Oct. 22, 1957

R. B. HIGLEY ET AL
REVERSING MECHANISM FOR A
HYDRAULICALLY-OPERATED
SCANNING ANTENNA

2,810,262

Filed May 3, 1954

2 Sheets-Sheet 1

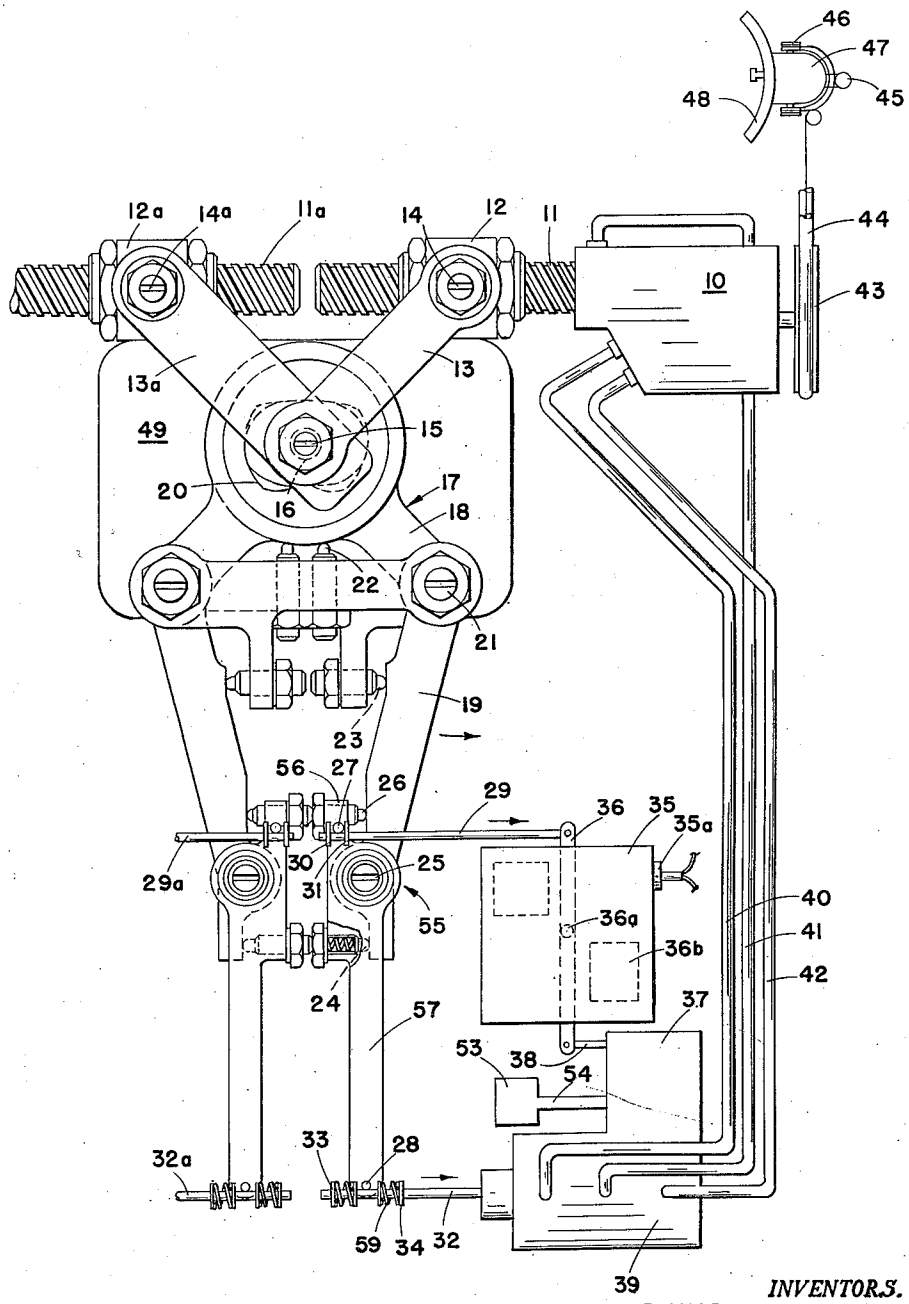


FIG. 1

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FIG. 2

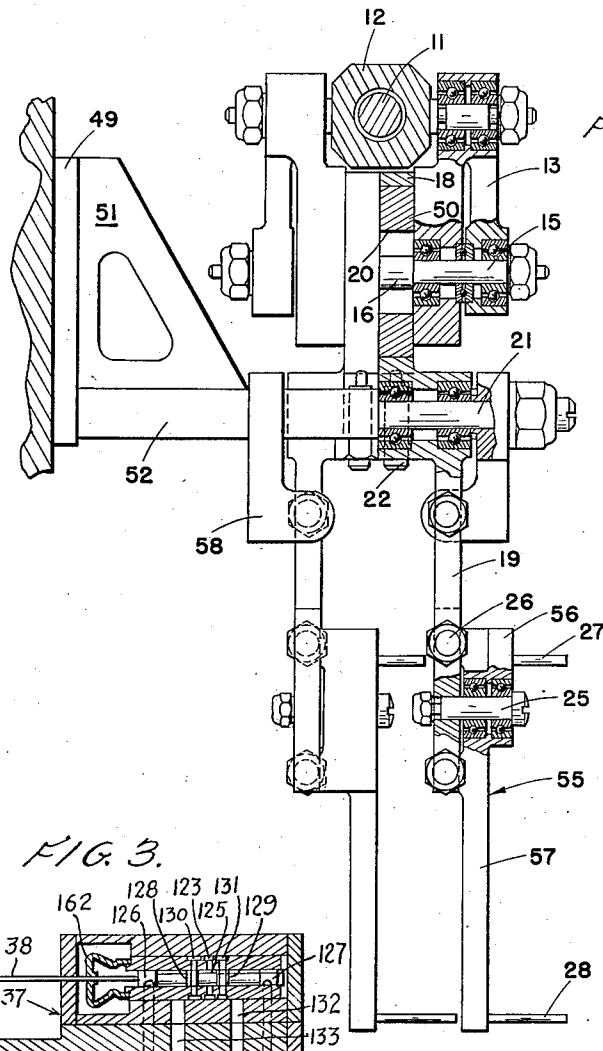
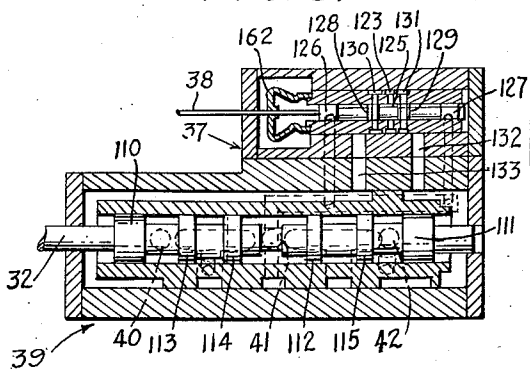


FIG. 3.



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2,810,262

Patented Oct. 22, 1957

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REVERSING MECHANISM FOR A HYDRAULICALLY-OPERATED SCANNING ANTENNA

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Application May 3, 1954, Serial No. 427,139

11 Claims. (Cl. 60—97)

This invention is concerned with a hydraulic type mechanical limit stop. More particularly this invention concerns a hydraulic type mechanical limit stop for a hydraulically driven radar antenna or the like.

Various means have been developed for limiting the angular elevation and angular train of a radar antenna. When the driving means for the antenna is a relatively low-powered device the use of rubber bumpers at the desired limits has been suggested. In hydraulically operated antenna mounts such mechanical limit stops have been provided for each axis of the antenna. The field of use of the antenna, in the latter devices, is limited to a rectangular shape since the azimuth limit and the elevation limit are on single axes. Further, the response of prior mechanical limit stops has been relatively low and does not provide the rapid response necessary in air craft scanning radar. In some instances, electrical means have been employed to limit the movement of various antennas. Use of electrical means, such as microswitches, is dependent upon satisfactory operation of the electrical equipment. Therefore, it has been found more satisfactory to provide a hydraulic type mechanical limit stop means which is in no way dependent upon the electrical circuit and provides rapid response.

The instantly developed hydraulic type mechanical limit stop enables the antenna to train and elevate and be limited in its movement to any desired field such as a circular or ovoidal pattern, as distinguished from the restrictive rectangular pattern of the prior art devices. Provision of a circular or ovoidal pattern of movement limit permits the antenna to train and elevate to a greater degree. The universal action of this hydraulic type of stop permits the stop to be a combined function of both the elevation and azimuth of the antenna as distinguished from the prior stops which are mere individual functions of either elevation or azimuth. In addition the instant device is capable of faster response than conventional limit stops. The particular limit stop herein disclosed is peculiarly adapted for airborne radar antenna and infrared scanners.

It is therefore an object of this invention to provide a hydraulic type mechanical limit stop.

A further object of this invention is to provide a radar antenna limit stop of the hydraulic mechanical type.

A still further object of this invention is to provide a hydraulic type mechanical stop for controlling the limit of an antenna moving in elevation and azimuth.

A further object of this invention is to provide a novel mechanical linkage for an antenna limit stop.

An additional object of this invention is to provide a hydraulic type mechanical limit stop for an antenna drive system, rate controlled by a torque motor.

A further object of this invention is to provide a hydraulic type mechanical limit stop for a hydraulically driven radar antenna.

A still further object of this invention is to provide a hydraulic type mechanical limit stop which permits a radar antenna to scan in a circular pattern.

An additional object of this invention is to provide a limit stop for mechanically overriding electrical signals controlling a hydraulic motor on a radar antenna drive mechanism.

A further object of this invention is to provide a cam-type limit stop for controlling auxiliary control rods capable of overriding electrical signals affecting the rate and direction of fluid flow in a hydraulic motor drive device.

A still further object of this invention is to provide a lost motion device and an oscillation preventing device in association with the auxiliary control rods and flow rate controller.

Other objects of invention will become apparent from the following description taken in connection with the accompanying drawings, in which

Fig. 1 represents a plan view of the over-all device in combination with a schematically shown radar antenna drive means;

Fig. 2 represents a side view of the limit stop of the mechanical linkage as illustrated in Fig. 1;

And Fig. 3 represents a typical rate controlling valve and slave valve combination.

The basic parts of the antenna drive means are shown in Fig. 1. In normal operation, hydraulic fluid is fed by the pump 53 through feed line 54 to a pilot valve 37 which, in turn, controls the main hydraulic or slave valve 39. High and low pressure lines 40 and 42 conduct the hydraulic fluid to a hydraulic motor 10. The hydraulic motor is driven in a direction dependent upon which of the lines 40 or 42 is in the high pressure position as dictated by the setting of the valve 39. The hydraulic fluid in the motor 10 is returned to the main valve through the opposite line 42 or 40. Line 41 allows the motor leakage oil to return to the pump. The hydraulic motor 10 rotates a drive pulley 43 which in turn drives a continuous cable 44. This continuous cable is wound around pulleys 46 and windlass 45 is adapted to move the radar antenna 48. It is to be understood that in illustrated Fig. 1 only one-half of the conventional radar antenna drive system is shown. The complete drive system includes two hydraulic motors and their associated equipment. The illustrated antenna mount and driving system for the radar antenna itself forms no part of the instant invention. A full explanation of the antenna mounting device and driving device may be seen in U. S. Patent No. 2,654,031, dated September 29, 1953, issued to W. D. Mullins, Jr., et al. In the system illustrated in Fig. 1 a torque motor 35 is provided to control the rate of fluid flow to the hydraulic motor 10. The torque motor 35 includes an armature 36 pivoted centrally thereof by a torsion bar 36*a* and adapted to operate a pilot valve rod 38 to control the pilot valve settings. Electrical signals are fed into the coil 36*b* of the torque motor 35 to move the armature 36 in a push-pull action to regulate the pilot valve 37 through the linkage 38. A proportional solenoid or any electromechanical transducer may be employed in place of the torque motor.

In addition to rotating the drive pulley 43 in either of two directions, as explained in the above-mentioned patent, the hydraulic motor 10 likewise rotates the screw 11 in either of two directions. A nut 12 is provided which freely rides on the threads of the screw 11. A flat lever 13, shown as a pair in Fig. 2, is pivotally connected to the nut 12 at point 14. The threaded shaft 11*a* is likewise rotated in one of two directions by another hydraulic motor (not shown) and a screw nut 12*a* moves thereon. A lever arm 13*a* is pivotally attached to the nut 12*a* at 14*a*. The arms 13 and 13*a* are attached to a common pivot point at 15. Extending concentrically from the common pivot point 15 is a stub shaft or cam follower 16 which rides in a cut-out space hereinafter

described. In the illustrated modification a cranked, first-order lever **17** is provided pivotally secured at **21** to a support arm **52**. The cranked lever **17** comprises an upper arm **18** and a lower arm **19**. The upper arm **18** is of cylindrical end configuration and is adapted to receive a removable cam piece **50**, as seen in Fig. 2. The removable cam piece **50** is shaped to provide a cam surface **20** of any desired configuration. This configuration is normally circular or ovoidal, dependent upon the desired movement limits of the radar antenna. In operation of the radar antenna in a position away from its predetermined circular or ovoidal limits, the cam follower **16** does not touch the cam surface **20**. When, however, the antenna arrives at a predetermined limiting point, as determined by the position of the nuts **12** and **12***a* traveling on the screws **11** and **11***a* and the change in angularity of arms **13** and **13***a*, the cam follower **16** will contact the cam surface **20**. This contact will result in the cranked, first-order lever **17** pivoting about the fixed pivot point **21**. Movement of the arm **18** of the lever **17**, of course, results in a following movement of the arm **19**. A second, first-order lever **55** is pivotally attached to the arm **19** at **25**. This second, first-order lever comprises an upper arm **56** and a lower arm **57**. Each of the arms **56** and **57** has an abutment **27** and **28** thereon.

Associated with each of the abutments **27** and **28** are auxiliary control rods **29** and **32** for overriding the main antenna drive mechanism. A lost motion device, comprising fixed discs **30**, **31**, **33** and **34**, is placed on each of the rods **29** and **32**. The spacing between the discs **30** and **31** is slightly greater than the diameter of the abutment **27**, while in the illustrated embodiment the spacing between the discs **33** and **34** is much greater than the diameter of the abutment **28**. The levers **17** and **55** of the instant limit stop are held in normal position by spring plunger means **22**, **23**, **24**, and **26**. The over-all limit stop mechanism is held on the antenna mount by a support arm **52**, a support plate bracket **51** and the main support plate **49**. These support members, as well as the holder **58** for the plunger **23**, may be an integral one piece member, if desired.

As stated above when the antenna **48** is moving within its predetermined limits with respect to its casing **47**, the arms **13** and **13***a* of the limit stop mechanism move in a scissors-like movement. In normal operation within the predetermined limits the cam follower **16**, behind the common pivot point **15** of the arms **13** and **13***a*, does not contact the cam surface **20** of the cranked lever **17**. The following is given as an example of the action of the limit stop when one of the predetermined limits is reached. When the cam follower **16** hits the cam surface **20** above the spring plunger **22** the arm **18** of the cranked lever **17** is forced in a downward position. The cranked lever **17** is thus rotated about the fixed pivot point **21** and arm **19** is rotated in a counter-clockwise direction. As the arm **19** moves to the right, as illustrated, the second, first-order lever **55** is likewise moved to the right until the abutment **28**, after about ⅛ inch travel, abuts against the spring **59** next to the disc **34**. At the same time, the abutment **27** begins to press against the disc **31** of the upper lost motion device and to push rod **29** to the right, as indicated. When the abutment **28** abuts against spring **59** and the disc **34**, the rod **32** and disc **34** restrain further movement of the arm **57** approximate that position of the abutment **28**. This restraining force, resulting from relatively high flow rate into the valve **39**, is sufficient to overcome the force of the abutment **28** against the disc **34** and causes the opposite arm **56** of the lever **55** to approach closer to the arm **19** of the lever **17**. It might further be said that this action is a buckling of the lever arms **19** and **57** at the pivot point **25**. As the distance between the arm **56** and arm **19** decreases the abutment **27** forces the disc **31** and rod **29** to the right which mechanically overrides any electrical signals entering coils **36***b* through connector **35***a* tending to displace the armature **36** in the torque motor **35**. The armature **36** pivots about the torsion bar **36***a* and creates a pulling action on the pilot valve rod **38** moving it to the left which causes fluid to flow into the left side of the main hydraulic or slave valve **39**. As the oil flows into the left end of slave valve **39**, the rod **32** and the disc **34** move toward the right. This allows abutment **28** to move to the right as it is hit by disc **33** and by the opposite of the process just described (i. e., leftward movement of rod **29**) allows the pilot valve to move back toward its center position. At the same time when rod **32** moves to the right the flow of hydraulic fluid to the motor **10** is reduced or actually reverses. This changes the direction of the motor **10** and likewise changes the direction of the antenna **48**. Such a definite auxiliary control of the main hydraulic valve **29** allows that valve to be open or allows flow in one of two directions and further allows maximum acceleration of the motor **10** at any one instant. The pilot valve **37** is combination with the transducer **35**, in non-overriding condition, provides a hydraulic flow which is proportional to the electrical signal arriving at said transducer at **35***a*. The mechanical motion from the transducer **35** and/or the mechanical override rod **29** provide a mechanical movement proportional to a desired hydraulic flow. The pilot valve **37**, as seen in Fig. 3, typically is of the spool type **125** with a series of working lands **128**, **129**, end lands **126**, **127**, and a series of pressure ports **130**, **131** leading to the slave valve **39**. Fluid is supplied under pressure through a pressure port **123** in valve **37**, is permitted to work around a particular working land (dependent on the spool or stem position of the pilot valve dictated by the position of rod **38**), and is conducted to one end **110** or **111** of the slave valve **39** by conduit **132** or **133**. Valve **39** is also of the spool type. The pressure on this end is thereby increased, causing motion of the slave valve spool or stem with a velocity proportional to the movement of rod **38** (from the electrical signal into transducer **35** and any overriding control by rod **29**). A reverse movement at varying rates is provided when the rod **38** positions a different working land opposite the pressure port **123**. As seen in the De Mott et al., disclosure (infra), the rate of flow from the pilot valve to the end of the slave valve is proportional to the pilot valve displacement. The slave valve stem is supplied with working lands **112**, **113**, **114** and **115**, the position of which provides for flow to the hydraulic motor **10** through either of conduits **40** or **42**. The particular flow ports and passageways from the lands to conduits **40** or **42** are set out in detail in said De Mott et al., disclosure. Reference is made to the U. S. patent application of De Mott et al., Serial No. 338,266, filed February 24, 1953, now abandoned, for further details of the typical pilot and slave valve usable in the instant combination.

It can easily be seen that it is not necessary that the rod **29** be linked with the top end of the armature **36**. For example, linkage of the lost motion discs **30** and **31** and the rod **29** may be made direct to the pilot valve rod **38**. When the motor **10** and antenna **48** are stopped from going past the predetermined limits by the action from going past the predetermined limits by the action of the auxiliary control rods **29** and **32**, and as the antenna **48** returns to its predetermined limits of travel, the cam follower **16** stays, for practical purposes, in contact with the cam surface **20** until the electrical signals into the torque motor or other transducer start movement of the antenna in a direciton away from the predetermined limits. It can be seen that the antenna will thus ordinarily oscillate at the limiting point assuming that a constant signal is being fed into the rate controlling means. Overcorrection by the movement of rod **29** causes this low amplitude oscillation.

It is possible to alleviate the above oscillations by providing a spring means such as a coil spring **59** between the abutments **27** and **28** and the lost motion discs while still

providing a lost motion space between such spring means and said abutments. This spring means will enable the rate controlling means to control the main hydraulic valve in such a manner that the valve is in a non-operating position and insures a steady state stop of the component parts of the motor and antenna. Such optional spring is shown for illustrative purposes as between the abutment **28** and the disc **34** in Fig. 1. It is to be understood that such springs, if used, will also be adjacent to the abutment **27** and its lost motion discs. The spring plungers **22, 23, 24,** and **26** tend to return the lever arms **17** and **55** to their starting position.

The rods **32** and **32***a* provide a means for reversing the direction of rotation of their respective motor means due to the action of the slave or main hydraulic valve. The term "reversal" encompasses both an actual reversal of movement back into the predetermined limits of travel and also a movement back to the predetermined limit of travel, the latter reversal tending thus to oscillate the antenna, as explained above, or to provide a steady state stop at the predetermined limit of travel. It is to be understood that in operation the auxiliary control rods **29***a* and **32***a* likewise over-ride and control an electromechanical transducer such as a torque motor, a pilot valve, and a main hydraulic valve leading to a second hydraulic motor (not shown), which aids in driving the mount in azimuth and elevation as described more fully in the Mullins et al patent.

Although the invention has been described and illustrated in detail, it is to be clearly understood that the same is by way of illustration and example only and is not to be taken by way of limitation, the spirit and scope of this invention being limited only by the terms of the appended claims.

We claim:

1. In a limit stop mechanism for a radar antenna, a rotary hydraulic motor means to move such antenna in elevation and azimuth, a hydraulic valve for controlling the direction of rotation of said motor means, a first auxiliary control rod connected to said valve, a flow rate controlling means for controlling the rate of fluid flow to said valve, a second auxiliary control rod connected to said rate controlling means, and means responsive to said hydraulic motor means at predetermined limiting points in its movement to move said second auxiliary control rod into overriding control of said rate controlling means, and to move said first auxiliary rod so that the hydraulic valve provides a reversal of the direction of rotation of said hydraulic motor means.

2. The invention as claimed in claim 1 in which the flow rate controlling means comprises a pilot valve associated with the hydraulic valve.

3. The invention as claimed in claim 1 in which the means to move the rods comprises a mechanical linkage from said hydraulic motor means, a cam means operable only at the predetermined limiting points, and pivoted lever means connected to and extending from said cam means to engagement with said auxiliary control rods.

4. The invention as described in claim 2 in which the second control rod is connected to a one end of torque motor armature, the other end of which is connected to said pilot valve.

5. The invention as described in claim 3 in which a lost motion device is provided between the pivoted lever means and the auxiliary control rods.

6. In a limit stop mechanism for a radar antenna, a rotary hydraulic motor means to move such antenna in elevation and azimuth, a hydraulic valve for controlling the direction of rotation of said motor means, a first auxiliary control rod connected to said valve, a torque motor including an armature, said torque motor providing main rate control means for said hydraulic motor means, a second auxiliary control rod connected to the armature of said torque motor, and means responsive to said hydraulic motor means at predetermined limiting points in its movement to move said second auxiliary control rod into overriding control of said torque motor, and to move said first auxiliary rod so that the hydraulic valve provides a reversal of the direction of rotation of said hydraulic motor means.

7. Means for limiting the training and elevating of a radar antenna adapted to be moved through any combination of azimuth and elevation angles in response to electrical signals, comprising in combination, hydraulic motor means to drive said antenna, valve means for controlling the flow of hydraulic fluid through said hydraulic motor means, an electrically controlled torque motor including an armature for controlling the flow rate through said valve to thereby control the azimuth and elevation of said radar antenna, cam follower means operably connected to said hydraulic motor means, a cranked, first-order lever having one end thereof adapted for cam contact with said follower means only when said hydraulic motor means reaches predetermined limits of travel, a second, first-order lever pivotally connected to the other end of said first-mentioned first-order lever, a first auxiliary control rod extending from said armature adapted to override electrical control of said torque motor, a second auxiliary control rod extending from said valve and adapted upon movement thereof to reverse the flow of hydraulic fluid through said hydraulic motor, the ends of said second, first-order lever adapted to move said auxiliary control rods when said hydraulic motor means reaches its predetermined limits.

8. The invention as recited in claim 7 in which lost motion devices are incorporated between the ends of said second, first-order lever and the respective control rods.

9. The invention as claimed in claim 7 in which said second, first-order lever has a relatively short fulcrum arm actuating said first control rod and a relatively long fulcrum arm actuating said second control rod.

10. The invention as claimed in claim 8, in which a spring means is associated with said lost motion devices to prevent oscillation of said antenna when said antenna is at its predetermined limits of travel.

11. A limit stop mechanism for a radar antenna, comprising a pair of hydraulic motors to drive the antenna in elevation and azimuth, respectively, a rotatable threaded shaft extending from each of said motors, a travelling nut on each shaft, a first lever arm pivotally extending from each nut, said first lever arms being pivotally connected together at the ends thereof opposite said nut and forming a common cam follower, a pair of centrally pivoted juxtaposed levers each having a cam cut-out surface formed in one end thereof, said cam follower adapted to ride within the cut-out cam surfaces, a third pair of lever members pivotally mounted on the other end of each of said juxtaposed levers, and auxiliary control means for each of said motors, said third pair of lever members being adapted to move said auxiliary control means when said motors reach predetermined limiting points in their movement, said cam follower contacting said cutout cam surfaces when said predetermined points are reached.

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