

June 16, 1953

R. GOLDSTEIN

2,642,557

FAIL SAFE LIMIT SWITCH

Filed Dec. 9, 1949

2 Sheets-Sheet 1

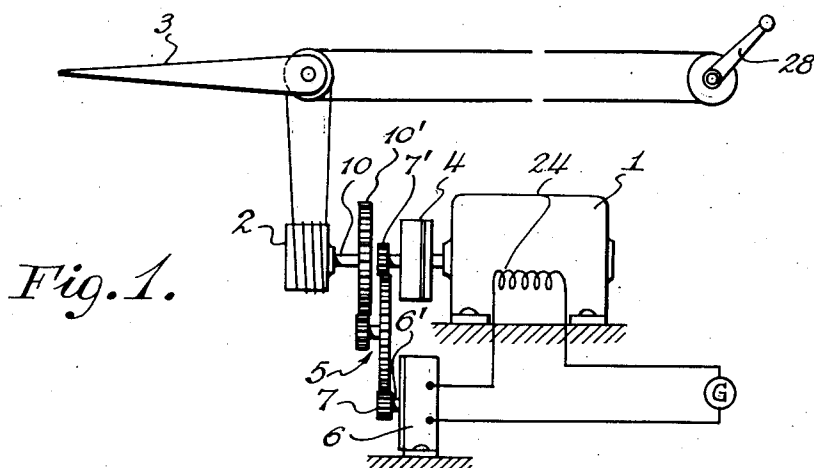
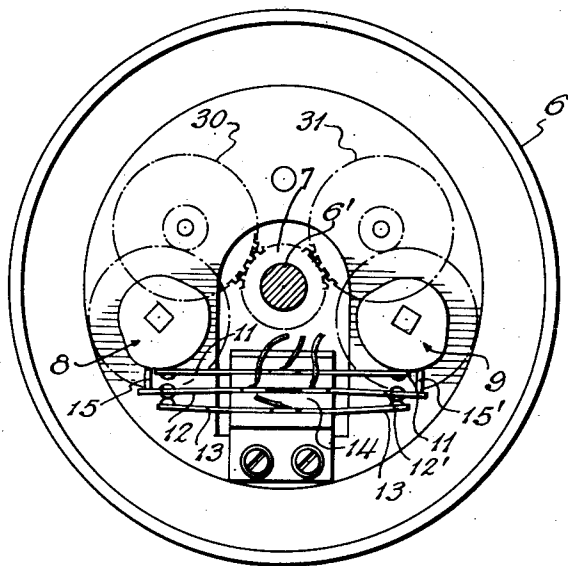


Fig. 2.



INVENTOR
RAYMOND GOLDSTEIN
BY
Herbert H. Thompson
his ATTORNEY.

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Fig. 3A.

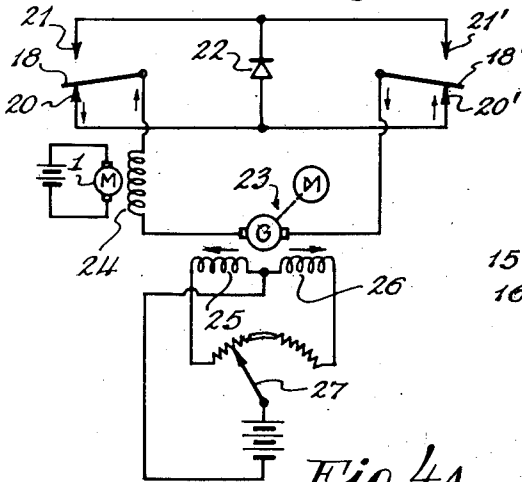


Fig. 3.

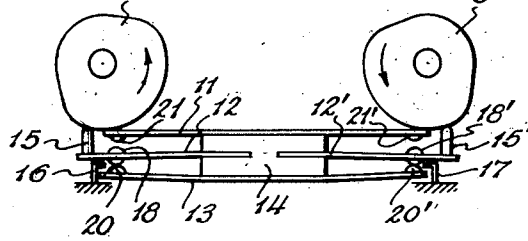


Fig. 4.

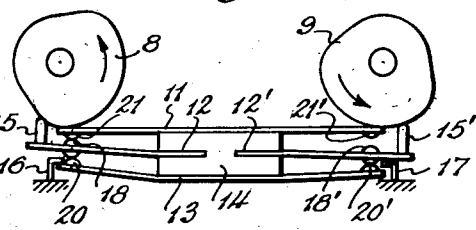


Fig. 5.

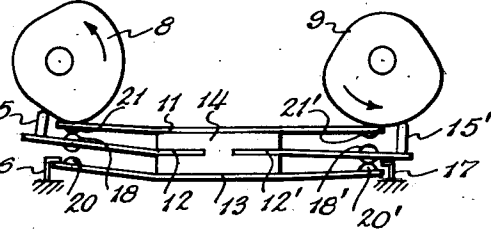


Fig. 6.

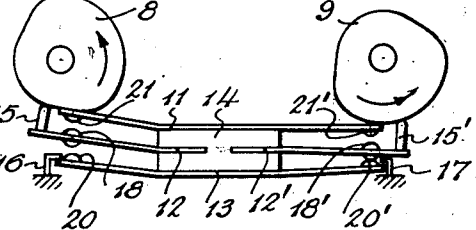


Fig. 5A.

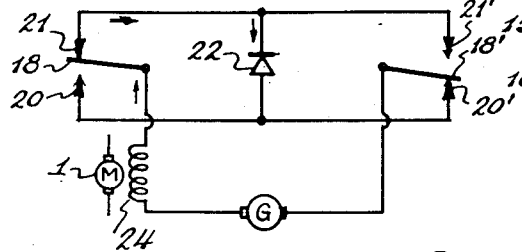
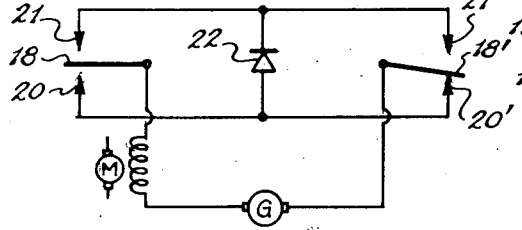


Fig. 6A.



INVENTOR

RAYMOND GOLDSTEIN

BY

Herbert H. Thompson
his ATTORNEY.

UNITED STATES PATENT OFFICE

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FAIL SAFE LIMIT SWITCH

Raymond Goldstein, Woodside, N. Y., assignor to
The Sperry Corporation, Great Neck, N. Y., a
corporation of Delaware

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This invention relates to limit switches for reversible servomotors designed to render such switches "fail safe," that is, to make certain, when the limiting position of the servo in either of two directions is reached, that it will be stopped even though the rectifier or rectifiers usually employed in such switches fail.

My invention is hence especially adapted for locations where the failure of the servo to stop, when the limit is reached, might lead to serious accidents, such as in the servomotors used to operate the control surfaces or trim tabs of airplanes.

In my invention, I provide a special switching arrangement such that in case the servo fails to stop in response to the throwing of the blocking rectifier into the circuit, any further movement of the servo will open the circuit and positively stop the motor.

At the present time, it is the practice to employ in connection with each limit switch, a separate rectifier so that when one limit is reached, the current flow in the prevalent direction will be blocked by one of the rectifiers, leaving, however, a closed path for the reverse current through the other rectifier when the current to the servo is reversed, so that the servo stands ready to operate in the opposite direction without interference.

It is a characteristic of selenium rectifiers that when one fails, it will conduct current in both directions so that the servo will continue to rotate when the blocking rectifier is thrown in. While it is usual to provide a slipping clutch and/or a throw-out clutch to avoid serious damage, accidents are likely to occur unless the servomotor is positively and automatically stopped upon such a failure. With my invention, I provide a positive means for opening the circuit of the servomotor in case of failure of either rectifier.

By my invention, I further simplify the prior arrangement which required the use of two rectifiers, so that only one need be employed, thus cutting the chance of rectifier failures in half, and lessening the cost.

Referring to the drawings, showing one form of my invention,

Fig. 1 is a diagrammatic showing of a servomotor operating a trim tab surface on an airplane showing the location of my limit switches;

Fig. 2 is a front elevation of the interior of the gear box and limit switch mechanism;

Figs. 3, 4, 5 and 6 are front elevations of the limit cams and contacts and the switches con-

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trolled thereby showing the position of the cams during normal operation and as the limiting position in one direction is approached and reached; and

Figs. 3A, 4A, 5A and 6A are wiring diagrams showing the switch as connected in circuit between the generator and reversible servomotor corresponding to each position of the cams and contacts in Figs. 3, 4, 5 and 6, respectively.

Referring first to Figs. 1 and 2, 1 represents any suitable form of reversible servomotor preferably of the direct current field controlled type. It is shown as connected to the cable drum 2 of a trim tab or other control surface 3 through a disconnectable friction clutch 4 and double reduction gearing 5 connecting pinion 7' on the clutch shaft and gear 10' on shaft 10 of drum 2. My limit switch mechanism is shown enclosed in a casing 6, the switch mechanism being geared to the aforesaid shaft 10 through gear 10', reduction gearing 5 and pinion 7 on shaft 6'. Two limit cams 8 and 9 are driven through other reduction gear trains 30 and 31 from the shaft 6' and are so arranged that each cam will open one of two groups of contacts as the limit is reached in each direction.

The aforesaid contacts preferably comprise a plurality of spring arms 11, 12, 12' and 13, which extend in both directions from a central insulating block 14 in which they are held. The outer ends of each spring are given an upward bias such that the two ends of the upper spring arm 11 are kept against the surfaces of the cams 8 and 9, as shown, and pins 15, 15' on the ends of springs 12 and 12' are kept against or close to the surface of the cam. The bottom spring 13 is preferably limited in its upward movement by fixed stops 16, 17 or by giving the ends insufficient bias to bend upwardly beyond the position shown in Figs. 5 and 6. In the normal running position, the contacts are in the positions shown in Fig. 3 with the double contacts 18 and 18' held against contacts 20 and 20' on the lower spring by the engagement of the pins 15 and 15' with the cam surfaces. At the same time, the upper contacts 18 and 18' are held out of engagement with contacts 21, 21' on the upper spring. If the cam 8 is further rotated in a counterclockwise direction, the pin 15 rides off the larger portion of the cam onto a smaller, noncircular portion (Fig. 4). This results in closing the upper contact 18 against contact 21. Lower contact 18, however, remains in engagement with lower contact 20 because of the resiliency of the arm 13. As the cam con-

tinues to turn (Fig. 5), the middle arm 12 will move its lower contact 18 away from contact 20 on arm 13, since the arm 13 cannot follow the upper arm in this extreme position, due either to its weaker bias or the use of the limit stop 16. This is the position in which the servomotor is normally stopped because current flow to the motor in the prevailing direction can only occur through the selenium rectifier 22, which is so connected as to permit flow only in the opposite direction. Therefore, Fig. 5 represents the normal limiting position of the contacts. In case, however, due to failure of the selenium rectifier or otherwise, further rotation occurs, the contacts assume the position shown in Fig. 6. In this position, upper contact 21 is moved further upwardly, thus breaking contact between 18 and 21 and severing all circuits to the motor. During all of this cycle the opposite contacts remain as in Fig. 3.

Referring now to the corresponding wiring diagrams, Figs. 3A to 6A, one of the two multi-position switches is represented at 18, 20 and 21 and the other 18', 20' and 21'. The single selenium rectifier is shown at 22 and the servomotor at 1. The servomotor is shown as having a separately excited armature and field, the armature being continuously excited from a suitable source and the field 24 being connected to a separately controlled source of supply. A Ward-Leonard system is shown having a motor generator set 23, in which the double wound generator field 25, 26 is controlled and reversed through reversing controller 27, as diagrammatically shown in Fig. 3A.

In the position shown in Fig. 3A with all contacts closed and assuming current to flow in the direction of the arrows, the motor will be excited to drive the cable drum and cams in the direction shown by the arrows in Fig. 3. In this position, it will be observed that the rectifier is out of the circuit. As the cam 8 continues to rotate (Fig. 4A), both contacts 18, 20 and 18, 21 are closed, thereby establishing a make-before-break condition to prevent the switch from opening the main circuit before the upper contacts are closed, thereby closing the circuit through rectifier 22 to the motor field 24. Further rotation of the cam will break the lower contacts, as described, leaving the upper contacts closed, so that the only supply to the field 24 of the motor is through the selenium rectifier 22, which is so arranged as to prevent passage of current in the direction shown by the arrows. The field of the motor will therefore be killed and the motor normally stopped.

It will be observed, that in case the current is reversed to drive the servomotor in the opposite direction with the cams positioned as in Fig. 5 (by opposite rotation of controller 27) a circuit will at once be established through the motor field because the rectifier will pass current in the reversed direction. Therefore, the cams will start rotating in the opposite direction and the contacts will quickly assume the position shown in Fig. 3, but rotating oppositely to the arrows. It is readily apparent that if this rotation is continued, the cam 9 will cause a similar sequence of operations of the associated contacts 18', 20', 21' beneath it. The reversal of the current in the field of the servomotor is shown as accomplished by reversing controller 27 in the exciter circuit for the field windings 25, 26 of the generator 23 in a manner usually employed in the Ward-Leonard system.

In case, however, that the rectifier fails and continues to pass current in the position shown in Figs. 5 and 5A, the cam 8 will continue to rotate counterclockwise until the closed contacts 18, 21 are opened, as shown in Figs. 6 and 6A. When this happens, the supply of current to the field 24 is completely severed and the servomotor will stop. In such case, the mechanism must be reset by hand as by operating the hand controller, represented at 28 (Fig. 1) to turn the trim tab 3 until the cams reset the contacts for reverse operation (Fig. 5). Obviously, a similar sequence would follow with the servo rotating in the opposite direction and cam 9 approaching its limiting position.

Disconnectable slip-friction clutch 4 not only operates as a safety device to prevent overrun but also permits resetting of the control surface and contact means from handle 28 without rotating the servomotor 1.

From the foregoing, it will be apparent that my invention will positively stop the servomotor even if the rectifier in the limit switching arrangement fails. My invention also possesses the advantage that only one rectifier is employed and this rectifier is normally entirely out of the circuit so that its life is prolonged.

As many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, 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.

What is claimed is:

1. A fail-safe limit switch arrangement for reversible servomotors, comprising a reverse current controller, a single rectifier, a limit cam for each direction of movement of the servomotor, a multi-throw switch operated by each cam, each switch having at least two positions besides the normal running position, one position in which the main circuit to the servomotor is broken and said rectifier placed between the supply and said motor to block current flowing in the prevailing direction, but permitting current flow through the other switch upon reversal of said controller, and a second position in which the circuit through said rectifier is broken, thereby preventing operation of said motor regardless of the position of said controller.

2. A fail-safe limit switch for a power operated control surface of aircraft and the like, including a reversible servomotor, a disconnectable clutch between said servomotor and the surface, a rectifier, a limit switch for placing said rectifier between the source of supply and the servomotor when a limiting position of said surface is reached, so that current of the prevailing polarity will be blocked, but passage of current of the opposite polarity permitted for reverse operation, means for opening said switch upon rotation of the surface beyond its limit in either direction, and means including said clutch for manually rotating said surface and switch to reset the same without rotating said servomotor.

3. A fail-safe limit arrangement for reversible motors including at least one normally ineffective rectifier, a multi-position limit switch for initially placing said rectifier in shunt between the source of supply and the motor as the limit is approached, means on said switch for then opening the direct supply from said source to said motor so that current of the prevailing polarity

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will be blocked by the rectifier but passage of current of the opposite polarity permitted for reverse operation, and means also on said switch operative upon further rotation of the motor beyond its normal limit for opening the circuit to said rectifier whereby no current can reach said motor regardless of its polarity or the condition of the rectifier.

4. A fail-safe limit system for reversible motors including at least one normally ineffective rectifier, a four-position limit switch normally passing current directly to said motor, a limit cam controlling movement of said switch through each of three further positions, said cam, as a limit is approached, first placing said rectifier in parallel with the main circuit to the supply, then in the second position opening said main circuit, and in case the servomotor fails to stop in such event, finally in its third position opens the circuit through said rectifier, and means whereby said switch may be manually reset to close said circuit in the opposite direction.

5. A fail-safe limit system for reversible servomotors, comprising a reverse current controller, a rectifier, a limit cam for each direction of movement of the servomotor, a multi-throw switch operated by each cam, each switch having at least three positions besides the normal running position, one position in which the rectifier is placed in parallel between the supply source and servomotor and in its second position the main circuit to the servomotor is broken and said rectifier left between the supply and said motor to block current flowing in the prevailing direction, but permitting current flow through the other switch upon reversal of said controller, and a

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third position in which the circuit through said rectifier is broken, thereby preventing operation of said motor regardless of the position of said controller.

6. In a fail-safe limit system for limiting the rotation in each direction of a rudder or the like, a pair of cam-operated switches, each comprising three normally spaced superimposed spring contact arms, each having a contact, a cam, all three arms being biased toward the cam, the first arm adjacent the cam normally resting thereagainst, a pin on the middle arm also normally bearing on said cam, means for limiting the movement of the third arm toward said cam, the cam being so shaped that in one position the pin holds the contact on the middle arm away from the first arm and against the contact on the third arm, in the second position all three contacts are closed, in the third position the contacts of the first and second arms are closed and in the fourth position all contacts are open, and a reversible servomotor controlled by the contacts of said switches.

RAYMOND GOLDSTEIN.

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