

[54] MACHINE CONTROL

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[51] Int. Cl. F16h 27/02

[58] Field of Search. 74/32, 52, 409, 568, 89.2, 74/89.21, 89.22, 781

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[57] ABSTRACT

A machine controller for connection to a repetitively linearly movable part on the machine to be controlled, which machine includes means for controlling its operation, comprising a rotatably mounted cam shaft having cams for selectively actuating each of the machine's control means, and means coupled to said shaft and to the linearly moving machine part to translate linear machine movement into rotational movement. Spring means is operably coupled to the assembly biasing it to a normal at rest position corresponding to the start position of the machine being controlled.

17 Claims, 9 Drawing Figures

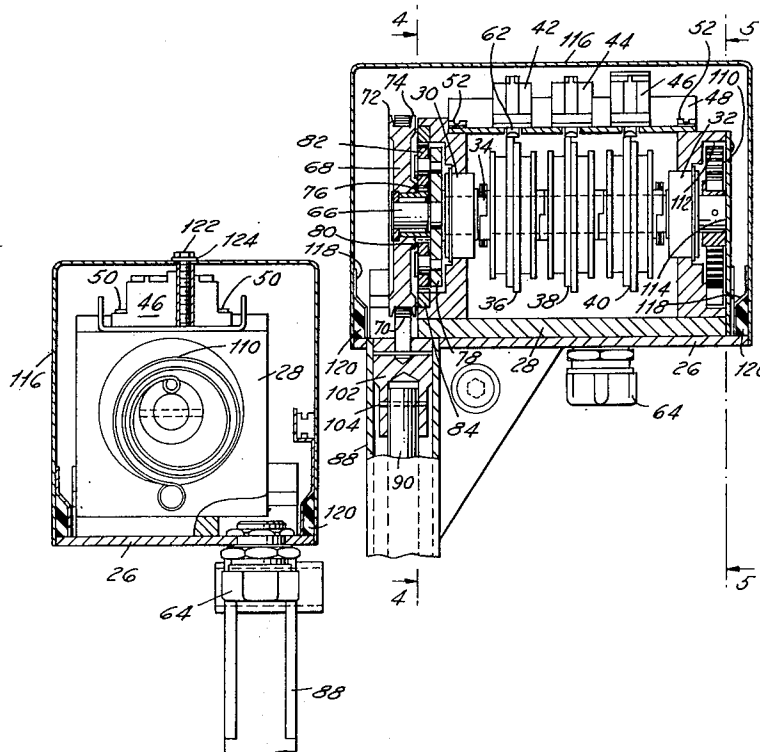


FIG. 1

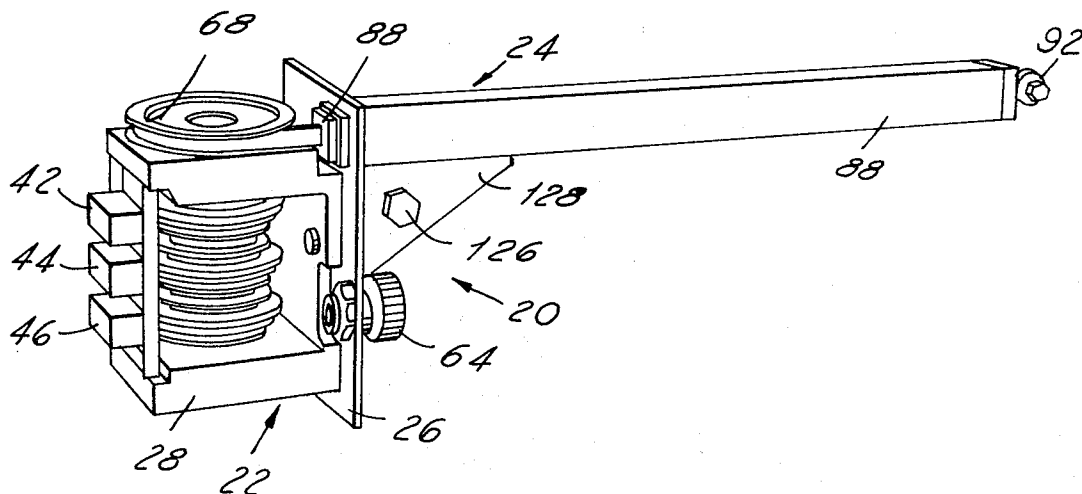
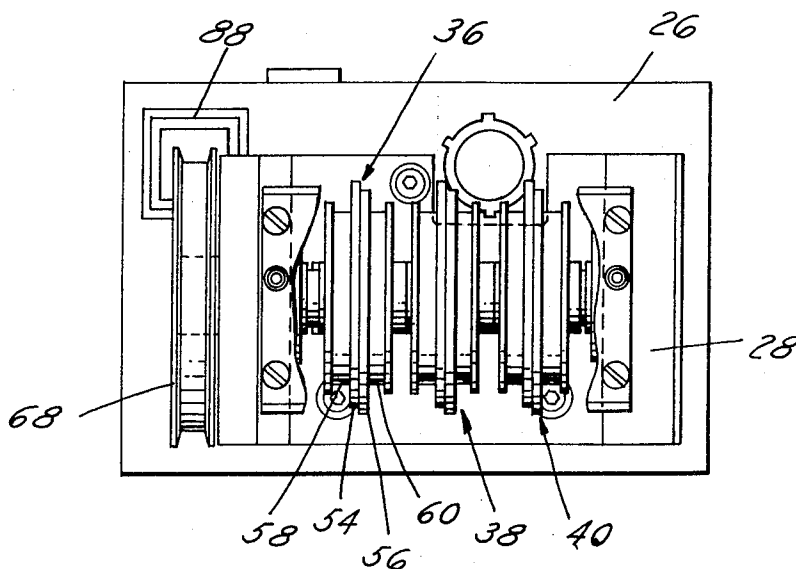


FIG. 2



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FIG. 4

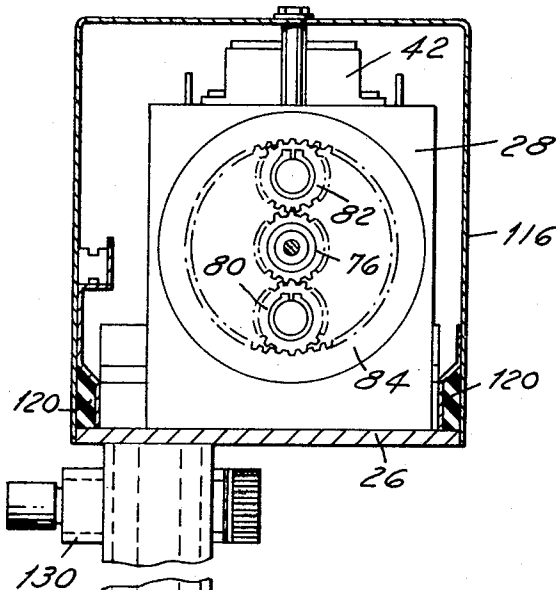


FIG. 3

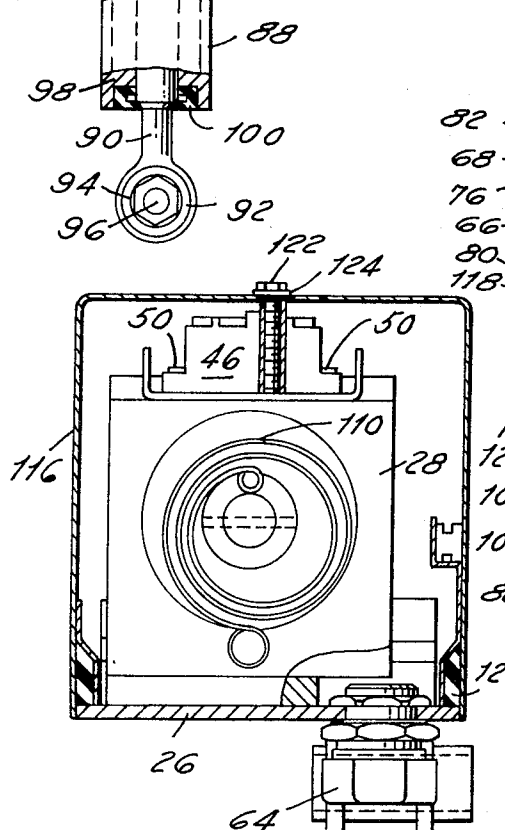
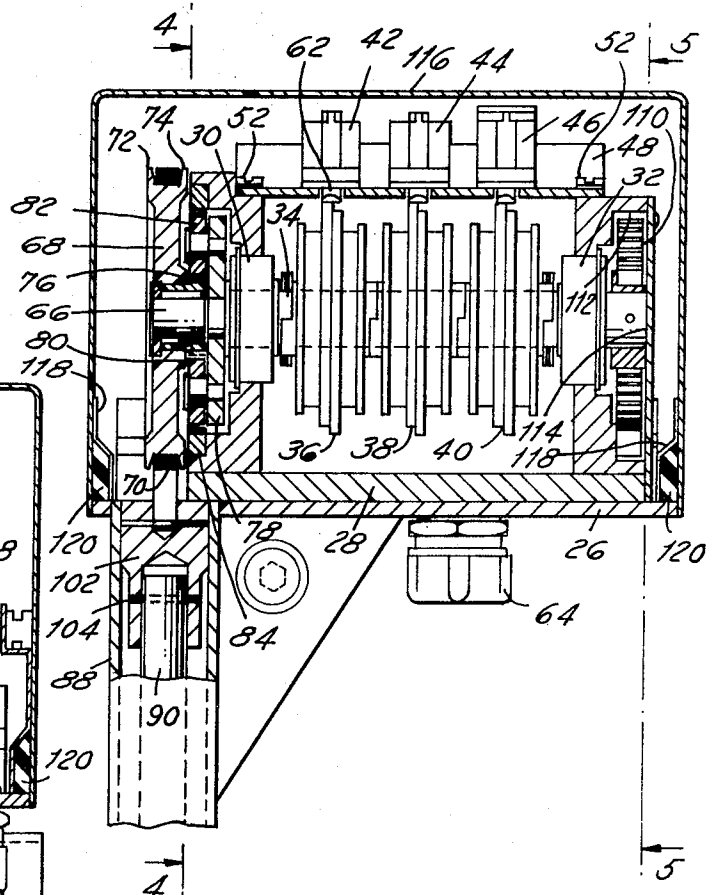


FIG. 5

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FIG. 6

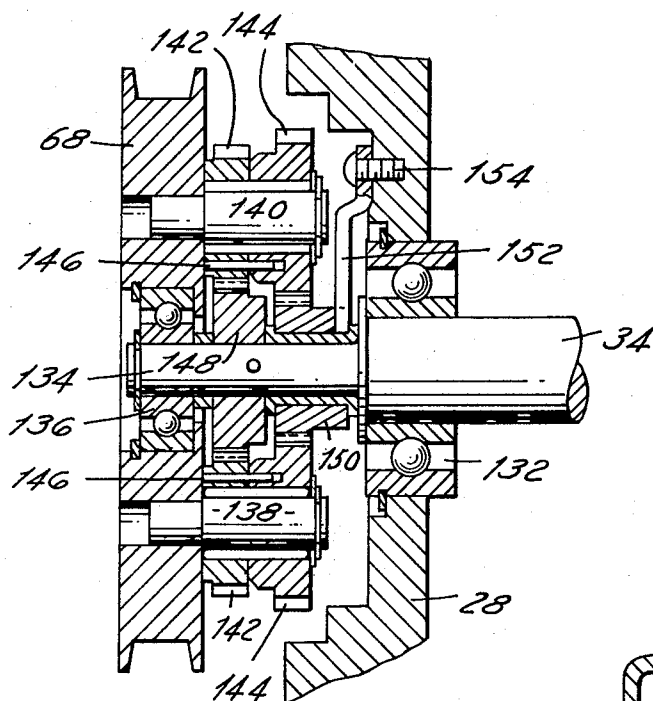


FIG. 8

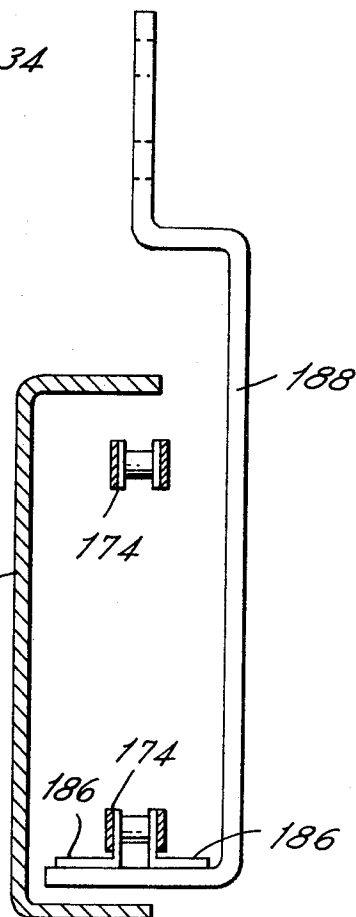
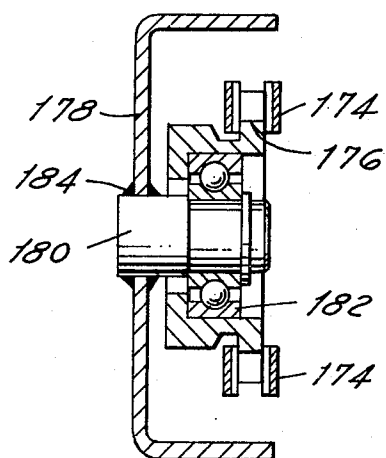
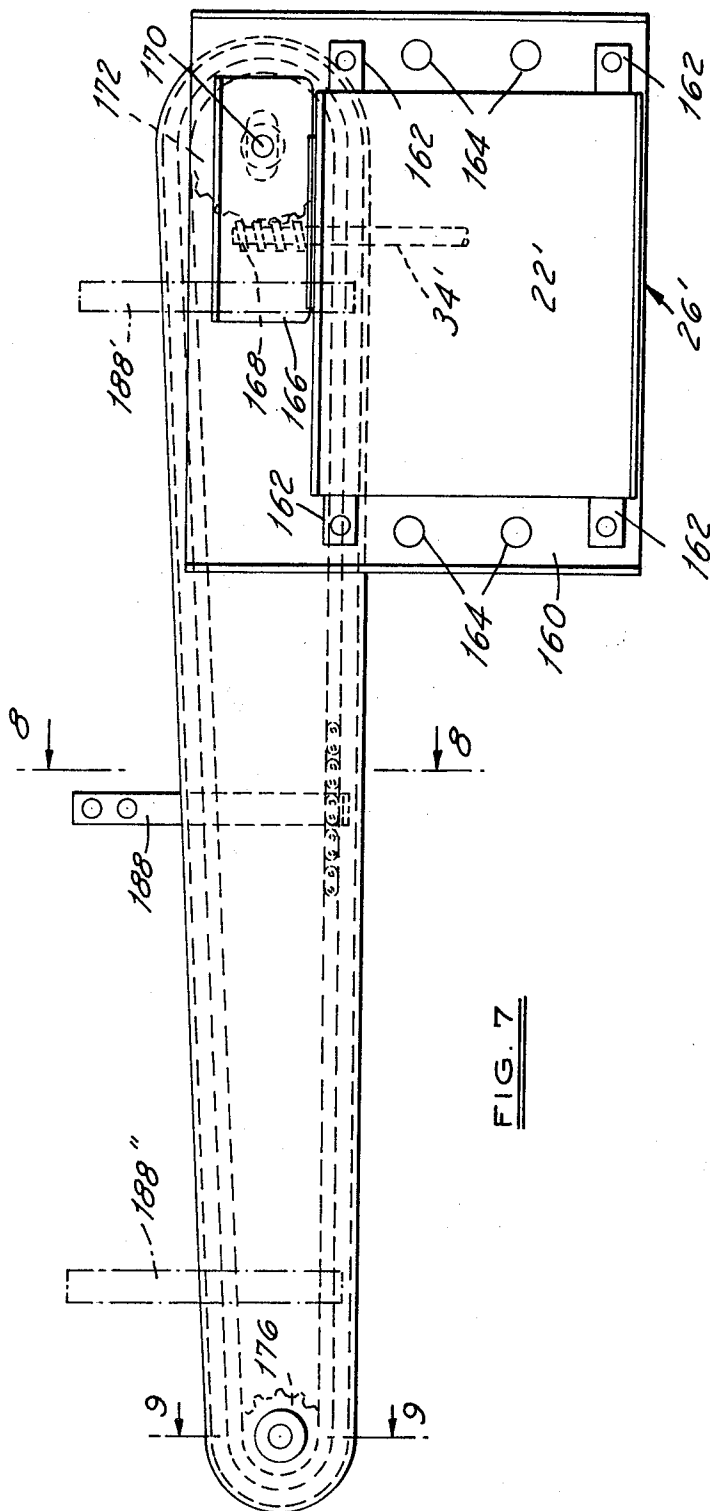


FIG. 9



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MACHINE CONTROL

BACKGROUND OF THE INVENTION

The invention relates generally to the field of machine control, and more particularly relates to a device for controlling the operation of a machine having a reciprocable part wherein various phases of machine operation must be accurately repetitively controlled. As the machine element shifts through one complete cycle of its operation, the device embodying the invention is operable to initiate the various phases of such operation accurately and unfailingly, and to repeat exactly such control functions during successive cycles of machine operation.

Heretofore, in machines having a repetitive operating cycle, it has been the general practice to position limit switches on the machine at preselected locations, which switches were actuated by a moving machine element during its travel to accomplish certain functions at specified times during the cycle. These controls have generally taken the form of electrical limit switches, or fluid pressure operated valves, in the case of a pneumatic or hydraulic machine control system. The biggest drawback to these prior are controls is that the actuating means, either in the form of limit switches or valves, must be positioned along the path of the movable machine element for actuation thereby, with the consequent exposure to contaminants in the form of oil, dust, metal particles and the like. In addition, each switch or valve requires a connection with a conduit leading from it to the central control mechanism. This of course results in a clutter of wires and conduits about the machine which are unsightly in appearance and difficult to install, as well as adding appreciably to installation costs.

The device herein disclosed provides for complete enclosure of all the controls within a single watertight, dustproof housing, with only a single connection to a moving part of the machine to accurately repetitively control the machine operation. A virtually infinite number of control sequencing arrangements are possible with no special levers, cams, arms or the like, thereby providing complete flexibility with a minimum of parts. As the switch or valve actuating members are totally enclosed within a housing remote from the movable machine element, there is virtually no possibility that they will be exposed to damage. Furthermore, the operating mechanism is protected from tampering, and is not exposed to the contaminants generally found on and about a machine tool, such as coolants, workpiece chips and the like.

SUMMARY

A device for controlling operation of a machine having a part which shifts through a predetermined path during each cycle of machine operation including a support having at least one actuating element rotatably supported thereon, one such element for each machine function to be controlled, control means positioned for actuation by each of said actuating elements, a rotatable member operably coupled to said actuating elements for rotation therewith, an elongate connecting member entrained about said rotatable member at one end and having a projecting portion connected to said shiftable machine element, and spring means coupled to said actuating elements biasing the latter to a normal at rest position corresponding to a cycle start position of said shiftable machine element.

The instant invention serves to eliminate the multiplicity of limit switches, control valves or the like which heretofore had to be fixed to the machine tool at precise locations thereon for actuation by the movable machine elements during their travel. By replacing the multiplicity of individual control units with a single unit incorporating all of the control functions within one housing, not only is a considerable saving achieved in material costs, but an appreciable reduction is also achieved in the engineering and installation of the complete machine control system. In addition, the single totally enclosed unit is less susceptible to damage and tampering during actual machine operation, resulting in a considerable reduction in

maintenance and also substantially obviating the waste of material and parts caused by machine malfunction. In providing for more efficient and reliable machine operation, the danger to operating personnel is also substantially decreased if not eliminated.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 is a perspective view of a controller device embodying the invention with the cover or housing being removed to show the working parts of the device;

FIG. 2 is an end elevation of the device shown in FIG. 1 with parts broken away to show details of construction;

FIG. 3 is a longitudinal section taken through the device of FIG. 2 with the cover or housing on;

FIG. 4 is a vertical section taken substantially along the line 4—4 of FIG. 3;

FIG. 5 is a vertical section taken substantially along line 5—5 of FIG. 3;

FIG. 6 is a partial longitudinal section similar to FIG. 3 showing a modified speed reducing gear system;

FIG. 7 is a side elevation of another embodiment of the invention;

FIG. 8 is a vertical section taken along line 8—8 of FIG. 7; and

FIG. 9 is a vertical section taken along line 9—9 of FIG. 7.

DESCRIPTION OF THE PREFERRED EMBODIMENT

In FIGS. 1–5 of the drawings there is shown a control device generally indicated at 20 that may be utilized for accurately controlling repetitive linear motion on various types of industrial equipment. The device 20 consists basically of a self-contained switch operator unit 22 and means 24 for connecting the operator unit 22 to a reciprocable part on the machine which is to be controlled. In the embodiments shown and to be described, electrical switches are utilized to control machine function. However, it will be apparent to those skilled in the art that other forms of devices could be utilized in place of the switches, as for example pneumatic valves or the like.

A generally rectangular base plate is provided, shown at 26 in the drawings, to one side of which is secured as by screws the bight portion of a U-shaped support 28, the upstanding legs of which support the operating parts of the device. Extending between the legs of the support 28 and journaled at its opposite ends in bearings 30 and 32 supported in the legs, is a cam shaft 34 upon which are mounted a plurality of switch actuating units 36, 38 and 40. While three such units are shown, any required number of units could be provided to accomplish a desired number of control functions. A plurality of switches 42, 44 and 46 are provided which are equal in number to the number of actuating units employed, which switches are mounted on a base plate 48 by means of screws or the like 50, the base plate being in turn secured adjacent its opposite ends to the upstanding legs of the support 28 as by the screws 52.

Each of the actuating units 36, 38 and 40 is preferably of the character disclosed in U. S. Pat. No. 3,120,595 or in U.S. Pat. No. 3,496,802, both of which are assigned to the assignee of the instant application. The units illustrated in the drawings correspond to the structure disclosed in the above identified pending application, and are fully delineated therein, so a detailed description of the structure will not be repeated herein. Referring to FIG. 2, a brief description of the unit 36, all of the other units being identical thereto, will suffice for a general understanding of the operation of the units.

The actuating unit 36 comprises a pair of closely adjacent parallel cams 54 and 56 each of which has an associated adjusting member 58 and 60 respectively, whereby rotation of the associated adjusting member causes rotational adjustment of the cam through a system of internal gears, so that the cams 54 and 56 may be adjusted relative to each other. This adjustment feature provides variation in the time and duration of switch actuation. As each cam of a given pair is provided with

a lobe which upon contact with the switch serves to actuate the latter, the relative rotational adjustment of the two cams 54 and 56 can be utilized to provide the desired time and duration of switch actuation. Referring to FIG. 3, each of the switches 42, 44 and 46 is provided with a projecting actuating button, the button of switch 42 being indicated by the numeral 62 in FIG. 3. Each switch projects through a suitable aperture in the mounting plate 48 into actuatable relation with the corresponding pair of cams on the units 36, 38 and 40, so that each switch is actuated by two cams. Each of the switches 42, 44 and 46 is connected by means of conventional wiring to the various parts of the machine to be controlled thereby. An electrical conduit connector 64 is mounted within a suitable aperture in the base plate 26 to accommodate the electrical connections.

Mounted on a stub axle 66 in axial alignment with the shaft 34 is a reel 68 about which is wound a flexible connecting member 70 in the form of a flat, relatively thin tape. The periphery of the reel 68 is preferably formed with two up-standing flanges 72 and 74 defining a channel therebetween within which the flexible tape is guidably positioned. Secured to the axle 66 for rotation therewith is a driving gear 76, while the shaft 34 has affixed thereto an end plate 78 which carries a pair of planetary gears 80 and 82 in meshing engagement with the driving gear 76. An internal ring gear 84 is fixed in the up-standing leg of the support 28, and is also in mesh with the planetary gears 80 and 82. There is thus formed what may be termed a simple planetary gear system which functions as a speed reducer between the reel 68 and the camshaft 34. Therefore, it is possible to accomplish speed reduction whereby only one complete revolution of the camshaft 34 occurs during a predetermined number of revolutions more than one of the reel 68.

Shown in FIG. 6 is an alternate gearing system which may be used to accomplish a desired speed ratio between the reel 68 and the camshaft 34. One leg of the support 28 is shown in FIG. 6 in which the camshaft 34 is journaled for rotation in bearing 132, the camshaft having a reduced end portion 134 upon which the reel 68 is journaled in a bearing 136 for rotation relative to the camshaft. Reel 68 has a pair of stub axles 138 and 140 fixed thereto 180 degrees apart, each axle having identical sets of two gears each mounted for rotation thereon. Each set of gears includes a smaller gear 142 and a larger gear 144 fixed to each other by a pin 146 for rotation together. The gears 142 mesh with a central gear 148 fixed to the camshaft 34, while gears 144 mesh with a reaction gear 150 which is held stationary by virtue of its connection to support 28 through a bracket 152 fixed to the gear at one end and to the support at its opposite end as by screw 154. The speed reduction which can be obtained with this gearing system is represented by the following equation:

$$\text{Reduction Ratio} = \frac{1}{1 - \frac{A}{B} \times \frac{C}{D}}$$

where the letters represent number of gear teeth, and A = gear 150, B = gear 144, C = gear 142 and D = gear 148.

The principal advantage of the gearing system illustrated in FIG. 6 and described above is the vast range of speed ratios which can be obtained without materially increasing the overall size of the unit. By varying the number of gear teeth, wide variations in ratios can be accomplished in a comparatively small gearing system.

It will be apparent that the inclusion of speed reduction gearing need be employed only in those situations wherein the length of travel of the machine element to which the device is connected is too great to permit direct connection between the reel 68 and the camshaft 34 to accomplish only one complete revolution of the actuating units 36, 38 and 40 during one complete machine cycle. As all of the control functions are accomplished during exactly one complete revolution of the camshaft 34 and the associated cam units 36, 38 and 40, it is essential to accurate operation that these elements

be rotated through only 360 degrees during linear movement of the connected machine element through its complete extent of movement. In controlling machines with relatively short travels, the reel 68 may be sized so that it may be directly connected to the camshaft 34 whereby a complete stroke of the machine element will accomplish 360 degrees rotation of the cam units 36, 38 and 40. Within limits, therefore, different machine strokes can be accommodated by variation of the circumference of the reel 68, but as stroke length increases, the circumference of reel 68 must also increase correspondingly, so that space limitations make a speed reduction system like that above described desirable.

Projecting from the base plate 26 and secured at its inner end thereto as by welding, is an elongate barrel 88 of non-circular cross-section, preferably square or rectangular for ease of manufacture. Disposed within the barrel 88 is an elongate rigid rod 90 having an outer end in the form of an eye 92 projecting beyond the free end of the barrel. Within the eye 92 of the rod 90 there is disposed a self-aligning bearing 94 through which extends a bolt 96 adapted to be threadably engaged with a linearly moving element of the machine to be controlled.

As shown in FIG. 4, a bearing 98, which may be made out of a relatively tough plastic material, is positioned adjacent to the projecting end of the barrel 88 closely embracing the rod 90 for guidable reciprocating movement therein. Also mounted in the projecting end of the barrel 88 is a sealing means 100 which is provided for the purpose of wiping the rod 90 as it retracts into the barrel, and also sealing against the entry of contaminants into the barrel. Such sealing means may comprise a generally U-shaped member in cross-section, the ends of the legs of which bear against and wipe the external surface of the rod.

Upon the inner end of the rod 90, (FIG. 3) there is secured a bearing 102 as by a pin or the like 104, the bearing 102 having an external configuration corresponding to the internal configuration of the barrel 88 to prevent rotation of the rod 90 during its movement, and to guidably support the inner end of the rod spaced from the walls of the barrel 88. Bearing 102 also serves as a stop member limiting inward movement of the rod, and as a connector to which the flexible tape 70 is secured to establish connection between the tape 70 and the rod 90.

At the end of the camshaft 34 opposite the reel 76, there is secured a helically wound spring 110, which is preferably disposed within a recess 112 formed in the support 28, and is enclosed by a cover plate 114 extending across and closing the recess. One end of the spring 110 is connected to the camshaft 34, while the opposite end is secured to the support 28, and the spring is so arranged as to bias the camshaft and associated cam units, together with the reel 76, tape 70 and rod 90 to a normal at rest position, as shown in FIG. 3 for example. Such position corresponds to the "cycle start" position of the machine element to which the rod 90 is connected, and operates to return the parts to the exact start position repetitively upon return movement of the machine element to its start position. In addition, the spring exerts a constant biasing force on the planetary gearing system coupling the reel 68 to the camshaft 34, and hence eliminates any backlash in the gears which could cause misalignment and malfunction of the control.

It is desirable that the operating parts of the device 20 be totally enclosed, and to that end there is provided a cover or housing 116, the marginal edges of which project over the corresponding edges of the base plate 26 throughout its periphery. Secured to the cover 116 adjacent to the marginal edge thereof as by welding is an inwardly offset flange 118, which together with the cover wall defines a recess within which there is positioned a sealing gasket 120 extending completely around the periphery of the cover and sealingly engaging the face of the base plate 26 when the cover is mounted in position on the plate. For securing the cover 116 to the unit, there are provided screws 122 extending through

suitable apertures in the cover and threadably engaged with correspondingly threaded holes in the end faces on the legs of the support 28. Suitable gaskets 124 are positioned under the heads of the screws 122 to seal against the entry of contaminants within the housing 116.

In order to secure the device 20 to the machine to be controlled, a mounting bolt 126 is provided which projects through a web 128 rigidly secured to the base plate 26 and barrel 88 as by welding, the mounting bolt 126 being supported within a sleeve 130 welded to the web 128. In order to install the control unit 20 on the machine, the movable member of the machine to be controlled is positioned at its "start cycle" position and the projecting end of the rod 90 is affixed to the movable machine element by the securing bolt 96, which is threadably engaged in a suitable tapped hole in the machine element. With the rod 90 in its fully retracted position as shown in FIG. 3, the mounting bolt 126 is threadably engaged within a suitable tapped hole in a relatively stationary part of the machine, and the unit is completely mounted and ready for calibration and operation.

For purposes of illustrating the operation of the above described control, we assume that it is connected to a machine in the manner described immediately above, and that such machine has a repetitive cycle of operation during which three separate control functions must be accomplished. The switches 42, 44 and 46 are provided to initiate and terminate each of the three machine functions, and are therefore suitably electrically connected to the respective parts of the machine being controlled.

In addition, the switch actuating units 36, 38 and 40 are each manually adjusted in the manner set forth in the above-referenced U.S. Pat. 3,120,595 and 3,496,802 to actuate and de-actuate each respective switch 42, 44 and 46 at the precise instant required, based upon the operating characteristics of the machine being controlled. It is understood that the camshaft 34 and hence the units 36, 38 and 40 are driven through exactly one complete revolution during the forward movement of the movable machine element, and are correspondingly rotated by spring 110 through exactly one complete revolution during the return movement of such machine element to complete a cycle of machine operation.

With the unit 20 properly mounted on the machine and the rod 90 connected to the linearly movable machine element, and the cam units 36, 38 and 40 properly adjusted, the cover 116 may be secured to the device, which is then ready for operation. At the start of each machine cycle, the parts are in the position shown in FIGS. 3 and 4, and as the movable machine element starts to shift, the rod 90 moves therewith and is extended out of the barrel 88, carrying with it the flexible connecting member or tape 70, thereby rotating the reel 68. Linear movement of the machine element is thus translated to rotational movement of the reel 68. Rotation of the reel 68 through the planetary gear arrangement causes rotation of the camshaft 34 and the associated cam units 36, 38 and 40. Because the gear system accomplishes speed reduction, the cam units and cam shaft rotate at a slower speed than the reel 68. As each cam unit 36, 38 and 40 traverses one complete revolution, its associated cams operate to actuate and thereafter de-actuate switches 42, 44 and 46 at preselected points during the machine cycle as determined by the setting of the cams, to accomplish the desired control of the machine. When the movable machine element reaches the limit of its travel, the camshaft 34 and associated cam units 36, 38 and 40 will have been rotated through exactly 360 degrees, and all desired machine functions will have been effectively carried out by the actuation of switches 42, 44 and 46. As the movable machine element begins its return stroke, the spring 110 operates to reversely rotate the camshaft 34 and hence the cam units 36, 38 and 40, and also the reel 68, winding the tape 70 back upon the reel, and retracting the rod 90 to its original start position as shown in FIG. 3. Thus, all of the movable elements of the device are returned to their exact original start positions at the end of each cycle of machine

operation, and are in proper position for the next successive machine cycle. In addition to returning the parts to their start position, the spring 110 exerts a constant biasing force which is transmitted to the planetary gear system, thus preventing backlash and insuring against the device getting out of phase with the machine being controlled.

In FIGS. 7 through 9 there is shown another embodiment of the invention comprising a switch operator unit 22' similar to that shown in FIGS. 1-6, but without the gearing system described above with reference to FIGS. 3 or 6. The unit 22' is enclosed within a housing 26' which is secured to a mounting plate 160 by means of four brackets 162 which are bolted to the plate. A plurality of holes 164 are formed in plate 160 for fixing the assembly on the machine to be controlled. Mounted atop housing 26' is an enclosed right angle speed reducer 166 of conventional construction, the worm gear 168 of which is fixed to camshaft 34' projecting out of housing 26'.

The output shaft 170 of speed reducer 166 has fixed thereto a drive sprocket 172 about which is entrained a continuous drive chain 174, which is also entrained around an idler sprocket 176 spaced from the drive sprocket 172 by a distance greater than the travel of the machine element, as explained below. A protective cover 178, substantially U-shaped in cross-section, embraces the chain 174 and is attached to plate 160 as by screws or the like (not shown). Idler sprocket 176 is journaled for rotation on a stub axle 180 by bearing 182, and the axle is fixed to cover 178 as by welding, as shown at 184 in FIG. 10.

Chain 174 is provided with a special link portion having outwardly projecting flanges 186 to which a bracket 188 is secured by welding, riveting or other suitable fashion. Bracket 188 exhibits a pair of apertures 190 through which machine screws or the like may extend to secure the bracket to the reciprocating part on the machine to be controlled. With the assembly secured to a stationary part on the machine and the bracket 188 connected to the movable machine part, the bracket 188 is shifted between the phantom positions shown at 188' and 188'' in FIG. 7 during each machine cycle, thereby driving chain 174 to rotate drive sprocket 172, which in turn rotates shaft 170 of the gear reducer 166. Worm gear 168 is rotated to produce 360° rotation of camshaft and the associated controls during each machine stroke, in the same fashion as described hereinabove with respect to FIGS. 1-5.

Thus it can be seen that there is provided an extremely simple and trouble free self-contained control unit for accomplishing the control of repetitive machine operations. In addition to being extremely reliable, the unit is versatile in that it can be provided with any desired number of actuating units to control a multiplicity of machine functions.

What is claimed is:

1. Apparatus for controlling operation of a machine having a linearly moving machine element, comprising: a support connected to a relatively stationary part of said machine; at least one actuating means journaled for rotation on said support for actuating control mechanism of said machine; a rotatable member coupled to said actuating means for rotation therewith; an elongate connecting member drivingly coupled to said rotatable member and having means thereon for connection to said linearly moving machine element; and biasing means coupled to said actuating means yieldably biasing the latter to a predetermined at rest position, whereby linear movement of said machine element and said connecting member is translated to rotational movement to rotate said actuating means.

2. The invention defined in claim 1 characterized in that said actuating means comprises a rotatable cam means on a shaft and means for selectively adjusting the rotative position of the cam means relative to the shaft.

3. The invention defined in claim 2 characterized in that said biasing means comprises a helically wound spring member encircling said shaft and connected at opposite ends to said shaft and said support respectively.

4. The invention defined in claim 1 characterized in that said elongate connecting member is flexible, and said rotatable member comprises a circular disc having circumferential flanges at opposite ends thereof defining a channel therebetween for guidably retaining said flexible connecting member.

5. The invention defined in claim 4 characterized in that said flexible connecting member comprises a relatively thin metal tape having a width less than the width of said channel on said reel for reception of the tape within the channel.

6. The invention defined in claim 1 characterized in that said rotatable member comprises a sprocket and said elongate connecting member comprises a chain entrained about said sprocket and having means thereon for connection to said linearly moving machine element.

7. The invention as defined in claim 1 characterized in that a speed reduction gearing system is interposed between said rotatable member and said actuating means whereby said actuating means will be rotated one complete revolution during rotational movement of said rotatable member through a predetermined cycle of movement related to the movement of said linearly moving machine element.

8. Apparatus for controlling the operation of a machine having a linearly shifting machine element, comprising: a housing having means thereon for securing the housing to a relatively stationary portion of said machine; a support mounted within said housing; a shaft journaled at opposite ends for rotation on said support; at least one actuating cam unit mounted on said shaft for rotation therewith; a cam-actuable machine control device mounted on said support for actuation by said cam unit; a reel rotatably mounted in said housing; means coupling said reel to said shaft for rotation therewith; a flexible, elongate connecting element wound upon and secured to said reel at one end and projecting through and beyond said housing and having means at its projecting end for connection to said linearly shifting machine element; and spring means coupled to said shaft yieldably biasing the shaft to a normal at rest position of rotation.

9. The invention defined in claim 8 characterized in that said means coupling said reel to said shaft comprises a speed reduction gearing system.

10. The invention defined in claim 9 characterized in that said speed reduction gearing system is in the form of a planetary system having a driving gear connected to one of the mem-

bers and a ring gear connected to the remaining member and at least one planet gear interposed between the driving and ring gears.

11. The invention defined in claim 8 characterized in that said actuating cam unit comprises a pair of parallel, closely spaced cam members for actuating a single machine control device, each of said cam members having an actuating lobe and being independently mounted on said shaft for separate selective rotational adjustment with respect to the remaining cam member.

12. The invention defined in claim 8 characterized in that said reel has a channel-shaped circumference and said flexible connecting element comprises a relatively thin, flat metallic strip of flexible material having a width adapted to fit within said channel for guiding support of the connecting element on the reel.

13. The invention defined in claim 8 characterized in that a rigid actuator rod is coupled between said flexible connecting element and said linearly shifting machine element and including means for connection to the machine element, and means embracingly supporting said rod for guided movement in a straight line path.

14. The invention defined in claim 13 characterized in that a hollow, elongate barrel is secured to said housing, with said actuator rod coupled to said connecting element at one end and in the normal at rest position extending through said barrel and having an opposite end projecting therebeyond for connection to said linearly shifting machine element for reciprocation in response to machine element movement.

15. The invention defined in claim 14 characterized in that said barrel is of non-circular cross-sectional configuration, and a bearing block corresponding to said barrel configuration is fixed to said actuator rod guidably supporting the rod for movement within the barrel.

16. The invention defined in claim 15 characterized in that said bearing block is fixed to said rod adjacent the end thereof coupled to said flexible connecting element and is adapted to abut a part on said support providing a positive stop for the rod and the connecting element at said normal at rest position.

17. The invention defined in claim 16 characterized in that said barrel is provided at its end opposite said housing with a resilient sealing means closely embraceably encircling said actuator rod and in wiping contact therewith to prevent entry of contaminants into said barrel.

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