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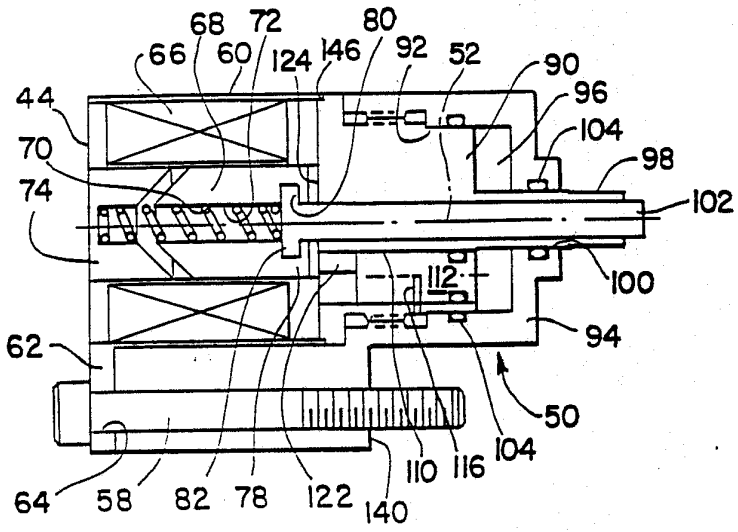
(54) Title: THERMAL OPERATOR FOR USE IN A MECHANICAL DISCONNECT OR THE LIKE



(57) Abstract

Inoperability due to solenoid freeze up, electrical malfunction or human error in a mechanical disconnect system can be avoided through the use of an electric and thermal operator including a pin (52) mounted for axial movement and having opposed ends (82, 102), a solenoid (44) having a coil (66) and an armature (68) adjacent to and connected to one end (82) of the pin (52), a housing (90, 94) including a cavity (96) containing a material that undergoes sudden, substantial volumetric increase in response to increasing temperature accompanied by a solid to liquid phase change and a movable element (112) in non-connected but abutting relation with one of the armature (68) and the end (82) of the pin (52) and extending toward the cavity (96) in contact with the material therein. The pin (52) may be moved to start a disconnect either in response to movement of the armature (68) or to the movable element (112).

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SPECIFICATION

THERMAL OPERATOR FOR USE IN A MECHANICAL DISCONNECT OR THE LIKE

Field Of The Invention

This invention relates to thermal operators, that is, operators which produce mechanical movement in response to a change of temperature, as, for example, may be used in a mechanical disconnect mechanism.

Background Of The Invention

It has long been known to provide, in mechanisms of various sorts, some sort of means of decoupling the driving side of the mechanism from the driven side of the mechanism in order to prevent damage to the latter in the event of a malfunction. In some instances, sensors for various malfunctions, most notably the generation of excess heat, are utilized to provide or allow some sort of mechanical movement which in turn triggers relative movement between two movable parts in the drive train to disconnect one from the other. For example, fusable links are utilized to prevent such movement but will allow it to occur when a predetermined temperature is exceeded.

Needless to say, it is highly undesirable that disconnections should occur inadvertently since, at the very least, that would result in an undesired shutdown of the system and the need to reset the same. It is just as important that the system be fail-safe, that is, that there be provided some measure of redundancy or other means that prevent the disconnect system from being rendered inoperative for any of a variety of reasons.

In those systems that rely upon, for example, electro-mechanical actuators to effect the desired mechanical movement that allows disconnection, there is always the problem that corrosion or the like may prevent the electro-mechanical actuator from responding to a proper signal and, of course, it is always possible that electrical circuit difficulties could prevent the disconnect signal from being generated in the first place.

In those instances utilizing thermally responsive material for effecting the mechanical movement, some difficulties may occur in terms of causing inadvertent disconnects as a result of unrestrained thermal growth as temperature of the mechanism rises, although not to the danger point.

Still other approaches using eutectic material frequently require substantial cleanup to be reset and in some instances, may allow eutectic material to enter machined parts of the mechanism and ultimately solidify when the mechanism cools down requiring substantial removal effort and/or replacement of parts.

The present invention is directed to overcoming one or more of the above problems.

Summary Of The Invention

It is the principal object of the invention to provide a new and improved thermal operator that may be used for any of a variety of purposes where mechanical movement is to be produced in response to an increasing temperature. It is a specific object of the invention to provide such a thermal operator that may be advantageously employed in, for example, mechanical disconnect system.

According to one facet of the invention, there is provided an operator including a pin mounted for generally

axial movement and having opposed ends, a housing mounting the pin for the axial movement such that at least one end of the pin extends from the housing, and a cavity within the housing and containing a material that undergoes a sudden, substantial volumetric increase in response to increasing temperature accompanied by a solid to liquid phase change. A piston is disposed in the housing and is subject to the material so as to be moved thereby upon volumetric increase thereof. The piston is located to act upon the pin remote from the end that extends from the housing.

Thus, movement of the pin will occur in response to the sudden, substantial volumetric increase in response to increasing temperature and the movement of the accompanying phase change may be utilized to produce any desired mechanical action.

In a preferred embodiment, the pin includes a head at the end thereof opposite the end that extends from the housing and the piston includes a finger that is movable with the piston and toward the head.

The invention also contemplates the provision of a washer about the pin adjacent the head such that the finger is engageable with the washer.

Another aspect of the invention contemplates a combined electric and thermal operator which includes the pin as aforesaid along with a solenoid having a coil and an armature adjacent one end of the pin with the armature connected to that end of the pin. The housing includes a cavity containing material that undergoes sudden, substantial volumetric increase in response to increasing temperature accompanied by a solid to liquid phase change and a movable element is in non-connected but abutting relation with one of the armature and the corresponding end of the pin and extends toward the cavity in contact with the

material so as to respond to expansion of the material to drive the pin, either directly or via the armature.

As a consequence of this construction, the pin may be driven either in response to an increase in temperature or in response to an electrical signal applied to the solenoid coil. In the event such a signal is supplied to the latter and the solenoid fails to respond, the arrangement is such that the pin can still be moved as a result of thermal expansion of the material contained in the cavity.

In still another aspect of the invention, such a mechanism may be included in a mechanical disconnect system which further includes a pair of aligned, relatively axially movable, rotatable shafts having interengaging teeth, an exterior thread on one of the shafts, a radially movable pawl aligned with the thread and movable into engagement therewith such that rotation of the shafts will cause relative axial movement thereof to disengage the teeth, and a plunger mounting the pawl and biased toward the shafts. The pin of the operator is employed to normally latchingly engage the plunger to prevent the pawl from engaging the thread but will release the plunger upon receipt of a signal to the solenoid or in response to increasing temperature.

In a preferred embodiment of the invention, the pin extends through the housing and the cavity is an annular cavity located about the pin. The housing further contains a cylinder in fluid communication with the cavity and the movable element or piston is located within the cylinder.

Typically, a shear pin is provided to normally interconnect the piston and the housing radially to position the piston as well as provide a measure of restraint against movement until the temperature of the apparatus is such that a disconnect should be made.

In a highly preferred embodiment, there is provided a thermal operator including a housing as mentioned previously with opposed faces with one end of the pin extending from one of the faces. Such face is configured for mounting to a disconnect mechanism or the like. The other of the faces of the housing is configured to mount a solenoid or the like and means are provided for mounting the housing one face with a solenoid mounted on the other face, to a disconnect mechanism or the like.

According to this facet of the invention, a thermal disconnect feature can be added to existing power trains having solenoid operator disconnects as an in-the-field retrofit.

Other objects and advantages will become apparent from the following specification taken in connection with the accompanying drawings.

Description Of The Drawings

Fig. 1 is a view of a mechanical disconnect mechanism made according to the prior art;

Fig. 2 is a view of the mechanical disconnect system with the addition of a thermal operator made according to the invention;

Fig. 3 is a view of a thermal operator made according to the invention with an electrical solenoid attached thereto showing the configuration of the components in the non-energized state;

Fig. 4 is a view of the thermal operator after being tripped in response to an increase in temperature;

Fig. 5 is a view of the thermal actuator showing the relation of the components after having been tripped in response to an electrical signal;

Fig. 6 is an end view of a piston utilized in the thermal actuator; and

Fig. 7 is a view similar to Fig. 6 but showing a modified embodiment of such a piston.

Description Of The Prior Art

A typical prior art construction in which an operator made according to the invention may find utility is illustrated in Fig. 1 in the form of part of a conventional drive train between, for example, the gear box associated with an aircraft turbine engine, and a constant speed drive or integrated drive generator forming part of the electrical system for such aircraft. However, it is to be understood that the invention may be employed with efficacy in other environments as well and that no limitation in any particular environment is intended except insofar as stated in the claims.

With reference to Fig. 1, an input spline shaft 10 is shown and will typically be connected to the gear box (not shown) of a aircraft turbine engine (also not shown). The input spline shaft 10 is journaled as by bearings 12 and at one end 14 includes axially facing teeth 16.

A so-called "worm shaft" 18 having an external thread 20 is mounted in alignment with the input spline shaft 10 and has axially facing teeth 22 which may interengage with the teeth 16 to couple the shafts 10 and 18 together so that rotary input applied to the former will result in driving the latter.

In the usual case, the worm shaft 18 will be axially movable on a driven shaft 24 which serves as the input to the constant speed drive or integrated drive generator while being splined thereto so that rotation of the shaft 18 will be conveyed to the shaft 24. A reset spring 26 may be

disposed between a shoulder 28 on the shaft 24 and an end 30 of the worm shaft 18 so as to bias the latter such that the teeth 22 will engage with the teeth 16 on the input spline shaft.

The system includes a housing which is partially shown at 32 and within such housing is a plunger 34 which is mounted for reciprocal movement in the radial direction, that is, toward and away from the shafts 10 and 18. On its radially inner end, the plunger 34 includes a pawl 36 with a thread surface 38 in alignment with the thread 20 on the worm shaft 18. A spring 40 operates against the plunger 34 so as to bias the same toward the shafts 10 and 18 while a latch pin 42 normally latchingly engages the plunger 34 to hold the same in the position shown, that is, with the pawl 36 spaced from the external thread 20. The latch pin 42 may be withdrawn by electrical operation of a solenoid 44 and when such occurs, the spring 40 will drive the plunger and the pawl 36 radially inward such that the thread surface 38 will engage the thread 20 on the worm shaft 18. The thread 20 is pitched such that continued rotation of the worm shaft 18 while engaged with the thread surface 38 will result in the worm shaft 18 axially moving to the left as viewed in Fig. 1 and against the bias of the spring 26. As such occurs, the teeth 22 will be disengaged from the teeth 16 and the driving connection between the shafts 10 and 18 quickly broken to ultimately terminate the rotary input on the shaft 24 to the constant speed drive or integrated drive generator.

In the usual case, sensors are employed along with appropriate circuitry to indicate manual activation of the solenoid 44 when it is determined that the input of further power to the mechanism connected to the shaft 24 could result in damage thereto. As alluded to previously, this

type of mechanism may be subject to problems as a result of circuit failure, human error and/or corrosion that limits movement between movable parts within the solenoid 44.

Description Of The Preferred Embodiment

According to one facet of the invention, it is desirable that a prior art apparatus such as shown in Fig. 1 be retrofitted with a thermal operator made according to the invention which provides increased fail-safe ability insofar as the disconnect operation described previously can result from the determination of an undesirably high temperature in the environment of the mechanism apart from any sensors, human input or electrical circuitry associated with the solenoid 44.

In particular, according to the invention, a thermal operator, generally designated 50 is interposed between the solenoid 44 and the plunger 34. A latching pin 52, as will be seen, normally restrains the plunger 34 as described previously but may be operated in response to either energization of the solenoid 44 or the determination of an undesirably high temperature by the thermal operator 50; and such movement of the pin 52 may occur in response to either such occurrence independently of the other.

Since the remainder of the components illustrated in Fig. 2 are identical to their counterparts shown in Fig. 1, in the interest of brevity they will not be redescribed, it being understood that like components bear like reference numbers. It is sufficient merely to note that a threaded bore 54 which receives a retaining bolt 56 for the solenoid 44 in the prior art embodiment shown in Fig. 1 receives a somewhat longer bolt 58 to mount both the solenoid 44 and the thermal operator 50.

Turning now to Figs. 3-5 inclusive, the solenoid 44 is seen to include a housing 60 terminating in an ear 62 provided with an aperture 64 for receipt of the bolt 58. Within the housing 60 is a coil 66 which may be connected to known electrical circuitry to receive signals directing operation of the disconnect mechanism.

Conventionally movably received within the coil 66 is an armature 68. A spring 70 received within a bore 72 in the armature and abutting an end piece 74 normally biases the armature 68 to the position illustrated in Fig. 3. However, upon energization of the coil 66 apart from any other operation of the device, the armature 68 will move to the left and the components will occupy the position illustrated in Fig. 5.

One end 78 of the armature 68 remote from the end piece 74 includes a T-slot 80 to receive a T-shaped head 82 or end of the pin 52. Thus, movement of the armature 68 will move the pin 52 axially.

The housing 60 for the solenoid 44 is fitted to a first housing component 90 of the thermal actuator 50. The housing component 90 is, for the most part, received within a bore 92 in a second housing component 94 forming part of the thermal actuator 50. The arrangement is such that an annular cavity 96 is formed intermediate the ends of the pin 52 and in surrounding relation thereto.

The housing component 90 includes an integral sleeve 98 which extends through an opening 100 in the housing component 94 and which essentially mounts the pin 52 for movement along its longitudinal axis such that an end 102 of the pin 52 normally extends out of the housing defined by the housing components 90 and 94. The end 102 is utilized to engage the plunger 34 to normally hold the same in the position illustrated in Fig. 2.

The interface of the housing components 90 and 94 is sealed by O-ring seals 104 and the annular chamber 96 is filled with a material that undergoes sudden, substantial volumetric increase in response to increasing temperature accompanied by a solid to liquid phase change. In a preferred embodiment of the invention, this material is any one of a number of conventional waxes as, for example, para-terphenyl.

To one side of the pin 52, the housing component 90 includes a cylinder 110. A piston 112 is reciprocally received within the cylinder 110 and has an end 114 that extends toward the cavity 96 to be in contact with the material therein. As a consequence, upon subjection of the thermal actuator 50 to an increased temperature, expansion of the material in the chamber 96 will act against the surface 114 and will drive the piston 112 to the left within the cylinder 110 from the position illustrated in Fig. 3 to that illustrated in Fig. 4.

To prevent such movement from occurring in several increments which could result in inadvertent disconnection, a shear pin 116 extends between the piston 112 and the housing component 90 to normally restrain movement of and radially position the piston 112. As a consequence of this construction, rather than expanding as temperature increases, the material within the cavity 96 will be confined to the volume thereof but the pressure will increase. Eventually, the pressure will be sufficient to rupture the shear pin 116 allowing movement of the piston 112 from the position illustrated in Fig. 3 to that shown in Fig. 4 in but a single increment. Typically, the pin 116 may be sized to shear at an internal pressure within the chamber 96 of about 615 psi.

On its end 120 opposite the end 114, the piston 112 carries an axially directed finger 122 which extends toward the head 82 of the pin 52. A washer 124 may be optionally slideably disposed on the pin 52 so as to abut the end 78 of the armature 68 as well as being located as to be engaged by the finger 122. It is to be specifically noted that the finger 122 is not connected to the armature 68 nor to the washer 124 but merely contacts the same. Positioning of the finger 122 to abut the washer 124 is assured by the positioning feature of the shear pin 116.

In any event, when the piston 112 moves from the position illustrated in Fig. 3 to that shown in Fig. 4, it will act against the washer 124 which in turn will uniformly distribute the force about the end 78 of the armature 68 to drive the latter to the position illustrated in Fig. 4 thereby carrying the pin 52 to the left. This causes the end 102 of the pin 52 to be withdrawn from latching engagement with the plunger 34 (Fig. 2) to ultimately cause a disconnection.

This will, of course, occur only upon the material within the cavity 96 reaching some predetermined temperature indicative of a system problem requiring shutdown. In the usual case, the material will undergo a phase change from the solid phase to the liquid phase which generates a large increase in volume more as a result of the phase change rather than merely as a result of ordinary thermal expansion not associated with a phase change.

It should be noted that because of the high pressures involved, even if the armature 68 were frozen within the coil 66 as a result of corrosion or the like, the change of position from Fig. 3 to Fig. 4 would likely occur to insure disconnection of the mechanism.

Fig. 5 also illustrates that the armature 68 may be moved to the left from the position illustrated in Fig. 3 solely in response to an electrical signal applied to the coil 66. In this case, the piston 112 remains in the same position as in Fig. 3, retained by the shear pin 116, but the end 102 of the pin 52 is nonetheless withdrawn from latching engagement with the plunger 34 (Fig. 2). While Fig. 5 illustrates the washer
124 as traveling with the armature 68 in that event, those skilled in the art will appreciate that it may remain in the position illustrated in Fig. 3 or occupy any position in between in that it is slideably received on the pin 52.

The housing component 94 includes an interior bore 130 that aligns with the bore 64 in the solenoid housing 60. Thus, the bolt 58 may extend through both of the bores 64 and 130 to be received in the bore 54 in the mechanism housing 32 as mentioned previously.

Fig. 6 illustrates one configuration of the finger 122. In this case, the finger 122 is simply a cylindrically shaped finger that is offset from the center line of the piston 112.

An optional configuration for the finger 122 is shown at 122'in Fig. 7. In this embodiment of the invention, the cross-section of the finger appears as a common area of two intersecting circles defined by arcs 132 and 134. In some instances the embodiment illustrated in Fig. 7 may be preferable in that it may permit one to dispense with the washer 124.

Lastly, it should be noted that the housing part 94 has a face 140 which is configured so as to mate with a face 142 on the housing 32 just as the solenoid 44 had a similar mating face. At the same time, the housing part 90 is provided with a face 146 to which the solenoid 44 may mate,

the face 146 being opposite the face 140.

As a result of this configuration, prior art devices such as shown in Fig. 1 may be readily retrofitted with the thermal operator 50 in-the-field simply by removing and partially disassembling the solenoid 44 and fitting the same to the housing part 94 on the face 146. All that need be provided is, of course, the thermal operator 50, a new pin 52 of greater length than the pin 42 and an bolt 58 of increased length. The resulting assembly, by reason of the mating nature of the face 140 to the face 142 may be readily installed on the mechanism.

From the foregoing, it will be appreciated that the invention provides a means whereby the additional fail-safe capability that attends the use of a thermal operator in addition to a solenoid operator is achieved. It will likewise be appreciated that when used in a mechanical disconnect system, difficulty associated with inadvertent disconnect is essentially eliminated as is the problem of clean up where eutectic materials are utilized as thermally responsive devices.

Still another advantage provided by the invention resides in the fact that after there has been a disconnect due to overheating, the coupling cannot be manually reset without disassembly of the operator. This feature virtually assures inspection to determine the cause of overheating and in any event, prevents inadvertant improper resetting.

It will further be appreciated that the ability to easily retrofit to add thermal disconnect capability in-the-field is a substantial advantage.

C L A I M S

1. An electric and thermal operator comprising:

a pin mounted for generally axial movement and having opposed ends;

a solenoid having a coil and an armature adjacent one end of said pin and having said armature connected thereto;

a housing including a cavity containing a material that undergoes substantial volumetric increase in response to increasing temperature; and

a movable element in non-connected but abutting relation with one of said armature and said pin one end and extending toward said cavity in contact with said material so as to respond to expansion of said material to drive said pin.

2. A mechanical disconnect mechanism including the operator of claim 1, a pair of aligned relatively axially movable, rotatable shafts having interengaging teeth, an exterior thread on one of said shafts, a radially movable pawl aligned with said thread and movable into engagement therewith such that rotation of said shaft will cause said relative axial movement to disengage said teeth, and a plunger mounting said pawl and biased toward said shafts, said pin normally latchingly engaging said plunger to prevent said pawl from engaging said thread.

3. The operator of claim 1 wherein said pin extends through said housing and said cavity is an annular cavity about said pin.

4. The operator of claim 3 wherein said housing contains a cylinder in fluid communication with said cavity and said movable element is a piston in said cylinder.

5. The operator of claim 1 wherein said housing contains a cylinder in fluid communication with said cavity and said movable element is a piston in said cylinder.

6. The operator of claim 5 wherein said piston includes a finger oppositely of said material and extending into contact with said one of said armature and said pin on end.

7. The operator of claim 6 further including a shear pin normally interconnecting said piston and said housing.

8. A thermal operator comprising:

a pin mounted for generally axial movement and having opposed ends;

a housing mounting said pin for said axial movement such that at least one end of said pin extends from said housing;

a cavity in said housing and containing a material that undergoes substantial volumetric increase in response to increasing temperature; and

a piston in said housing and subject to said material so as to be moved thereby upon volumetric increase thereof, said piston acting upon said pin remote from said one end.

9. The thermal operator of claim 8 wherein said housing has opposed faces with said pin one end extending away from one of said faces, said one face being configured for mounting to a disconnect mechanism or the like, the other of said faces being configured to mount a solenoid or the like, and means for mounting said housing one face, with a solenoid mounted on said other face, to a disconnect mechanism or the like.

10. The thermal operator of claim 8 wherein said cavity is an annular cavity about said pin.

11. The thermal operator of claim 10 wherein said housing includes a cylinder displaced from said pin and opening to said cavity, and said piston is within said cylinder.

12. The thermal operator of claim 11 wherein said pin includes a head at the end thereof opposite said one end and said piston includes a finger movable with said piston and toward said head.

13. The thermal operator of claim 8 wherein said pin includes a head at the end thereof opposite said one end and said piston includes a finger movable with said piston and toward said head.

14. The thermal operator of claim 13 wherein a washer is disposed about said pin adjacent said head, and said finger is engageable with said washer.

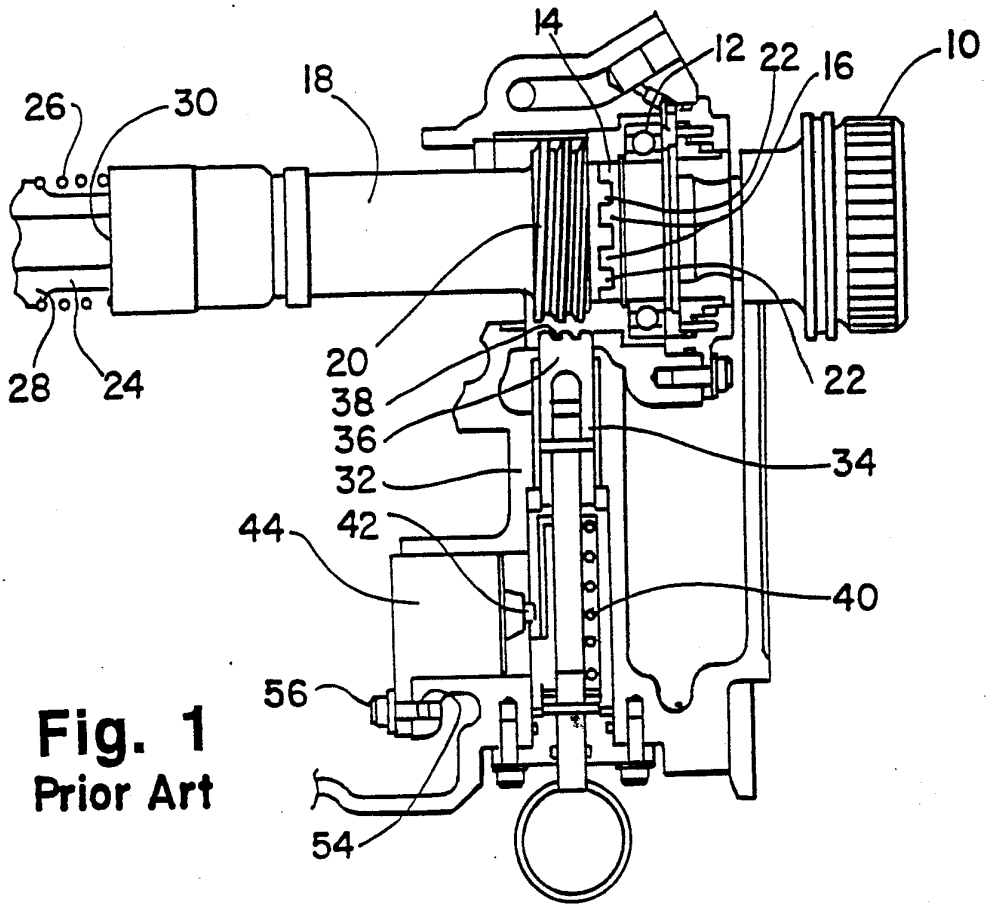


Fig. 1
Prior Art

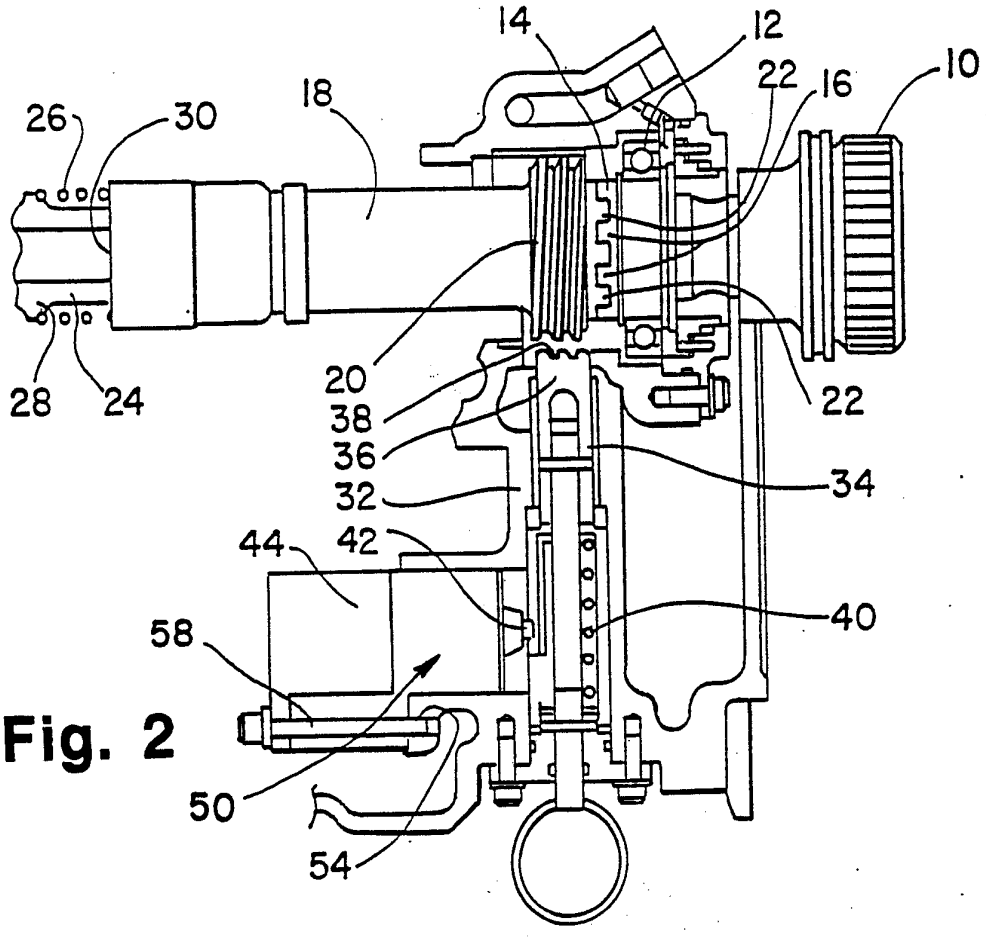


Fig. 2

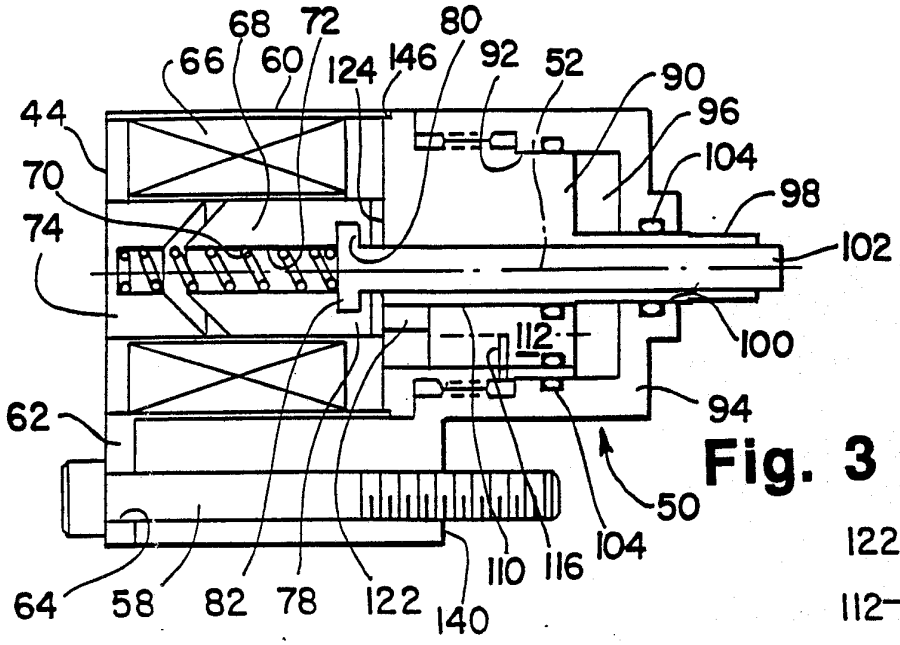
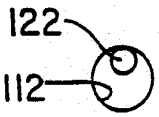


Fig. 3



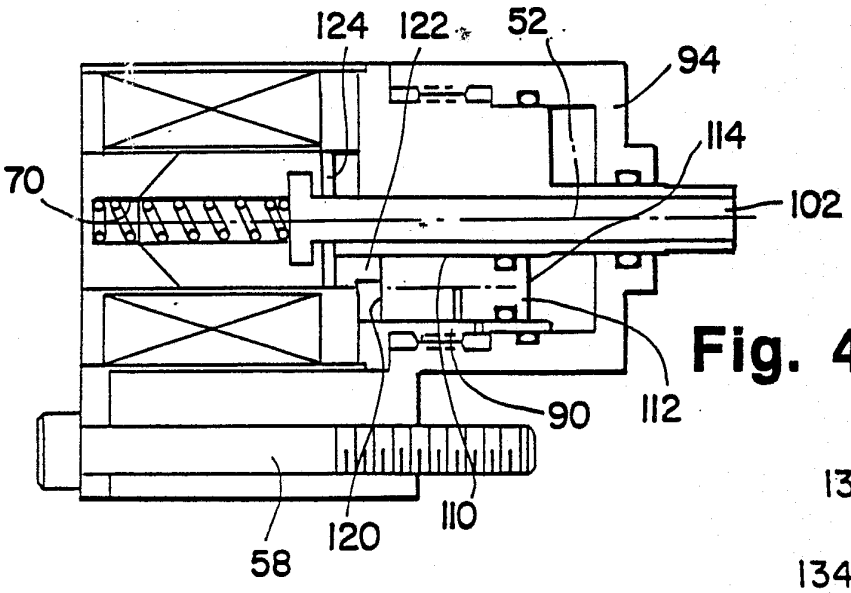


Fig. 4

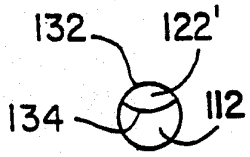


Fig. 7

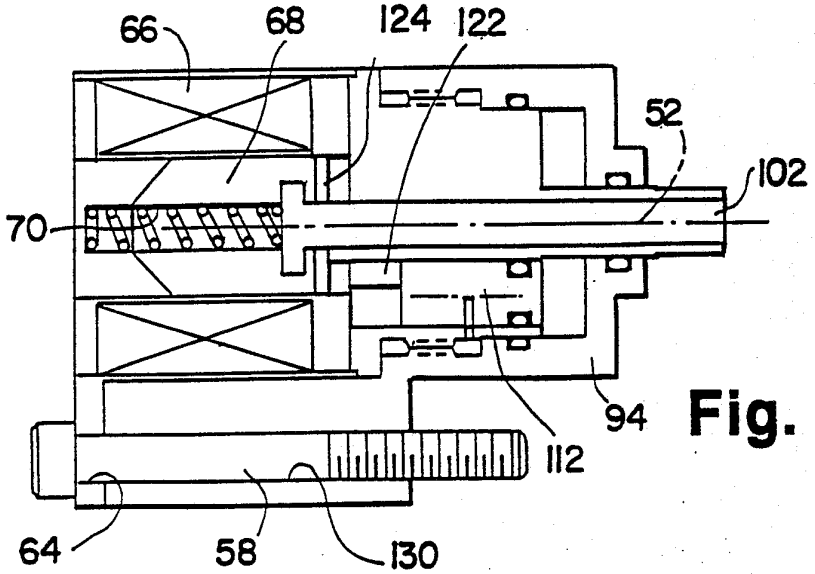


Fig. 5

INTERNATIONAL SEARCH REPORT

International Application No PCT/US90/05715

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC(5): H01H 9/00
U.S. CL.: 335/141

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
U.S.	335/141, 142, 143, 144, 145, 146; 60/527, 528, 529, 530, 531; 337/148

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
X/Y	US, A, 4,288,770 (GILLETTE) 08 September 1981, Figures 1,3,4, Col. 3, lines 26-44, Col. 4, lines 25-38.	1,3-6,8-13 / 14
Y	US, A, 4,016,722 (NIEDERER, SR.) 12 April 1977.	1,3-6,8-14
X/Y	US, A, 1,571,182 (BARNUM ET AL.) 02 February 1926, Fig. 2, page 1, lines 73-81, page 2, lines 91-98, ;age 3, lines 85-97.	8 and 10 / 1,3-6,8-13
A	US, A, 4,235,304 (LAMB ET AL.) 03 March 1981, see entire document.	1-14
A	US, A, 2,127,319 (ZAHRADNIK) 16 August 1938, see entire document.	1-14
A	US, A, 3,609,635 (HARRIS) 28 September 1971, see entire document.	1-14
A	US, A, 3,805,528 (HUEBSCHER) 23 April 1974, see entire document.	1-14
A	US, A, 3,712,052 (STASCHKE ET AL.) 01 April 1973, see entire document.	1-14

* Special categories of cited documents: [15]

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
02 NOVEMBER 1990	22 FEB 1991
International Searching Authority [1]	**Signature of Authorized Officer**
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