Aug. 9, 1966 J. S. LORY ETAL 3,265,941

ELECTROMAGNETIC OPERATOR

Filed Sept. 24, 1963

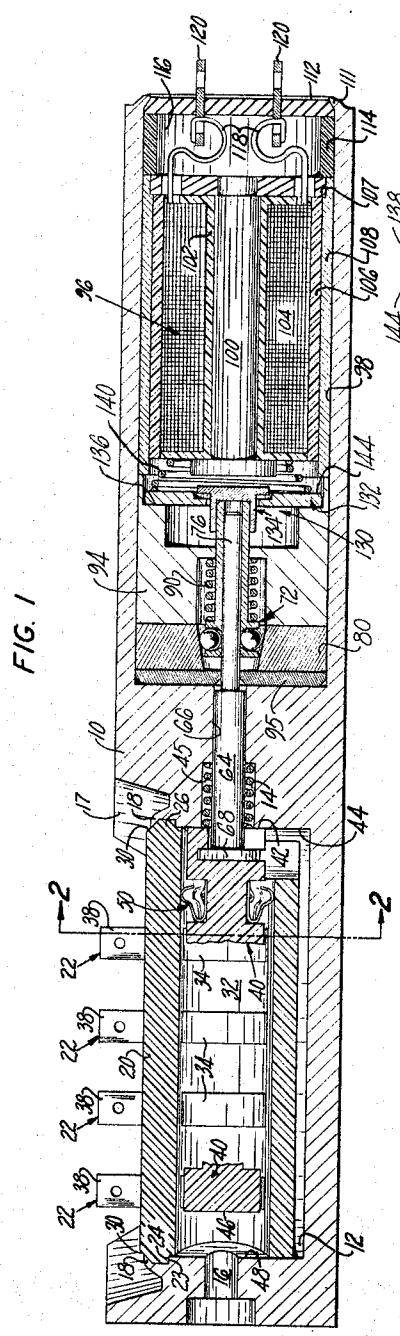

FIG. 1

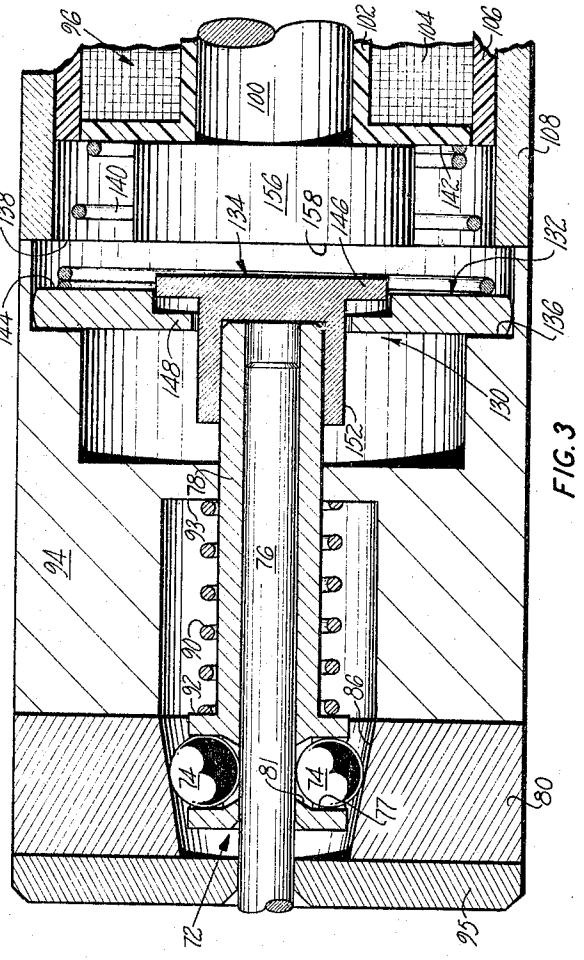

FIG. 3

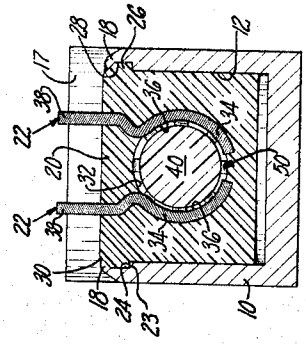

FIG. 2

INVENTORS
JOHN S. LORY
HARRY ASHWORTH
HYMAN L. GLUCK

BY Lindsey, Prutzman and Hayes

ATTORNEYS

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ELECTROMAGNETIC OPERATOR

John S. Lory, Bloomfield, Harry Ashworth, Thompsonville, and Hyman L. Gluck, West Hartford, Conn., assignors to Hi-G Incorporated, Windsor Locks, Conn., a corporation of Connecticut

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The present invention relates to improvements in electromagnetic operators which are particularly adaptable for actuating electrical switches.

It is a principal aim of the present invention to provide a new and improved electromagnetic operator for use in high gravity environments, as in aerospace vehicles for operating electrical switches of the type shown in the pending application entitled "Switch" of John S. Lory et al., Serial No. 270,447.

It is another aim of the present invention to provide a new and improved electromagnetic operator having a compact and economical construction and which provides reliable operation with a minimum of electrical energy.

It is a further aim of the present invention to provide an improved electromagnetic operator which gives quick and effective operation even when the opposing load is greater than its incipient magnetic attractive force.

Other objects will be in part obvious and in part pointed out more in detail hereinafter.

The invention accordingly consists in the features of construction, combination of elements and arrangement of parts which will be exemplified in the construction hereafter set forth, and the scope of the application of which will be indicated in the appended claims.

In the drawings:

FIG. 1 is a generally longitudinal section view, partly broken away, of a switch embodying the electromagnetic operator of the present invention;

FIG. 2 is a transverse section view of the switch taken along line 2—2 of FIG. 1; and

FIG. 3 is an enlargement of a portion of FIG. 1.

Referring now to the drawings in detail, a preferred embodiment of the electromagnetic operator of the present invention is shown installed for operating a switch of the type described in the aforementioned pending application of John S. Lory et al., the switch being one having particular application in aerospace vehicles designed to operate under considerable gravity forces.

The switch has an elongated casing or support body **10** with a longitudinally extending opening or cavity **12** adjacent one end thereof, and a pair of longitudinally extending coaxial bores of varying diameters generally designated by the numerals **14** and **16**. The cavity **12** and the bores **14**, **16** thereby provide a longitudinal passage in the casing **10**, which passage is dimensioned to receive the parts of the switch. As seen in FIG. 2, the cavity **12** is of generally rectangular cross section and opens into a recess **17** in the casing defined in part by a peripheral lip **18** about the cavity **12**. A molded insert **20** is received within the casing cavity and is accurately positioned therein by the engaging peripheral shoulders **23** and **24** provided by an outer flange **26** of the insert and a complementary recess **28** in the casing. The insert is securely retained in the casing by crimping the lip **18** over a peripheral chamfered edge **30** of the insert.

The insert **20** has a central longitudinal bore **32** coaxial with the casing bores **14** and **16** and has a plurality of longitudinally spaced pairs of electrical contacts **22** which have arcuate contact portions **34** with contact faces **36** concentric with the bore **32** and spaced slightly inwardly thereof. Terminals **38** of the contacts **22** extend within the recess **17** of the casing **10** for making appropriate electrical connections.

A movable contact support or spool **40** is loosely mounted in the insert bore **32** for longitudinal movement, to the left as seen in the drawing, from a preset position with its inner end **42** in engagement with the casing shoulder **44**. The spool is actuated to its alternative released position where the opposite end **46** of the spool engages the opposed shoulder **48** of the casing by a compression spring **45** interposed between the spool and a lateral shoulder of the casing **10**. The spool has five longitudinally spaced lands defining four annular recesses which receive a corresponding number of annular resilient contacts **50**, only one of which being shown in the drawings for simplicity. The annular recesses and therefore the resilient contacts **50** in this embodiment are positioned out of electrical contact with the stationary contacts **22** when the spool **40** is in the preset position. When the spool is in its alternative released position the resilient contacts **50** are in engagement with the stationary contacts to complete the electrical circuit between the pairs of terminals **38**.

The spool **40** is connected for longitudinal movement with a plunger **64** slideably mounted in a bore portion **66** of the longitudinal bore **14**. The plunger **64** has an enlarged circular head **68** received within a T-shaped slot in the spool **40** which thereby enables the plunger to be assembled with the spool when the insert and spool subassembly is placed in the cavity **12** of the casing.

The spool is retained in its preset position shown in the drawings by a one-way latch, generally denoted by the numeral **72**, which is adapted to retain the plunger **64** and the spool **40** against the force of the compression coil spring **45**. This retention is provided by the engagement of a plurality of ball bearings **74** of the latch **72** with a reduced rod **76** of plunger **64**. Preferably, there are three ball bearings **74** equally spaced in a transverse plane angularly about the rod **76**. The ball bearings are assembled in three radially extending apertures **77** in a carrier sleeve **78** that is slideably mounted on the rod **76** intermediate the rod and a camming bushing **80**. The radial apertures **77** are preferably inwardly tapered at **81** to provide pockets which receive the balls **74** and thereby assist in retaining the ball bearings with the carrier sleeve during assembly of the switch. The camming bushing **80** has a frustoconical or axially tapering rearwardly facing camming surface **86** engageable by the ball bearings which thereby serve as cam followers. A compression coil spring **90** encircling the carrier sleeve **78** is compressed between a radial shoulder **92** of the carrier sleeve and an opposed radial flange **93** of an end bushing **94**, thereby biasing the ball bearings into engagement with the frustoconical camming surface **86** to provide the one-way latching of the plunger **64**. The camming bushing **80**, the end bushing **94**, and a washer cap **95**, all of the same outside diameter, are secured within a complementary bore portion **98** of the bore **14** thereby locating the camming surface **86** and the carrier sleeve **78** in coaxial relationship with the plunger **64**. The washer cap **95** provides a support for the rod **76** which cooperates with the flange **93** for enclosing and thereby sealing the latching mechanism against foreign elements.

In accordance with the present invention, an electromagnetic operator, generally denoted by the numeral **96**, is received within the bore portion **98** of the bore **14** rearwardly of the latch. The electromagnetic operator includes, coaxially arranged with the casing **10**, a central magnetic core **100**, a pair of insulating sleeves **102**, **106**, an energizing coil **104**, a magnetic sleeve **108** and a magnetic end piece **107** secured to the core **100**. The electromagnetic operator is rigidly retained within the casing **10** through the engagement of the magnetic sleeve **108** with the bushing **94** and by crimping a peripheral lip **111**

formed on the end of the casing over a beveled peripheral edge of a switch cap **112**. The cap **112** engages an insulator bushing **114** bearing against the sleeve **108** and cap **107** and forms with the bushing **114** an enclosed cavity **116** which receives coil leads **118** electrically connected to terminals **120** integrally molded with the switch cap **112**.

An armature of the electromagnetic operator, generally denoted by the numeral **130**, comprises a pair of outer and inner cooperating armature elements **132**, **134**, respectively. The outer aramature element **132**, of washer-like shape, encircles the inner armature element **134** and is adapted for longitudinal movement between active and inactive positions within an annulus defined by a shoulder **136** of the bushing **94** and an end shoulder **138** of the magnetic sleeve **108**. The outer armature element **132** is biased away from the core **100** to its inactive position by a light compression spring **140** interposed between the element **132** and a face portion **142** of the insulating sleeve **102**. An inner portion of the rear face **144** of the armature element **132** is recessed to provide an annulus for receiving an annular flange **146** of the inner armature element **134**.

The inner armature element **134** is press-fit on the sleeve **78** whereby with the electromagnetic operator deenergized and the armature element **132** in its deactive position the flange **146** is longitudinally spaced from an inner flange portion **148** of the armature element **132**. Preferably, this longitudinal spacing provides for slight axial overlapping of the armature elements **132**, **134** to reduce the incipient air gap reluctance when the electromagnetic operator is energized. For the same reason, it is preferable that the inwardly extending flange **148** of the armature element **132** is in close proximity with a cylindrical surface **152** of the armature element **134**.

The core **100** is provided with an enlarged circular head **156** with a forward face **158** in the plane of the edge **138** of the magnetic sleeve **108**. The core head **156** is of larger diameter than the inner armature element **134** whereby upon energization of the electromagnetic operator and movement of the armature elements from their inactive to their active positions the core is engaged simultaneously by the armature elements **132**, **134**, for which purpose the annulus provided on the armature element **132** is dimensioned so that when the armature elements are in contact, their rear faces lie in a common transverse plane. The magnetic circuit of the electromagnetic operator therefore comprises the core **100**, cap **107**, sleeve **108**, and the armature elements **132**, **134**, whereby, upon energizing the coil **104**, the armature elements are attracted rearwardly to reduce the air gap reluctance in the magnetic circuit.

In order to ensure reliable operation of the latching mechanism, even in environments where the gravitational force on the switch urges the sleeve **78** in a longitudinal direction tending to release the latch, to the right as seen in the drawings, the compression spring **90** must be sufficiently stiff to offset any gravitational force on the carrier sleeve **78**. Accordingly, the summation of the incipient magnetic forces on the armature elements **132**, **134** may be insufficient to overcome the bias of the spring **90** unless the electromagnet is made undesirably large. In accordance with the present invention, however, the electromagnetic operator is capable of releasing the latch even though these incipient forces are less than the opposing summation of force and the spring **90** and the static friction between the ball bearings and the rod **76** and bushing **80**. The outer armature element **132** moves initially from its inactive position independently to the armature element **134** against the bias of the light coil spring **140** into contact with the armature element **134**. Whereupon the flange **148** of the armature element **132** engages the overlapping flange **146** of the armature element **134** which thereby receives the impact of the armature element **132** to assist in shifting the sleeve **78** for releasing the latch. The mass and independent motion of the armature element **132** are therefore made to develop a sufficient inertial force for overcoming the bias of the spring **90** and the static resistance between the ball bearings **74** and the bushing **80** and rod **76**. The armature elements **132**, **134** will thereafter normally be drawn into contact with the core **100** and the sleeve **108** due to the increased attraction resulting from the substantially reduced air gap reluctance in the magnetic circuit.

In operation the spool **40** can be preset, as by a tool inserted within the bore **16**, with the one-way latch **72** automatically retaining the spool in the preset position for subsequent selective activation by the electromagnetic operator **96**. In the preset condition the switch is capable of withstanding loads of over 500 g's even in the longitudinal directions, without causing an inadvertent release of the latch. However, upon energizing the electromagnetic operator **96**, the latch is released to enable the spring **45** to shift the spool for completing the electrical circuits between the pairs of terminals **38**. This latch releasement is ensured by the inertial force of the armature element **132** against the armature element **134**. Thus, it can be readily seen that the improved electromagnetic operator of the present invention provides a highly compact and economical construction which is operable with minimum electrical power. Additionally, the improved electromagnetic operator is useful even where the opposing force is greater than its incipient magnetic attraction for providing responsive and quick actuation.

As will be apparent to persons skilled in the art, various modifications and adaptations of the structure above described will become readily apparent without departure from the spirit and scope of the invention, the scope of which is defined in the appended claims.

We claim:

1. In an electrical switching mechanism having an electrical switch; a shiftable switch controller; a latch for retaining the switch controller in one operative position, said latch having a longitudinally reciprocable control member operable in one longitudinal direction for releasing the latch and a spring urging the control member in the opposite longitudinal direction; and an electromagnetic operator having an electromagnet and an armature longitudinally shiftable by the electromagnet in said one direction from an inactive position for actuating the control member in said one direction; the improvement wherein the electromagnetic operator comprises, an armature having an inner circular armature element connected to the control member and an outer annular armature element, one of said armature elements having an annular flange adapted for engagement with the other armature element, said flange being longitudinally spaced from the other armature element with the outer armature element in its inactive position; a magnetic core longitudinally spaced from the control member, an electric coil encircling the core, and a magnetic sleeve encircling the coil whereby upon energization of the electrical coil the outer armature element initially shifts independently of the inner armature element to develop momentum which assists upon engagement with the inner armature element in actuating the control member in said one direction.

2. In a control device having a longitudinally reciprocable control member and an electromagnetic operator having an electromagnet and an armature longitudinally shiftable by the electromagnet from an inactive position longitudinally spaced from the electromagnet toward the electromagnet to an active position to decrease the reluctance between the electromagnet and the armature, the armature thereby longitudinally actuating the control member from a first position, the improvement wherein the armature comprises a longitudinally shiftable first impact armature element and a second impact receiver armature element connected to the control member, said first and

second armature elements with the armature and control member in their inactive and first positions respectively having engageable parts longitudinally spaced to allow longitudinal movement of the first armature element relative to the second armature in the longitudinal direction toward the electromagnet before engagement therewith, said first armature element being longitudinally shiftable from its inactive position toward the electromagnet by the electromagnetic force thereof into engagement with the second armature element to reduce the reluctance between the first armature element and the electromagnet and to develop momentum for actuation of the second armature, whereby upon energization of the electromagnetic operator the first armature element is initially shifted independently of the second armature element longitudinally toward the electromagnet to develop momentum which assist upon impact with the second armature element in actuating the control member and which at the same time reduces the reluctance between the armature and the electromagnet before impact to increase the magnetic force on the armature.

3. The improvement of claim 2 wherein the electromagnetic operator further comprises a magnetic core longitudinally spaced from the control member and a magnetic sleeve encircling the core and wherein said armature elements together provide a magnetic circuit between the core and sleeve.

4. The improvement of claim 2 wherein the first and second armature elements are coaxially mounted and are provided with opposed cooperating cylindrical surfaces in contiguous relationship to reduce the reluctance between the elements.

5. In a control device having a longitudinally reciprocable control member and an electromagnetic operator having an electromagnet and an armature longitudinally shiftable by the electromagnet from an inactive position for actuating the control member from a first position; the improvement wherein the electromagnetic operator comprises an armature having a first impact armature element and a second impact receiving armature element connected to the control member, said first and second armature elements having engageable parts longitudinally spaced with the armature and control member in their inactive and first positions respectively, said first armature element being longitudinally shiftable by the electromagnet from its inactive position into engagement with the second armature element whereby upon energization of the electromagnetic operator the first armature element is initially shifted independently of the second armature element to develop momentum which assists upon impact with the second armature element in actuating the control member from its first position; and wherein the electromagnetic operator further comprises a magnetic core longitudinally spaced from the control member and a magnetic sleeve encircling the core; said armature elements together providing a magnetic circuit between the core and sleeve; said armature elements being coaxially arranged with their engageable parts being provided by an annular flange on one of the element adapted for engagement with the other of the elements, and said core having a face engageable by both of the armature elements.

6. In an electrical switching device having an electrical switch; a shiftable switch controller; a latch for retaining the switch controller in one operative position, said latch having a longitudinally reciprocable control member operable in one longitudinal direction for releasing the latch and a spring urging the control member in the opposite longitudinal direction; and an electromagnetic operator having an electromagnet and an armature longitudinally shiftable by the electromagnet in said one longitudinal direction from an inactive position longitudinally spaced from the electromagnet toward the electromagnet to an active position to decrease the reluctance between the electromagnet and the armature, the armature thereby longitudinally actuating the control member in said one longitudinal direction, the improvement wherein the armature comprises a longitudinally shiftable first impact armature element and a second impact receiver armature element connected to the control member, said first and second armature elements having engageable parts longitudinally spaced to allow longitudinal movement of the first armature element relative to the second armature in the longitudinal direction toward the electromagnetic before engagement with the second armature element, said first armature element being longitudinally shiftable from its inactive position toward the electromagnet by the electromagnetic force thereof into engagement with the second armature element to reduce the reluctance between the first armature element and the electromagnet and to develop momentum in the first armature element prior to its engagement with the second armature element, whereby upon energization of the electromagnetic operator the first armature element is initially shifted independently of the second armature element longitudinally toward the electromagnet to develop momentum which assists upon impact with the second armature element in actuating the control member to release the latch and which at the same time reduces the reluctance between the armature and the electromagnet before impact with the second armature element to increase the magnetic attraction of the electromagnet.

7. In an electrical switching device having an electrical switch; a shiftable switch controller; a latch for retaining the switch controller in one operative position, said latch having a longitudinally reciprocable control member operable in one longitudinal direction for releasing the latch and a spring urging the control member in the opposite longitudinal direction; and an electromagnetic operator having an electromagnet and an armature longitudinally shiftable by the electromagnet in said one direction from an inactive position for actuating the control member in said one direction; the improvement wherein the electromagnetic operator comprises an impact armature and an impact receiver connected to the control member, said impact armature and impact receiver having engageable parts longitudinally spaced with the armature in its inactive position, said impact armature being longitudinally shifted by the electromagnet from its inactive position into engagement with the impact receiver whereby upon energization of the electromagnetic operator the impact armature initially shifts independently of the impact receiver to develop momentum which assists upon impact with the receiver in actuating the control member in said one direction, and a spring biasing the impact armature in said opposite longitudinal direction to its inactive position.

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BERNARD A. GILHEANY, *Primary Examiner.*

JOHN F. BURNS, *Examiner.*

G. HARRIS, JR., *Assistant Examiner.*