation of a salient-pole type of machine with a belt-driven exciter, and illustrates certain other features of the invention applied thereto;

Fig. 5 is a view similar to Fig. 4 showing a toothed-pole type of machine with a concentric, directly-driven exciter;

Fig. 6 is a longitudinal section, partially in elevation, showing a compound form of machine with the belted form of exciter;

Fig. 7 is a diagrammatic longitudinal section showing a compound machine with both salient-pole and toothed-pole characteristics;

Fig. 8 is a plan view of a resistance control, parts being broken away, the view being taken substantially on line 8—8 of Fig. 9;

Fig. 9 is a view taken substantially on line 9—9 of Fig. 8;

Fig. 10 is a right-side elevation of Fig. 9, parts being broken away;

Fig. 11 is a section taken on line 11—11 of Fig. 10; and,

Fig. 12 is a fragmentary, diagrammatic detail of an alternative form of shunt resistance.

Similar reference characters indicate corresponding parts throughout the several views of the drawings.

In Patent 2,106,542, above mentioned, there is disclosed the fact that the torque curve for an eddy-current generator employing salient poles, such as shown in Reissue Patent 20,225, is different from the torque curve of an eddy-current generator employing a toothed polar means. For example, in Reissue Patent 20,225, a method by means of which high torques may be obtained was explained in connection with the use of individually wound, salient poles of opposite polarity sweeping past given points on an iron armature. In Patent 2,106,542 is shown how high torques may be obtained by the use of a non-wound, toothed rotor and a toric magnetic field generated by a separate coil.

The present invention effects a regulation of the torque obtainable from either of the above types of eddy-current machines, when constructed as dynamometers, so that, with either type, an automatic means is had for controlling the speed of a prime mover under test. It also permits, with greater advantage, the use of either or both types of machines mounted in tandem for compound action.

In order to obtain a correct understanding of the present invention, it is desirable to note the characteristics of the torque curves of the two types of machines above referred to, at several usable degrees of magnetization of their inductors.

Referring now more particularly to Fig. 1, which shows a family of torque curves 1, 2, 3 and 4 for a salient-pole type of machine such as disclosed in Patent 2,106,542 and illustrated in Figs. 3 and 4 herein, it may be noted that the torque promptly rises to a relatively high value at a relatively low pole speed, and then drops off, so that at relatively high speeds the torque is lower. (For a further discussion of this phenomenon, see Patent 2,106,542.)

It will also be noted from Fig. 1 that the drooping characteristic of the torque curve is inherent and occurs with various values of excitation. All of the family of curves 1, 2, 3 and 4 have a maximum torque which is under 650 feet per minute of pole surface sweep. This is indicated by the line 5 of maximum torque. This drooping characteristic is unfavorable for certain (though not all) dynamometer purposes. For example, if the engine under test is permitted to decelerate from a given higher speed, the dynamometer torque increases, if the dynamometer is supplied with a constant excitation of its field. The result is that the engine may be stalled when its speed drops to a predetermined low point. On the other hand, if the engine accelerates from a given low speed, the resisting torque of the dynamometer ultimately decreases, thus permitting the engine to become underloaded and to run away.

From the above it will be seen that it is desirable to have automatic means to decrease the excitation of the salient-pole type of dynamometer (illustrated in Figs. 3 and 4) at lower engine speeds, and to increase the excitation at higher engine speeds.

Referring to Fig. 2, there is shown a family of curves 6, 7, 8, 9 and 10, at different excitations, for the toothed-type of dynamometer such as disclosed in said Winther Patent 2,106,542 and illustrated in Fig. 5 herein. In this type of machine all poles passing a given point on the stator have like polarity. The characteristics of this type of machine are quite different, the torque continually rising with speed. Such a rise is quite satisfactory for general purposes when the higher excitations can be used, but, should it be desired to test an engine whose torque is substantially less than the maximum torque capacity of the dynamometer, some difficulty is encountered.

In both Figs. 1 and 2, low-capacity engine torque curves A and B respectively are shown, requiring the provision of an automatic means of regulating the excitation of the respective dynamometer. This requirement exists, because at low dynamometer excitations the lower torque curves of both dynamometers are relatively flat, and do not satisfactorily follow the engine torque curves. Even the higher curves of Fig. 1 and the higher curves of Fig. 2 are not correct for the purpose.

For example, at point L in Fig. 1, the curves 1 and A cross, and likewise curves 7 and B in Fig. 2 cross at L. Under these unstable conditions of torque balance between dynamometer and engine, either engine (the curves A and B for which are shown in Figs. 1 and 2) will "run away" and "search" until crossing point H is reached. This "searching" or "hunting" condition destroys the value of any tests that the operator of the engine may want to make at a certain engine speed, say, for example, at a speed corresponding to point L on the curve. Hence, in the examples given, it is desirable to have an automatic means for increasing the excitation of the dynamometer with incipient increase in engine speed, in order to prevent the engine from "searching." If this is accomplished, then the engine may be operated at a constant speed, and at a constant torque, without attention from the operator.

Although hand regulation of dynamometer excitation can be used in an attempt to match the torque curve of a given dynamometer and that of a given engine, it is very difficult to follow closely the engine speed with such hand regulation, and the most desirable results cannot be obtained. The present invention makes use of a speed-responsive governor and a resistance contact bank which is speed responsive thereto. The invention also makes use of a direct-current, exciting generator, whose output is low, at relatively low speeds, and the output curve of which rises steeply as the speed of the dynamometer increases.

Referring to Figs. 3 and 4, there is shown a salient-pole type of dynamometer in which a rotary or swinging stator case 11 rests in bearings 13 on pedestals 15. This case carries the usual lever arm for contact with the torque-measuring scales or the like (not shown). Passing through the case and rotatable therein is the dynamometer shaft 17 to which is connected the prime mover, or engine to be tested (not shown). Upon the shaft 17 is carried the rotor 19 having the salient poles 21, adjacent ones of which are of opposite polarity, as indicated by the characters N and S. Each pole carries a winding 23 wound to provide the proper polarity and excited by means of current brought in from circuit 55 through brushes 25 and slip rings 27. The flux from the poles 21 passes through the water-circulating ring 29 and through the metal of the case 11. Thus, when the rotor 19 is rotated, the moving flux induces eddy currents in the ring 29, and their magnetic reactions tend to force the case 11 against the measuring scales. Grooves 31 in the ring 29 serve to form water passages to receive water from, and to send water to, an entry box 33, so that the heat engendered by the eddy currents may be carried away by said water. The details of this general type of cooling construction have been described in the United States patent application of Martin P. Winther and Mark Kindt, Serial No. 196,346, filed March 17, 1938, for Dynamometer. In said application, the advantages of this type of cooling construction are shown in connection with a toothed rotor. The advantages are also important with a salient type of rotor, because such rotors tend to drive the flux deeper into the separating walls 35 between water channels of the ring 29, from which heat would otherwise be difficult to abstract.

The connections for bringing water to, and taking water from, the apparatus are flexible to permit free swinging of the stator against its force-registering scale.

In Fig. 4 is shown a governor G driven by a flexible connector 37 from the shaft 17. The governor shaft 39 may be mounted in bearings on a stationary frame; or it may be mounted on the case 11, if it be required that the small amount of torque required to drive the governor be recorded upon the torque-measuring device, with which the case 11 cooperates. Usually the requirement of measuring this added torque is unnecessary, because the energy required to drive the governor is little more than that required to drive a tachometer, or the like. In certain alternative forms of the invention, the governor is shown as mounted on the dynamometer case or stator (see Figs. 6 and 7).

The governor G is of the fly-ball type shown, in which centrifugal force of balls 103 causes a sleeve 41 to be drawn against the restoring force of a spring 43, upon increase in speed. The sleeve is grooved to cooperate with a shifter fork 45 on a bell-crank 47 which has a contactor 49 for cooperation with the last of a row of normally separated spring contacts 51 of a shunt contactor K. The contactor may be of the type shown in the United States Patent 2,050,479 of Anthony Winther, dated August 11, 1936. Each pair of contacts 51 as successively closed is shunted across a respective resistance 53 in the circuit 55. The governor G is arranged so that a decrease in speed of the shaft 17 causes the contact points 51 to open, one from the other, and thus to insert more and more of the resistances 53, so that, for low speeds of the shaft 17 and of the prime mover being tested, the dynamometer has less excitation, and hence has less resisting torque against the engine and hence will not stall the engine.

On the other hand, if the speed of the shaft 17 rises, the governor G successively closes the points 51 to shunt out the resistances 53 and to increase the resisting torque against the prime mover.

By the above means, the dynamometer, besides having its normal dynamometer function, is also used as a speed controller for the engine, the governor having the effect of tending to resist engine speed increase by increasing the dynamometer torque, and vice versa.

The resistance 53 can readily be selected, so as to give any desired type of dynamometer torque-curve. Arrangement can be made first to suppress torque at low speeds, and then increase torque at the higher speeds. The rate of change of torque may also be varied to suit the circumstances. For example, in Fig. 12 each resistance 53 is provided with a manually adjustable shunt 52 for making desired adjustments. Regardless of how the resistances 53 are arranged, once they are fixed, the activity of the dynamometer in matching engine torque is thereafter automatic, in view of the governor G.

At numeral 59 is shown a manually operated rheostat which can be used in place of the governor G for hand regulation, if desired, as an independent adjustable shunt (by removing belt 37), or in combination with the action of the resistances 53 and contacts 51. By this means, the governing range may be limited, if desired, to certain ranges of speed and torque.

At numeral 63 is a bracket on the stator case 11 which carries an exciting generator 65 driven by a flexible connector 67 from the shaft 17. Step pulleys 69 are used to effect a change in speed of the exciter 65, when desired. The object of driving the exciter from shaft 17 is to use energy from the prime mover under test which otherwise would be lost as heat of absorption in the dynamometer stator. Another object in this respect is to gain the advantage of the automatically increased excitation with speed increase, which is inherent when the exciter is driven by the prime mover. The object of fastening the frame 63 of the exciter 65 to the stator 11 is to cause any torque that is required to drive the exciter to be applied to the force-measuring means associated with the stator 11. A field control rheostat 71 is used in the field circuit of the exciter 65.

In all cases where the exciting generator is driven from shaft 17, the exciter also will produce a useful rise in excitation with increase in speed. However, if the dynamometer is to be operated at low speeds and the current supplied from the exciter is too low, it is then necessary to increase the speed of the exciter, so that it will be operated at a steep point on the curve of its voltage rise with speed. Hence, the step pulleys 69 are used to meet the conditions in this respect, that is, to provide a steepness of voltage curve when necessary for any given dynamometer speed range, which may be desired.

In Fig. 5 is shown the use of the above-described apparatus in connection with a toothed-rotor type of dynamometer. In this figure, like numerals designate like parts.

In Fig. 5, the case of the exciter is supported upon the stator 11 by means of a bracket 70. The hollow portion of the case is made concentric with the shaft 17, hence making it possible to place the armature 68 of the exciter 65 upon the shaft 17. Thus, the armature, instead of being driven through a drive such as drive 67 (Fig. 4), is driven directly from the shaft 17. This optional form of exciter eliminates the speed change arrangement in connection with the exciter drive, but in certain applications of the invention this is not necessary, particularly where the correcting effect of the governor-controlled resistance bank 53 is used to its full extent.

In Fig. 6 is shown how two dynamometers of the toothed-rotor variety may be compounded on a single shaft, like numerals designating like parts. In Fig. 6 the governor G is shown as being mounted upon the stator 11 and driven by a chain from the shaft 17.

As shown in Fig. 7, a salient-pole type of machine (shown at the right) and a toothed-rotor type of machine (shown at the left) may be compounded on one shaft. This results in a steep torque curve such as shown at numeral 73 in Fig. 2. Such a steep torque curve is desirable because it bounds a large area underneath which a large number of torque-curve forms may be included, the forms being made according to the governing variations which may be effected as above described.

The field windings of the two machines in both Figs. 6 and 7 are in series and under the control of one governor, as shown.

Referring again to the curve 73 in Fig. 2, it may be noted that, in view of the governor control herein provided, the compound form of dynamometer may be made to simulate almost any type of load. By the proper selection of resistances 53 in the contact bank K, the dynamometer may provide a load which increases directly as the speed, as the square of the speed, or as the cube of the speed, or the like. In addition to the above, the load curve of the dynamometer may be adjusted to any modification of the above, and in fact to any form of curve desired, regardless of what said curve may be, as long as it lies within the wide area covered by the curve 73 illustrated in Fig. 2.

The curve 73 is based upon the use of an iron induction member 11. If copper induction surfaces are provided on the inside of member 11, as taught in the application, Serial No. 196,346, filed March 17, 1938, then the torque curve becomes even more steep, and includes more area, such as indicated by the curve 77 in Fig. 2. In this case, a still greater rise in torque (greater than the cube of the speed) is possible.

As a practical example of what can be done by means of the invention, an engine to be tested may be considered, which is of the type indicated to be used to drive a ship. Such engines have a torque which rises approximately as the square of the speed. For testing such an engine, the bank of resistances 53 would be chosen so as to cause the torque of the dynamometer to rise as the square of the speed of the engine. Thus, the same type of load would be applied to the engine as would be expected under marine running conditions. Hence the engine could be automatically, fully and accurately tested under the exact conditions which it would meet in service.

The invention is also very valuable from the standpoint of the ability properly to set engine governors and to study their efficiencies at various speeds under various load conditions. The advantage also accrues in the case of aircraft engines, or any other engines called upon for special purposes, where the speed-load curves have special characteristics. Although it is conceivable that these characteristics might be roughly simulated by manual control of the dynamometer, the present invention makes it possible repeatedly to obtain a precise, automatic and perfect duplication of actual conditions under controlled test conditions.

In Figs. 8–11 is illustrated a special form of the governor G and contact bank K, particularly applicable to the aforegoing methods of dynamometer regulation. This governor and contact bank is an improvement upon the one shown in United States Patent 2,050,479, of Anthony Winther, dated August 11, 1936. In said patent, all of the contacts in the contact bank were arranged serially. We have now found that the pressure required to compress a long series of contacts (spring mounted) varies approximately as the square of the number of leaves compressed. For example, if twenty-eight leaves were used in series, requiring one pound to compress seven leaves, then it would require four squared, or sixteen pounds to compress the twenty-eight leaves. On the other hand, if four, seven-leaf banks were placed in parallel, it would require only four pounds to compress twenty-eight such leaves.

In view of the above, and taking the twenty-eight leaf bank as an example, we provide four, seven-leaf banks of contacts 51, as indicated at the four numerals 79, 81, 83 and 85 in Figs. 8–10. Each bank contains seven slightly spaced contacts 51. Numerals 87 indicate the spring conducting leaves which support the contacts 51; numerals 89 indicate the bolts which support the leaves. The bolts and the leaves are insulated from one another.

Numerals 91 indicate adjustable abutments for the four rows of contacts, respectively. Numerals 93 indicate terminals from which wires respectively lead to respective taps 95 of resistances 97. For example, the row of seven terminals 93 associated with the row 85 of contacts 51 would be connected respectively to the taps 95 of a resistance 97. Four tapped resistances 97 are used, each being connected with one of the rows of terminals 93. The tap wires have not been shown because of the manifest complications, without increased clarity, that would be brought about in the drawings.

At numeral 99 is shown a lever which is keyed to a shaft 101. The shaft 101 (Fig. 11) has keyed thereto a fork 45 (corresponding to fork 45 in Figs. 4 and 5). This fork 45 is moved by a sleeve 41 which is under control of centrifugally operable weights 103, to which the sleeve 41 is connected by means of links 105. The spring 43 provides restoring force for return of the weights 103 to the positions shown in Fig. 11. The weights 103 are pivoted at 107 to a shaft 109, the outer end 111 of which is provided for receiving a pulley, if the device is to be belt-driven, as in Figs. 4 and 5, or a sprocket, if the device is to be chain-driven, as in Fig. 6.

In order to transmit motion from the lever 99 on shaft 101 to the contacts 51, the linkage shown in Fig. 9 is provided.

This linkage is for the purpose of operating a pressure plate 113, which contacts the endwise contacts 51 in each of the rows 79, 81, 83 and 85. The contact, though theoretically simultaneous between the four adjacent contacts in the four rows, is in practice such that each contact is made at a time different from the adjacent three, thereby providing serial operation. A predetermined crosswise sequence of closure as between the four pairs of contacts in a given group of contacts 51 crosswise of rows 79, 81, 83, 85 may be assured by adjustably bending the spring leaves 87. Since the resistances 97 are comprised of the sectional resistances 53, such as shown in Fig. 4 (for example), and since said resistances 97 are serially wired, the result is a serial shunting action as between the twenty-eight contacts 51 as the plate 113 moves toward stops 91. Resistance values across contacts 51 are chosen to give the desired excitation according to the sequence of their closures.

If a great number of contacts is used in each row 79, 81, 83 and 85, then it may not be necessary to adjustably bend the spring leaves 87 to obtain a predetermined closure sequence of the rows 79, 81, 83 and 85, because under such circumstances, the four resistance values for any given four pairs of contacts (considered crosswise of the rows 79, 81, 83 and 85) may be made the same so that it would not matter which pair of the four closed first. This however would not preclude the desirability under many circumstances of making different the total values of the successive resistances associated with each four lateral pairs of contacts, so that the desired relationship could be maintained between the value of torque transmission and prime mover speed on the one hand, and the value of prime mover torque and prime mover speed on the other hand.

Plate 113 carries spaced extensions between which is rotatably mounted a roller 117. The extension 115 has attached thereto a link 119 to which is attached a spring 121 for normally drawing the plate 113 away from the contacts, thus permitting the contacts to swing open.

To the case 123 which surrounds the device is pivoted at 125 a bell-crank 127 carrying on one arm a fulcrum roller 129. A link 131 which is pivoted at 133 to the outer end of the lever 99 rests upon the fulcrum roller 129 and has an outer end 132 which rests under the roller 117. Hence when the lever 99 is turned counter-clockwise (Fig. 9), the link 131 functions as a lever fulcruming at 129 to force the plate 113 gradually to move the contact 51 in accordance with the movement of said lever 99.

From the above it will be seen that, if the fulcrum 129 be moved to the left or right, the motion of the plate 113 may be controlled. This control is effected by providing a swiveling nut 134 on the other arm of the bell-crank 121 into which is threaded a screw 135. The screw 135 has a bearing in the box 123 and an outside control knob 137. It is clear that by turning the knob 137 the position of the bell-crank 127 may be varied, and thus the position of the fulcrum 129. Hence the initial starting point for the action of the end of the lever 132 (at roller 117) may be varied. To attain the desired effect, the back of the link 131 may be suitably formed as indicated.

From the above it will be seen that the governor can be so adjusted as to cause a larger or smaller movement of the end of the lever 131 at the pivot 133 to produce the same movement of the bar 113. For example, if the machine is operating at a low angular velocity, the response to the governor weights 103 will be smaller for a given change in angular velocity than would be the case at higher speeds. This is because the centrifugal force is proportional to the square of the angular velocity. By adjustment of the fulcrum 129, this smaller change at the lower velocity may be made to have as great an effect upon the bar 113 as the greater change at the higher velocities or speeds. Hence the governor is capable of governing as closely at 100 R. P. M. as it is when it is operating at 3000 R. P. M., simply by making a suitable adjustment at the knob 137. Thus by properly selecting the values of the resistance connected between contact points, it is possible closely to regulate the excitation furnished to the dynamometer, so that the dynamometer may be held within a fraction of one percent of the speed which is determined as being proper. The values of the resistances between taps 95 may be varied by a suitable choice of tap connections, or of resistance values between adjacent taps. This choice may be made at the factory when it is known in advance what torque curve is to be reproduced. If this is not known in advance, then the arrangement 52, 53, shown in Fig. 12, may be used between taps 95.

It will be seen that other equivalent means may be used for obtaining a similar result such as by adjusting the governor spring 43, or travel of the governor weights. Electronic means might also be used.

Another feature of the device shown in Figs. 8–11 is a special use of one of the pair of contacts 51*a* and 51*b* in one of the rows of contacts, for example, in row 85. It is intended to use such a pair of contacts near the center of the row as a source of indication as to when the governor is operating so as to open and close the contact leaves in all the banks at their central portions. This condition of operation is most desirable, because it affords the maximum range of either increase or decrease in speed with forward or backward movement of the compression bar 113. Thus the resistances which are between the contact points 51 are so selected that the smallest changes take place toward the center of the banks 79, 81, 83 and 85, and thus permit the use of larger values for either the increase or decrease of excitation to be used toward the end of the contact banks.

In order to make clear this point, two of the leaves have been indicated as 51*a* and 51*b*, in bank 85. These have been shown as links extending through an opening in the case so as to be visible. They provide an indicator to show whether or not the governor at a particular setting of the fulcrum is rotating at a speed which tends to regulate the opening of all contact banks at about their centers. While the indication may be in the nature of a physical movement of the contacts 51*a* and 51*b*, nevertheless, it is clear that these may be insulated and made to close an auxiliary circuit 52 to a lamp or the like on a control panel or the equivalent.

For example, suppose that it is desired to govern the speed of the dynamometer at 1200 R. P. M. The governor is then adjusted as follows:

Without any excitation, the driving engine is idled by adjusting its throttle until a tachometer indicates 1200 R. P. M. The knob 137 is then turned until there is an indication at the contacts 51*a* and 51*b* that they are just opening. It is then clear that the governor is adjusted so as to maintain a speed of 1200 R. P. M. Then, by means of a hand rheostat, such as shown at 139 in Figs. 4–7, the load can be built up upon the dynamometer, at the same time opening the throttle of the engine until the resistance of the rheostat 139 is entirely removed from the circuit, and the governor G begins to function by cutting in or adding resistance as speed of the engine and the dynamometer incipiently increases or decreases above or below 1200 R. P. M.

After the engine throttle is wide open, as above arranged, further turning of the knob 137 will automatically increase or decrease the speed above or below 1200 R. P. M. at which governing takes place, and, in view of the proper choice of resistances 53, the torque of the dynamometer will always equal the torque of which the engine is capable at any setting of the governor, and therefore at any desired speed.

Therefore, it is apparent that the invention provides the means not only for regulating the speed of a dynamometer, but it also provides the means for permitting the engine under test to operate at any desired speed with a wide open or any other opening of the throttle, so that the full torque or any fractional torque of which the engine is capable at any speed can be developed and read directly on the dynamometer scales. At the same time, the governor functions to hold the speed to which it is set, regardless of other considerations. The dynamometer scale reading in pounds torque will thus show whether or not the engine either loses or gains torque for any change in speed.

The governor operates on a steep excitation curve, that is, such that small changes in current value due to the action of contact points in the governor have a large effect upon the torque of the dynamometer through its excitation. It should be understood that, if necessary to obtain this result, part of the dynamometer excitation may be made to by-pass the governor, or may be furnished by an outside source independent of the governor, so that at all times the governor may be caused to operate at the steep part of the excitation curve. Appropriate series or shunt rheostats may be used for this purpose, and even double coils in the dynamometer, if necessary.

In view of the above, it will be seen that the several objects of the invention are achieved and other advantageous results attained.

As many changes could be made in carrying out the above constructions without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

We claim:

1. In a dynamometer, a driven and swinging stator member, a driving rotor member, a field winding to provide a flux field interlinking the

driving and stator members, circuit means for exciting said field winding, and governing means responsive to the speed of the driving rotor member adapted to control the current in said circuit to vary the excitation of said field means, said governing means comprising centrifugal apparatus mounted upon the stator member and driven from the rotor member, whereby the torque for driving the centrifugal apparatus is applied to said stator member.

2. In an eddy-current dynamometer, a swinging stator, a rotor adapted to be driven by a prime mover, a field winding adapted to produce a flux field linking said stator and said rotor, and an exciter for energizing said winding, said exciter being mounted upon the stator and driven from the rotor whereby energy is abstracted from the prime mover for excitation and whereby the stator receives the force due to reactions caused by drag in said exciter.

3. In a dynamometer, a swinging stator providing means for measuring torque, a rotor, field means providing flux interlinking the stator and the rotor, a generator for exciting said field means and having a stationary element mounted upon the swinging stator and a movable element driven from the rotor, whereby torque applied to the generator is included along with the torque from the rotor to be measured by the swinging stator.

4. In a dynamometer, a swinging stator providing means for measuring torque, a rotor, field means providing flux interlinking the stator and the rotor, a generator for exciting said field means and having a stationary element mounted upon the swinging stator and a movable element which is driven from the rotor and which is concentric therewith, whereby torque applied to the generator is included along with the torque from the rotor to be measured by the swinging stator.

5. In a dynamometer, a swinging stator providing means for measuring torque, a rotor, field means providing flux interlinking the stator and the rotor, a generator for exciting said field means and having a stationary element mounted upon the swinging stator and a movable element which is rotary about a center different from that of said rotor, and a mechanical drive between the rotor and the movable element of the generator, whereby torque applied to the generator is included along with the torque from the rotor to be measured by the swinging stator.

6. A dynamometer comprising a swinging stator providing means for measuring torque, a rotor, field means providing flux interlinking the stator and the rotor, a generator for exciting said field means, said generator having a stationary element mounted upon the swinging stator and having a movable element driven from the rotor, a circuit connecting the generator and the field means, a variable resistance in the circuit, a governor responsive to and driven from the rotor to vary the resistance, said governor being also mounted upon said swinging stator, whereby torque applied to the generator and the governor is included along with the torque applied directly to the stator from the rotor, all of said torque being measurable on the stator.

7. In a dynamometer, a swinging stator providing means for measuring torque, a rotor, field means providing flux interlinking the stator and rotor whereby torque is transmitted from the rotor to the stator, an auxiliary machine having a stationary part on the stator and a movable part, a drive between said rotor and said movable part of the auxiliary machine, whereby torque for the auxiliary machine is supplied by the rotor and included along with the torque measured by the swinging stator.

8. A dynamometer comprising a swinging stator, a rotor driven by a prime mover, the latter having a certain speed-torque relationship, a field member providing flux interlinking the rotor and stator for torque transmission to the stator, a governor which moves in response to the speed of the prime mover, means adapting the governor to control said flux, and hence the torque transmission, in a manner such that the relationship between the value of torque transmission and prime mover speed on the one hand is substantially identical to the relationship between the value of prime mover torque and prime mover speed on the other hand, said identity being maintained over a substantially wide range of speeds.

9. A dynamometer comprising a swinging stator, a rotor driven by a prime mover having a known speed-torque relationship, a field member providing flux interlinking the rotor and the stator, an exciting circuit for the field member, resistances in said circuit, shunt switching means associated with the respective resistances, means responsive to the speed of the rotor adapted sequentially to operate said shunt switching means, the values of said resistances being such that under said sequential operation of the shunt switching means the exciting circuit is over a substantial speed range energized at all times in respect to speed in substantial proportion to the torque of the prime mover prevailing at said speed.

10. A dynamometer comprising a swinging stator, a rotor driven by a prime mover having a known speed-torque curve relationship, a field member providing flux interlinking the rotor and the stator, an exciting circuit for the field member, resistances in said circuit, shunt switching means associated with the respective resistances, means responsive to the speed of the rotor adapted sequentially to operate said shunt switching means, the values of said resistances being such that under said sequential operation of the shunt switching means the exciting circuit is over a substantial speed range energized at all times in respect to speed in substantial proportion to the torque of the prime mover prevailing at said speed, and an exciter in said exciting circuit driven by the rotor.

11. A dynamometer comprising a swinging stator, a rotor driven by a prime mover having a speed-torque curve of known form, a field member providing flux interlinking the rotor and the stator, an exciting circuit for the field member, resistances in said circuit, shunt switching means associated with the respective resistances, means responsive to the speed of the rotor adapted sequentially to operate said shunt switching means, the values of said resistances being such that under said sequential operation of the shunt switching means the exciting circuit is over a substantial speed range energized at all times in respect to speed in substantial proportion to the torque of the prime mover prevailing at said speed, an exciter in said exciting circuit and driven by the rotor, and means for adjusting the speed-responsive means to effect substantially equally close regulation at various rotor speeds.

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