March 11, 1969 G. E. STUART, JR., ET AL 3,431,678

POSITION RESPONSIVE ACTUATOR

Filed Oct. 17, 1966 Sheet 1 of 2

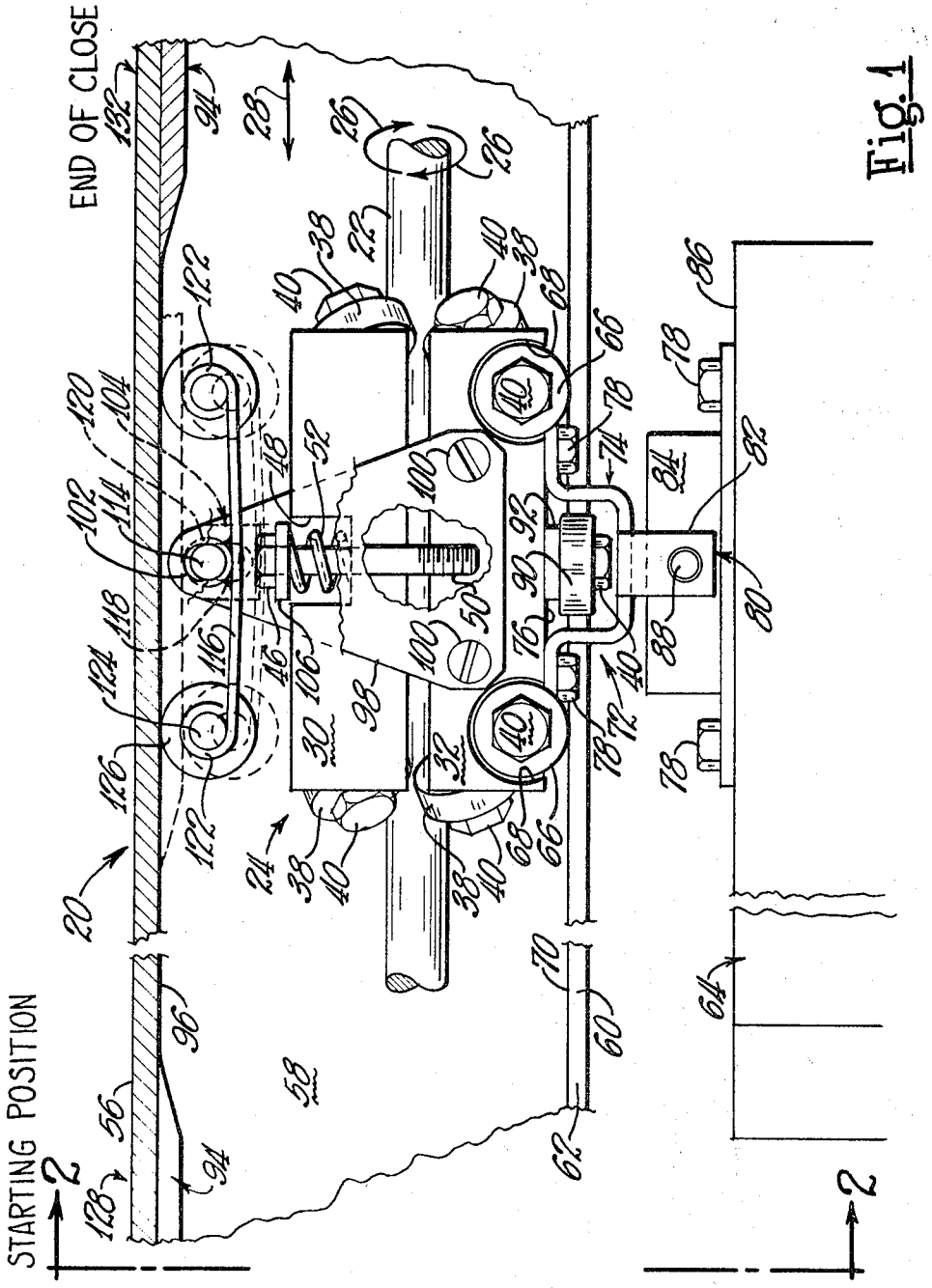


Fig. 1

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Filed Oct. 17, 1966 Sheet 2 of 2

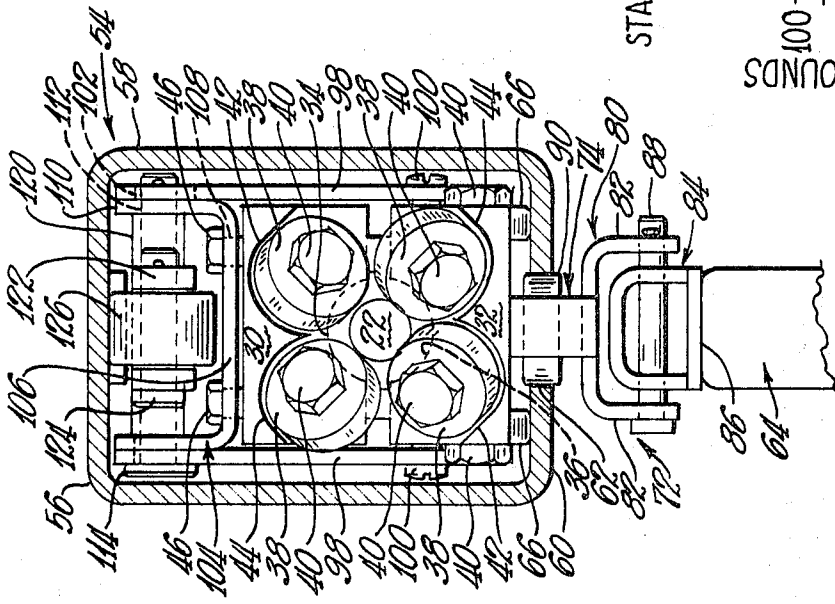


Fig. 2

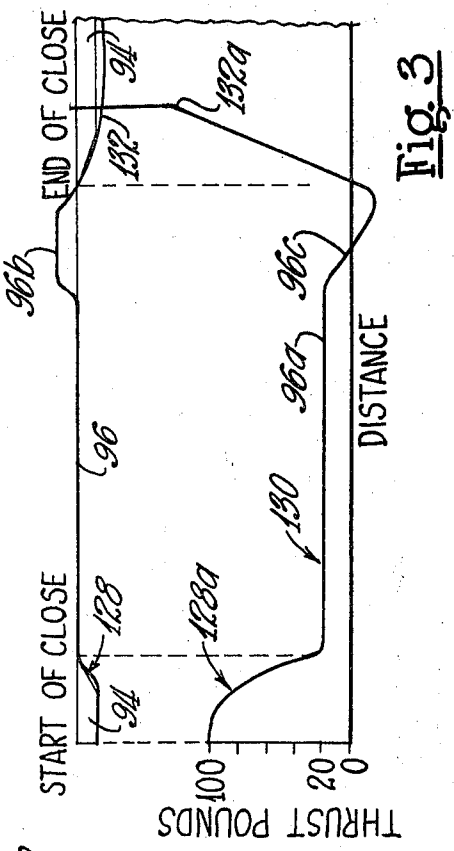


Fig. 3

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POSITION RESPONSIVE ACTUATOR

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U.S. Cl. 49—360 11 Claims
Int. Cl. E05f 11/00, 15/10, 15/02

ABSTRACT OF THE DISCLOSURE

A variable-output linear actuator useful, e.g., in door opening and closing mechanisms for operating doors of buses, subway cars, commuter trains, elevators and the like. The actuator has as basic components, a shaft and a carrier through which the shaft extends and with respect to which the carrier is frictionally engaged through skewed rollers allowing relative movement by sliding in a linear path or by rotation in a spiral path. This invention is directed to structure for varying the frictional pressure of carrier on the shaft.

The problem

The closing of a sliding door on public buildings or transportation vehicles must be accomplished by appropriate safeguards in order to prevent injury to entering and departing persons. Particularly, a provision must be made to stop the closing, should an individual be in the way, so that he will not be injured by crushing by the door.

In the past, it has been one common practice to close doors by means of pneumatic or electric motors, with a contact guard along the closing or exposed edge of the door. When a pedestrain or passenger engages the contact guard with sufficient force, the guard deactivates the motor unit and may automatically reverse its travel to reopen the door. Thus, door pressure against the passenger or obstruction is relieved so that the door area can be cleared and the door may be moved to a closed position.

In the prior art door closers of the air cylinder actuated type, the closing pressure has been constant, though interruptable, along the entire length of door travel. Thus, the closing air pressure remains constant through the entire cycle. Output has not been position responsive. Accordingly, there has been no increased force at the beginning in order to get the door started; thereby preventing a passenger from leaning against the door to intentionally hold it open.

Further, there has been no decreased force for median travel distance; and, no further decreased force for some inches of travel prior to final closure to prevent passengers trapping or crushing and permit removal of any limbs or clothing so captured; and finally, no marked force increase at the instant of final closure to positively lock, seal and position the door.

Thus, prior art door closure devices employing either a pneumatic or electrically powered engine connected to a lever rotating in an arc, linked to a driving arm, provide an output force generally inconsistent with actual requirements. That is, with the door open and the driving arm at a 90° position to the drive link, output force is the least value possible. The highest output is, therefore, forthcoming as the arm approaches 0° angle to the drive link.

Thus, in the prior art, closure force is lowest when the possibility of a stalling or intentional prevention of closure by passengers is the highest; and closure force is highest immediately prior to complete closure when the possibility of passenger injury by trapping clothes or limbs is also highest.

Neither the prior art of direct actuators by pneumatic or hydraulic cylinder ram and consequent constant output, nor the variable output of the arc of a driving arm are satisfactory. Also, such applications require elaborate valving or electrical control to overcome these inherent disadvantages and provide a more properly controlled force output in relation to door position.

Accordingly, a refined, position responsive door actuator would provide a substantial advancement to the art. Thus, an important advance to the art would be provided by a door closer of the linear type wherein the door is automatically stopped upon engagement of an overload obstruction at any point along the travel; yet, which provide position responsive closing pressure varying along the length of travel.

An important object of the invention is to provide an improved linear actuator which is position responsive to thereby have automatically induced variable output at different stages or positions of its operation.

Another object of the invention is to provide a novel position responsive opening and closing actuator wherein the closing pressure is variable along the length of travel of the actuator; yet, where the closing action may be instantly arrested upon engagement of an overload obstruction.

A further object is to provide a position responsive door actuator which increases closing pressure or force at the beginning of the door closing travel, to prevent the door from being intentionally held open; which decreases output during the interim position of the closing travel to prevent injury to obstructing passengers; decreases pressure further immediately prior to closing to allow removal of trapped limbs or clothing; and, then increases closing pressure again at the final instant of closing to provide positive lock, a weather-tight seal and prevent rattling.

A further object is to provide a position responsive actuator which increases the closing pressure at both the beginning and end of closing travel and also increases the opening pressure at the beginning and end of the opening travel to overcome initial movement inertia.

Other objects will appear in the following description and appended claims, reference being had to the accompanying drawings forming a part of this specification.

FIGURE 1 is a side-elevational view of the invention as applied to a rolling door;

FIGURE 2 is an end-elevational view taken along the line 2—2 of FIGURE 1; and,

FIGURE 3 is a graph illustrating variations in output thrust dependent upon the position of the carrier **24** along the drive shaft **22**, with the starting position shims **128** and the end position shims **132** superimposed above the graph line **130**.

It is to be understood that the invention is not to be limited in scope to the particular details of construction shown in the drawings. Also, it is to be understood that the terminology employed is for the purpose of description and not of limitation.

It is known that a smooth, rotatable shaft extending axially through a carrier including a cluster of properly aligned and canted, free-running rollers will propel the carrier along the shaft. The carrier will move in either direction, dependent upon the direction in which the shaft is rotated. However, since the shaft is of uniform diameter all along its length and roller pressure against the shaft remains the same, the linear force output produced by the carrier is the same throughout the travel of the carrier. This is true even though an overload force against the carrier will stall carrier movement (cause the rollers to slip on the shaft), and even though the shaft may continue to rotate.

It is clearly evident that the smooth shaft, as compared to a screw, will provide an automatic clutching action when the overload stops the carriage and causes the carriage rollers to slide relative to the shaft. However, it is equally evident that the clutching action is constant; and, not variable.

A further aspect of the prior art devices of this type is that the shaft has been subjected to two harsh factors: (1) the shaft has been relied upon to carry the load of the carriage and its burden thus subjecting the shaft to distortions, creating extreme operating vibration, excess wear, and limiting usable length; and, (2) both the shaft and the carrier have been exposed to the elements so that corrosion and damage to working parts result.

From the foregoing it will be evident that position responsive carrier output with retained automatic overload clutching, at any point of operation, will contribute substantially to the advancement of the linear actuator art.

Our invention provides a substantial contribution to the operation of the roller carriage-shaft principle by providing position responsive variable force between the carrier rollers and the shaft to provide variable linear force output by the carrier at different positions along the length of the shaft. Thus, the present invention utilizes the simplicity of the rollers and the uniform diameter shaft for greatest economy of manufacture and durability, but adds some very substantial improvements. Thus, variable force of engagement between the rollers of the carriage and the shaft is provided in a unique manner. Also, distortion producing loading is absolutely removed from the shaft. This makes it possible to reduce the size of the shaft without reducing the efficiency of the unit. Further, the carriage and shaft are enclosed in a housing for protection against corrosive elements, thereby providing improved durability and longer life.

A feature of our invention is that the variable carrier drive force is provided by means of only a very simple alteration to the carrier, but without any alteration to the shaft or carrier rollers.

The general nature of the invention and its relationship to the prior art have been provided in order that the description thereof that follows may be better understood, and in order that the contributions to the art may be better appreciated. There are, of course, additional features of the invention that will be described hereinafter and which will form the subject of the claims.

Now by specific reference to the drawings, it will be noted that the novel linear actuator of the invention is designated by the reference numeral **20**. The drive shaft **22** extends through the movable carrier **24** and is rotatable in both directions as indicated by the double direction arrows **26**. Suitably, the drive shaft **22** is mounted for rotation on axial thrust bearings, not shown, and is driven, for example, by a reversable electric motor, not shown. In this application, the drive shaft **22** is mounted horizontally, but for other applications it could be mounted vertically or somewhere between vertical and horizontal. This will become apparent to those skilled in the art as the description progresses. Within the scope of the invention, the drive shaft orientation is not to be considered limiting.

It is significant to note that the drive shaft **22** is of relatively small diameter for the job which it performs, because it is not subject to radial distortion loading. The tensile strength of the shaft is thus utilized to the maximum. Also, the drive shaft **22** has a smooth surface and is of uniform diameter all along its length; these factors contribute significantly to the economy of manufacture.

The carrier **24** moves back and forth along the drive shaft **22** as indicated by the double-headed arrow **28**. The direction of movement is determined by the direction of rotation of the drive shaft **22**.

In basic construction, the carrier **24** comprises rollers for engaging the shaft **22** and relatively movable portions for supporting the rollers which may be simultaneously urged toward the shaft to increase the roller pressure thereon.

As shown, the movable carrier **24** is made up of two halves. The upper half **30** rides along the top of the drive shaft **22**, and the lower half **32** rides along the bottom of the drive shaft **22**. As indicated in FIGURE 2, the upper half **30** is of generally rectangular section, but has a semicylindrical channel **34** to accommodate the upper part of the drive shaft **22**. The lower half **32** is also of generally rectangular section and has a semicylindrical channel **36** to accommodate the lower part of the drive shaft **22**.

At each end, the carrier upper half **30** is provided with two freely rotatable rollers **38**. These are mounted on holding bolts **40**, tightened and locked into threaded holes, hidden, formed coaxially in the bottom of canted cavities **42** and **44**. Also, each end of the carrier lower half **32** is provided with two freely rotatable rollers **38**. These are also mounted on holding bolts **40**, tightened and locked into threaded holes, hidden, formed coaxially in the bottom of canted cavities **42** and **44**.

The upper half **30** and the lower half **32** of the movable carrier **24** are held together in operable relationship by means of bolts **46**. The bolts **46** extend down through stopped holes **48**, formed in the upper half **30** of the movable carrier **24**, and are secured in threaded holes **50** formed in the lower half **32** of the movable carrier. In surrounding relationship to each bolt **46**, in stopped holes **48**, is a compression spring **52**. It is by means of the compression springs **52** that the halves **30** and **32** are urged toward one another to cause the rollers **38** to frictionally engage the drive shaft **22**.

It will be evident that varying compression of springs **52** will result in the varying frictional engagement force between the rollers **38** and the drive shaft **22**. The manner of varying the compression force of the springs **52** forms important subject matter of the invention, as will be brought out later.

Before describing the spring compression mechanism, however, it is important to point out the equally novel mounting of the carrier **24** for nonradial loading traverse along the drive shaft **22**. For this purpose, an elongated housing **54** of box-like section is employed. As will be apparent, the housing **54** protects the carrier **24** and the drive shaft **22** and the associated mechanism against physical damage to working parts and also protects against atmospheric exposure and corrosion, and provides the means whereby the radial loads imposed on the carrier are absorbed instead of being directed into the drive shaft. The housing **54** comprises a plate-like top **56**, sides **58** and a bottom **60**. The bottom **60** has an axially extending slot **62** through which the lower half **32** of the carrier **24** is connected to a door **64** for operating the door.

Four supporting rollers **66** are employed, one at each lower corner of the lower half **32** of the movable carrier **24**. These rollers **66** are mounted within recesses **68** by means of bolts **40**. The rollers **66** straddle the slot **62** and roll along the upper surface **70** of the bottom **60** of the housing **54**. The weight of the door **64** is thereby supported by the housing **54** as will now be described. No thrust is imparted to shaft **22**.

Thus, a hanger bracket **72** having an upper portion **74** of generally U-shaped construction is fastened to the bottom surface **76** of the lower half **32** of the movable carrier **24** by means of bolts **78**. The hanger bracket **72** has a lower portion **80** of generally U-shaped construction, the ears **82** of which extend down over and straddle a connecter **84**. The connecter **84** is secured to the top surface **86** of door **64** by bolts **78**. A cross pin **88** is passed through the ears **82** and the connecter **84** to complete the assembly.

The movable carrier **24** is guided for accurate lineal movement within the box-like support housing **54** by

means of a roller **90**. The roller **90** is mounted on a bolt **40**, inserted into the bottom of the lower half **32** of the movable carrier **24**, using a spacer **92**. The guide roller **90** assures free passage of the movable carrier **24** along the length of the housing **54** and also assures free passage of the hanger bracket **72** along the length of the slot **62**, thereby providing free movement of both the carrier **24** and the door **64**.

The automatically induced variable output mechanism

Now to be considered is the control means for varying the pressure with which the rollers **38** engage the shaft **22** to achieve position responsiveness as the carrier moves lengthwise of the shaft **22** and the housing **54**. Such means includes especially contoured undersurface **96** of the top housing wall **56** as shaped by a pair of loading shims **94**, and mechanism carried by the carrier for sensing, i.e., slidably engaging, the surface **96** and translating any sensed surface variations into variations in pressure of the carrier halves on the shaft.

Triangular guide plates **98** are fastened at the bottom ends by screws **100** to each side of the bottom half **32** of the movable carrier **24**. At the top ends, the plates **98** are provided with elongated slots **102**. An inverted U-shaped compression yoke **104** is nested between the triangular plates **98**. The bight portion **106** of the compression yoke **104** has holes **108** through which the bolts **46** are passed in slidable relationship. Also, it will be noted that the bight portion **106** is positioned between the heads of the bolts **46** and the top ends of the compression springs **52**. It will be evident that downward movement of the compression yoke **104** will compress the springs **52**, thereby forcing the upper half **30** of the movable carrier **24** toward the lower half **32**. This causes the rollers **38** of both halves **30** and **32** to engage the drive shaft **22** with greater frictional force so that the carrier **24** will move along the drive shaft **22** with a greater resultant linear output force.

The arms **110** of the compression yoke **104** are provided with circular holes **112**, as compared to the elongated slots **102** of the triangular guide plates **98**. A pin **114** is passed through the holes **112** of the arms **110** of the compression yoke **104**, and also through the elongated slots **102** of the triangular guide plate **98**.

A pair of roller yokes **116** are welded **118** at the center to a cross sleeve **120**, through which the pin **114** is also passed. Each end of each roler yoke **116** is turned over to form a loop **122** to receive a roller pin **124**. A roller **126** is thereby straddled by the spaced roller yokes **116**.

The position responsive shims **94** are secured as by bolts or other standard fasteners, not shown. This allows adjustability or change to predetermined higher or lower force areas. The shims **94** are fastened to the bottom surface **96** of the top **56** of the housing **54**. The shims **94** are positioned along the length of travel of the movable carrier **24**. The positions indicated are exemplary and not limiting. Also, the thickness of the shims **94** is illustrative and not limiting. The shims **94** and the surface **96** produce a variable profile track, effective through the compression yoke **104** and springs **52** to cause the carriage rollers **38** to frictionally engage the drive shaft **22** with varying force in accordance with the position of the carrier **24** along its path of travel, so that the thrust output movement of the carrier varies relative to its position.

For reasonably practical purposes, it may be presumed that a static condition of the compression springs will cause the door **64** to close with an output force of 20 lbs. thrust before the movable carrier **24** will stall on the shaft **22**.

At the exemplary starting position, however, the shim **94** will lower the rollers **126** and the bight portion **106** of the compression yoke **104** a sufficient amount to compress the springs **52** to a level where the linear output force of the carrier **24** will cause the door to move against an obstructing force of up to 100 lbs. thrust before the rollers **38** will stall or slip on the shaft **22** to provide a declutching action.

The spring loading effect is indicated in dotted outline in FIGURE 1 and in the graph of FIGURE 3 by the load level line **130**. Thus, for example, when the rollers **126** are at the starting position **128** and thus pressed downwardly by the shim **94**, the door will have an initial closing force of 100 lbs. thrust, FIGURE 3. This is portion **128***a* of curve **130**. Thereafter, when the rollers **126** leave the starting position **128**, they leave the shims **94** and the output of the carrier **24** will drop off and the door thrust will drop to 20 lbs. to prevent injury to a person during the main closing passage of the door. This is illustrated by the **96***a* portion of the curve **130**.

Near the end a recess can be provided as at **96***b* to provide a further drop for some inches of travel prior to final closure to prevent passenger trapping or crushing and permit removal of any limbs or clothing so captured. This is illustrated by the **96***c* portion of the curve **130**.

At the very end of closing travel of the door **64**, the rollers **126** will engage the shims **94** at the very end position **132**. The thrust is then sharply increased to 100 lbs., exemplary, as shown by the portion **132***a* of the curve **130**. The springs **52** are, therefore, again compressed and the door **64** closes tightly to provide a weather-tight seal and prevent rattling and provide a locking action against opening.

It will be understood that the door is provided with suitable guide means, not shown, such as another carrier, not shown, a floor guide channel or the like.

Extended scope of invention

It will be understood that it is within the scope of the invention to have the shims **94** of different thickness, as the particular application dictates.

The invention is applicable to hinged doors by utilizing appropriate direction change linkages and pivots.

We claim:

1. In a position responsive linear actuator for producing variable lineal output thrust along the length of travel,

a shaft and means supporting the shaft in space,

a carrier movable along said shaft comprising relatively movable portions disposed around the shaft and skewed rollers rotatably supported by said portions frictionally to engage said shaft so that the carrier is propelled along the shaft upon relative rotation between said rollers and said shaft,

means producing relative rotation between said rollers and said shaft to thereby produce movement of said carrier along said shaft, and

control means including means simultaneously biasing said portions toward the shaft, said control means being shaped and arranged to vary the pressure of frictional engagement between said rollers and said shaft in accordance with positions of said carrier along said shaft.

2. The invention according to claim **1** wherein said shaft is of uniform diameter along its length and said carrier comprises two halves, each half comprising certain of said portions and shaft-engaging rollers, and the control means comprises means biasing said carrier halves toward one another, and external means engageable with said biasing means with differing force in accordance with positions of said carrier along said shaft.

3. The invention according to claim **2** wherein said shaft is rotatable, and including means for rotating said shaft, elongated support means operably engaging one of said carrier halves and absorbing radial thrust of said carrier and restraining said carrier against rotation around said shaft, and said support means including a position-variable profile track means, and said means biasing said carrier halves toward one another including

means engageable between said variable profile track means and the other of said carrier halves.

4. In a position responsive actuator,

an elongated box-like housing and having a top and a bottom,

a shaft within said housing, means supporting said shaft for rotation, and means for rotating said shaft in both directions,

a carrier within said housing and movable along said shaft, said carrier having first and second portions opposed to one another with said shaft therebetween, and said first and second portions including freely rotatable roller means frictionally engaging said shaft to produce movement of said carrier along said shaft upon rotation of the shaft,

antifriction means on one of said carrier portions and engageable with said housing and absorbing radial thrust of said carrier and restraining said carrier against rotation about said shaft, guide means on said one carrier portion retaining the other carrier portion in opposed relationship,

position variable profile track means on said top of said housing,

follower means carried by said guide means and engageable with said profile track means,

and resilient compression means between said follower means and said other carrier portion, biasing said other carrier portion towards said one carrier portion, whereby said roller means of said carrier portions frictionally engage said shaft with varying pressure in accordance with the position of said follower means along said profile track means, to produce varying thrust output movement of said carrier along the length of travel.

5. The invention according to claim 4 wherein said antifriction means comprises a plurality of rollers on said one carrier portion and engageable with said bottom of said housing to thereby support said carrier for movement along the length of said housing, the top of said housing is flat, and said profile track means includes shims at spaced positions on said top of said housing.

6. The invention according to claim 4 wherein said bottom of said housing includes an elongated slot,

a hanger connected to said one carrier portion and extending through said slot to support a load,

and antifriction means on said one carrier portion and engageable within said slot to guide said carrier along said housing, and provide free movement of said load hanger along said slot.

7. The invention according to claim 6 wherein said load is a door-like barrier to ingress or egress.

8. In a sliding door closing system,

a door having a top and positioned in vertical orientation for edgewise movement between closed and opened positions along a linear path,

an elongated support housing above said door and horizontally oriented to support the door for movement, and the housing having an upper portion and a lower portion,

a shaft of uniform diameter within said housing, means supporting said shaft for rotation, and means for rotating said shaft in both directions,

a carrier within said housing and movable along said shaft, said carrier having first and second halves opposed to one another with said shaft between, and said first and second halves including freely rotatable roller means frictionally engaging said shaft to produce movement of said carrier along said shaft upon rotation of the shaft,

roller means on said first carrier half engageable with the lower portion of said support housing, absorbing radial loading imposed on said carrier and restraining said carrier against rotation,

means on said first carrier half retaining the other carrier half in opposed relationship,

position variable profile track means on said upper portion of said housing,

follower means guided by said guide means and engageable with said profile track means,

compression means engageable with said follower means and said other carrier half biasing said carrier halves toward one another, dependent upon the position of said follower means along said profile track,

a hanger connected to said one carrier half and connected to said top of said door to support said door,

and guide means between said lower half of said housing and said carrier to guide said carrier and said door along said linear path,

whereby said roller means of said carrier frictionally engage said shaft with varying force in accordance with the position of said follower means along said profile path, producing varying thrust output movement of said carrier along said profile path and varying the closing force of said door.

9. The invention according to claim 8 wherein said lower portion of said housing includes an elongated slot and said hanger connected to said one carrier half extends through said slot,

and antifriction means on said one carrier half and engageable with said slot to guide said carrier within said housing and guide said hanger along said slot for said edgewise movement of said door.

10. The invention according to claim 8 wherein said door has a starting position for closing and a closed position, and wherein said profile track means includes elevated shims at said starting and closed positions for engagement with said follower means at said starting and closed positions for increasing the closing force of said door, and with an intermediate portion of relatively depressed profile between said spaced shims, for lower closing force during the intermediate stages of door closing.

11. The invention according to claim 10 wherein said profile track means includes a flat plate having cam surfaced shim elements at spaced positions thereon.

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U.S. Cl. X.R.

49—28, 138; 74—89.15; 188—42; 187—52