Nov. 19, 1946. F. V. HART ET AL 2,411,270

CONTROL MECHANISM

Filed Feb. 9, 1942 5 Sheets-Sheet 1

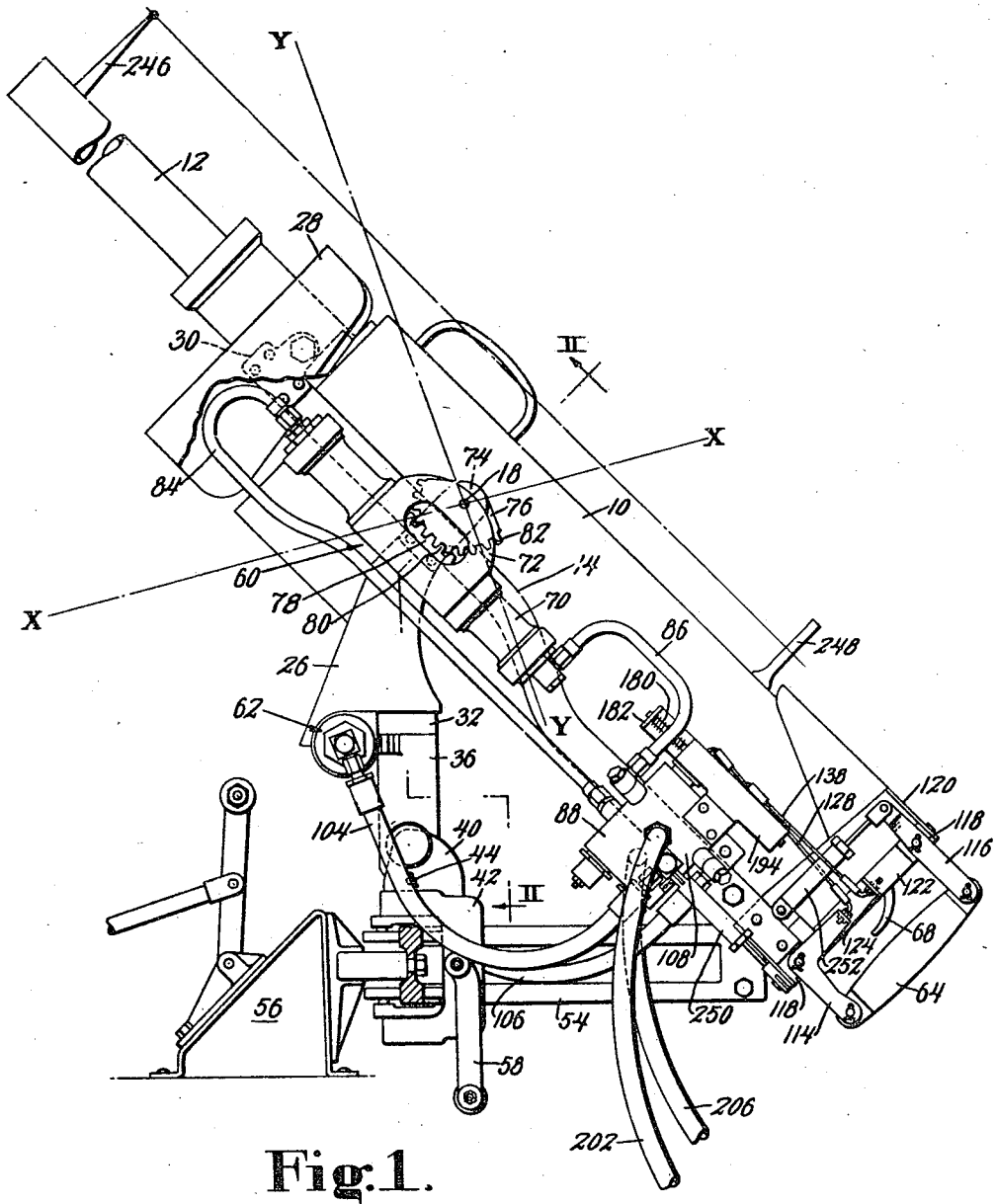

Fig. 1.

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CONTROL MECHANISM

Filed Feb. 9, 1942 5 Sheets-Sheet 2

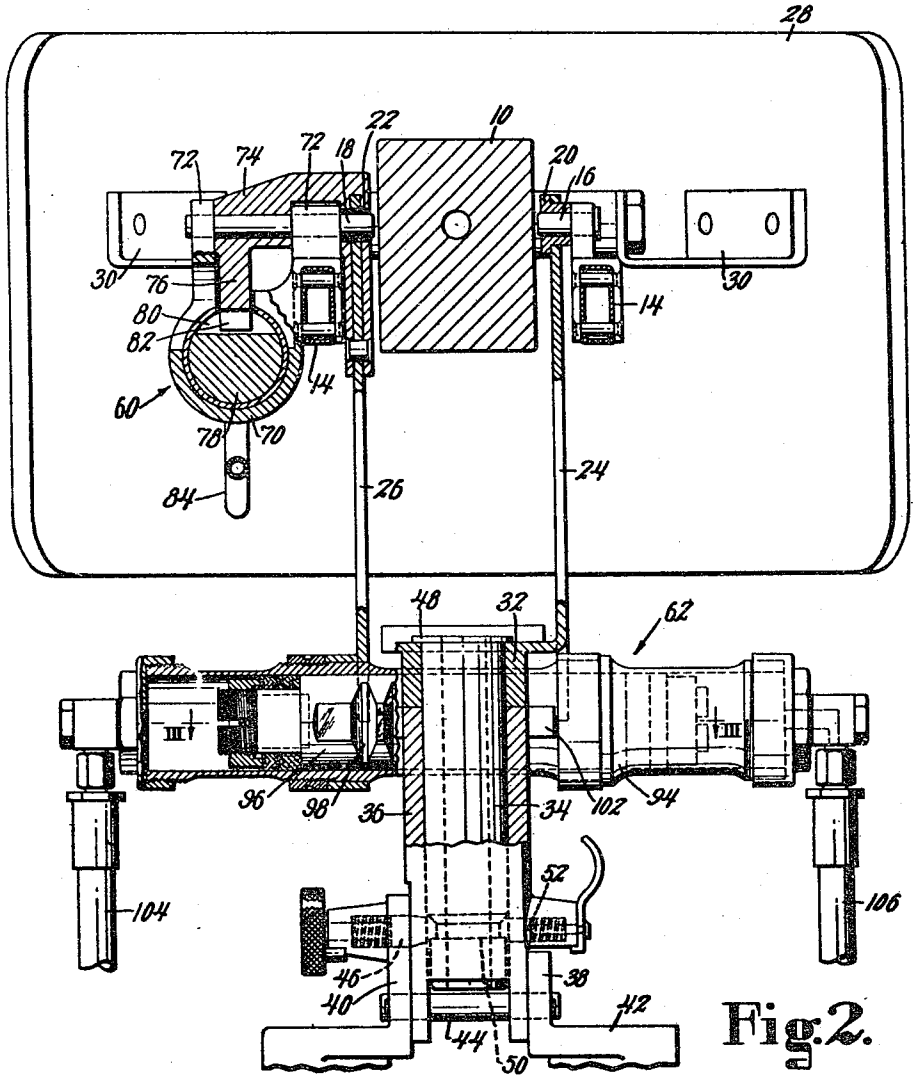

Fig. 2.

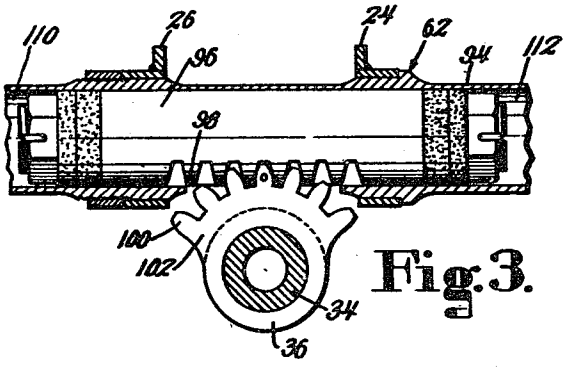

Fig. 3.

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CONTROL MECHANISM

Filed Feb. 9, 1942 5 Sheets-Sheet 3

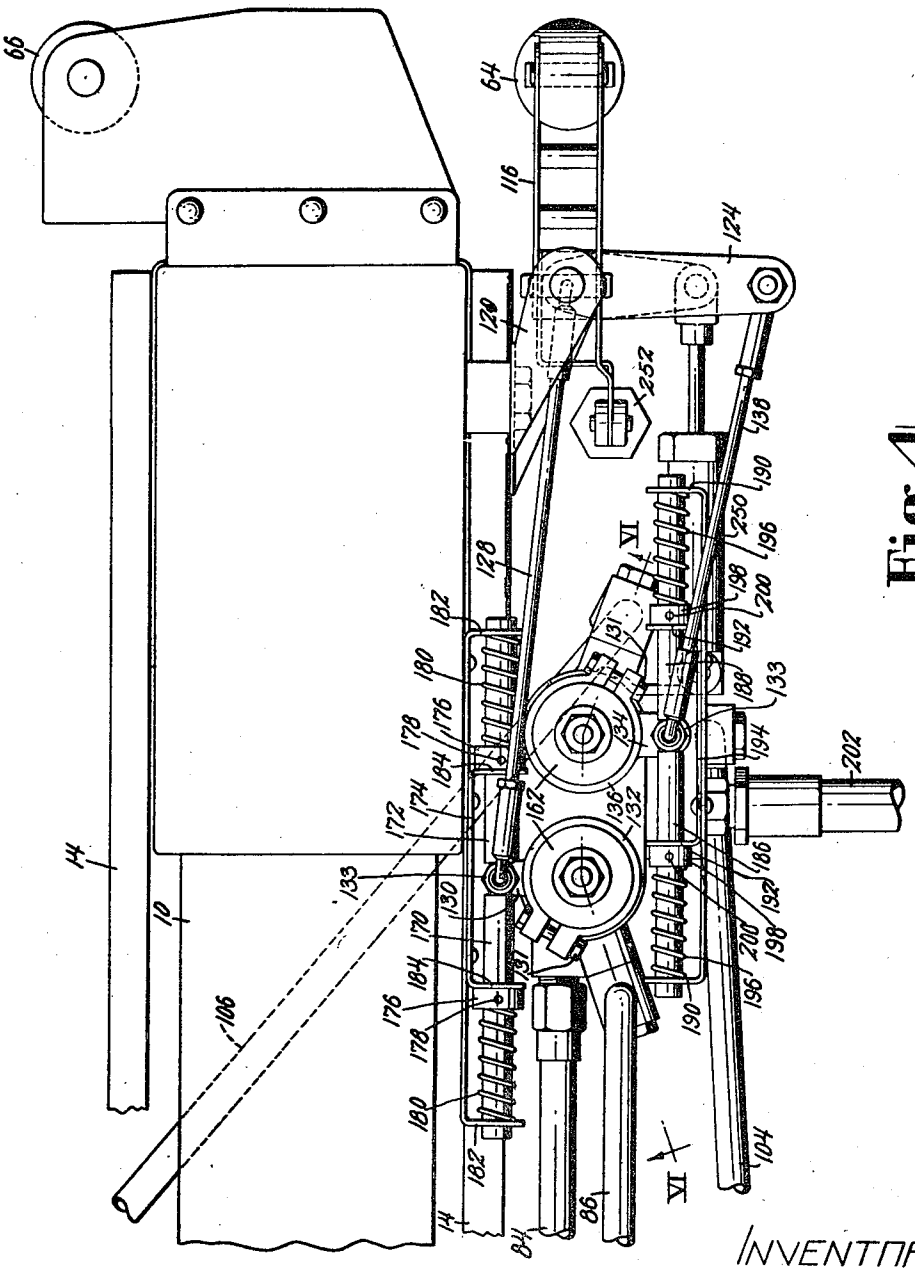

Fig. 4.

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CONTROL MECHANISM

Filed Feb. 9, 1942 5 Sheets-Sheet 4

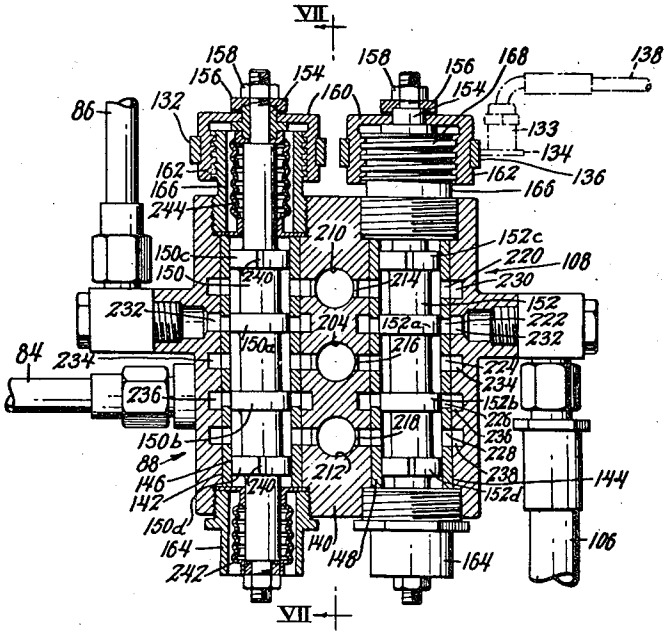

Fig. 6.

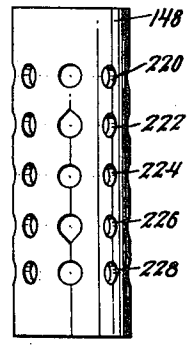

Fig. 8.

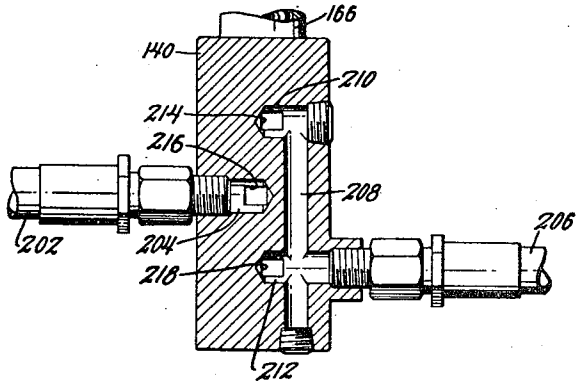

Fig. 7.

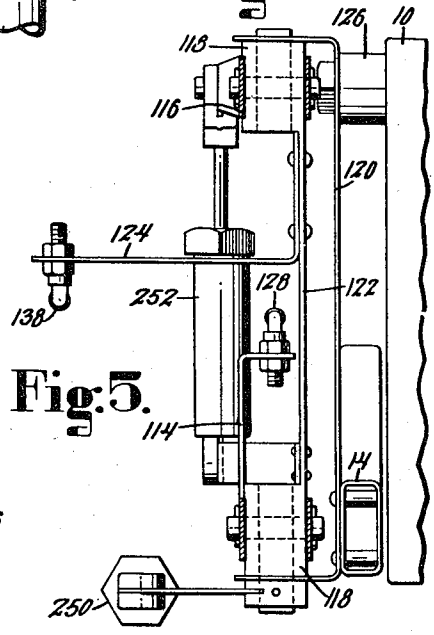

Fig. 5.

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CONTROL MECHANISM

Filed Feb. 9, 1942 5 Sheets-Sheet 5

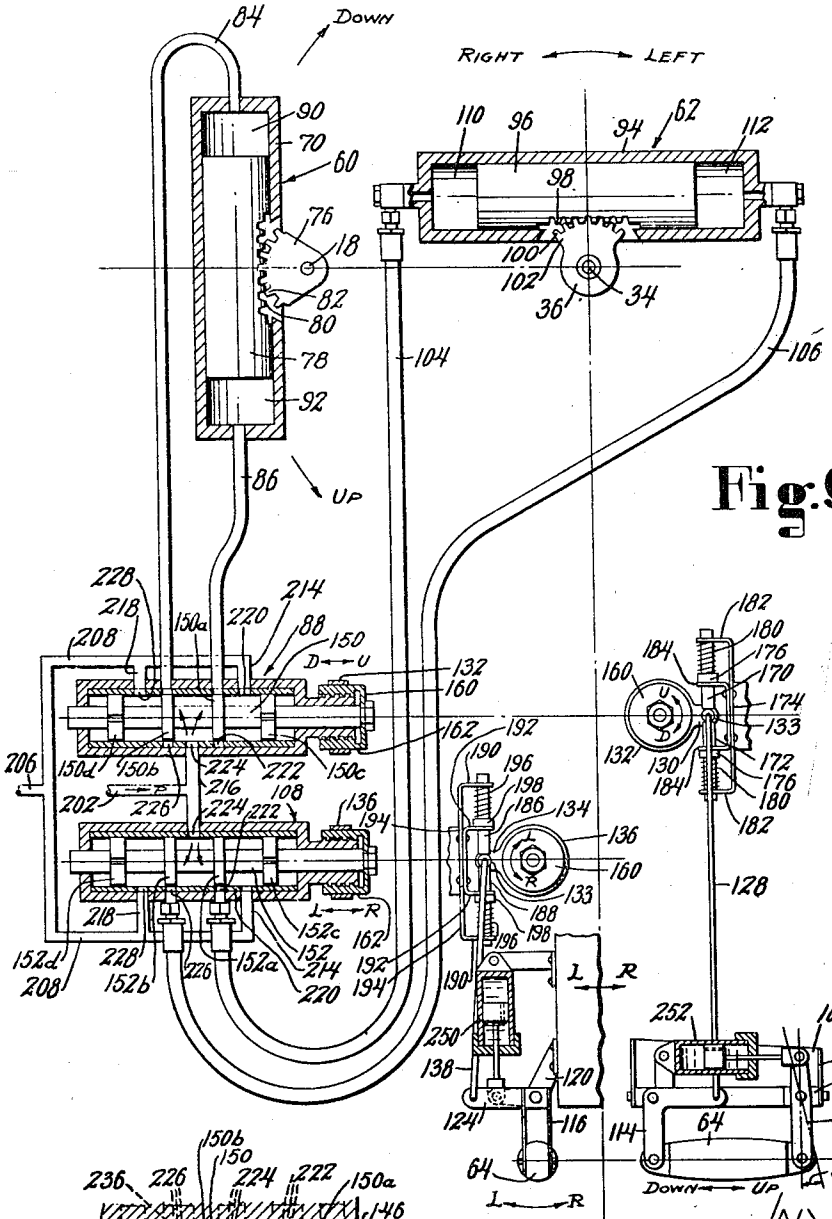

Fig.9.

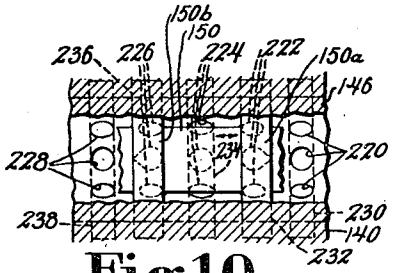

Fig.10.

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Patented Nov. 19, 1946

UNITED STATES PATENT OFFICE

2,411,270

CONTROL MECHANISM

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Application February 9, 1942, Serial No. 430,182

9 Claims. (Cl. 89—41)

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This invention relates to control mechanism for power-operated gun-training apparatus and has for an object the provision of novel and improved means for controlling the power movement of the gun.

In apparatus for training a machine gun, or other relatively small caliber gun, it is usual to mount the gun for swinging movement about two axes at right angles to each other and to provide hand grips on the back end of the gun by means of which it may be moved around until its sights are brought to bear on the target and thereafter held in this position while it is fired, as, for example, is disclosed in United States Letters Patent No. 2,051,034, granted on August 18, 1936, upon an application filed in the name of Ralph M. Ferguson. Where the gun is heavy, or subjected to the action of some exterior force, such, for example, as that caused by the slip stream from the propellers of an airplane, the physical effort required for moving the gun, and also for holding it trained on the target, is considerable and such as materially to decrease the speed and accuracy of aiming. This is especially the case when the gunner is operating at high altitudes, where even the slightest physical effort becomes very tiring. It has, therefore, been proposed to employ power-operated means for moving a gun to train it and to provide manual controls, operated by the gunner, for controlling the operation of the power-operated means. However, in prior apparatus of this type, the control of the power-operated mechanism is remote, indirect and/or discontinuous, so that direct manual movement of the gun is not simulated, or are so constructed that an awkward technique unfamiliar to the gunner must be employed in training the gun. Thus, while the use of prior apparatus of this type relieves the gunner of most of the physical effort required for moving the gun, it does not give him the same natural "feel" which he would experience in moving the gun by hand and which is quite essential for highest accuracy and most ready manipulation of the gun. Also, such apparatus usually involves the use of complicated, bulky and expensive control mechanisms.

It is, therefore, a more specific object of this invention to provide novel and improved mechanism for so controlling the movements of a power-operated gun that direct manual movement thereof by means of the usual hand grips is simulated and the operator enabled to employ the same technique in training the gun as he would if he were actually moving the gun manually and by means of the usual hand grips. To this end, an important feature of this invention resides in the provision in power-operated gun-training apparatus of universal control means including a control handle, located in substantially the same position as and corresponding to one of the usual hand grips, the speed, direction and extent of movement of which directly and continuously determine the speed, direction and movement of the gun.

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More particularly and when, as in the herein illustrated embodiment of the invention, the power-operated means for moving the gun are two double-acting fluid-pressure motors arranged to swing a gun about two transverse axes, the novel controlling mechanism may comprise, in accordance with further features of the invention, two reversing valves, each having a shiftable valve member, for directly controlling the direction and rate of flow of pressure fluid to and exhaust from the motors; a control handle common to both valves and carried in substantially the same location on the back end of the gun as a conventional hand grip, the handle being movable at will by the operator along any of a plurality of paths corresponding to the paths along which the back end of the gun moves as it is swung about either or both of said axes; and operating connections directly connecting the control handle and the shiftable valve members so that the shiftable valve members are directly and continuously under the control of the control handle. The reversing valves and operating connections, as herein illustrated, are so constructed and arranged that when the control handle is moved by the operator in any direction, at any speed and to any extent, one or both of the fluid-pressure motors are immediately operated to swing the gun about one, or both, of said axes, so that its back end will be moved in the same direction, at the same speed and to the same extent as the handle is moved. That is, the direction in which the handle is moved determines the direction in which one or both of the shiftable valve members are moved with respect to neutral positions in which they are normally retained by yieldable means, so that the path along which the back end of the gun is moved by the fluid-pressure motors, and the direction of its movement along this path, are directly and continuously determined by the movement of the handle; while the speed of movement of the handle determines the amount the shiftable members are displaced, at any instant, thus directly and continuously determining the speed of movement

of the gun. The extent to which the gun is moved is likewise directly and continuously determined by the extent of movement of the handle since, when movement of the handle is stopped, the operating connections return the shiftable valve members to their neutral positions, thus cutting off the flow of pressure fluid to and exhaust from the motors to stop movement of the gun and effectively to block its movement until the handle is again moved by the operator. The power-operated means, e. g., the fluid-motors, are hence directly and continuously under the control of the movable control handle and the operator, simply by moving the handle against the very small resistance of the above-mentioned yieldable means, can cause the gun to be moved by power in exactly the same manner as if he were actually moving it by hand and by stopping movement of the handle can cause the gun to be securely held against movement while it is fired.

Other more specific features of the invention reside in the provision; in mechanism for controlling the operation of fluid-pressure-operated means for moving a gun, of the type of reversing valves here employed for controlling the flow of pressure fluid to and from fluid-pressure motors; of novel mechanism for operating the reversing valves from a single control handle mounted on the back end of the gun; and of means for steadying the movements of the control handle so that the operation of the motors and movements of the gun are smooth and even.

The above and other objects and features of the invention will appear in the following detailed description of the illustrated embodiment thereof shown in the accompanying drawings, and will be pointed out in the claims.

In the drawings,

Fig. 1 is a view in side elevation of an apparatus embodying the features of this invention;

Fig. 2 is a sectional view at an enlarged scale of the apparatus shown in Fig. 1 taken on the line II—II of that figure and looking in the direction of the arrows;

Fig. 3 is a sectional view of a portion of the apparatus taken on the line III—III of Fig. 2 and looking in the direction of the arrows;

Fig. 4 is a plan view at an enlarged scale of the right-hand end portion of the apparatus shown in Fig. 1 illustrating the controlling valve mechanism, the control handle, and the operating connections between the control handle and valve mechanism;

Fig. 5 is a view in end elevation of a portion of the apparatus shown in Fig. 4 with some parts in section;

Fig. 6 is a sectional view of the control valve mechanism taken on line VI—VI of Fig. 4 and looking in the direction of the arrows;

Fig. 7 is another sectional view of the control valve mechanisms taken on line VII—VII of Fig. 6 and looking in the direction of the arrows;

Fig. 8 is a view in side elevation of one of the elements of the control valve mechanism shown in Fig. 6;

Fig. 9 is a schematic layout of the operating and controlling mechanisms of the apparatus shown in Figs. 1 to 8; and

Fig. 10 is a view on an enlarged scale of a portion of the control valve mechanism shown in Fig. 6, with some parts broken away and others in section.

Referring to the drawings, and particularly Figs. 1, 2, 3 and 4 thereof, the invention is herein illustrated as embodied in an apparatus for training a gun having a breech portion **10** and a barrel **12**. Two adaptor bars **14, 14** are mounted one on each side of the gun and each of these bars extends from the back end of the breech portion forwardly to a joint adjacent to the barrel. These adaptor bars support the gun for swinging movements about a horizontal axis on trunnion pins **16, 18** (Fig. 2) journaled in bearing bushings **20, 22** carried by the upper ends of two supporting plates **24, 26**. A shield of armor plate **28** is also secured to the forward ends of the adaptor bars by means of brackets **30, 30**. At their lower ends these two supporting plates **24** and **26** are joined to a hub **32** which is journaled for swinging movements on a kingpin **34**, the axis of which is at right angles to the axis of pins **16** and **18**, that extends through the hub and into a post **36**. At its lower end the post is flattened to fit between upstanding portions **38, 40** of a carrier block **42** and is held in assembled relation on this block by means of a cross-pin **44** and a spring-pressed plunger **46** in the portion **40**. The upper end of the kingpin is provided with a flange **48** while its lower end has an annular locking groove **50** into which a spring-pressed locking pin **52** projects. The flange **48** holds the hub **32** down on the upper end of the post **36**. When the plunger **46** is withdrawn, the post may be swung forwardly (Fig. 1), about the pin **44**, into a horizontal position for stowing the gun away.

The carrier block **42** is adjustably supported on an arcuate track **54** mounted on a member **56** (Fig. 1) and has a clamping mechanism, including a handle **58**, by means of which the block may be locked in any desired position on the track. The member **56** may be any fixed structural member on which it is desired to mount the gun and, in the illustrated arrangement, is a part of the fuselage adjacent to one end of the gunner's cockpit in an airplane. Thus the gun is not only mounted for training movements about two transverse axes at right angles to each other, by moving its back end in one direction or the other along any of a plurality of paths, but the whole mount may be quickly moved along the arcuate track **54** into any one of a number of different adjusted positions to render the gun more effective in use, particularly when firing at targets on either side of the cockpit.

Movements of the gun in the above manner about the two transverse axes provided by the trunnion pins **16, 18** and the kingpin **34** are effected by power-operated means comprising double-acting fluid-pressure motors **60** and **62** (Figs. 1 and 2) both of which, as illustrated, are under the control of a single movable control handle **64** which preferably, and as shown, is mounted directly on the back end of the gun itself (Figs. 1, 4 and 9). Also mounted on the back end of the gun is a fixed handle **66** (Fig. 4) adjacent to which is the firing trigger **68** (Fig. 1). These handles are in the same location on the gun as the usual hand grips heretofore provided for use in training the gun manually. As will presently be explained, the control handle **64** is so connected to the shiftable valve members of two reversing valves for directly controlling the operation of the motors **60** and **62** that movements of the control handle by the operator will cause like movements to be imparted to the back end of the breech portion **10** of the gun by the motors, while holding the control handle against movement will cause the shiftable valve members to be so positioned that the gun is held fixed

by fluid trapped in the motors. The arrangement is, therefore, such that manual movement of the gun is exactly simulated with substantially no effort required by the operator either in aiming the gun or in holding it fixed on a target.

The motor 60, which swings the gun about the trunnion pins 16, 18, comprises a double-ended cylinder 70 which is secured to the adaptor bar 14 on one side of the gun (Figs. 1 and 2) and which has ears 72, 72 journaled on the pin 18. Secured to the upper end of the supporting plate 26 is a block 74, through which the pin 18 extends, and this block is shaped to form a quadrant 76 that extends down between the ears 72, 72 and midway between the opposite ends of the cylinder 70. Mounted in the cylinder is a double-ended piston 78 provided with rack teeth 80 which mesh with pinion teeth 82 cut on the quadrant (see Figs. 1, 2 and 9). Pipes 84 and 86 lead from the opposite ends of the cylinder 70 to a reversing valve 88 which controls the flow of pressure fluid to, and its exhaust from, the spaces or chambers 90 and 92 back of each end of the piston 78 (Fig. 9). Since the block 74 and quadrant 76 are fixed to the supporting plate 26, when a shiftable valve member of the reversing valve 88 is moved into position to permit pressure fluid to flow through pipe 84 into the chamber 90 at the left-hand end of cylinder 70 (Fig. 1) (upper end in Fig. 9), and to permit fluid to be exhausted from the chamber 92 at the opposite end of the cylinder through the pipe 86, the cylinder will move relatively to the piston and will be rocked about the pin 18 in a clockwise direction (Fig. 1), and the back end of the breech portion of the gun, to which this cylinder is secured through the adaptor bar 14, will move downwardly. Conversely, when the shiftable valve member of the reversing valve 88 is moved into position to permit pressure fluid to flow through pipe 86 into the chamber 92 and fluid to exhaust from the chamber 90 through pipe 84, the gun will be swung reversely in a counterclockwise direction about the axis of pin 18 and the breech portion of the gun accordingly will be moved upwardly. As will be seen from an inspection of Fig. 9 and the legends thereon, and as will be explained more in detail below, movement of the control handle 64, up or down from a mid-position, moves the shiftable member in the direction immediately to start the motor 60 into operation for moving the back end of the breech portion of the gun in the same direction. When the handle is in the mid-position, as shown in Figs. 1 and 9, the shiftable valve member is held in a neutral position in which flow through the pipes 84 and 86 is entirely cut off and movement of the gun about the horizontal axis of pins 16 and 18 is effectively blocked by the fluid trapped at each end of the piston 78.

The motor 62, which swings the gun about the axis provided by the kingpin 34 (Figs. 2 and 3), comprises a double-ended cylinder 94 which is secured to the lower ends of the supporting plates 24, 26. Mounted within this cylinder is a double-ended piston 96 which is provided with rack teeth 98. These rack teeth are in mesh with pinion teeth 100 cut on a quadrant 102 which is formed integral with the post 36. Flexible hoses 104, 106 lead from the opposite ends of the cylinder 94 to a second reversing valve 108 which controls the flow of pressure-fluid to, and its exhaust from, spaces or chambers 110, 112 at the opposite ends of the piston 96. Inasmuch as the quadrant 102 is fixed to the post 36, when a shiftable valve member of the reversing valve 108 is moved into position to admit pressure fluid through hose 104 to the space 110 at the left-hand end of cylinder 94 (Figs. 3 and 9) and to exhaust fluid from the space 112 at the opposite end of the cylinder through hose 106, this cylinder will be swung about the axis of pin 34 in a counterclockwise direction (Figs. 3 and 9), and the back end of the breech portion of the gun, which is carried by the supporting plates 24, 26, will be swung to the right, as viewed in Fig. 9. Conversely, when the shiftable valve member of the reversing valve 108 is moved into position to admit pressure fluid through hose 106 and to exhaust it through hose 104, the breech portion of the gun will be moved in the opposite direction or to the left. As is shown by the legends on Fig. 9 and as will be explained in detail below, movement of the control handle 64 to the right or left, from a mid-position, moves the shiftable valve member in the direction immediately to start the motor 62 into operation for moving the back end of the breech portion of the gun to the right or left, respectively. When the handle is in the mid-position, as shown in Fig. 9, the shiftable valve member is held in a neutral position in which it cuts off the flow of fluid through the hoses 104, 106 and traps fluid at each end of the piston 96, thus blocking movement of the gun about the axis of pin 34. Thus the direction of movement of the back end of the gun by the motors 60 and 62 is directly and continuously determined by the direction of movement of the control handle 64 by the operator.

The control handle 64 (Figs. 1, 4, 5 and 9), which is common to both reversing valves, is mounted on the back end of the breech portion of the gun for movement relative thereto in opposite directions along any of a plurality of paths in the following manner. This handle is pivoted at its lower end to one arm of a bell-crank lever 114 and at its upper end to a straight lever 116. Each of these levers is fulcrumed for turning movement about a horizontal axis on a block 118 and these blocks are each pivotally connected to a bracket 120 for swinging movement about an axis at right angles to said horizontal axis. These blocks are joined by a strap 122 from which an arm 124 extends. The bracket 120 is secured at its lower end to one of the adaptor bars 14 and at its upper end to a boss 126 (Fig. 5) on a cross-member secured to the adaptor bars. A link 128 connects the other arm of the bell-crank lever 114 to an ear 130 on a clamping ring 132, and the arm 124 on the strap 122 is similarly connected to an ear 134 on a clamping ring 136 by means of a link 138. In the schematic view of Fig. 9, the operating handle 64 is shown twice, the showing of the handle at the lower right-hand part of the view, and that of the fluid-pressure motor 60, is in side elevation, while the showing of the handle at the lower center, and that of the motor 62, is in plan. The valves 88 and 108 are shown in schematic cross-section and right-hand end views of these valves, shown associated with the handle 64, have been swung into the plane of a plan view and, as will be apparent from this figure, the handle 64 can be moved, from a mid-position, in opposite directions along any of a plurality of paths. These movements of the handle are transmitted through the links 128 and 138 directly to the two clamping rings 132 and 136 which, as will now be explained, operate the shiftable valve members of reversing valves 88 and 108.

Referring to Figs. 6 and 9, these two valves are made in a single block 140 which has two parallel through-and-through bores 142, 144. Liner sleeves 146, 148 within the bores provide operating cylinders respectively for two valve spindles 150, 152. The spindle 150 has four spaced piston portions 150*a*, 150*b*, 150*c* and 150*d*, and the spindle 152 is likewise provided with spaced piston portions 152*a*, 152*b*, 152*c* and 152*d*, as shown. The upper end of each spindle is of reduced diameter to receive a sleeve 154 which is held in place by means of a thrust washer 156 and a nut 158. Mounted for rotation between the thrust washer and a shoulder on each sleeve 154 is the flange 160 of a valve-operating nut 162 (see Figs. 4, 6 and 9). The sleeves 146, 148 are held in place against endwise movement within the bores 142, 144 by means of thimbles 164, 166 threaded into the opposite ends of the bores and bearing against opposite ends of the sleeves. The thimbles 166, which are on the top of the block 140, are provided with square threads 168 on which the nuts 162 are mounted. The lead of the threads 168 is right-handed so that the valve spindles 150 and 152, which are the shiftable valve members, above referred to, will be shifted to the left in Fig. 9, and down in Fig. 6, when their operating nuts are rotated in a clockwise direction as viewed in plan in Fig. 9 and in the opposite direction when the nuts are rotated in a counterclockwise direction. The clamping rings 132 and 134 are secured to these operating nuts by binding screws 131, 131, see Fig. 4, so that movements of the control handle 64, transmitted directly to these clamping rings through links 128, 138, will result in movements of one or both of the valve spindles, depending on the direction of movement of the handle from its mid-position with respect to the back end of the gun. That is, if the handle is moved up and down relative to the gun, only the valve spindle 150 of the reversing valve 88 will be moved, or if the handle is moved back and forth from left to right relative to the gun, only the spindle 152 of the reversing valve 108 will be moved. This is due to the fact that the connection point of the link 128 to the lever arm 114 is on the axis line of the blocks 110, 118 while the link 138 is connected to the arm 124, the position of which is not changed by up-and-down swinging movements of the levers 114, 116. However, by moving the handle 64 at an angle on either side of the vertical and either up or down, both valve spindles will be shifted from the neutral positions which they occupy in Figs. 6 and 9 and, as has already been stated, the motors 60 and 62 each will be started into operation.

The valve spindles are held in their neutral positions, and the operating handle in the mid-position shown in Figs. 1 and 4, by means of opposed spring-pressed plungers bearing against cylindrical portions 133 on the ears of the clamping rings 132 and 136. Referring to Figs. 4 and 9, plungers 170 and 172 bear against the cylindrical portion 133 on ear 130 of the clamping ring 132 and these plungers are slidably mounted in a bracket member 174 that is mounted on the adaptor rod 16. Each plunger is provided with a thrust collar 176 adjustably secured thereto by means of a setscrew 178 (Fig. 4). Compression springs 180, 180, surrounding the plungers and interposed between ears 182, 182 on the bracket 174 and the collars 176, thrust the plungers toward each other to the extent permitted by a second set of ears 184, 184 also carried by the bracket 174. Similarly, the plungers 186, 188, which bear on the cylindrical portion 133 of ear 134 of the other clamping ring 136, are slidably mounted in two sets of ears 190, 192 of a bracket 194 that is secured to the valve block 140 and springs 196, 196 are provided for holding the thrust collars 198, 198 against the inner ears 192, 192 of this bracket. The collars 198, 198 are adjustably secured to the plungers by setscrews 200 (Fig. 4). The adjustable collars 176, 176 and 198, 198 are preferably set so that when the operating handle is released the plungers 170, 172 and 186, 188 just touch the cylindrical portion 133 of their associated clamping ring ears and the operating nuts 162, 162 are adjusted within their clamping rings in such a manner that the valve spindles 150, 152 will be in neutral position under these conditions.

Pressure fluid is conducted from a suitable source (not shown) to the valve block 140 by means of a flexible hose 202 which connects into a centrally located transverse duct 204 (Figs. 6 and 9). Pressure fluid is exhausted by means of a flexible hose 206 which is connected to a vertically extending duct 208 (Fig. 7) that opens into two short transverse ducts 210, 212. Extending at right angles to these transverse ducts 204, 210, 212 are three lateral ducts 214, 216 and 218 (Fig. 6). Each of the sleeves 146, 148 is provided with five sets of circumferentially arranged apertures 220, 222, 224, 226 and 228 (Fig. 8), and the block 140 is cored out to form annular grooves 230, 232, 234, 236 and 238 which are in alinement with the apertures. In the illustrated construction there are eight apertures in each set and in sets 222 and 226 four of each eight apertures are of elongated "tear-drop" shape, while the other four are circular and arranged as shown in Figs. 8 and 10. To avoid confusion in Fig. 6, the reference characters for these apertures and annular grooves are applied, for the most part, only to the sleeve 148 and the right-hand side of the block associated with this sleeve but it will be understood that these elements are duplicated in the sleeve 146 and in the left-hand side of the block. Also, in the schematic view of Fig. 9, some of the elements of the valves have been omitted in order further to simplify the disclosure. The pipe 84 communicates with groove 236 and the pipe 86 with groove 232 associated with valve spindle 150 of valve 88, while the hose 104, which is in front of the plan of Fig. 6, communicates with the groove 236 and the hose 106 with the groove 232 associated with the valve spindle 152 of valve 108. The pressure fluid supply hose 202 communicates with grooves 234 of both valves, through ducts 204 and 216, while the exhaust hose 206 communicates with grooves 230 and 238 of both valves, through ducts 210, 212, 214 and 218.

The operation of each of the two reversing valves is the same and will be described by reference to valve 88 which controls the operation of the motor 60 that swings the gun about a horizontal axis. With the valve spindle 150 in its neutral position, the piston portions 150*a*, 150*b* just cover the "tear-drop" shaped apertures of the sets 222, 226 in the sleeve 146 (see Figs. 6, 9 and 10) and thus cut off flow through grooves 232, 236 and the pipes 84, 86. Pressure fluid is, however, being supplied to the space between these two piston portions from hose 202, ducts 204 and 216, and through groove 234 and apertures 224. Now, assuming that the control handle 64 is moved down, the nut 162 on the spindle 150

will be rotated and the spindle immediately shifted down in Fig. 6, and to the left in Figs. 9 and 10, an amount which will be proportional to the displacement of the handle. Just as soon as the spindle 150 starts to move in this direction, the large ends of the "tear-drop" shaped apertures 226 (see Fig. 10) will begin to be uncovered by piston portion 150*b* on the side toward apertures 224 while the small ends of the "tear-drop" shaped apertures 222 will begin to be uncovered by the piston portion 150*a* on the side toward aperture 220, since these piston portions have no lap beyond these "tear-drop" shaped apertures. Pressure fluid will now flow through the "tear-drop" apertures 226 into the groove 236 and thence, through hose 84, to the space 90 at the upper end of piston 78 and will be exhausted from the space 92 at the bottom of this piston through pipe 86, groove 232, "tear-drop" shaped apertures 222, apertures 220, groove 230, ducts 214, 210 and 208, to hose 206. As previously explained, this will cause the motor 60 to swing the back end of the gun down and this movement will, of course, continue so long as the valve spindle is held in this opened position. Similarly, upward movement of the operating handle will effect upward movement of the back end of the gun. Now the valve spindle moves up (Fig. 6) or to the right (Figs. 9 and 10), uncovering the large ends of the "tear-drop" shaped apertures 222 on their sides toward apertures 224 to admit pressure fluid to groove 232 and to pipe 86 and the small ends of the "tear-drop" apertures 226 on their sides toward apertures 228, thus opening groove 236 and pipe 84 to permit exhaust of fluid through "tear-drop" shaped apertures 226, apertures 228, groove 238, ducts 218, 212 and 208, and hose 206. The action of the other valve spindle 152 to control the operation of the motor 62 is exactly the same as that just described and, as has been already pointed out, movements of the back part of the gun sidewise are in the same direction as the lateral movements of the handle 64.

The speed at which the two motors operate will be determined by the rate of flow of pressure fluid thereto and exhaust therefrom and the apertures 222, 226 are shaped and arranged to provide for regulating this flow. As has been stated, the piston portions 150*a* and 150*b*, and also piston portions 152*a* and 152*b*, have no lap and are of such width as just to cover the "tear-drop" apertures when in neutral position. Accordingly, the instant that either of these spindles 150, 152 is shifted from its neutral position, the "tear-drop" apertures 222 and 226 of its associated valve are uncovered and the motor controlled thereby is immediately started in operation at a speed depending on the amount the apertures are uncovered. Accordingly, if the handle 64 is displaced only a little the flow of pressure fluid will be small and the action of the motor, or motors, slow. On the other hand, if the displacement of the handle is greater, the flow of pressure fluid will be larger and the speed of the motor, or motors, increased. Due, however, to the "tear-drop" shape of certain of the apertures 222 and 226 and the arrangement of the circular apertures 222 and 226 with respect to the "tear-drop" shaped apertures 222 and 226, the increase in the amount of uncovering of these apertures for admitting pressure fluid occurs at a greater rate than does the uncovering for exhausting fluid. This will be understood by reference to Fig. 10 from which it will be seen that, when the spindle

150 is moved to the left, the "tear-drop" shaped apertures 226, through which pressure fluid is admitted, are progressively uncovered at their large ends while the "tear-drop" shaped apertures 222, through which pressure fluid is exhausted are likewise progressively uncovered but at their small ends. Also, the circular apertures 226 are uncovered before the circular apertures 222. The same action takes place in the opposite sense when the spindle is moved to the right. The shape and arrangement of the apertures 226 and 222 thus provide for a metered flow of pressure fluid to, and exhaust from, the motors by the progressive uncovering of these apertures, the rate of which is greater for those apertures through which the pressure fluid flows to the motors than for those through which fluid is exhausted. This shape and arrangement of apertures 222 and 226 insures smoothness of action in the motors by causing a slight back pressure in their exhausting ends. This back pressure is maintained by the action of apertures 222 and 226 until just before the trailing edge of the piston portions *a* or *b* reaches the middle of the circular apertures 222 or 226, which point is substantially at the extreme normal limit of movement of the valve spindles 150, 152. In this manner there is always a back pressure, due to exhaust throttling, in the two motors so that overtravel or running away of the motors is prevented and a very smooth action is obtained. It will be understood that the number, size and shape of these apertures, as well as the ratio of the number of circular apertures to "tear-drop" shaped apertures, may be varied to suit the different operating conditions, which may be encountered in this or other types of apparatus, while still obtaining the metered flow and back pressure action above described. The valve pistons are all of the same diameter so that the spindles are balanced and grooves 240 are provided in the end pistons *c* and *d* to drain back any leakage fluid to exhaust. Sylphon seals 242, 244 are connected to opposite ends of each spindle, as shown.

By mounting the control handle on the device which is to be moved by the two motors, i. e., on the back end of the gun, a virtual follow-up action is obtained. Referring to Figs. 1, 2 and 9, and considering first movements of the gun about the horizontal axis provided by pins 16, 18, let it be assumed that the operator wishes to elevate the back end of the gun to aim it along the line X—X (Fig. 1). To do this he grasps the handle 64 and lifts it up, turning the levers 114 and 116 through the angle α (Fig. 9). This movement of the handle moves the shiftable member 150 of the valve 88, through the connections 114, 128, 162, 168, immediately to start the motor 60 in operation to move the back end of the gun upwards in the same direction as the movement of the handle, and this movement of the gun will continue until the shiftable member 150 is returned to its neutral position. Return of the shiftable member 150 is effected by a follow-up action from the gun, back through the lever 114, link 128, nut 162 and threads 168 from the handle 64, to the valve spindle 150 when movement of the handle 64 is stopped. Hence, so long as the operator keeps moving the handle up, the valve spindle 150 will be displaced and the back end of the gun will be moved by the motor 60. When the desired orientation is reached, in this case when the axis of the gun coincides with line X—X, the operator holds the handle still

and movement of the gun, by virtue of the follow-up action just mentioned, returns the spindle **150** to neutral position, whereupon the gun stops. The same kind of action occurs when the handle is moved down for the purpose of aiming the gun along the line Y—Y. Hence the extent to which the gun is moved is directly and continuously determined by the extent of movement of the handle **64**. Also, the speed at which the gun moves will be determined by the magnitude of the angle α as this governs the displacement of the spindle **150** from neutral position. Since, at any instant during the movement of the gun the magnitude of the angle α will depend on the amount the hand is kept ahead of the gun, it follows that the speed of movement of the operator's hand, directly and continuously, determines the speed of movement of the gun. As has already been explained, the direction of movement of the gun is also directly and continuously determined by the direction of movement of the handle **64**. Swinging movements of the gun about the vertical axis provided by the kingpin **34**, by means of the other motor **62**, are controlled through the valve **108** by appropriate movements of the handle **64** laterally about the pivotal axis of blocks **118**, **118** and with the same follow-up action and direct and continuous control of the speed direction and extent of such movement, as will be understood. Combinations of lateral and up-and-down movements of the handle **64**, of course, will produce corresponding oblique swinging movements of the gun about two axes at right angles to each other. In fact, the back end of the gun follows all movements of the handle **64** in substantially the same manner as if the handle **64** were fixed thereto, the gun being continuously and directly under the control of the hand which grasps the handle. However, the forces which move the gun are supplied by the pump which delivers pressure fluid to the hose **202**, and the only muscular effort required of the operator is the small amount necessary to overcome the resistance of the relatively light springs **180**, **196**. In operating the gun, the gunner experiences the same feel as though he were actually moving the gun in the usual manner, i. e., by gripping the two handles **64** and **66**, and he can readily aim the gun, by means of sights **246**, **248**, on a fixed target or cause it to track a moving target with the greatest of ease. Furthermore, being relieved of the muscular effort which would otherwise be required quickly to move a heavy gun through a large angle or to move the gun against an exterior force, such as for example the slip stream of the propeller of the plane, or to hold it aimed against such exterior force, this manipulation of the gun is greatly facilitated. Inasmuch as the two operating handles **64** and **66** occupy the same positions on the gun as those usually provided for manual operation, no new technique need by mastered by the gunner.

As has been previously stated, the springs **180** and **196** are relatively light to reduce the effort required for operating the handle **64**. With such an arrangement, only a slight pressure of the hand is required to move the handle away from its neutral position and thus start the gun moving. If the handle is moved quite far, a very rapid movement of the gun will follow, and when the gun catches up with the handle it will be suddenly stopped. There is considerable flexibility in the gun mount and this springiness may cause the gun to bounce somewhat and shake the operator's hand which is on the handle **64**. Such movements of the operator's hand are, of course, transmitted back to the reversing valves with the result that the movements of the gun become jerky and it would be difficult to aim with any degree of accuracy or to follow a moving target in a satisfactory manner. To overcome this tendency, dashpots **250**, **252** are connected to the lever **116** and arm **124**. These serve to steady the movements of the handle **64** and to dampen out any vibrations either of the gun or of the operator's hand.

Having described the invention, what we claim as new and desire to secure by Letters Patent of the United States is:

1. In apparatus for training a gun, the combination with a gun mounted for universal swinging movement about two transverse axes, of fluid-pressure-operated mechanisms for swinging the gun, a control means for each of said mechanisms, an operating member common to all of said control means comprising a control handle movably mounted on the back end of the gun, in substantially the same location as the usual hand grip, to start said mechanisms in operation, and means for operating the control means directly by movements of the handle, said control means and said operating means being so constructed and arranged that the direction, speed and extent of swinging movement of the gun are directly and continuously determined by the direction, speed and extent of movement of the handle.

2. In apparatus for training a gun, the combination with a gun mounted for universal swinging movement about two transverse axes, of a double-acting fluid-pressure motor for swinging the gun about each axis respectively, two reversing valves movable with the gun and adapted selectively to control the direction and rate of flow of pressure fluid to and from said different motors respectively, operating means for said reversing valves, and means for actuating said valve-operating means including a control handle mounted on the back end of the gun, in substantially the same location as the usual hand grip, for movement relative thereto at will by an operator to start said motors in operation and connections between the handle and the gun and between the handle and the operating means, said connections and said valves being so constructed and arranged that the direction, speed and extent of the swinging movement of the gun are directly and continuously determined by the direction, speed and extent of movement of the control handle.

3. In apparatus for training a gun, the combination with a gun mounted for universal swinging movement about two transverse axes, of a double-acting fluid-pressure motor for swinging the gun about each axis respectively, two reversing valves, each of said reversing valves having a piston for controlling selectively the direction and rate of flow of pressure fluid to and from one of the motors, means for normally holding each piston in position to cut off flow to or from a motor, and means for displacing each of said pistons in opposite directions from said position including a control handle mounted on the back end of the gun, in substantially the same location as the usual hand grip, for movement relative thereto at will by an operator to start said motors in operation and connections between the handle and the gun and between the handle and the displacing means, said con-

nections and said valves being so constructed and arranged that the direction, speed and extent of the swinging movement of the gun are directly and continuously determined by the direction, speed and extent of movement of the control handle.

4. In apparatus for training a gun, the combination with a gun mounted for universal swinging movement about two transverse axes, of a fluid-pressure motor including a double-acting piston for swinging the gun about each axis respectively, a reversing valve associated with each motor for controlling the operation of that motor, each of said reversing valves comprising a body portion provided with a longitudinal bore and a valve member having spaced piston portions slidable in the bore, a supply conduit leading from a pressure fluid source to each of said valves and opening into the bores between said piston portions, connections between the bore of each reversing valve and opposite ends of its associated motor including apertures in the body portion normally just covered by said piston portions, exhaust conduits connected to the bore of each reversing valve, operating means for moving the valve members of said reversing valves selectively to connect their supply conduit to one end of the associated motor through the space between the piston portions and simultaneously to connect the opposite end of the motor to one of the exhaust conduits, and a member common to both operating means comprising a control handle mounted on the back end of the gun in substantially the same location as the usual hand grip and movable at will by an operator for operating said reversing valves, said apertures being so shaped and arranged that the valve members progressively uncover them as said members are moved, thereby to provide a metered flow of pressure fluid to, and exhaust from, the fluid-pressure motors.

5. In apparatus for training a gun, the combination with a gun mounted for universal swinging movement about two transverse axes, of a fluid-pressure motor including a double-acting piston for swinging the gun about each axis respectively, a reversing valve associated with each motor for controlling the operation of that motor, each of said reversing valves comprising a body portion provided with a longitudinal bore and a valve member having spaced piston portions slidable in the bore, a supply conduit leading from a pressure fluid source to each of said valves and opening into the bores between said piston portions, connections between the bore of each reversing valve and opposite ends of its associated motor including apertures in the body portion normally just covered by said piston portions, exhaust conduits connected to the bore of each reversing valve, operating means for moving the valve members of said reversing valves selectively to connect their supply conduit to one end of the associated motor through the space between the piston portions and simultaneously to connect the opposite end of the motor to one of the exhaust conduits, and a member common to both operating means comprising a control handle mounted on the back end of the gun in substantially the same location as the usual hand grip and movable at will by an operator for operating said reversing valves, said apertures being so arranged and so shaped that the valve members progressively uncover them, as the members are moved, with the rate of uncovering of the apertures through which pressure fluid is supplied to one end of a motor greater than the rate of uncovering of the apertures through which pressure fluid is exhausted from the opposite end of that motor whereby a back pressure is maintained in said motors during their operation.

6. In apparatus for training a gun, the combination with a gun mounted for universal swinging movement about two transverse axes, of a fluid-pressure motor including a double-acting piston for swinging the gun about each axis respectively, a reversing valve associated with each motor for controlling the operation of that motor, each of said reversing valves comprising a body portion provided with a longitudinal bore and a valve member having spaced piston portions slidable in the bore, a supply conduit leading from a pressure fluid source to each of said valves and opening into the bores between said piston portions, connections between the bore of each reversing valve and opposite ends of its associated motor including apertures in the body portion normally covered by said piston portions, exhaust conduits connected to the bore of each reversing valve, operating means for moving the valve members of said reversing valves selectively to connect their supply conduit to one end of the associated motor through the space between the piston portions and simultaneously to connect the opposite end of the motor to one of the exhaust conduits, and a member common to both operating means comprising a control handle mounted on the back end of the gun in substantially the same location as the usual hand grip and movable at will by an operator for operating said reversing valves, said piston portions being of such size as exactly to cover said apertures so that the motors are operated immediately upon the slightest movement of the valve members in either direction from a neutral position and are blocked against movement by exterior forces acting on the gun when said valve members are returned to said neutral position.

7. In apparatus for training a gun, the combination with a gun mounted for universal swinging movement about two transverse axes, of a double-acting fluid-pressure motor for swinging the gun about each axis respectively, two reversing valves, each of said reversing valves having a casing and a piston for controlling selectively the direction and rate of flow of pressure fluid to and from one of the motors, means for normally holding the pistons in position to cut off flow to or from the motors, means for displacing each of said pistons in opposite directions from said position, a control handle mounted on the back end of the gun, in substantially the same location as the usual hand grip, for movement relative thereto by an operator, connections between the handle and the gun and between the handle and the displacing means so constructed and arranged that the direction, speed and extent of the swinging movements of the gun by said motors are directly and continuously determined by the direction, speed and extent of movement of the control handle by the operator, each of said piston-displacing means comprising a nut threaded to the casing and operatively connected to the corresponding piston and said connections between the handle and piston-displacing means including linkages for effecting rotation of the nuts and displacement of the pistons by movement of the handle.

8. In apparatus for training a gun, the combination with a gun mounted for universal swinging movement about two transverse axes, of fluid-pressure motors for swinging the gun respec-

tively about said axes, valve means for directly controlling the direction and rate of flow of pressure fluid to and from the motors, a control handle mounted on the back end of the gun, in substantially the same location as the usual hand grip, and movable relatively thereto at will by an operator for operating said valves selectively to effect swinging movement of the gun by the motors, operative connections between said handle and the valve means so constructed and arranged that the direction, speed and extent of swinging movement of the gun by the fluid-pressure motors are directly and continuously determined by the direction, speed and extent of movement of the handle by the operator, and dash pots associated with said handle for steadying its movements relative to the gun.

9. In apparatus for training a gun, the combination with a gun mounted for universal movement about two transverse axes, of a double-acting fluid-pressure motor for swinging the gun about each axis respectively, two reversing valves, each of said valves having a casing and a piston

for controlling selectively the direction and rate of flow of pressure fluid to and from one of the motors, means for normally holding the pistons in position to cut off flow to or from the motors, means for displacing each of said pistons in opposite directions from said position, a control handle mounted on the back end of the gun, in substantially the same location as the usual hand grip, for movement relative thereto by an operator, connections between the handle and the gun and between the handle and the displacing means so constructed and arranged that the direction, speed and extent of the swinging movements of the gun by said motors are directly and continuously determined by the direction, speed and extent of movement of the control handle by the operator, each of said piston-displacing means comprising a rotatable member and said connections including linkages for effecting rotation of said members by movement of the handle.

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