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DOOR ACTUATING MECHANISM

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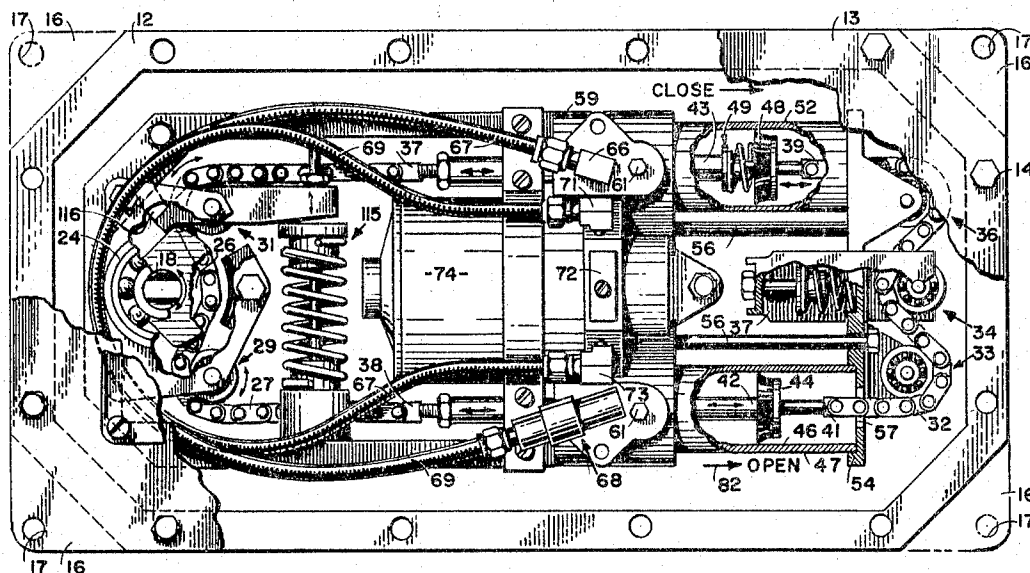


Fig. 1.

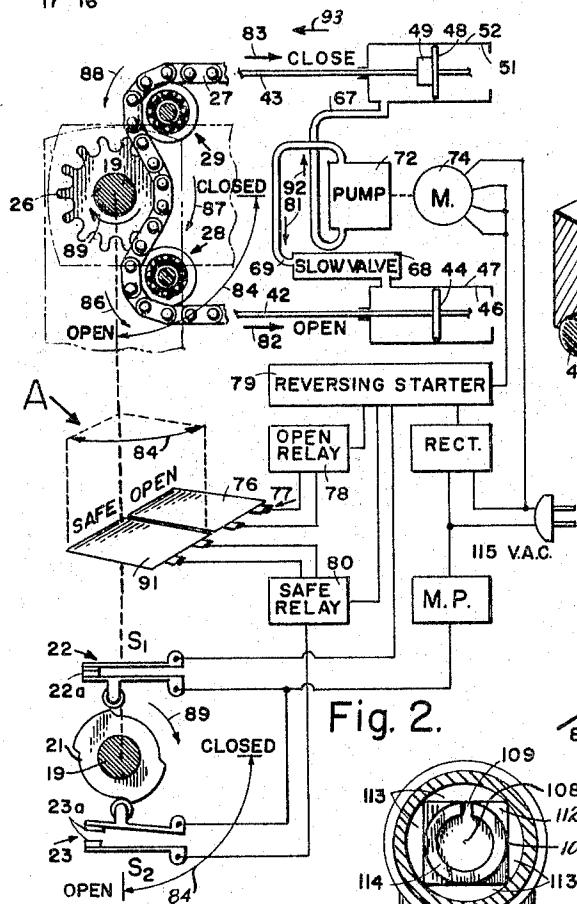


Fig. 2.

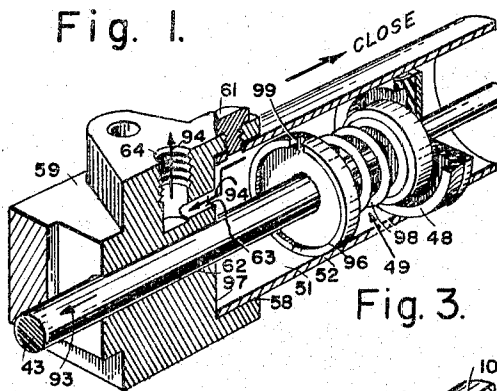


Fig. 3.

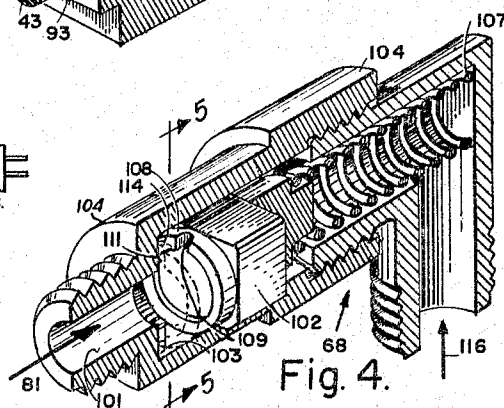


Fig. 4.

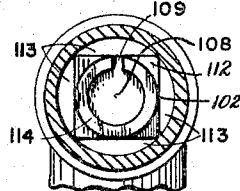


Fig. 5

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1

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## DOOR ACTUATING MECHANISM

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7 Claims. (Cl. 49—264)

This invention relates to a door opening and closing mechanism and more particularly to such a mechanism that is hydraulically and automatically actuated.

In recent years it has become quite common to provide many buildings, particularly those generally used by the public such as supermarkets, government installations and the like, with automatic door opening devices. Such devices have particular utility where a shopper may be entering or leaving a building with bundles in hand or where the inertia of large external doors makes manipulation difficult particularly for the aged, the young or the disabled.

A number of problems have been encountered in the development of automatic door actuators. For example, many systems with which we are familiar employ positive control over the opening of the door but rely upon a spring or other suitable relaxation device to close the door. In this type of arrangement the use of mechanical springs and the like are often subject to fatigue failure after a relatively short period of usage. In addition, this type of closure presents difficult problems for the arrangement of a positive safety device to prevent the door from closing in the event that a person or an obstruction occupies the region of door swing.

Another problem quite common to many automatic door actuators is the difficulty of arresting the door opening swing at the end of its path of travel without causing inertial impact and shock to the door itself and surrounding structure. In some systems with which we are familiar this is overcome by permitting the door to coast or glide to the fully open position after being powered only part of the way. This has certain disadvantages; for example, when a door opens to the outside it may be subject to external factors such as wind which will then prevent the door from opening entirely. Also, in the case of successive passages by pedestrians close together, the door may be unable to obtain sufficient inertia during its second and successive swings to open completely.

As mentioned above, many door opening mechanisms rely upon springs or other relaxation devices to effectuate closing of the door after controlled opening. Few designs with which we are familiar attempt to overcome this by some form of positive door closure actuator; and those that do generally involve relatively complex mechanical solutions such as additional hydraulic valving, electrical circuitry, and the like. Even where positive closure is not a design feature, the prior art devices which we have seen generally involve somewhat extensive hydraulic or electrical installation procedures and do not provide a simple, compact, and relatively inexpensive installation.

Thus it is an object of this invention to provide a hydraulic actuator for the automatic opening and closing

2

ing of a door which embodies within a single enclosure a reversible electric motor and hydraulic pump adapted to hydraulically actuate a door in either direction of travel by means of a novel hydraulic cylinder and piston arrangement. The actuator may be energized to open the door whenever a pedestrian approaches the immediate vicinity of one side of the doorway if the other side is free of any obstruction such as another pedestrian or an object placed in the pathway of the door.

It is another object of this invention to provide an automatic door actuator which utilizes a reversible rotation electric motor and hydraulic means coupled to the motor to open and close a door when an object is present at one side of the door and which may be adapted to respond to an object on either side of the door. The novel system proposed employs actuating means capable of energizing the electric motor to rotate in one direction or the other which in turn urges the hydraulic means to either open or close the door being serviced. An hydraulic snubber or restrictor is employed in combination with the hydraulic means to dissipate the inertial energy of the door when the latter is displaced to the open and closed positions.

It is also an object of this invention to provide suitable sensing means on either side of the door to be actuated which are electrically interconnected to the motor and hydraulic pump to cause rotation of the door to the open position in a relatively rapid manner. The hydraulic cylinders and pistons, which transmit the hydraulic fluid pressure to linear and rotational movement of the door, are in combination with a novel hydraulic snubbing device which decelerates the door and dissipates its inertial energy when the door swings to the open position. In this way the door swings open to a stop with minimum shock and impact to the door and surrounding structure. In addition, the sensing means, which may be in the form of a mat which occupies the floor under the path through which the door swings to the open position, is capable of causing de-energization of the electric motor and hence stoppage of the door swing if an obstruction occupies said mat before or even after the door swing has commenced.

Another object of our invention, after a pedestrian has passed through the passageway, is to provide for positive door closure under full control of the electrohydraulic system without reliance upon springs or other relaxation devices.

A feature and advantage of this invention is that by the use of hydraulic snubbing at the end of the open cycle of the door it is possible to maintain full positive door actuation until the very end of the opening swing. In this way the usual impact observed at the end of the opening swing may be minimized without de-energizing the door operator prematurely and relying upon the door's own inertia to complete its swing. By such an arrangement the achievement of a full open passage may not be frustrated by such external influences as wind and the like.

It is another object of this invention to provide a hydraulic restrictor which is automatically interposed into the hydraulic circuit in the door closing portion of the

3

operation. By means of such restrictor the door is returned under positive electrohydraulic operation but with a greatly reduced rate of speed as compared to the door opening action. The advantage of this is that the likelihood of injury is reduced in the situation where the pedestrian has crossed through the passageway and walked on. In such case the door closing swing is unobserved and uncontrolled in respect to persons or objects that may inadvertently be placed in the door's path of swing and before the safety switch acts.

A further object of this invention is to provide a novel hydraulic flow restrictor comprising a housing which defines a source for hydraulic fluid and an opening for the discharge therethrough by means of a movable member which has attached to it a resilient portion. When the movable member is relatively close to the opening, the resilient portion covers said opening and restricts the flow of fluid therethrough to a small passage formed between the housing and the resilient portion in the region surrounding the opening.

It is also an object of this invention to provide a novel flow restrictor of the type described above which may be adapted to restrict flow through a housing in one direction of travel during the entire duration of such flow and permit unrestricted flow of fluid through the housing in the other direction. Such a novel restrictor may be referred to as a slow valve.

A feature and an advantage of the above described novel restrictor devices is that the restricted passage for the flow of fluid therethrough is opened and exposed to the flushing action of the hydraulic fluid flowing through the device during those periods of usage when the flow is not being restricted. In this way small particles of matter may be flushed from the walls which form the restricted passage, thus assuring relatively trouble free operation. Such self cleaning action is not available generally to prior art devices of the restricted orifice type with which we are familiar.

A further object of this invention is to provide a single and compact enclosure containing all of the electrohydraulic components necessary for door actuation with the exception of the floor mats and their electrical leads. Such an integral actuator unit is one which may be relatively easily and inexpensively installed in the vicinity of the door to be serviced.

A feature and advantage to the unitary type of construction that we employ is that the single enclosure necessary to house our invention may also be utilized as an oil reservoir in which the motor and the hydraulic pump may be partially immersed in hydraulic fluid. In this way, any hydraulic leakage which may occur is immediately returned to the reservoir of usable hydraulic oil and brought back into the system through the pump without the necessity of expensive and inconvenient maintenance shut downs. In addition, the reservoir is adapted to have a capacity of oil sufficient to actuate the various hydraulic components as well as dissipate the heat generated by normal operation of the electric motor and the hydraulic pump and provide an immediate lubricant for the various mechanical components which are either near or immersed in the reservoir.

Another feature and advantage of our invention is that by the novel design of certain of our hydraulic components and the arrangement thereof, opening and closing of the door is accomplished without the use of reversing hydraulic valves, intricate electrical circuitry, or the like.

It is a further object of this invention to provide novel structure in the hydraulic snubber and hydraulic restrictor which includes means for restricting the passage of hydraulic fluid during critical portions of the cycle while causing full hydraulic flow at other times. The restricting passage referred to is in the form of a relatively small groove which causes reduced flow of hydraulic oil in one

4

direction of door travel during part of the cycle. During the remainder of the cycle the groove is relieved of its restricting function and placed so that it is flushed by the hydraulic fluid when the door is caused to travel in the opposite direction. In this way the groove is cleaned free of any particulate matter that may be in the fluid to cause clogging of the groove and impede proper operation of the unit. Moreover, in the arrangement that we utilize our novel snubber and restrictor are relatively immune to variations in output and performance due to environmental temperature changes.

Other numerous objects, features and advantages will become apparent upon a reading of the specification which follows with reference to the accompanying drawing in which similar characters of reference correspond to the same parts in the various views.

Turning now to the drawings, FIG. 1 is a plan view of our invention, with the top cover plate partially removed to show various details, some partially sectioned, of certain components.

FIG. 2 is a schematic diagram of the invention showing both mechanical and electrical components and where in the electrical portion is partly in block form.

FIG. 3 is a cut away isometric view of one of the hydraulic cylinders embodying a portion of the invention.

FIG. 4 is a cut away isometric section of another portion of the invention referred to as a slow or restrictor valve.

FIG. 5 is a sectional elevation taken along line 5—5 in FIG. 4.

Our invention employs the use of a pair of hydraulic cylinders equipped with certain novel flow control devices for automatically opening and closing a door pivotally mounted in a conventional manner. The device or door actuator provides a foot mat, called an open mat, on one side of the doorway or entrance which is responsive to the foot pressure of a pedestrian as he or she approaches the closed door which causes the door to swing open. The door actuator is also provided with a pressure sensitive mat on the opposite side of the entrance so that the presence of an object or another pedestrian on the latter mat, called a safety mat, prevents swinging of the door by the presence of an entering pedestrian on the open mat. When the door is caused to open, the entire open swing occurs in less than about two seconds; and the door is held open until both sides of the doorway are free of persons or objects. The door is then caused to close at a greatly reduced rate of speed taking about four seconds to resume its fully closed position. Despite its rapid opening motion, a novel hydraulic snubbing device built into one of the hydraulic cylinders virtually eliminates shock or slamming of the door upon being fully opened, and closing at the reduced rate of speed continues until the door is completely shut. Both actions are achieved by a reversible hydraulic pump operating at a relatively constant speed with the fluid flow in the closing direction of pumping modified by a novel restrictor valve.

The entire electro-hydraulic mechanism which makes up our invention, with the exception of the open and safety mats, can be contained in a single compact case-mat or enclosure which may be readily placed under or over a door threshold. Upon installation of the single integral unit, the entire actuator may be placed into operation by merely providing ordinary 115 volt electrical current not in excess of about 3 amps for operation; no further plumbing, wiring or mechanical hook-up is necessary. The case-mat is designed to be at least partly filled with hydraulic fluid which acts as a reservoir for the various moving hydraulic components and also as a coolant for the entire system including the electric motor and close coupled reversible hydraulic pump.

Although the specification and accompanying drawing describe the invention as adapted for installation under

5

a door threshold in a floor slab or the like, it is evident that the actuator may be installed in a number of positions, including over the top of the door, by making only minor changes.

The invention is best understood by first referring to FIG. 1 wherein casement 12, to which is bolted lid 13 by means of cap screws 14 or other suitable means, contains nearly all of the essential components with the exception of the open and safety mats which are secured on either side of the door to be serviced by the device. The corners of lid 13 overhang the body of casement 12 to form mounting ears 16 having holes 17 for convenience of mounting the casement in a floor slab or the like immediately underneath the door to be serviced, such as that indicated generally by A in FIG. 2.

The details of mounting the door indicated at A are not a part of this invention and are not described in detail herein; however, the bottom pivotal edge of the door should be provided with a suitable member for cooperative engagement with protruding stub 18, shown in FIG. 1, so that rotation of the stub causes the same corresponding rotation of the door.

Stub 18 is the uppermost extremity of shaft 19 which can be seen in section in both the upper and lower portions of FIG. 2. Although for convenience of illustration the schematic FIG. 2 shows the door indicated generally at A as mechanically coupled to portions of shaft 19 above and below the door, it is understood that in the actual physical embodiment of the invention described herein the entire shaft and stub assembly are mounted as a unit as below the door.

As best seen in the lower portion of FIG. 2, limit switch cam 21 is mounted concentrically on shaft 19 immediately below stub portion 18 and the inside portion of lid 13 when the latter is bolted in place on enclosure 12. The shape of cam 21 and its relationship to the limit switches indicated at 22 and 23 is explained in greater detail hereinafter; but it is to be noted at this time that such placement of the limit switch cam and limit switches is part of an arrangement whereby all of the electrical components, with the exception of the open and safety mat contactors mounted in the vicinity of the door, may be included as a part of a single, compact, electrohydraulic package. A suitable oil seal (not shown) is mounted immediately below limit switch cam 21 and, with a portion of lid 13, acts to prevent any hydraulic oil from invading and hindering the proper operation of the limit switches indicated at 22 and 23, also denoted on the drawing as S1 and S2, respectively. The remainder of the electrical components, with the exception of the mat contactors mentioned above and certain interconnecting wiring, are mounted within other splash-proof enclosures on the underside of lid 13. Lower bearings 24, seen in the cut away portion of FIG. 1, receives the lowermost and stepped portion of shaft 19 and, together with an upper bearing (not shown), provides the necessary rotatable support of shaft 19. Immediately above bearing 24, chain sprocket 26 is concentrically mounted on shaft 19 by means of welding or other suitable means. Roller chain 27, selected to cooperate with chain sprocket 26, is held in engagement therewith by means of suitable idler sprocket assemblies indicated at 28 and 29 which are of conventional form and not described further. Chain 32, similar to but shorter than chain 27, is mounted at the opposite end of casement 12 and supported by idler sprocket roller assemblies indicated at 33, 34 and 36, similar to those indicated at 29 and 31. The central idler sprocket indicated at 34 bears resiliently against chain 32 by means of its spring urged mounting bracket 37 whereby the entire interconnected chain system described below, including chain 27, is maintained in a relatively taut condition thus insuring engagement of the chains in their respective sprockets relatively free of backlash.

Chain ends 37 and 38 of chain 31 are in direct alignment, respectively, with chain ends 39 and 41 of chain 32;

6

ends 38 and 41 are linked together by means of rod 42 while ends 37 and 39 are similarly connected by means of rod 43. The portion of rod 42 seen in the lower right of FIG. 1 supports piston 44 which is suitably secured thereto and in close slidable contact with wall 46 of cylinder 47. The portion of rod 43 seen in the upper right hand of FIG. 1 supports piston 48 which is suitably secured thereto and in close sliding contact with wall 51 of cylinder 52. Directly adjacent to piston 48 there is mounted on rod 43 the novel snubber assembly indicated at 49 and seen in greater detail in FIG. 3. Both cylinders 47 and 52 are capped by closure plate 54 which is best seen in the partial cross-sectional portion in the lower right hand section of FIG. 1 where the plate is shown held in place by suitable high tensile bolts 56. Closure plate 54 is also provided with openings 57 to permit passage of ends 41 and 39 and portions of chain 32 during movement of the aforementioned pistons as will be explained. The fluid end of both cylinders 52 and 47 are similar; thus a description of one may serve to describe both. Cylinder 52, best seen in FIG. 3, terminates at its fluid end in close fitting counter bore 58 of mounting block 59 and is secured therein by means of cap screw 61. The mounting block is provided with a through bore 62 for sliding passage of rod 43 and an off center bore 63 with right angle portion 64 for fluid communication with cylinder 52. Opening 64 terminates at the top surface of block 59 where it receives right angle hose fitting 66 in fluid communication with flexible hydraulic tubing 67. Similarly, cylinder 47 at its fluid end is in fluid communication with the slow valve indicated at 68 (which also acts as a right angle fitting similar to that of fitting 66) and hose 69. Avoiding sharp bends, hose 69 turns gradually and leads to right angle fitting 71 which terminates at one port of a conventional, reversible, hydraulic pump 72 which is not further described herein or shown in greater detail in the drawings except to note that said pump's other port is connected in fluid communication with right angle fitting 73 which in turn communicates and holds the end of hose 67 opposite its point of connection to fitting 66. A close coupled, conventional, two-winding, reversible, capacitor start, single phase, 115 volt AC motor 74 is mounted and close coupled to rotate pump 72 in either direction so that hydraulic fluid may be pumped from cylinder 52 into cylinder 47 or vice versa. The electrical connections to motor 74 are not seen in FIG. 1 since, as mentioned earlier, substantially all of the electrical components of our invention are positioned directly under the inside surface of lid 13 to form a compact and unitary door actuating mechanism; however, the various functional interconnections of said electrical components are shown in FIG. 2.

It should be noted here that throughout this specification and appended claims reference is variously made to the fluid end of a cylinder and the "dry" end thereof. By these terms, the fluid end means that end of the cylinder into which hydraulic fluid is introduced through a suitable port or the like in order to actuate the piston in the cylinder; the dry end of the cylinder is the end opposite the end into which hydraulic fluid is introduced through a port or the like and which is always separated by the piston from the direct fluid communication with the pumped in fluid. It is understood, however, that the so-called dry end of the cylinder in our invention may be immersed in oil because all of the hydraulic components, including the cylinders, may be positioned within a reservoir, described in more detail elsewhere herein, and that the dry ends of the cylinders have openings for mechanical linkage between the pistons and other actuator components.

Referring now to FIG. 2, the operation of our invention is further described assuming that a pedestrian approaches the normally closed door indicated at A and begins to walk on open mat 76. The weight of the pedestrian on the open mat causes contact to be made between normally separated conductive surfaces indicated

at 77 which in turn energizes open relay 78 and energizes its normally opened contactors (not shown) to a normally closed position. The details of this and other electrical components referred to hereinafter, and shown in block representation in FIG. 2 are well-known expedients in the electrical control art and are not set forth or described in detail except to refer to their various general functions as applied in the present invention. Energization of open relay 78 further energizes reversing starter 79 which then causes 115 volt AC electrical energy, indicated to the right of FIG. 2, to be supplied to motor 74. It should be noted that one leg of the 115 volt AC power is initially completed through the limit switch indicated at 22. Contacts 22a are normally closed when door A is in the closed position indicated by the line marked "Closed" in the upper and lower portions of FIG. 2. At this point motor 74 rotates pump 72 in a direction whereby hydraulic fluid is delivered in the direction of arrow 81 through the slow valve indicated at 68 into cylinder 47 best seen schematically in the upper portion of FIG. 2. The operation of the slow valve is explained in greater detail below; however, it is to be noted here that the flow of oil in the direction of arrow 81 is virtually unimpeded so that piston 44 may be displaced at a maximum rate of speed. As explained above, cylinder rod 42, chain 32, cylinder rod 43, and chain 27 are all interconnected. Consequently, the displacement of piston 44 in the direction of arrow 82 causes piston 48 to be moved in a direction of arrow 93 which causes the oil on the fluid side of cylinder 52 to be expelled through hose 67 and into pump 72 for circulation to cylinder 47.

The hydraulic displacement of pistons 44 and 48 described above causes motion of chain 27 in the direction of arrows 86, 87 and 88 and the rotation of shaft 19 in the direction of arrow 89. As can be seen in the lower portion of FIG. 2, as soon as door A rotates at least about 5° in the open direction of arc 84, the limit switch indicated at 23 closes together previously open contactors 23a.

So long as no obstructions or persons come into contact with safe mat 91, the door at A continues to open and obtains its full open swing, the position indicated by "Open" on the drawing, in about two seconds or less. If an obstruction or person does occupy safe mat 91, safe relay 80 is energized which in turn interrupts the hold-on current of reversing starter 79; as a result, motor 74 is de-energized, after a brief time delay, and the door swing arrested. If the obstruction is present before energization of open relay 78, the open relay cannot be energized at all by the interruption of the open relays energizing circuit by safe relay 80. During the last 5° of travel toward the open position, limit switch contactors 22a are opened, and power to motor 74 is interrupted. The inertia of the rapidly swinging door carries it to its fully open position but could, however, cause harmful shock or slamming. This is reduced, if not entirely eliminated, by the action of the snubber indicated at 49 and explained in greater detail below.

The brief time delay referred to above is for the purpose of preventing the open relay contactors from "chattering" due to the variation of pressure on the open mat as a pedestrian walks along it and also to prevent interruption of the open action as the pedestrian crosses over from the open to the safe mat.

Upon passing over the threshold of the door, the pedestrian comes into and remains in walking pressure contact with safe mat 91 which causes energization of safe relay 80. The reversing starter at this point returns to its normally de-energized position, after the brief interval caused by discharge of the time delay circuit. At this point motor 74 would be energized in the reverse direction to cause closing of door A, but completion of this circuit would be through the limit switch indicated at 23 whose contacts 23a are now closed. This is prevented so long as the pedestrian is present on the safe mat since this interrupts limit switch 23a's circuit and completion of

the motor main winding across the line through a normally closed, and now open, safe contactor (not shown). After the pedestrian leaves safe mat 91, and if no further obstructions or persons occupy said mat or open mat 76, motor 74 may be energized in the reverse direction so that hydraulic oil is pumped in the direction of arrow 92 to the fluid side of cylinder 52. This causes rod 43 to move in the direction of arrow 83 and chain 27 to move in a direction opposite to arrows 86, 87 and 88. This in turn causes shaft 19 to move in the direction opposite to arrow 89 and the door indicated at A is swung from its open position through arc 84 in the direction of the closed position also marked in FIG. 2.

Motor 74 and pump 72 are coupled together in the same manner for both the opening and closing portions of the cycle; however, during the closing portion piston 44 moves in a direction opposite to arrow 82 and discharges hydraulic oil out of cylinder 47 into the slow valve indicated at 68. In this direction of oil circulation, the slow valve offers a restriction to the flow of oil so that the door at A closes at a much reduced speed compared to the door opening swing; and the door requires in the neighborhood of about four seconds to fully close.

Reference is now made to FIG. 3 which shows in greater detail close cylinder 52 and more particularly the door opening snubbing device indicated at 49. As was mentioned before, while the door is being opened, oil is being discharged from the cylinder 52 by the action of rod 43 urging piston 48 in the direction of arrow 93. This displaces oil out of cylinder 52 through passages 63 and 64 in the direction of arrow 94. When the piston approaches the end of its travel, i.e. when the door is in its nearly open position, snubbing plate 96 which is slidably mounted on rod 43 and spaced apart from piston 48 by means of short compression spring 98, approaches wall 97 in block 59. Up to this point oil may be expelled freely through passages 63 and 64, back through pump 72 and ultimately into the fluid end of cylinder 47 which results in rapid movement of chain 27 and the opening of the door at A. As plate 96 seats against wall 97, the large passage 63 which permits free exit of the fluid now becomes substantially blocked by plate 96. The outside diameter of plate 96 is somewhat less than the inside diameter of the wall 51 of cylinder 52; but, with plate 96 seated against wall 97, all oil flow out of cylinder 52 is restricted through notched opening 99 in the ridged portion of plate 96. Thus the movement of rod 43 and piston 48, as soon as snubber plate 96 begins to contact wall 97, is greatly reduced in speed and cushioned against shock. This is so since the speed of said rod and cylinder is a function of the amount of oil being discharged from cylinder 52, which at this point is reduced to a very small flow; both pistons 44 and 48 and their respective rods and chains 27 and 32 are mechanically interconnected as explained earlier; and the amount of oil available to be pumped from cylinder 52 through the slow valve into cylinder 47 is greatly reduced at this moment. When the door swing operation is reversed and the door caused to close, cylinder 48 moves away from wall 97, and compression spring 98 moves snubbing plate 96 back to its normal position preparatory to the next door opening event.

Reference is now made to FIG. 4 showing the slow valve indicated generally at 68 in FIG. 1. During the door opening swing described in greater detail above, pump 72 delivers hydraulic fluid in the direction of arrow 81 through hose 69, as indicated in the upper portion of FIG. 2. As seen in FIG. 4, fluid enters the slow valve through inlet port opening 101. Control block 102 is slidably mounted in cylindrical passage 103 of slow valve housing 104 and is normally maintained in contact with inner valve body face 111 by means of relatively low compression spring 107. The forward portion of block 102 is provided with an annular ring portion 108 which has a small groove 109 machined across its face. As the hydraulic oil enters in the direction of arrow 81 during

the door opening cycle, the flow of oil at first tends to be constricted to passage through groove 109, between the interface of ring portion 108 and wall 111 of housing 104, around annular opening 112 toward the sector spaces 113 between body bore 103 and straight sides of block 102. The pressure of the hydraulic oil impinging upon portion 108 of block 102, however, tends to slide block 102 against the relatively low resistance of compression spring 107 and away from the position indicated by dotted line 114. As a result, the hydraulic oil entering the opening cylinder during the opening of door A is relatively unimpeded in its flow so that the open piston is moved in the relatively rapid fashion described earlier. However, during the door closing cycle, when rod 42 and piston 44 are moved in the direction opposite to that of arrow 82 shown in the upper portion of FIG. 2, the flow of hydraulic fluid away from the cylinder through outlet port 116 shown in FIG. 4 tends to move block 102 and portion 108 into the position indicated by the dashed lines of FIG. 4. In addition, compression spring 107 urges block 102 to this position. Accordingly, all of the fluid leaving the cylinder 47 during the door closing cycle must find its way through sectoral openings 113, annular opening 112, and groove 109 between portion 108 and housing wall 111. This constricts the flow of the fluid so that the closing action of the door is greatly reduced in speed as described earlier.

During closing of the door, if either persons or obstructions occupy on the safe mat, the power circuit to motor 74 is interrupted immediately and no further action of the door may occur. During the rotation of the electric motor to cause the door at A to close, the reversing starter is in its normally de-energized condition and is not interrupted by the action of safe mat 91 and its relay 80; but since the motor during all but the first 5° of door opening is powered through the circuit completed by the limit switch indicated generally at 23, and because this circuit is opened immediately by energization of the safe mat, there is instantaneous interruption of the motor power circuit. In this condition it is also noted that occupation of the open mat by an incoming pedestrian will have no effect since the open relay cannot be energized while the safe mat contactors are closed energizing the safe relay.

Because of the reversal of fluid through the slow valve during the door opening and closing cycles explained earlier, restrictor groove 109 is automatically flushed through each cycle of door opening and closing. In this way dirt or other particles which may invade the groove and impede proper operation of the system are flushed away before such trouble can develop. The same is true of the general arrangement of the door snubbing device indicated generally at 49 and in particular restrictor groove 99 in that portion of our invention. In addition, both devices are relatively unaffected by changes in the environmental temperature in which they operate.

Although not shown in the drawings, our invention may include a relief valve in the slow valve circuit immediately between the port of cylinder 47 and the discharge inlet of the slow valve in the region of flow indicated in FIG. 4 by arrow 116. In this way, undue motor load and/or excessive pressures are prevented during discharge of oil from cylinder 47 through the slow valve. Any oil which may be discharged by such a relief valve is returned to the oil reservoir and available for re-introduction into the hydraulic circuit.

Reference is made once again to FIG. 1 and the "panic linkage" indicated therein at 115. This linkage is required by a number of safety codes if the door indicated at A is a door leading to the outside and normally opens inward. By means of such linkage the door may be opened outwardly beyond the closed position indicated in FIG. 2 merely by a pedestrian forcing it in this direction from the inside. When the door is one of an internal nature, and where its opening in a direction opposed

to its operation is not deemed necessary under local safety requirements, the linkage indicated at 115 is replaced by block 116 which is made of a suitable material and indicated by a dotted line. The panic linkage indicated on the drawing at FIG. 1 is of a conventional type whose operation will be apparent to one of ordinary skill in the art viewing the various components and is not further described herein.

Hydraulic fluid is maintained to a level about equal to the half way point of the depth of casing 12. This fluid is available at all times to the hydraulic pump so that fluid which may tend to find its way out of the hydraulic loop described in greater detail above may be replenished automatically and without attention by outside maintenance. Because all fluid which may leak from the closed hydraulic system will find its way into the casement reservoir, virtually no makeup hydraulic fluid is required by this invention. The fluid is also valuable as a coolant for the electric motor and the various moving parts present in the immediate environment around it and provides ready lubrication for the springs, roller chain, bearings and other mechanical components described earlier. With the oil level as described above, the electric motor (and pump) in this embodiment of our invention is nearly completely submerged in oil. Although the level of oil may vary somewhat from one design embodiment to another, in general the motor is submerged sufficiently to achieve such features as cooling, oil replenishment and the like.

It is also to be noted that because of the positive operation of our actuating device, i.e., the use of a reversing motor and hydraulic pump which positively actuates the door in both directions of travel, practically no external influences such as wind may affect the proper operation of the door itself.

Although we have described our novel door actuator in the foregoing description as applied to a swinging door, it is understood that the novel actuating mechanism itself may be applied to other types of doors as well including, but not limited to, sliding doors of both horizontal and vertical orientation. This may be done by making certain modifications in the linkage that we show between the actuator and the door.

It is further understood that, although we have described our invention as including a safety mat, our novel actuator mechanism may be practiced without this component under certain circumstances in particular applications. When such be the case, our actuator system may be modified, for example, to provide for a time delay at the end of the door opening operation after which door closing, in a manner similar to that described hereinabove, may occur. Moreover, although we have described our invention using floor mats for initial energization of the electrical system, other devices may be used such as photoelectric sensing switches, solar scatter devices, manual or foot kick switches, and the like.

It is understood that the novel actuator circuit that we have described above may also incorporate certain conventional hydraulic safety devices that are well-known in the art and not described herein. Such devices may include a relief valve or valves in the circuit to limit the hydraulic pressure in the door actuator lines so that persons or objects inadvertently caught in the path of a moving door, whose motion is not arrested otherwise, will not be exposed to undue likelihood of injury; to prevent excessive hydraulic pressures from being imposed during a power failure when the doors may be manipulated by hand; and to give reasonable assurance of smooth hydraulic action during normal operation.

A complete summary of the operation of our invention may be seen in the following table which describes the various operations of the door swing which may occur under the various conditions of pedestrian occupancy on the open mat and pedestrian or object occupancy on the safe mat.

| Open Mat              | Safe Mat        | Door Pos.—<br>0°=Closed,<br>90°=Open | Limit Switch S <sub>2</sub> | Limit Switch S <sub>1</sub> | Motor and Pump Rotation and Remarks                                                                                                                                                                                                                                                                                                                                                                     |
|-----------------------|-----------------|--------------------------------------|-----------------------------|-----------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Unoccupied.....       | Unoccupied..... | At 0°.....                           | Open.....                   | Closed.....                 | None.                                                                                                                                                                                                                                                                                                                                                                                                   |
| Occupied.....         | do.....         | 0° to 5°.....                        | Closes.....                 | do.....                     | Starts and proceeds to pump in the Open direction.                                                                                                                                                                                                                                                                                                                                                      |
| Do.....               | do.....         | 5° to 85°.....                       | Closed.....                 | do.....                     | Continues to Open.                                                                                                                                                                                                                                                                                                                                                                                      |
| Do.....               | do.....         | 85° to 90°.....                      | do.....                     | Opens.....                  | As the last 5° (from 85° to 90°) are travelled, S <sub>1</sub> opens and pump operation ceases; RC time circuit prevents "chattering" either as a result of varying foot pressure on Open mat or cross-over to Safe mat. Continuing rapid evacuation of hydraulic fluid from "close" cylinder and novel design of "close" piston prevents shock at end of swift (less than about 2 seconds) open swing. |
| Remains occupied..... | do.....         | At 90°.....                          | do.....                     | Open.....                   | None.                                                                                                                                                                                                                                                                                                                                                                                                   |
| Unoccupied.....       | Occupied.....   | At 90°.....                          | do.....                     | do.....                     | Do.                                                                                                                                                                                                                                                                                                                                                                                                     |
| Do.....               | Unoccupied..... | At 90°.....                          | do.....                     | do.....                     | Starts and proceeds to pump in the reverse Close direction.                                                                                                                                                                                                                                                                                                                                             |
| Do.....               | do.....         | 90° to 85°.....                      | do.....                     | Closes.....                 | Continues to pump in the reverse Close direction.                                                                                                                                                                                                                                                                                                                                                       |
| Do.....               | do.....         | 85° to 5°.....                       | do.....                     | Closed.....                 | Continues to Close. Novel restriction valve (relatively insensitive to temperature changes, self-cleaning of restrictor orifice) prevents close swing of door from being as rapid as open swing; close swing takes about 4 seconds.                                                                                                                                                                     |
| Do.....               | do.....         | 5° to 0°.....                        | Opens.....                  | do.....                     | As the last 5° (from 5° to 0°) are travelled, S <sub>2</sub> opens and pump operation ceases.                                                                                                                                                                                                                                                                                                           |

NOTE.—Presence of persons or objects on Safe Mat during any phase of the operation prevents any further motion of motor pump; if occurs during Open swing (22 and 23 both closed) operation stopped after RC circuit (not shown but explained) discharges.

Although the invention has been described in some detail in the foregoing specification, this has been done in respect to the one embodiment shown for purposes of clarity and understanding of the invention. It is understood that our novel door actuating mechanism may be fabricated in a number of different mechanical configurations within the spirit of our invention and scope of the appended claims.

What is claimed is:

1. A door controlling mechanism comprising: first and second hydraulic cylinders each having a drive piston; drive means interconnecting said pistons in a push-pull relationship; means to attach said drive means to a door and cause said door to open when said drive means is moved in one direction and cause the door to close when the drive means is moved in the opposite direction; a reversible hydraulic pump connected to supply hydraulic fluid under pressure and, alternately, draw hydraulic fluid from one of said hydraulic cylinders and force said fluid into the other of the cylinders to drive said pistons in push-pull relationship in accordance with the direction of movement of the hydraulic pump; switch means mounted adjacent to said door; pump drive means connected in controlled relation to said switch means to cause said hydraulic pump to operate selectively in the forward or reverse directions of movement upon actuation of said switch means; means mounted within one of said cylinders to restrict the amount of hydraulic fluid being drawn from the one cylinder when said pistons drive in push-pull relationship immediately prior to and during completion of movement causing said door to open, whereby the door opening movement is decelerated immediately prior to coming to the fully opened position.

2. A device according to claim 1 having means connected in fluid communication with the other of said cylinders and said reversible pump to restrict the amount of hydraulic fluid being drawn from last said cylinder when said pistons drive in push-pull relationship during movement causing said door to close, whereby said door is opened by said door controlling mechanism more rapidly than it is closed.

3. A door operator to open and close a door comprising: first and second hydraulic cylinders each having a drive piston; drive means interconnecting said pistons for driving in a door opening and a door closing direction; means for connecting said drive means to a door to open said door when said pistons drive in said door

opening direction and close said door when the pistons drive in the door closing directions; a reversible hydraulic pump connected to operate in a first condition to draw hydraulic fluid out of said first cylinder and apply such fluid in a first direction of flow under pressure through valve means into said second cylinder to cause said pistons to drive in the door opening direction, and, alternately, in a second condition to draw hydraulic fluid out of said second cylinder in a second direction of flow opposite to said first direction through said valve means and apply such fluid under pressure into said first cylinder to cause said pistons to drive in the door closing direction, said valve means causing relatively unrestricted fluid flow therethrough in said first direction of flow and restricted fluid flow therethrough in said second direction; and means to actuate said reversible hydraulic pump to operate in said first condition and, alternately, in said second condition, whereby said valve means causes the flow of fluid into said first cylinder during door closing to be restricted compared to the flow of fluid into said second cylinder during door opening so that the door connected to said drive means is opened more rapidly than it is closed.

4. The door operator as defined in claim 3 and wherein said valve means comprises: a hollow valve body having a first opening at one end connected in fluid communication with said hydraulic pump and a second opening at the other end connected in fluid communication with said second cylinder; a block slidably mounted within said valve body with a first side facing said first opening and having a surface area at least as large as the opening, said first side shaped to fit fluid-tightly against the inside surface of said valve body substantially surrounding the opening; a passageway formed between a second side of said block and the inside of said valve body establishing relatively unrestricted fluid communication between said openings; a groove formed in said block establishing relatively restricted fluid communication from said passageway to said first opening when the block is positioned with said first side in fluid-tight contact with the inside surface of said valve body; means responsive to the direction of fluid flow urging said block to position said first side in fluid-tight contact against the inside surface of said valve body surrounding said one opening when said fluid flows in said first direction and, alternately, holding said block away from said openings when the fluid flows in said second direction.

13

5. A door operator to open and close a door comprising: a first hydraulic cylinder having a first drive piston and a second hydraulic cylinder having a second drive piston; a first port formed in one end of said first cylinder and a second port formed in one end of said second cylinder; drive means connecting said pistons for driving in a door opening and a door closing direction, said first drive piston driving in the door opening direction when advancing toward said first port and forcing hydraulic fluid out of the cylinder through the port; means mounted within said first cylinder between said first piston and first port to restrict the flow of hydraulic fluid out of the first cylinder through the port after the first piston drives relatively close to and continues toward the first port; means for interconnecting said drive means to a door to open the door when said pistons drive in said door opening direction and close said door when the pistons drive in said door closing direction; a reversible hydraulic pump connected to each said port to operate in a first condition to draw hydraulic fluid flowing out of said first cylinder and apply such fluid under pressure into said second cylinder to cause said pistons to drive in the door opening direction and, alternately, to operate in a second condition to draw fluid flowing out of said second cylinder and apply such fluid under pressure into said first cylinder to cause said pistons to drive in the door closing direction; and means to actuate said hydraulic pump to operate in said first condition, and alternately, in said second condition; whereby said means within said first cylinder restricts the flow of oil flowing out of the first cylinder as the pistons approach the end of the drive in the door opening direction and a door interconnected to said drive means is decelerated when approaching the open position.

6. The door operator as defined in claim 5 and wherein said means mounted within said first cylinder comprises: a plate movably mounted within said first cylinder between said first piston and first port with the faces of said plate generally normal to the axis of the cylinder and the periphery of the plate out of contact with the walls of the cylinder, said plate being shaped to form a relatively unrestricted passageway for fluid flow between the periphery of the plate and the inside wall of said first cylinder and having one face shaped to contact fluid-tightly the inside wall of said first cylinder substantially surrounding said first port; a groove formed in said plate to establish relatively restricted fluid communication between said first port and said passageway when said one face of the plate is in fluid-tight contact with the inside wall of said cylinder surrounding the first port; means urging said plate to contact fluid-tightly said one face with the wall of the cylinder around said first port when said first piston drives relatively close to and continues toward the first port and, alternately, holds said plate away from the first port when the piston drives away from the port.

14

7. A door operator to open and close a door comprising: a first hydraulic cylinder having a first drive piston and a second hydraulic cylinder having a second drive piston; a first port formed in one end of said first cylinder and a second port formed in one end of said second cylinder; drive means connecting said pistons for driving in a door opening and a door closing direction, said first drive piston driving in the door opening direction when advancing toward said first port forcing hydraulic fluid therethrough, and said second drive piston driving in the door closing direction when advancing toward said second port forcing hydraulic fluid therethrough; means mounted within said first cylinder between said first piston and first port to restrict the flow of hydraulic fluid out of the first cylinder through the first port after the first piston drives relatively close to and continues toward the first port; means for interconnecting said drive means to a door to open the door when said pistons drive in said door opening direction and close said door when the pistons drive in said door closing direction; a reversible hydraulic pump connected to operate in a first condition to draw hydraulic fluid through said first port in the first cylinder and apply such fluid in a first direction of flow under pressure through valve means in fluid communication with said second port in the second cylinder to cause said pistons to drive in the door opening direction, and, alternately, in a second condition to draw fluid out of the second cylinder in a second direction of flow opposite to said first direction through said valve means and apply such fluid under pressure into said first cylinder to cause said pistons to drive in the door closing direction, said valve means causing relatively unrestricted fluid flow therethrough in said first direction of flow and restricted fluid flow therethrough in said second direction; and means to actuate said reversible hydraulic pump in said first condition and, alternately, in said second condition, whereby said door is caused by said valve means to open more rapidly than it is closed and by said means within said first cylinder to decelerate immediately prior to and during completion of movement of the door to the open position.

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