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VARIABLE LIMIT SWITCH

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Fig. 1.

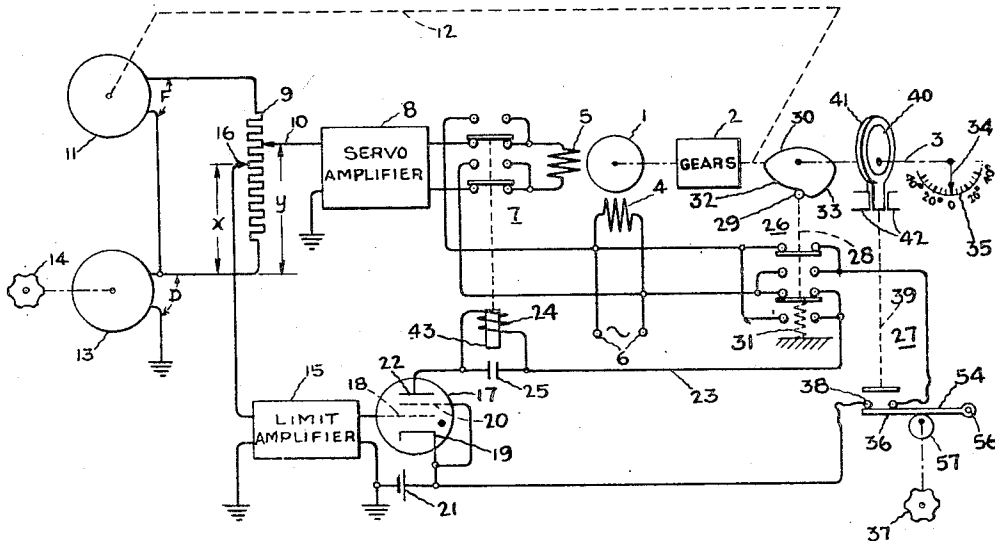
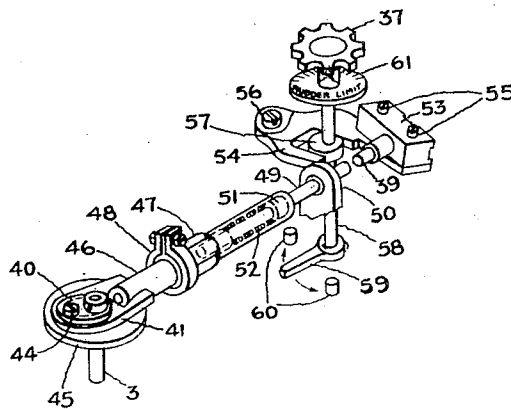


Fig. 2.



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UNITED STATES PATENT OFFICE

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VARIABLE LIMIT SWITCH

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This invention relates to an arrangement for limiting the angular travel of a rotating mechanism and more particularly, to a continuously adjustable limit switch.

Electrical servo systems are employed for a great many purposes, including the control of guns, searchlights and rotatable directive antennas. In certain applications, it is desirable to limit the angle of travel of the directed object and heretofore, with two-phase motors, this has been accomplished with limit arrangements of the "jam stop" variety which are somewhat crude and not adapted to variable limiting. In certain applications for example, it has been necessary in the past to provide special circuits to permit "backing out" from the limiting position.

It is an object of my invention to provide simple, variable and novel means for establishing a limit of travel of a moving mechanism.

It is a further object of my invention to provide means for controlling the return travel of a rotating mechanism from its limiting position.

Another object of my invention is to provide electronic means responsive to polarity variation of a single signal, to both effect a positive, non-jam, limit of output shaft travel on a servo system as well as to control the return of the shaft from its limiting position.

The invention will be more fully understood by referring now to the accompanying drawings wherein:

Fig. 1 is a schematic diagram of a servo system having a variable limit switch in accordance with my invention and

Fig. 2 illustrates the detailed structural embodiment of a portion of Fig. 1.

For purposes of disclosure, the invention will be described as employed in conjunction with a system for steering a ship, it being understood of course, that the invention has many other applications.

Referring to Fig. 1, a reversible electric motor 1 connected to gears 2 drives a shaft 3, the angular position of which may correspond to the angular position of the ship's helm or an instrument indicating this angular position. The motor 1 is illustrated as being of the two-phase type having a first-phase winding 4 and a second-phase winding 5. Winding 4 is connected to a source of alternating voltage at 6. Winding 5 is fed through a relay or solenoid operated switch generally indicated at 7 from a servo amplifier 8 which derives its input signal from the impedance 9 through a tap 10. The impedance 9 may

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be simply a resistor connected directly across the Selsyn or synchro 11 which provides a follow-up signal F through feedback linkage 12, this signal being directly related to the position of output shaft 3. Another Selsyn or synchro 13 provides a director signal D which is a measure of instantaneous heading error and which is counter-balanced in magnitude and polarity by the follow-up signal F when the output shaft is at rest and not in the limits. In order to alter the angular position of shaft 3 as when calling for a change in course, the magnitude and polarity of the director signal D may be controlled in the pilot house by a knob 14 which sets the desired course of the ship. When a director signal at D causes a voltage to be impressed across the input of the servo amplifier 8, motor 1 operates through gear train 2 to position shaft 3 and feedback linkage 12, thus restoring the balance between the follow-up signal F and the new director signal D whereupon the two voltages cancel each other out completely, the net voltage applied to the amplifier 8 becomes zero, and the motor 1 stops. The output shaft 3 will thus be repositioned in accordance with the changed director signal D. The arrangement thus far described is well understood and is commonly referred to in the art as a servo system.

The manner in which servo operation may be limited to restrict the angular travel of shaft 3 will now be described. From Fig. 1, it will be observed that the director signal D which is applied to the servo amplifier 8 may also be applied to the limit amplifier 15 through a tap 16 on resistor 9. The limit amplifier 15 as well as the servo amplifier 8 is connected to ground. The output from the limit amplifier 15 is applied to an electric valve 17 by means of a connection to a grid 18. The cathode 19 of the valve 17 is connected to a second grid 20 which is also connected to ground through a bias source 21. The valve 17 is of the gaseous type known in the art as a thyatron. The anode 22 of the valve 17 is connected to cathode 19 through an output circuit 23 comprising a winding 24, in parallel with which is connected a condenser 25, the circuit of a polarity reversing switch generally indicated as 26, power source 6, and the circuit of a limit switch generally indicated as 27.

Polarity reversing switch 26 comprises an armature 28 having switch contact members at one end and a bearing 29 disposed at the opposite end to ride on a cam 30 which is rigidly connected to the output shaft 3 adapted to rotate in a plane normal thereto. Armature 28 is loaded

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by a spring 31 so as to exert an upward pressure tending to insure its continuous cooperation with cam surfaces 32 and 33. In Fig. 1, cam 30 is shown as being in a zero or neutral position which is that existing when the ship is proceeding along a straight course. Cam 30 is so designed that armature 28 upon operation will cause the output circuit 23 to be supplied with a voltage from source 6 of a predetermined polarity depending upon whether roller 29 is riding on cam surface 32 or on cam surface 33. Thus, when roller 29 is riding cam surface 32, the armature 28 will close the back contacts of switch 26 (upper position) thus providing the anode 22 with a voltage of a first polarity, whereas when roller 29 is following cam surface 33, the armature 28 will close the front contacts of switch 26 (lower position) thus providing the anode 22 with a voltage from source 6 of opposite polarity. Assuming that the arrow 34 diagrammatically shown as pointing to zero on scale 35 represents the neutral position of the helm when the ship is following a straight heading, it will be apparent that as the helm is moved from its neutral position that the action of cam 30 and of reversing switch 26 will be such as to apply a voltage of a predetermined polarity to the anode 22 of output circuit 26.

Looking now at the diagrammatic representation of limit switch 27 shown in Fig. 1, it will be seen to comprise an adjustable member 36 operable by a knob 37. Member 36 has contacts 38 mounted thereon which may be bridged by the vertical movement of an armature 39 in response to the turning action of an eccentric cam 40 which is rigidly connected to the output shaft 3 in a plane normal thereto and is adapted to rotate therewith within an eye member 41 slidably positioned within bearings 42 provided to guide the movement of the eye member 41. It will be seen that the member 36 may be arranged to close contacts 38 at any desired position of output shaft rotation by merely adjusting the spacing between the contact carrying member 36 and the armature 39. When contacts 38 are bridged, the anode circuit 23 is supplied with a voltage which will cause valve 17 to fire, provided that a signal exists on the grid 18 which is of a proper polarity and magnitude.

When the anode circuit 23 is energized, a current will flow through winding 24, and the solenoid armature 43 will move to open the back (lower) contacts and close the front (upper) contacts of switch 7. This action will immediately interrupt the amplified signal from the servo amplifier 8 to the phase winding 5 of motor 1 and will shunt winding 5 across winding 4 through the front (upper) contacts so as to immediately effect dynamic braking of the motor 1.

In Fig. 2, there is shown in more detail, the actual structural features of the limit switch 27 together with the armature linkage which is cam operated from shaft 3. Elements of Fig. 2 which correspond to elements schematically illustrated in Fig. 1, are represented by like reference numerals. Eccentric cam 40 is secured, by means of a pin 44, to an annular table 45 which is in a plane normal to and forms a part of shaft 3. The upper surface of table 45 acts as a support for the eye member 41. Connected to eye member 41 is a tube 46 which is disposed within a cylindrical housing 47 having at one end, a collar 48 adapted to securely clamp the housing 47 to tube 46. A rod 49 is supported at one end by a bearing 50 and is adapted at its other end to slide within the housing 47 and the tube 46. The rod 49 is

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constructed with a shoulder 51 to prevent its exit through the right opening of the housing 47, which is smaller in diameter, and to act as a stop for one end of a spring 52 which is concentrically disposed between the housing 47 and the rod 49. Spring 52 exerts a compression force between the tube 46 and shoulder 51 tending to keep rod 49 yieldably extended from the eye member 41. The right end of rod 49 is adapted to engage the armature 39 of a switch 53 having two contacts brought out through terminals (not shown). The housing of the switch 53 is mounted on a J-shaped bracket 54 by bolts 55. The bracket 54 is adapted to turn about a pivot 56 which is fixed with respect to a support (not shown). The member 54 may be positioned to vary the gap between the right end of rod 49 and the armature 39 by means of cam member 57 which is disposed between the legs of the J member and in the same plane. Cam 57 is rigidly fixed and adapted to be rotated by a shaft 58 by means of a knob 37. The angular travel of shaft 58 from a neutral position is limited by a member 59 keyed to shaft 58 and operating between two stops 60. A scale 61 which remains stationary is calibrated to indicate how many degrees shaft 3 may be displaced from a neutral position before armature 39 bridges the contacts of switch 53. It will be seen therefore that the above-described arrangement makes it possible by merely adjusting knob 37 to variably set the point at which circuit 23 will be closed with respect to any angular position of shaft 3.

With the foregoing understanding of the elements and their organization, the operation of the complete system described in Fig. 1 will now be explained. Let us take an actual example wherein a ship has been following a straight course and it is now desired to effect a 90° change in heading but to place a 20° limit on the angle through which the rudder may be turned.

Rudder limit knob 37 is first set to adjust the rudder limit switch contacts 35 to a position whereby they will be bridged by armature 39 when the helm has turned 20°. A director signal D is now produced at 13, by turning the knob 14, thus calling for servo operation to move the rudder to the right from its neutral position.

The angular position of knob 14 corresponds at all times to the angular heading which the ship is to follow. In the present example, let us assume that the knob is set say at 90 degrees, and the ship has been traveling a straight course and is headed due east. Now, in order to change the course heading 90 degrees, say to south, the knob is turned to a position corresponding to 180 degrees (due south) and the system will then operate to effect turning of the ship until it heads south. As the turning of the ship progresses, the departure between its actual instantaneous heading and the desired heading, as set by knob 14, will continuously decrease so that there will be a continuing reduction in heading error. When the ship eventually reaches its on-course position, the heading error will have been reduced to zero and therefore the director signal D will again become zero.

Servo operation per se is well understood. Briefly, Selsyn 13 produces a director signal D, which is transmitted to the amplifier 8 to drive two-phase motor 1 in a direction depending upon the polarity of the director signal D which, in the instant case, is chosen such as to effect right helm. Motor 1 will cause rotation of shaft 3 and, in addition, will drive feedback linkage 12 so as to reduce the voltage unbalance created by

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the change in director signal D with respect to the follow-up signal F. Helm 34 will continue to turn until the initial signal demand is satisfied or until servo operation is otherwise interrupted. As the output shaft 3 rotates, cam 30 will be rotated so that roller 29 will ride on cam surface 32 and the back contacts of switch 26 will be closed thus insuring that the voltage from source 6 to be supplied to anode 22 will be of the same polarity as the director signal D. At the instant that voltage y initiates servo operation, a voltage x , also taken from resistor 9 will be transmitted to the limit amplifier 15 and applied to the grid 18 of valve 17.

As the shaft 3 rotates, eccentric cam 40 is also rotated within the eye member 41 causing the armature 39 to descend into closing relationship with contacts 38. Closure will be effected when the rudder has turned 20° at which instant, the anode circuit 23 will become energized, valve 17 will fire, armature 43 will open the back contacts of switch 7 thereby interrupting the servo amplifier signal to the motor 1 and the front contacts of switch 7 will be closed whereby winding 5 will be shunted across the source of alternating voltage 6 in parallel with winding 4 thereby dynamically braking the motor 1.

It will be appreciated of course that braking may be accomplished in any known manner. For example, load torques act on the output shaft 3 when in the limits contacts may be arranged in switch 7 to energize a friction or other type brake to insure positive braking.

At the completion of a change in course, it is particularly desired to control the point at which the rudder leaves the limiting position in order to shorten the time required to set on a new course. To avoid any possible loss of time and to obtain a tighter turning circle, the rudder is held in the limiting position until the turn is nearly completed before it relinquishes control. Then the arrangement is adapted to move the rudder quickly to neutral or beyond to check the turning movement of the ship. Once the valve 17 has been energized, it can not be de-energized until a change in the signal D has caused the input to the limit amplifier 15 to be reduced to zero. This signal will become zero once the ship has completed its turn at which time the heading error will no longer exist. Bias voltage 21 is so adjusted that valve 17 will cease firing when the input to amplifier 15 is zero. When the valve 17 ceases firing, switch 7 will become de-energized and armature 43 will drop to its normal position to close the back contacts thus connecting the director signal D of opposite phase polarity to winding 5 whereby the motor 1 will be driven in the reverse direction out of the limits.

It will be apparent that by decreasing the voltage fraction x of F, it is possible to cause the limit circuits to hold the motor 1 in the braked position until D has decreased to some value smaller than that which drove the motor into the limiting position. If x is made zero, the motor 1 will be held until D is zero whereupon the motor will be driven rapidly back to its zero or neutral position. Thus x can have any value between 0 and y , though it should be restricted to a maximum value slightly less than y to insure that the input to amplifier 15 will be of the same polarity as D when the motor is driving the helm into a particular limiting position.

While I have shown a particular embodiment of my invention, it will be understood, of course, that I do not wish to be limited thereto since

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many modifications may be made, and I therefore contemplate by the appended claims to cover any such modifications as fall within the true spirit and scope of my invention.

What I claim is:

1. An arrangement for variably limiting angular rotation of an output shaft comprising signal means, a servo for rotating said shaft in either direction in response to a signal, electronic means having its input connected to said signaling means, said electronic means further either direction in response to a signal, electric valve having an anode circuit, switch means adjustable to energize the anode circuit at a predetermined limit of shaft rotation, and actuating means responsive to anode circuit energization for arresting rotation of said shaft.

2. An arrangement for variably limiting angular rotation of an output shaft comprising directional signaling means, a servo for rotating said shaft in response to a signal, an amplifier having its input connected to said signaling means and further comprising an output circuit, means responsive to shaft position for determining the polarity of the voltage applied to said circuit, means adjustable to close the output circuit at a predetermined limit of shaft rotation, and means responsive to circuit closure for arresting rotation of said shaft.

3. An arrangement for variably limiting angular rotation of an output shaft comprising, directional signaling means, a servo for rotating said shaft in response to a signal, an electric valve fed from said signaling means and further comprising an anode output circuit, a switch operable to open and close said circuit in dependence upon said shaft position, and a relay responsive to circuit closure for arresting rotation of said shaft.

4. An arrangement for variably limiting angular rotation of an output shaft comprising, directional signaling means, a servo for rotating said shaft in response to a signal, an electric valve fed from said signaling means and further comprising an anode output circuit, a cam integral with and adapted to move with said shaft, a linkage adapted to ride on said cam, contact means adjustable to energize said circuit upon a predetermined travel of said linkage, and actuating means responsive to anode circuit energization for arresting rotation of said shaft.

5. An arrangement for variably limiting angular rotation of an output shaft comprising, directional signaling means, a servo for rotating said shaft in response to a signal comprising a reversible motor having two windings, an amplifier having its input connected to said signaling means and comprising an output circuit, a switch operable to open and close said circuit in dependence upon said shaft position, a relay responsive to circuit energization, and means actuated by said relay for opening one of said windings.

6. An arrangement for variably limiting angular rotation of an output shaft comprising, directional signaling means, a servo comprising a motor having two phase windings for rotating said shaft in response to a signal, an amplifier having its input connected to said signal means and comprising an output circuit, connections for connecting a source of voltage to said circuit and a first phase winding, means adjustable to close said circuit at a predetermined angle of shaft rotation, relay means responsive to energization of said circuit, and switch means for

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connecting the other phase winding in parallel with said first winding to effect dynamic braking of the motor.

7. An arrangement for variably limiting angular rotation of an output shaft comprising, means for producing a polarized signal, a servo for rotating said shaft in response to said signal, an amplifier having its input connected to said signaling means, an output circuit connected to said amplifier, a means adjustable to close said circuit at a predetermined angle of shaft rotation, means responsive to circuit closure for braking said shaft, said braking means being adapted to release said shaft only upon receipt of a signal having a polarity opposite to that effecting said braking.

8. An arrangement for variably limiting angular rotation of an output shaft comprising, means for receiving a signal of alternating polarity, a follow-up circuit for effecting shaft rotation in response to said received signal, means for interrupting said follow-up circuit, a limit amplifier responsive to said receiving means further comprising an electric valve having an anode circuit, contact means movable to open and close said anode circuit in dependence upon a predetermined limit of shaft rotation, a reversible switch for applying to said anode circuit, a voltage of a polarity dependent upon the direction

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of shaft rotation from a normal position, and a relay energized by anode circuit closure for operating said interrupting means whereby rotation of said shaft is arrested.

9. An arrangement for variably limiting angular rotation of an output shaft comprising, means for generating an alternating signal of selective polarity, a servo for rotating said shaft in response to a signal, an electric valve having its input connected to said generating means and further comprising, a cam integral with said shaft, a reversible switch operable by said cam to apply to said output circuit, a voltage of the polarity selected, a limit switch variable to close said output circuit upon reaching a predetermined angular travel of said shaft, and solenoid means for braking said shaft upon closure of said output circuit.

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The following references are of record in the file of this patent:

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Certificate of Correction

Patent No. 2,492,745

December 27, 1949

ALFRED D. HAMMES

It is hereby certified that errors appear in the printed specification of the above numbered patent requiring correction as follows:

Column 4, line 1, for the word "exist" read *exit*; column 6, line 12, strike out the words and comma "either direction in response to a signal," and insert instead *comprising an output circuit including an*;

and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 16th day of May, A. D. 1950.

[SEAL]

THOMAS F. MURPHY,
Assistant Commissioner of Patents.

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