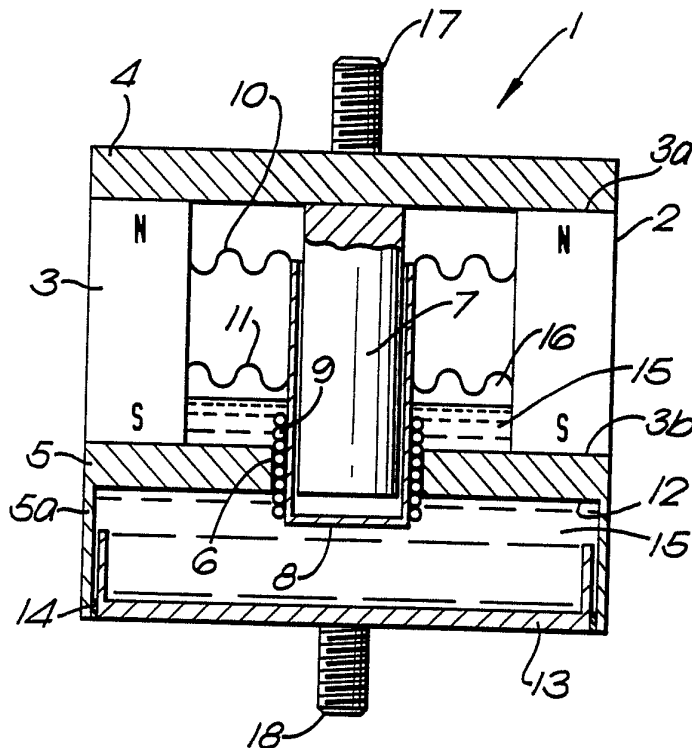




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(54) Title: HYDRAULIC LEVER ACTUATOR



(57) Abstract

An actuator having a linear current force characteristic comprises a moving coil transducer and a hydraulic lever. The moving coil (9) is capable of producing only a relatively low force but with a relatively large displacement. The coil (9) is formed on a piston (8) which acts as an input piston to a hydraulic lever. An output piston (13) has a much larger area than the input piston (8). Thus, the long throw, low force input to the hydraulic lever is converted into a short throw, high force output at the second piston (13).

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+ It is not yet known for which States of the former Soviet Union any designation of the Soviet Union has effect.

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## HYDRAULIC LEVER ACTUATOR

### DESCRIPTION

5       The present invention relates to an improved  
electromagnetic actuator for use in vibration  
cancellation systems.

10       It has been proposed to cancel vibrations in a  
mechanical system by sensing the vibrations and  
utilising an electronic control circuit to drive a  
mechanical actuator in order to apply vibrations to the  
system which tend to cancel out the original source of  
vibration. For example, it has been proposed to use a  
15       mechanical actuator in association with an engine mount  
for an internal combustion engine to apply cancelling  
vibrations to the engine for producing smooth running.

20       Known actuators are of the moving-iron type, wherein a  
magnetic field is produced which interacts with a metal  
armature to generate a force thereon. The armature then  
moves under the influence of the generated force. A  
disadvantage of these actuators is that the force

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generated is non-linear with respect to armature displacement. It is, therefore, an object of the present invention to provide an actuator having more linear characteristics than moving-iron type actuators  
5 by employing either a constant or variable volume hydraulic lever.

According to a first aspect the present invention there is provided an electromagnetic actuator comprising a  
10 moving-coil electrical signal-to-displacement transducer and a hydraulic lever wherein the hydraulic lever transforms the transducer output.

According to a second aspect of the present invention  
15 there is provided an electromagnetic actuator comprising a rotary electric motor and a hydraulic lever wherein the hydraulic lever transforms the motor output. Preferably, the motor drives an Archimedean screw in order to transfer hydraulic fluid between a  
20 hydraulic fluid reservoir and a hydraulic lever working chamber. However, other forms of reversible rotary pump may usefully be employed.

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Advantageously, two counter-rotating Archimedean screws may be used in order to balance out stator rotational reaction forces.

5 Conveniently, the actuator according to the present invention may be employed as an engine mounting as part of a vibration cancellation system.

Embodiments of the present invention will now be  
10 described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 shows an actuator according to the first  
aspect of the present invention;

15

Figure 2 shows a single screw version of an actuator according to the second aspect of the present invention;

20 Figure 3 shows a double screw actuator according to the second aspect of the present invention; and

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Figure 4 shows an active vibration control system applied to an internal combustion engine.

Referring to the Figure 1, an actuator 1 includes a  
5 body 2, formed from an annular permanent magnet 3  
having first and second axial extremities 3a,3b, a  
disc-shaped first end-piece 4 and a dish-shaped second  
end-piece 5. The first end-piece has a diameter  
substantially the same as the outer diameter of the  
10 magnet 3 and is affixed coaxially across the first  
axial extremity 3a thereof. The second end-piece 5 has  
the same diameter as the first end-piece 4 and is  
similarly affixed across the second axial extremity 3b  
of the magnet 3 with its wall portion 5a extending away  
15 from the magnet 3.

The second end-piece 5 is provided with an aperture 6  
in the centre of its planar portion. A column 7  
extends coaxially from the centre of the first  
20 end-piece 4 in the direction of the second end-piece 5,  
passes through the aperture 6 therein.

- 5 -

A first piston 8, comprising a tube having a closed end, supports an energisable coil 9 wound about the tubular portion adjacent the closed end thereof. The first piston 8 is mounted for axial movement relative to the column 7 and is supported by a pair of spiders 10, 11 extending radially inwardly from the inner wall of the magnet 3 such that a portion of the coil 9 is within the aperture 6.

10 A chamber 12 is defined by the outwardly facing planar surface and the inner surface of the wall portion of the second end-piece 5, and the equivalent surfaces of a dish-shaped second piston 13, coaxially located within the second end-piece 5. An annular sealing member 14 is provided between the outer surface of the wall portion of the second piston 13 and the inner surface of the wall portion of the second end-piece 5. The sealing member 14 ensures a fluid-tight seal between the second piston 13 and the second end-portion 5. The inner surface of the wall portion of the second end-piece 5 and the outer surface of the wall portion of the second piston 13 cooperate to relieve

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pressure from the sealing member 14 so as to provide a reliable seal.

5 The actuator 1 is provided with a quantity of hydraulic fluid 15 which occupies the chamber 12 and a portion of an airtight-sealed space 16 within the magnet 3. The space 16 within the magnet 3 communicates with the chamber 12 by means of the restricted gap in aperture 6 between the coil 9 and the second pole piece.

10

A pair of threaded studs 17, 18 extend axially outwardly from the first end-piece 4 and the second piston 13 respectively for mounting the actuator between a support and a load.

15

The operation of the actuator will now be described. When the coil 9 is energised a magnetic field is generated within the body portion 2 which interacts with magnetic field produced by the magnet 3. As a result of this interaction a force is generated on the coil 9 which moves it axially thus moving the first piston 8 into or out of the chamber 12. The movement of the first piston 8 is transferred to the piston 13 by

20

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means of the hydraulic fluid in the chamber 12. Since  
the area of the piston 13 is greater than that of the  
first piston 8, the piston 13 moves axially a smaller  
distance than the first piston 8 but exerts a greater  
5 force, and thus the arrangement acts as an hydraulic  
lever.

The first piston 8 is required to have a long travel  
relative to the travel of the second piston 13 and it  
10 might be thought that a fluid tight sliding member  
would be required for the piston 8 in order to seal the  
chamber 12. However, in this example of the invention  
the aperture 6 is provided between the coil 9 and the  
second end piece 5. At low frequencies fluid from the  
15 chamber 12 can flow through the aperture 6 to the  
chamber 15 and vice versa, but at high frequencies the  
small aperture 6 prevents rapid fluid flow, thus  
effectively sealing chamber 12 and allowing force to be  
transmitted to the piston 13. The construction also  
20 prevents the static loading of the actuator displacing  
the coil 9 away from its central quiescent position  
(shown in the drawing). The sealed air chamber 16 and  
the resulting air-gap between the column 7 and the

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piston 8 means that upon movement of the piston, no hydraulic fluid has to be forced thereby from between the column 7 and piston 8, which would otherwise impede high frequency movement of the piston. Furthermore,  
5 the immersion of the coil 9 in the hydraulic fluid 15 leads to improved cooling of the coil.

The actuator shown in Figure 1 will function in the orientation shown. However, if the actuator 1 is to  
10 be used angled or inverted, a high compliance membrane will be required, fixed between the inner wall of the magnet 3 and the first piston 8, such that it retains the hydraulic fluid substantially as shown in Figure 1 at all orientations of the actuator 1.

15  
The actuator 1 has the advantage that the moving coil device has a linear current force characteristic. The hydraulic lever transforms the low force, long throw output of the moving coil device into a higher force  
20 over a shorter throw, which is particularly suited for use in vibration cancellation systems.

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Referring to Figure 2, an actuator 20 comprises a cylindrical body 21 having first and second axial extremities 21a, 21b. A rotary electric motor 23 is mounted in a motor chamber 22, defined within the body 21 adjacent the first axial extremity thereof. A reservoir chamber 24, for storing hydraulic fluid, is located within the body 21 adjacent the motor chamber 22, from which it is separated by a wall 25. The wall 25 has a centrally located aperture 25a through which the shaft 27 of the motor 23 passes. A fluid tight seal 26 is formed between the shaft 27 and the wall 25.

A resiliently flexible annular membrane 28 is located within the reservoir chamber 24, its outer margin being sealingly fixed to the wall 25, where it meets the body 21, and its inner margin being sealingly attached to the shaft seal 26.

A working chamber 29 is defined by a cylindrical recess extending into the body 21 from the second axial extremity 21b thereof and a piston 30, arranged to travel a small distance into and out of the cylindrical recess. A sealing member 31 is located between the

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periphery of the piston 30 and the radial wall of the cylindrical recess.

The working chamber 29 is connected to the reservoir chamber 24 by a passageway 32. The shaft 27 of the motor 23 extends through the length of the passageway 32 wherein it supports an Archimedean screw 33.

In operation, control signals are supplied to the motor 23 causing it to rotate. The rotation of the motor 23 drives the Archimedean screw 33, either causing hydraulic fluid to be transferred from the reservoir chamber 24 to the working chamber 29 or vice versa. As hydraulic fluid is pumped into and out of the working chamber 29 the piston 30 is caused to moved out of and into the cylindrical recess in sympathy with the changing volume of hydraulic fluid within the working chamber 29. The annular membrane 28 flexes into and out of the reservoir chamber 24 as the volume of hydraulic fluid therein changes.

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This arrangement allows a relatively low torque motor to produce high forces on the piston with moderate displacements. Furthermore, the return path for the hydraulic fluid through the screw thread, between the working chamber 29 and the reservoir chamber 24, limits the static pressure that can be generated on the piston 30. However, with rapidly changing forces, the mass of hydraulic fluid within the screw thread presents an impediment to the motion of the hydraulic fluid thus effectively closing it to high frequency pressure changes. Likewise, static forces acting on the piston 30 will not cause rotation of the motor armature. This makes the actuator particularly suitable for use in active engine mounts where it is necessary for the system to ignore the slowly changing forces associated with cornering etc. of a vehicle.

Should rotational reaction forces on the motor stator be undesirable, they may be balanced out by using two counter-rotating Archimedean screws 32, 33, as shown in Figure 3. In Figure 3, a working chamber 34 is provided with two opposed Archimedean screw feeds 36,

- 12 -

37 arranged with their axes normal to the direction of travel of the piston 35.

5 By proper design of the Archimedean screws the frequency response of the actuator may be tailored to suit a particular application.

10 In an alternative embodiment, the function of the member 28 is performed by a compressible air-filled bag located in the reservoir chamber 24.

15 Actuators according to the present invention may be employed as part of a vibration cancellation systems, for example, for an i.c. engine in a vehicle. The actuator serving as an engine mount. Referring to Figure 4, a sensor 40 detects vibrations in a vehicle body caused by an engine 41 and an electronic control circuit 42 produces an actuator energising current in response thereto which drives an actuator 43. High  
20 frequency vibrations are thereby cancelled. However, the structure of the actuators of the present invention means that low frequency force changes e.g. those due to cornering, do not propagate through the actuator.

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CLAIMS

1. An electromagnetic actuator comprising an electrical signal-to-displacement transducer and a hydraulic lever wherein the hydraulic lever transforms the transducer output.
- 5
2. An electromagnetic actuator according to claim 1, wherein the hydraulic lever comprises first piston means, for transmitting an input displacement, second piston means, for transmitting an output displacement, and a fluid filled chamber therebetween.
- 10
3. An electromagnetic actuator according to claim 1 or 2 wherein the transducer is a moving coil transducer.
- 15
4. An electromagnetic actuator according to claim 3, wherein the coil of said displacement transducer is mounted on said first piston means.
- 20

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5. An electromagnetic actuator according to any preceding claim, wherein a chamber is substantially defined by and within said displacement transducer, said chamber serving as a reservoir for hydraulic fluid  
5 for the hydraulic lever.

6. An electromagnetic actuator comprising a rotary electric motor and a hydraulic lever wherein the hydraulic lever transforms the motor output.  
10

7. An electromagnetic actuator according to claim 6 wherein the motor drives an Archimedean screw such that hydraulic fluid is transferred between a hydraulic fluid reservoir and a hydraulic lever working  
15 chamber.

8. An electromagnetic actuator according to claim 7 comprising two counter-rotating Archimedean screws.

9. An active vibration cancellation system including  
20 an actuator according to any preceding claim.

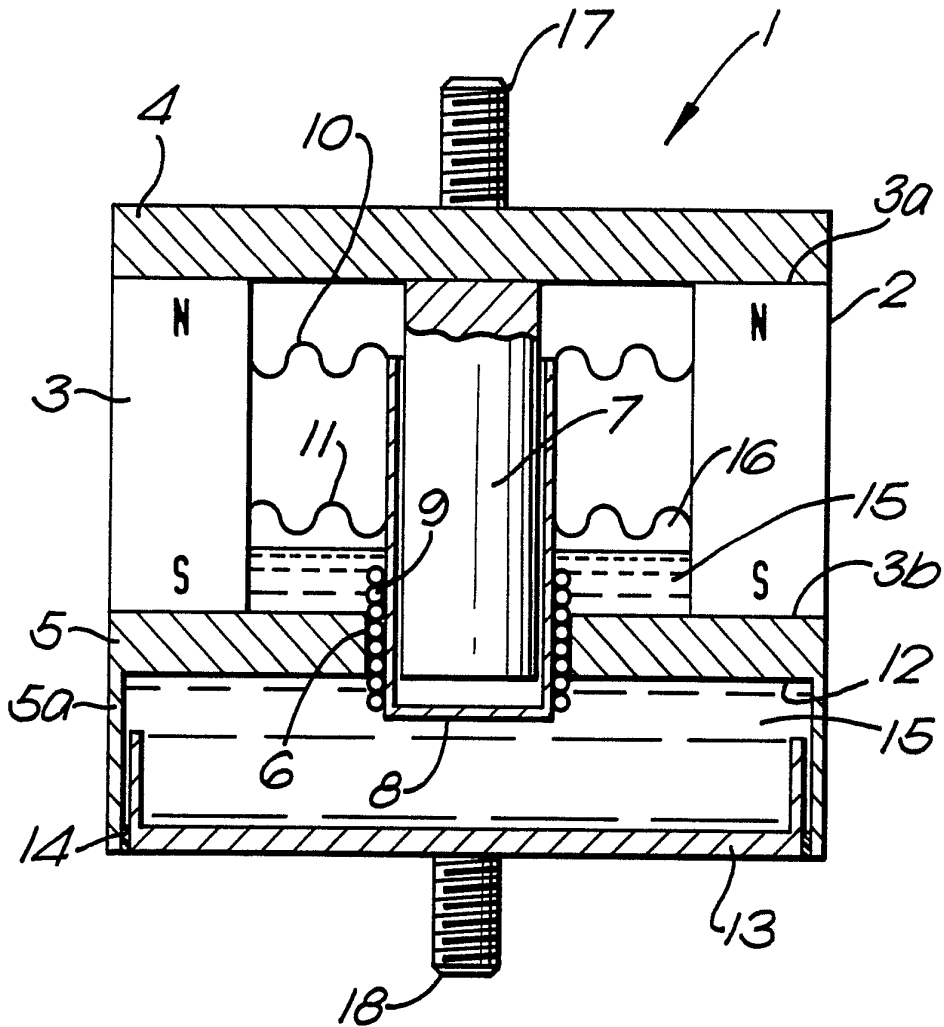
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10. An active vibration cancellation system according to claim 9 wherein the actuator acts as an engine mounting.

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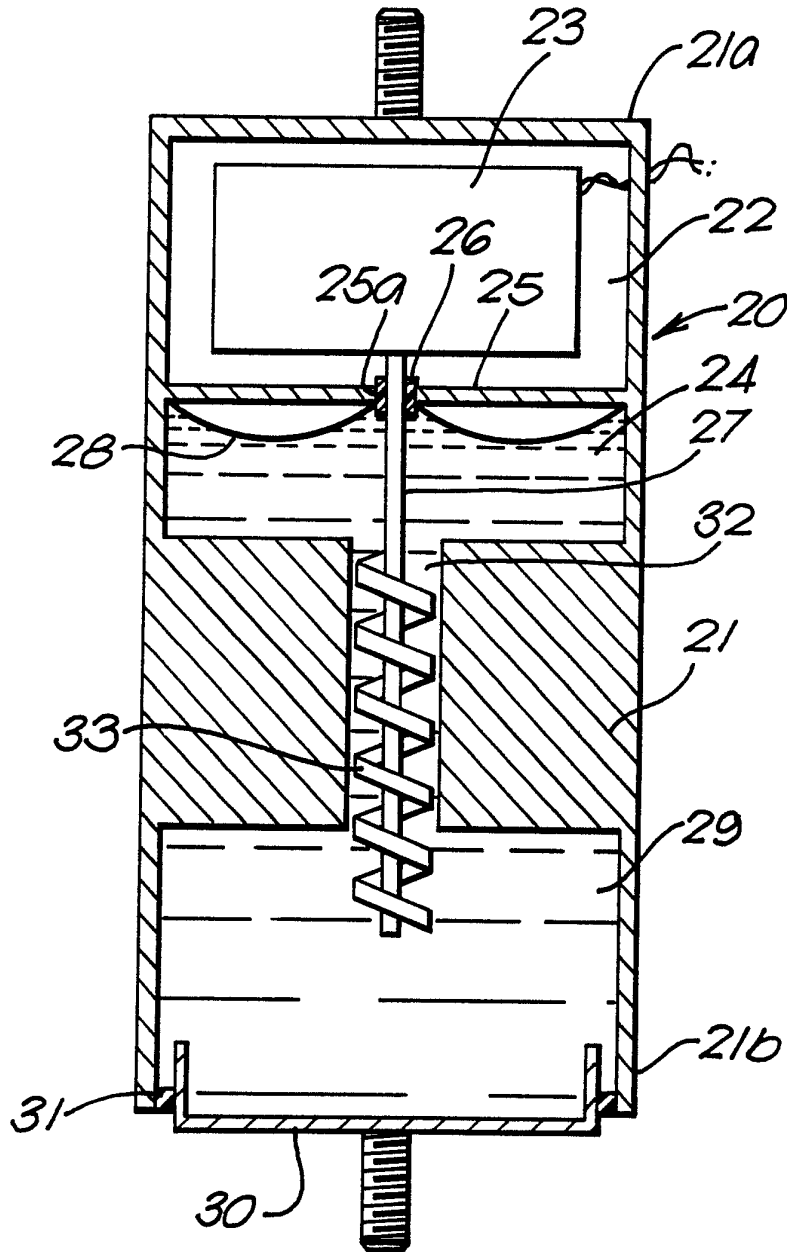
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FIG. 1



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FIG. 2



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FIG. 3

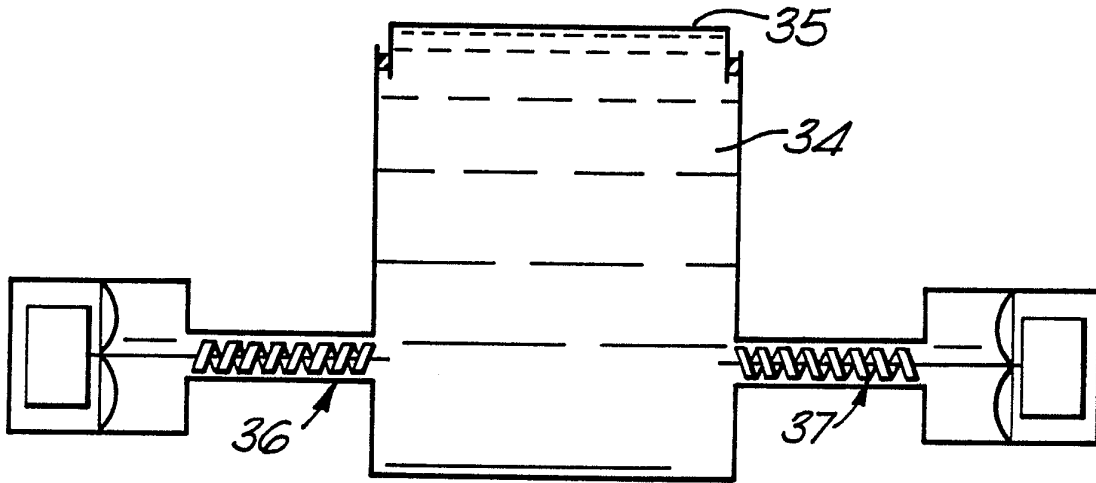
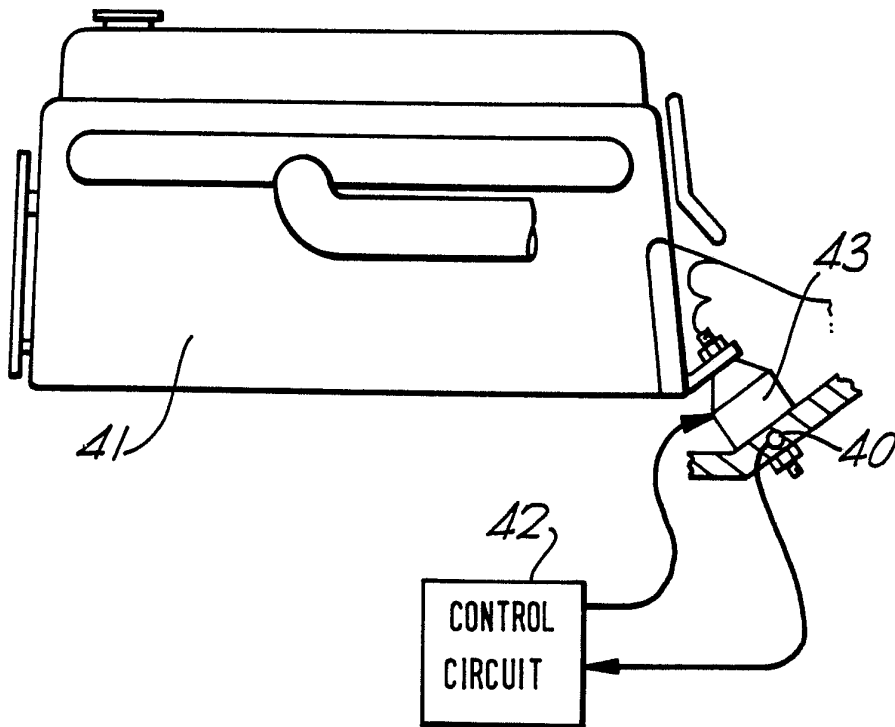



FIG. 4



## INTERNATIONAL SEARCH REPORT

International Application No

PCT/GB 91/01210

<b>I. CLASSIFICATION OF SUBJECT MATTER</b> (if several classification symbols apply, indicate all) <sup>6</sup>		
According to International Patent Classification (IPC) or to both National Classification and IPC		
Int.Cl. 5 H04R1/42; F16F15/02; F15B7/00		
<b>II. FIELDS SEARCHED</b>		
Minimum Documentation Searched <sup>7</sup>		
Classification System	Classification Symbols	
Int.Cl. 5	G05D ; F15B ; F16F ; H04R F04D	
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched <sup>8</sup>		
<b>III. DOCUMENTS CONSIDERED TO BE RELEVANT<sup>9</sup></b>		
Category <sup>10</sup>	Citation of Document, <sup>11</sup> with indication, where appropriate, of the relevant passages <sup>12</sup>	Relevant to Claim No. <sup>13</sup>
X	US,A,3 456 755 (J.WALKER) 22 July 1969 see column 2, line 15 - line 56; figure 1	1,3,4
Y		2
A		5
X	PATENT ABSTRACTS OF JAPAN vol. 5, no. 205 (E-88)(877) 25 December 1981 & JP,A,56 125 190 ( MATSUSHITA DENKI SANGYO KK ) 1 October 1981	1,3
A	see abstract	2,4
Y	DE,A,2 210 608 (G.B.BOUCHERIE) 28 September 1972 see claim 1; figures	2
X	FR,A,714 339 (M.-A.-J. VINER) 12 November 1931 see the whole document	1
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28 NOVEMBER 1991	13 DEC 1991	
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GB 9101210  
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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US-A-3456755	22-07-69	None	
DE-A-2210608	28-09-72	None	
FR-A-714339		None	

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