(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 751 089 A2

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
02.01.1997 Bulletin 1997/01

(51) Int Cl.[6]: **B66B 13/08**

(21) Application number: **96304844.2**

(22) Date of filing: **01.07.1996**

(84) Designated Contracting States:
DE ES FR GB IT

(30) Priority: **30.06.1995 US 497630**

(71) Applicant: **OTIS ELEVATOR COMPANY**
Farmington, CT 06032 (US)

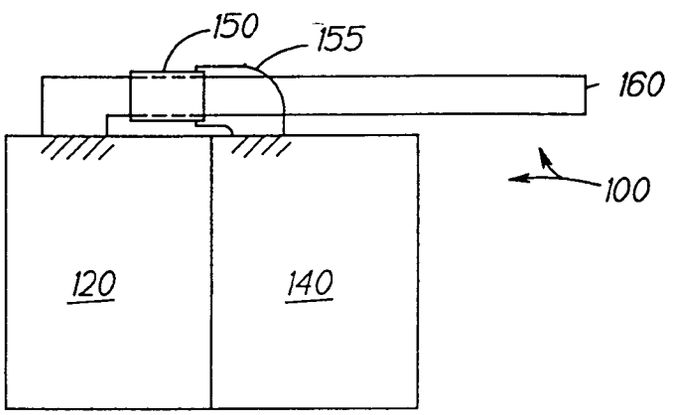
(72) Inventors:
- **Barrett,David W.**
  East Hartland, Connecticut 06027 (US)
- **Jaminet,Jerome F.**
  South Windsor, Connecticut 06074 (US)
- **Mchugh,Thomas M.**
  Farmington, Connecticut 06032 (US)
- **Kowalczyk, Thomas M.**
  Farmington, Connecticut 06032 (US)
- **Peruggi, Richard E.**
  Glastonbury, Connecticut 06033 (US)
- **He,Thomas**
  Unionville, Connecticut 06085 (US)
- **Ahigian, Edward E.**
  Chicago,Illinois 60622 (US)
- **Kulak,Richard E.**
  Bristol, Connecticut 06010 (US)

(74) Representative: **Tomlinson, Kerry John et al**
Frank B. Dehn & Co.,
European Patent Attorneys,
179 Queen Victoria Street
London EC4V 4EL (GB)

(54) Linear motor door system for elevators

(57) A linear motor door system (100) for elevator car doors (120,140) includes first and second doors movable horizontally toward or away from one another, and a linear motor attached to the doors. The primary (150) of the linear motor is fixed to and movable with the first door (140) and the secondary (160) of the linear motor is fixed to and movable with the second door (120).

FIG. 4A



EP 0 751 089 A2

Description

The present invention relates to door systems and, more particularly, to linear motor door systems useful for elevator cars.

Elevator doors systems typically include single or dual sliding doors which are powered to effect automatic opening and closing of the doors. The door panels slide open in a horizontal plane to provide access and slide close to provide security for elevator passengers. See Figure 3.

Many traditional automatic systems are powered by an electric motor supplying rotational torque, as shown in Fig. 1. A mechanical linkage converts the rotational force provided by the motor into a linear force required to move the door(s). Two known mechanical linkages include, for example, a two-bar linkage and a threaded lead screw.

It is also known to replace the combination of a rotational motor and linkage with a linear electric motor. See, for example, U.S. Patent Nos.: 3,462,383; 3,872,622; 4,067,144 and 4,090,113. Also, linear motors are known for various types of doors, as shown, for example, in U.S. Patent Nos.: 3,708,915; 3,793,944; 4,188,552; 4,365,442; 4,858,452, and 5,134,324.

Various speed control and control circuits are known for traditional and/or linear motors. See, for example, U.S. Patent Nos.: 3,891,907; 4,305,481; and Great Britain Patent Specification 1,148,144.

A linear door system is known from U.S. Patent No. 5,373,120. The system of '120 controls the doors while minimizing undesirable rotational torques about the doors caused by the momentum for the horizontal force. In Fig. 2 (corresponding to Fig. 2 of '120), there is shown a pair 10 of elevator doors 12, 14 in a closed position whereby linear motor actuators 16, 18 are attached to both an overhead support 20 (of the cab) and the doors 12, 14 for opening and closing the doors 12, 14 in a reciprocating fashion.

The present inventors believe that known linear motor systems for elevator car doors are sometimes complex because of a plurality (e.g., two) of linear motors used, and because of at least a primary or a secondary of a linear motor being fixed to a portion of the elevator cab other than to a car door.

It is a principal object of the present invention to provide a linear motor system for controlling elevator car doors which is economical both to manufacture and to maintain.

According to the present invention, a door system includes a movable first door, a second door movable relative to the first door, a linear motor primary attached to the first door so as to be movable with the first door, and a linear motor secondary attached to the second door so as to be movable with the second door, said primary being spaced from said secondary by a substantially constant air gap.

Further and still other objects of the present invention will become more readily apparent from the following detailed description of preferred embodiments of the invention, given by way of example only, in conjunction with the accompanying drawings, in which:

Fig. 1 is a partial perspective view of a prior art door operator wherein a rotational motion of the motor is transmitted into linear motion by means of linkages.

Fig. 2 is a partial perspective view of a pair of elevator doors driven by two linear motors according to teachings of prior art U.S. Patent 5,373,120.

Fig. 3 shows schematic plan views of three different door opening configurations of the prior art: Fig. 3A shows center-opening doors; Fig. 3B a side-opening door; and Fig. 3C a two-speed side-opening door.

Fig. 4 shows three schematic diagrams of a linear motor door system according to the present invention during various stages of opening/closing. In Fig. 4A the doors are closed, in Fig. 4B they are partially opened, and in Fig. 4C the doors are fully opened.

Fig. 5 is a schematic diagram of a primary part of a linear motor attached (e.g., fixed) to a door hanger plate via a mount or bracket, according to the present invention.

Fig. 6 is an end view taken in the direction of an arrow A of Fig. 5, showing the primary disposed on an offset portion of the mount, and also showing a secondary part of the linear motor, all according to the present invention.

Fig. 6A is a view similar to Fig. 6, but showing more detail of one preferred secondary having a copper sheet.

Fig. 6B is a view similar to Fig. 6, but showing an alternative preferred embodiment for the secondary, and for the primary and secondary mounts.

Fig. 7 shows an alternative embodiment of the instant inventive door system.

Fig. 8 is a schematic diagram showing a bearing B which is rotatably fixed to the primary 150 so that the secondary and the primary can move in opposite directions S', P' and S", P", while the bearing B maintains a substantially constant air gap G.

Fig. 9 is a schematic circuit diagram to permit electronic control of the door system of the present invention.

Figs. 10 and 10A show two schematic diagrams of the secondary part of Fig. 6 attached (e.g., fixed) to a door hanger plate, according to the present invention.

Figs. 11A and 11B show views of a relating mechanism (e.g., cable, pulleys) which optionally may be used as part of the invention to help counteract any unbalanced frictional forces acting on the doors.

Referring to Figs. 4A, 4B, 4C, 5, 6, 6A, 6B, 7, 8, 9, 10, 10A, 11A and 11B, a preferred linear motor door system includes two doors 120, 140 movable toward or away from each other in a horizontal plane, and a linear motor 150, 160 attached to the doors 120, 140. The motor includes a primary part 150 fixed to the door 140 and a secondary part 160 fixed to the door 120 so that the

part 150 is movable with the door 140 while the part 160 is movable with the door 120.

The primary 150 includes, for example, a metallic or magnetic slotted solid core with electrical windings (not shown), while the secondary includes, for example, an elongate solid magnetically permeable material such as a metallic (e.g., steel, iron) bar or sheet (preferably covered with an electronically conductive layer such as copper or aluminium - see Fig. 6A) extending a suitable distance in the directions of travel of the doors 120, 140. When fully opened, the doors 120, 140 are separated by a distance D. Preferably, a length L of the secondary 160 is greater than the distance D.

The linear motor 150, 150 is supplied with suitable time varying electrical signals by means of a 3-phase AC source connected to drive/control circuits 170 connected via lead 172 to the primary 150 (Fig. 9). An arrangement to maintain a substantially constant air gap G between the secondary part 160 and the primary part 150 while the parts 150, 160 move in opposite directions is shown schematically in Fig. 8. This consists of a bearing ball B which permits parallel relative linear motion whilst maintaining the constant gap G.

Construction of the motor 150, 160 and drive/control circuits 170 is well within the skill of the art when taken in conjunction with the disclosure of the instant specification. See previously referenced U.S. Patent No. 5,373,120. See also the book *Linear Electric Motors: Theory, Design and Practical Applications,* by S.A. Nasar and I. Boldea (1987, Prentice-Hall, Inc.) - Chapters 1-5 inclusive.

The linear motor primary may be directly fixed to the first door and the linear motor secondary directly fixed to the second door.

In Fig. 5, the primary 150 is fixed (e.g., bolted, screwed) to a mount 155 made of, for example, a metal such as steel. The mount or bracket 155 is fixed (e.g., bolted or welded) to a door hanger plate 240 (e.g., steel) fixed to the door 140 and carrying the door rollers.

A spatial relationship of the parts 150, 160 is shown in the end view of Fig. 6, which is a view taken in the direction of an arrow A in Fig. 5. The primary 150 is fixed to a primary offset portion O of the mount 155. The offset portion O includes a suitable bend in the mount 155. The secondary 160 is fixed to another hanger plate 241 (which is, e.g., identical in construction to the plate 240) via a secondary support extension 161 and a secondary mounting plate 165 (e.g, steel) (Fig. 10) which is fixed to the door 120. The extension 161 is, for example, a unitary portion of the secondary 160, which portion is not utilized as a reaction plate during normal operation of the motor 150, 160. The plate 165 includes a respective secondary offset portion O' which in combination with the offset portion O helps to establish a proper gap G. Fig. 6A shows one preferred embodiment of the secondary 160, while Fig. 6B shows another preferred embodiment of a secondary.

In Fig. 6A the secondary backiron S moves with the copper sheet C, but in Fig. 6B the secondary backiron is fixed to the primary mount and the copper sheet C moves with the door 120. The secondary backiron completes the magnetic circuit with the primary - the force between the backiron and the primary is the attractive force that pulls them together. The copper sheet part of the secondary generates the linear force or thrust from the primary and thus must move with the secondary door. The backiron can either be the same length as the copper sheet and move with the secondary door, or else can just cover the primary area and remain fixed in place relative to the primary (per the "U" shaped bracket). The advantage of this latter configuration is that backiron is smaller (less moving mass) and also that the attractive (normal) force between the backiron and primary can be counteracted by a fixed mounting bracket to maintain the air gap.

In normal operation, the primary 150 and the secondary 160 electromagnetically interact to move in opposite directions together with the doors 120, 140, all as is understood from the instant disclosure.

Fig. 7 shows an alternative embodiment of the inventive door system including a primary having two core pieces 150A facing opposite sides of an elongate secondary sheet 160A mounted to the other door. The pieces 150A are fixed within a metallic (e.g., steel) holder 155A having a U-shaped cross-section.

The primary 150, secondary 160, and the offset portions of the secondary mounting plate and the primary mounting plate, are all arranged and dimensioned to effect proper operation of the linear motor 150, 160, all as would be well understood by those skilled in the art when combined with the teachings herein.

Fig. 9 shows an AC source connected to drive/control circuits 170 (inverter; microprocessor; memory - including, e.g., suitable control profiles; buses, etc.) suitably connected (via wires 172) to windings of the primary

To summarize, a preferred embodiment of the present invention includes, among other elements, a mounting configuration for a primary part and a secondary part of a linear motor (LIM). The primary part is fixed to and moves with one of two center opening doors and the secondary part is fixed to and moves with the other door in a center opening elevator door configuration. The primary part may be mounted on an offset bracket as shown in Figure 6 to eliminate any overhang of the secondary part beyond the limits of door travel. This mounting configuration is such that, when the primary is suitably excited, equal and opposite thrusts are produced to drive each of the doors through a particular motion profile (e.g., same profile for both doors). The thrust generated by the LIM results from the electromagnetic forces generated in the LIM secondary by the LIM primary. Force generated in the secondary is counteracted by an equal and opposite force in the primary, resulting in substantially no net (imbalanced) forces acting on the combined moving masses. A single control and

drive controls the forces acting between the primary and secondary such that the resulting motion of the doors will follow a desired profile based, e.g., on a feedback signal from one of the doors. The control and drive arrangement will automatically compensate for any external factors (e.g., friction) by allowing slip between the doors resulting in slightly different travel times if unbalanced forces are present.

Although the invention has been shown and described with respect to a best mode embodiment thereof, it should be understood by those skilled in the art that various other changes, omissions and additions in the form and detail thereof may be made therein without departing from the scope of the invention as set out in the claims. For example, a small, light duty relating mechanism may be included to positively couple the two moving doors together to compensate for external, unequal loads, such as friction. See Figure 11. This relating mechanism is not essential, however, because the mounting arrangement of the present invention will automatically compensate for any external factors by allowing slip between the doors (without the relating mechanism) resulting in slightly different travel times if unbalanced forces were present.

In Fig. 11A a relating cable or aircord A is a continuous cable loop passing around a pulley at each end. One door attaches to the top of the cable loop and the other to the bottom of the cable loop. The relating cable loop rotates one way as both doors open, and the other way as both doors close. The doors are related in that they must always move the same distance in opposite directions.

In Fig. 11B a ground angle G is fixed to the cab and to the top run of the aircord. The pulleys are mounted on the 'slow' door and the 'fast' door is connected to the lower run of the aircord, thus providing a 'two-speed drive' in which the 'fast' door moves at twice the speed of the 'slow' door but in the same direction.

Claims

1. A door system comprising:

   a movable first door;
   a second door movable relative to said first door;
   a linear motor primary attached to said first door so as to be movable with said first door, the doors moving parallel and simultaneously to each other;
   a linear motor secondary attached to said second door so as to be movable with said second door, said primary being spaced from said secondary by a substantially constant air gap.

2. A system as claimed in claim 1, wherein said linear motor primary is fixed to said first door and said linear motor secondary if fixed to said second door.

3. A system as claimed in claim 1, further including a bracket, said bracket being fixed to said primary and being fixed to said first door.

4. A system as claimed in claim 3, wherein said bracket is detachably fixed to said primary.

5. A system as claimed in claim 3, further including a screw for detachably fixing said primary to said bracket.

6. A system as claimed in claim 3, wherein said bracket includes an offset portion, said primary being located on said offset portion.

7. A system as claimed in claim 3, wherein said linear motor secondary has a length (L) which is greater than a distance (D) between said doors when said doors are fully opened.

8. A system as claimed in claim 3, further including a second bracket, said second bracket being fixed to said linear motor secondary and being fixed to said second door.

9. A system as claimed in claim 8, wherein said second bracket includes a secondary offset portion, and wherein said linear motor secondary is fixed to said secondary offset portion.

10. A system as claimed in any preceding claim, wherein said linear motor secondary includes a magnetically permeable material having a side covered with an electrically conductive material.

11. A system as claimed in claim 10, wherein said magnetically permeable material is steel, and wherein said electrically conductive material is copper.

12. A system as claimed in any preceding claim, wherein a cable couples said first door to said second door.

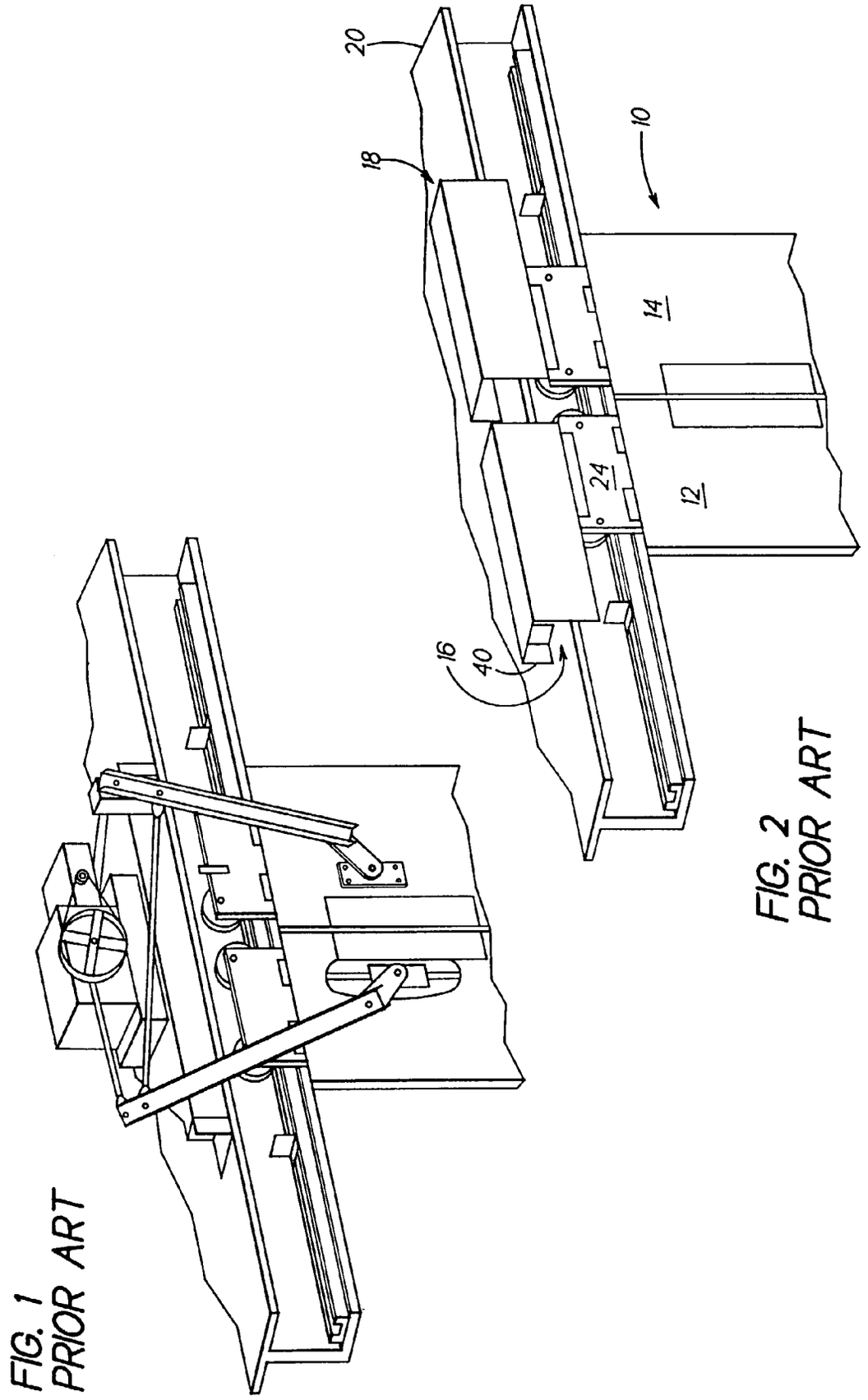


FIG. 2
PRIOR ART

FIG. 1
PRIOR ART

FIG. 3A
PRIOR ART

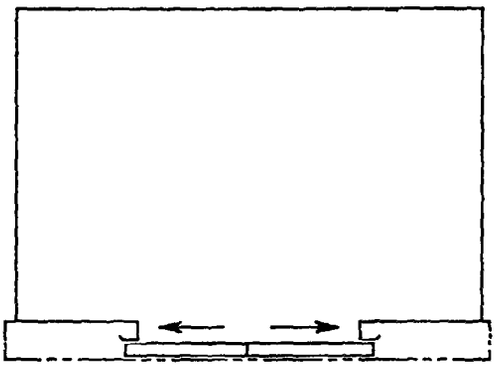


FIG. 3B
PRIOR ART

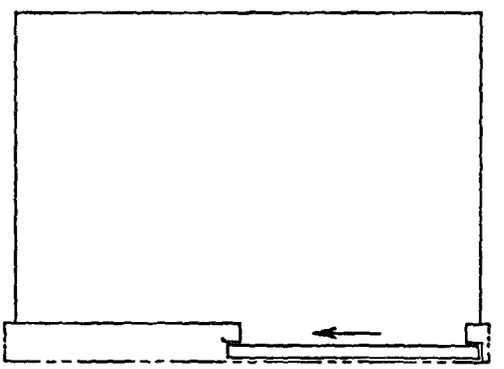


FIG. 3C
PRIOR ART

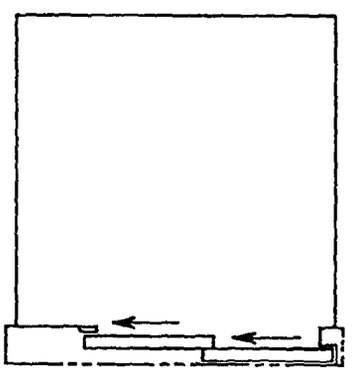


FIG. 4A

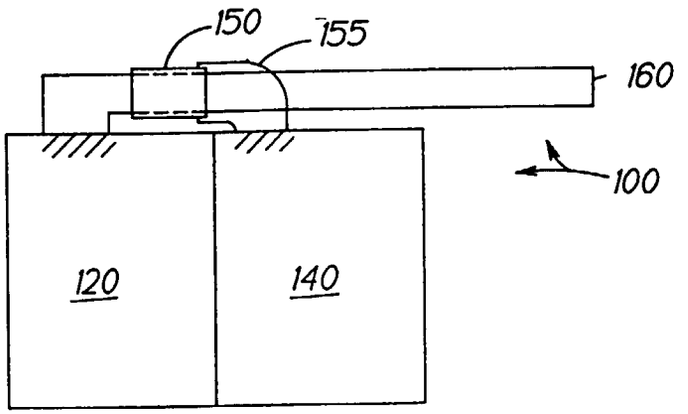


FIG. 4B

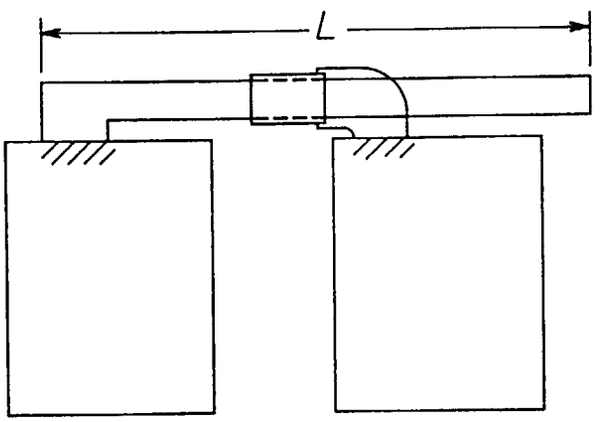


FIG. 4C

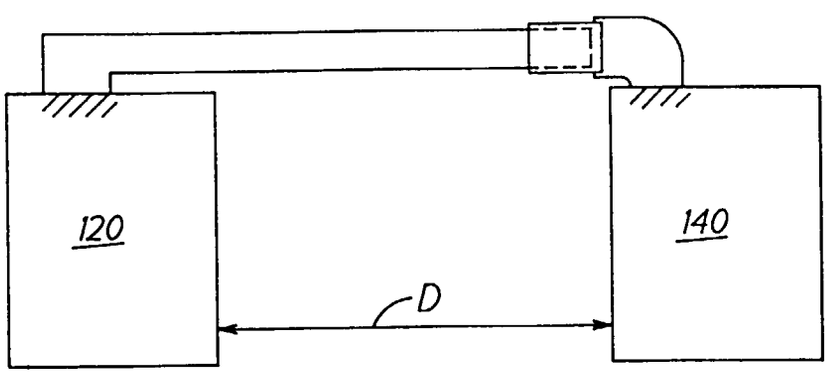


FIG. 5

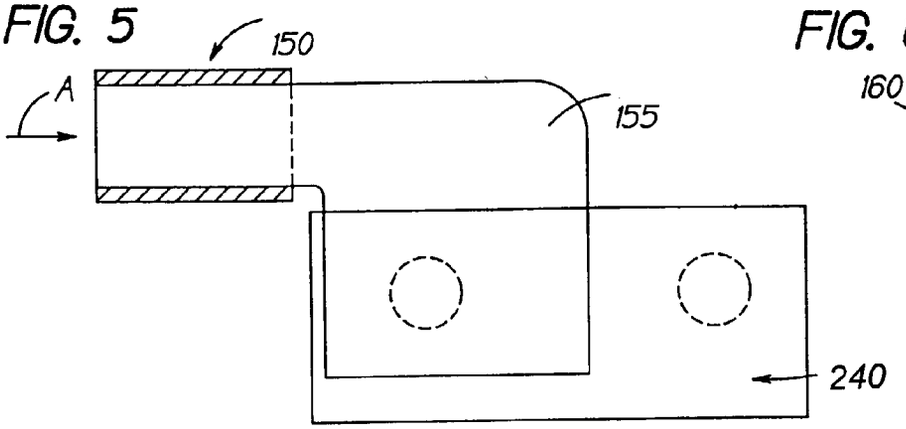


FIG. 6

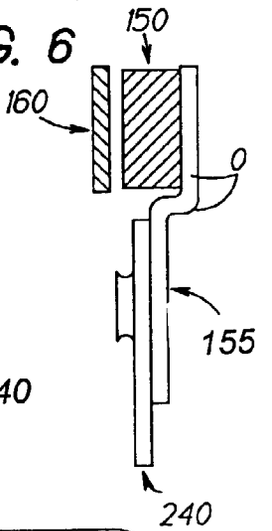


FIG. 6A

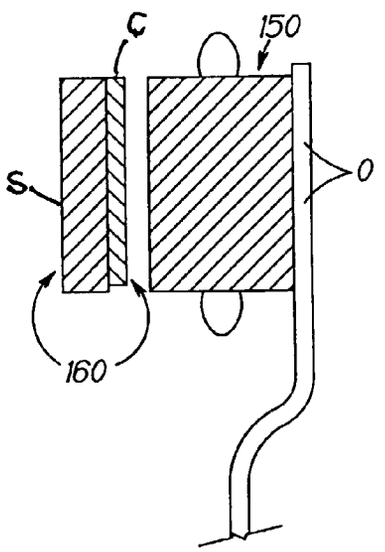


FIG. 6B

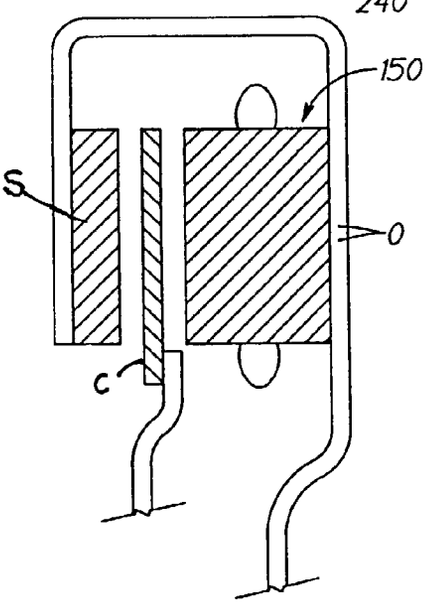


FIG. 7

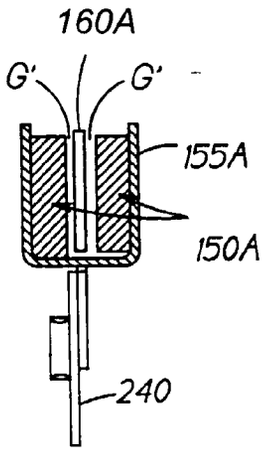


FIG. 8

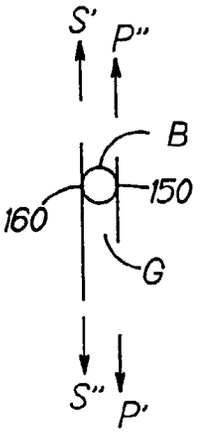


FIG. 9

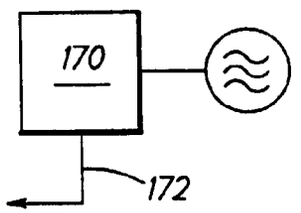


FIG. 10

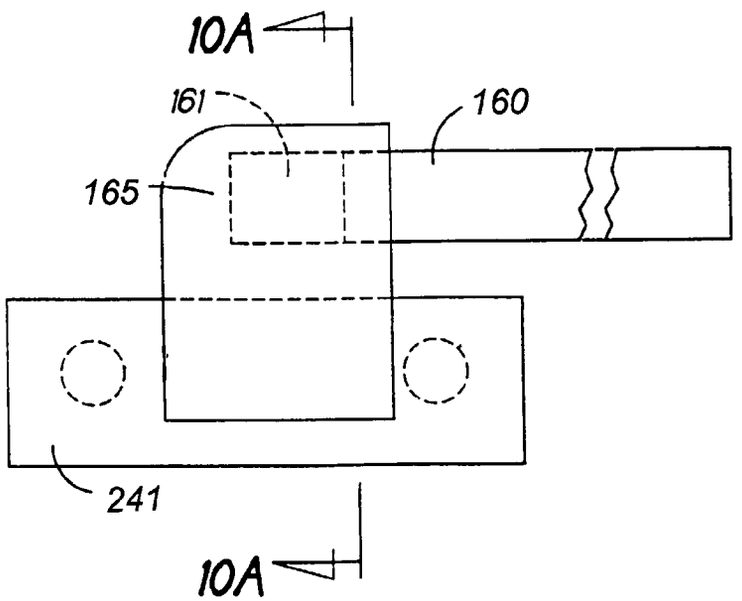


FIG. 10A

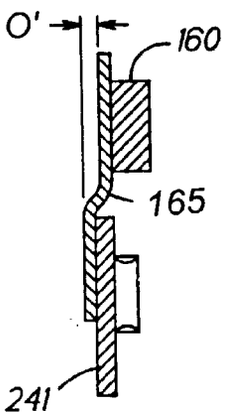


FIG. 11A

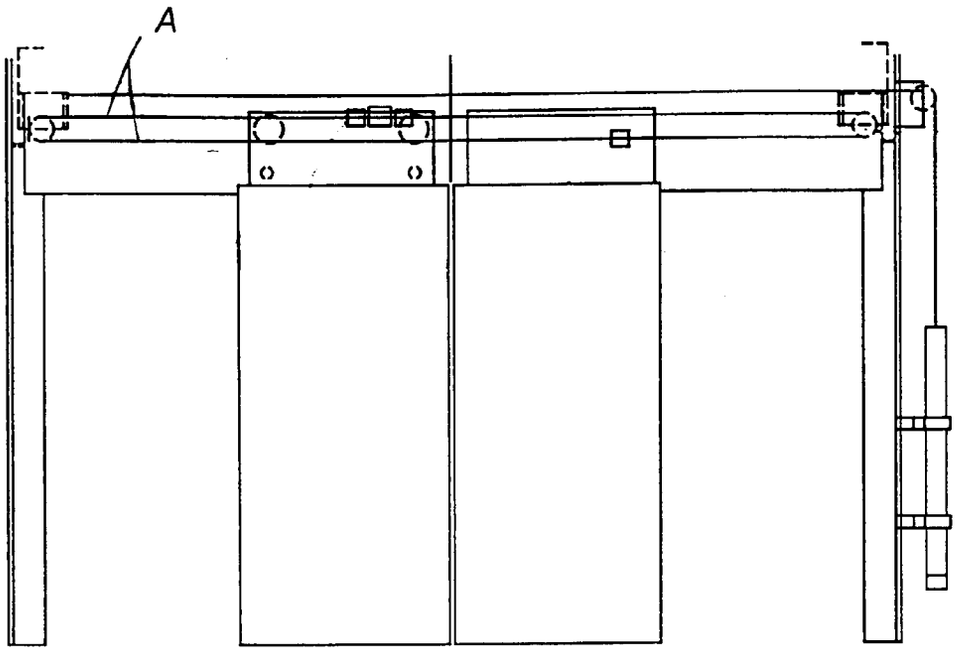


FIG. 11B