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(54) **SYSTEM AND METHOD FOR CONTROLLING THE MOVEMENT OF AN AIRCRAFT ENGINE COWL DOOR**

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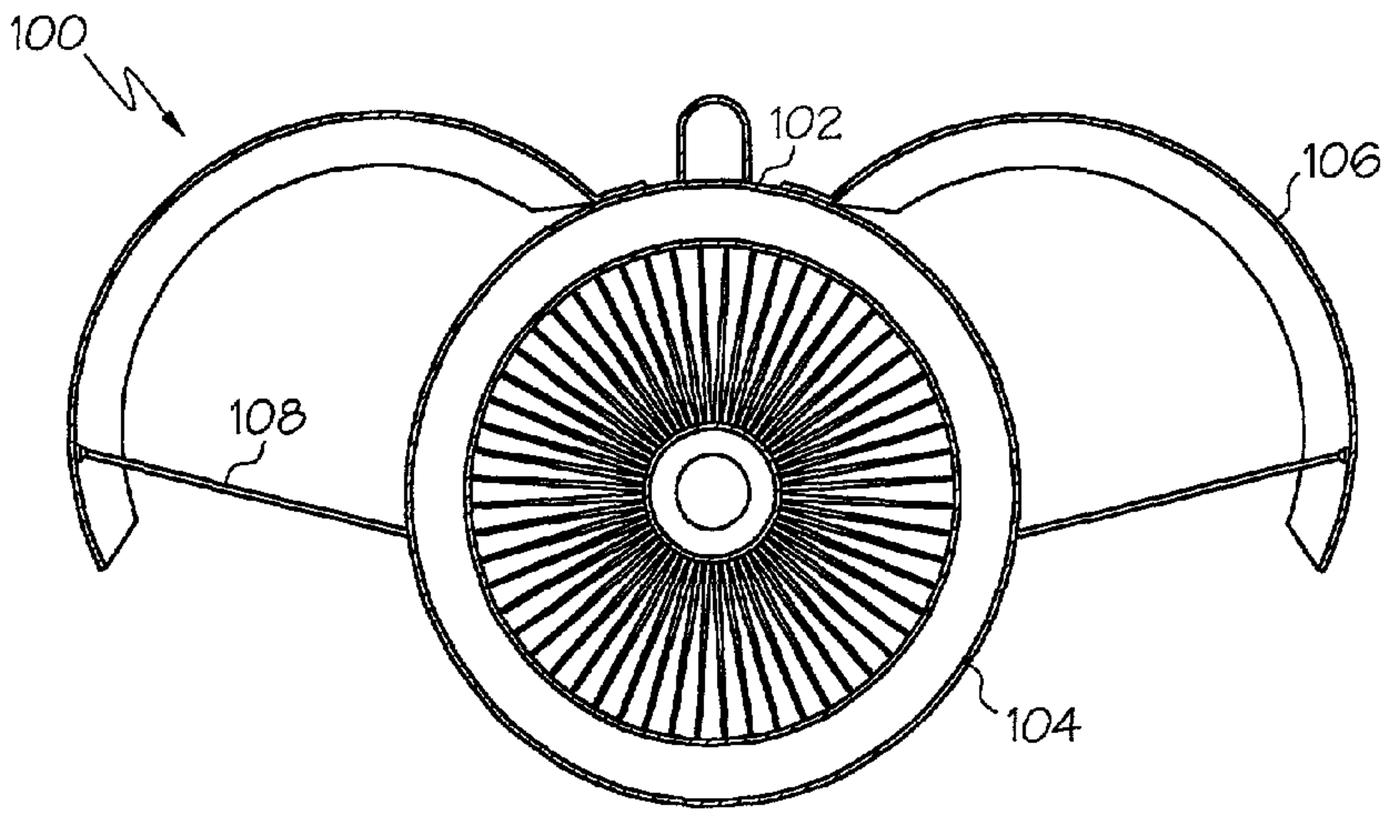
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(57) **ABSTRACT**

An electric control system and method for operating the cowl doors of an aircraft engine that includes one embodiment with one or more electric motors that are energized to move the cowl doors to the open position. The motor is de-energized and the cowl doors are allowed to close under their own weight, driving the motor and causing it to operate as a generator. An electrical load absorbs the energy generated by the motor while the cowl doors close, thereby limiting the speed at which the doors close.



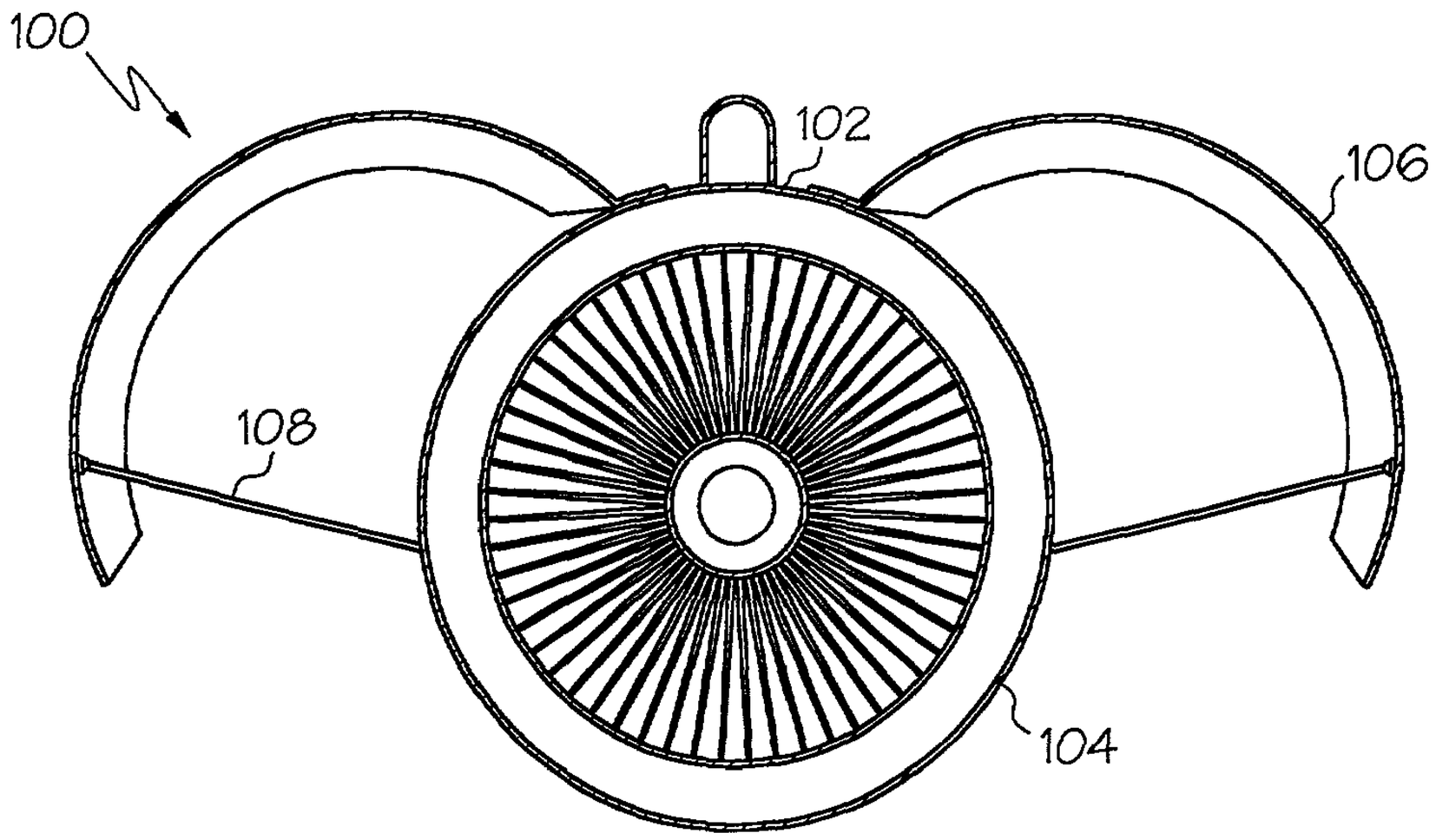


FIG. 1

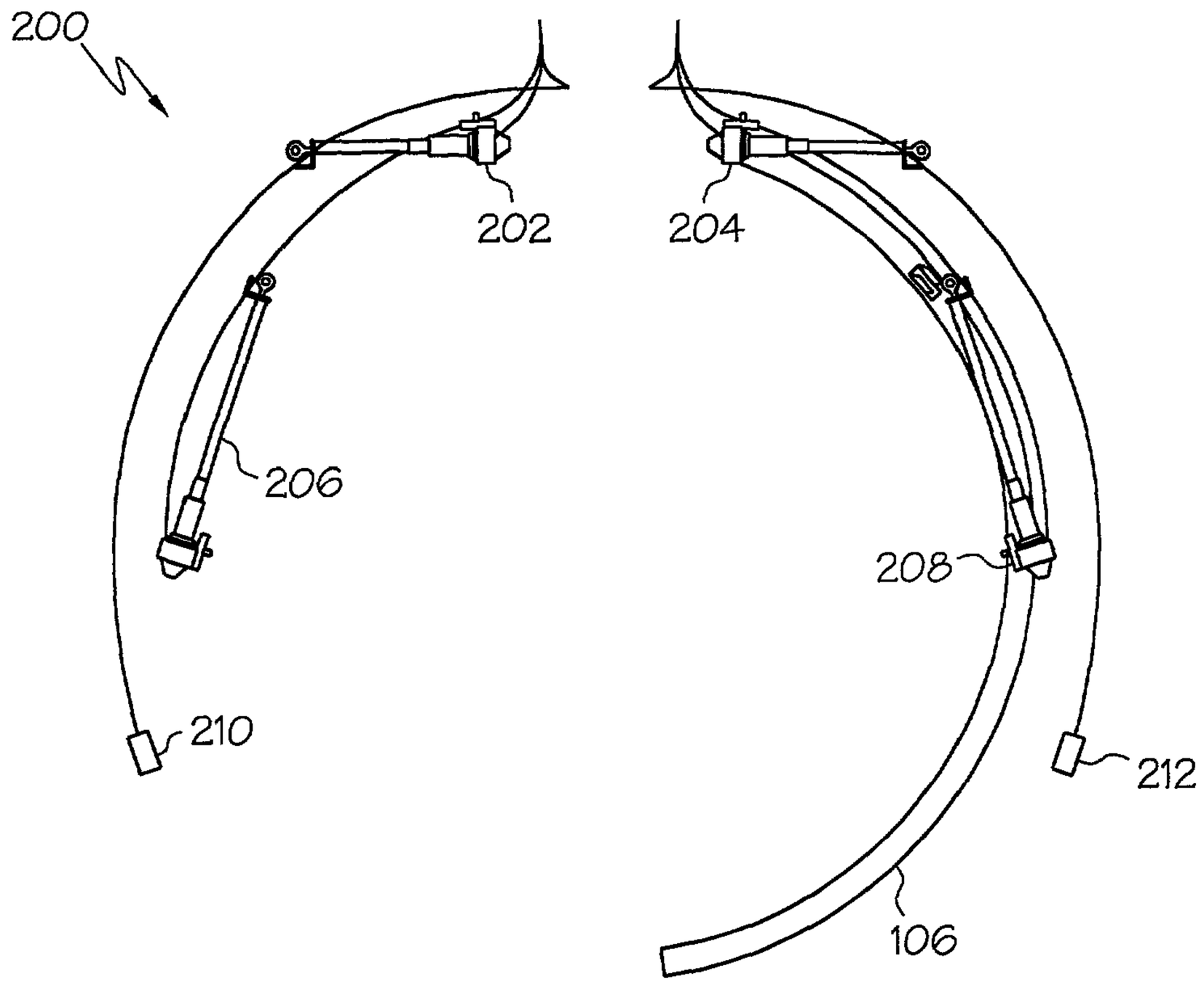


FIG. 2

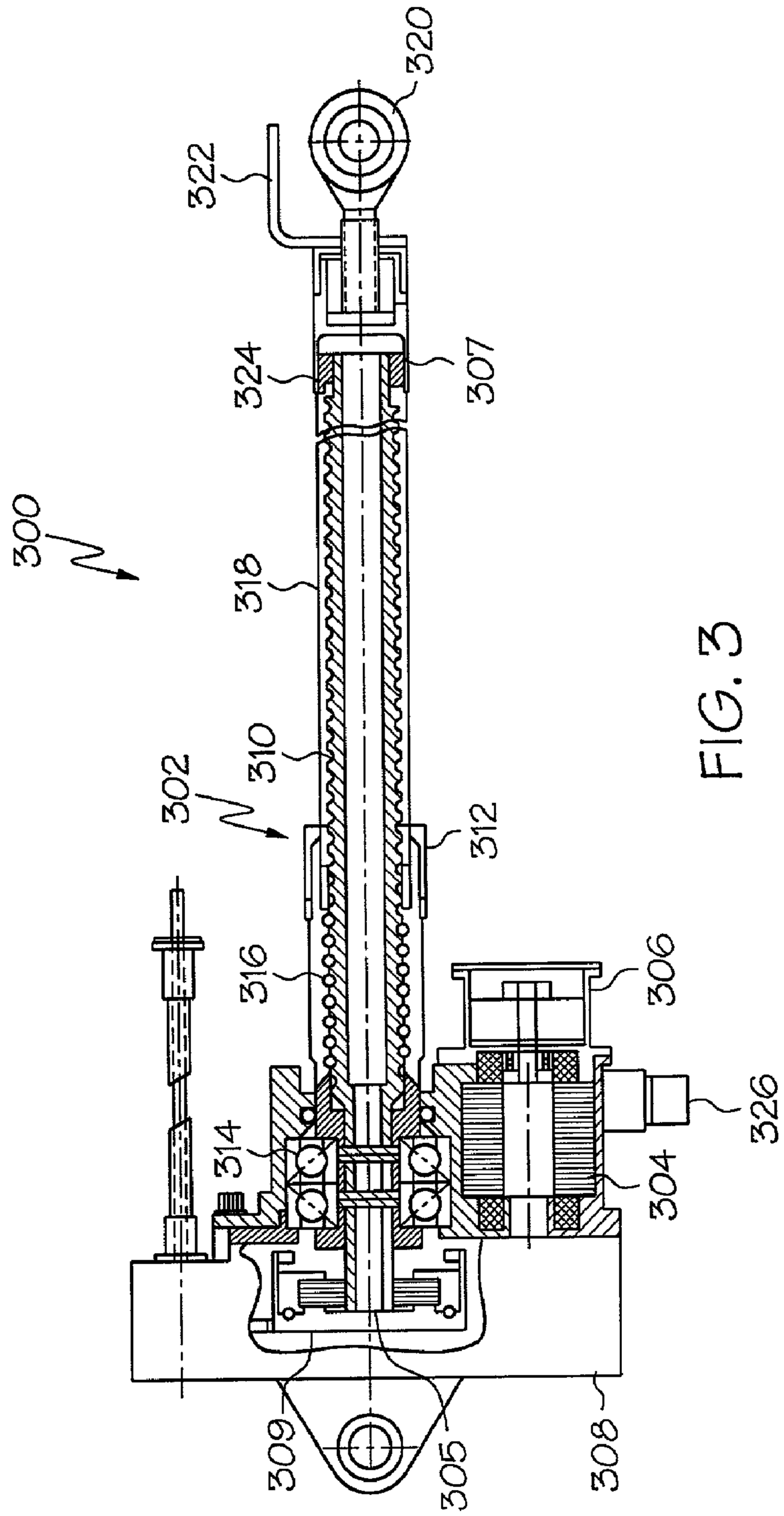

320
322
324
307
300
318
302
310
312
316
306
314
326
304
309
305
308

FIG. 3

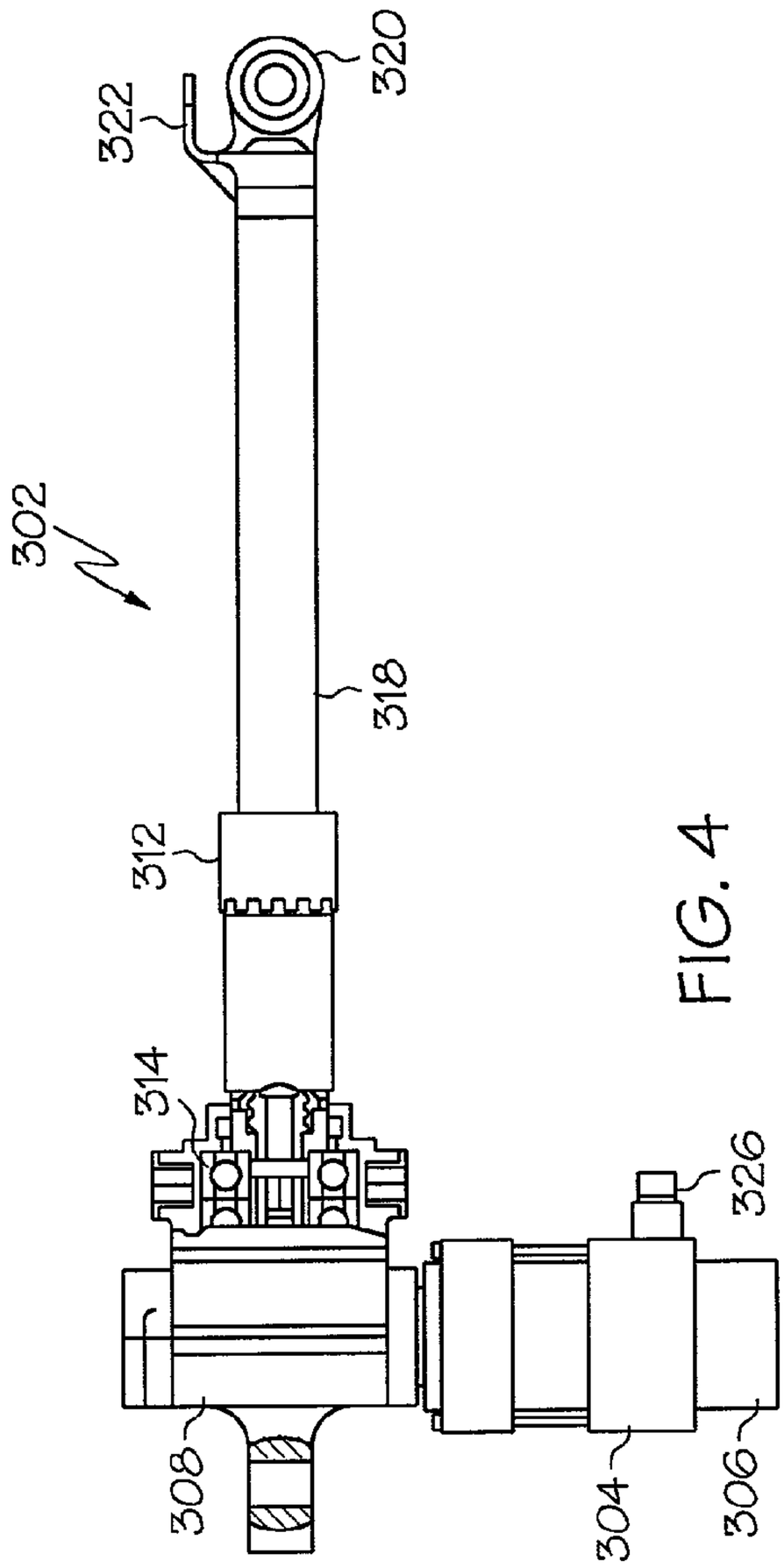

320
322
302
318
312
314
326
308
304
306

FIG. 4

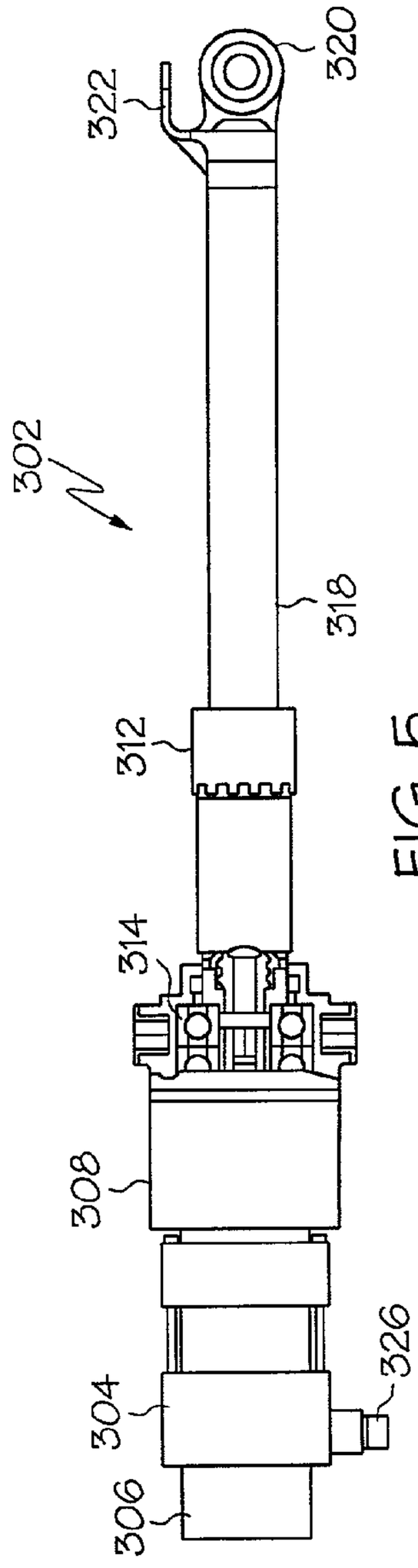

320
322
302
318
312
314
308
304
326
306

FIG. 5

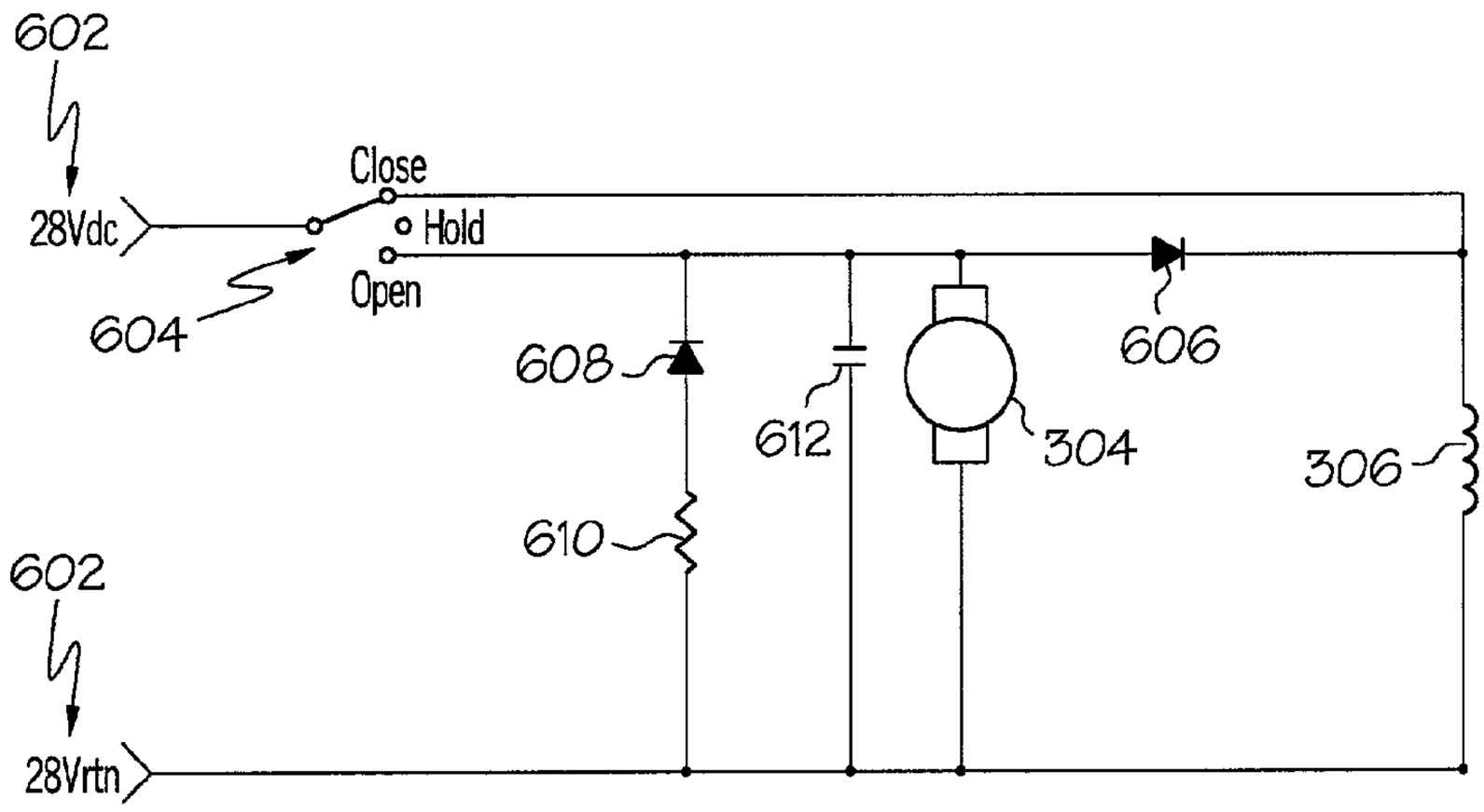

602
Close
28Vdc
Hold
Open
604
608
612
304
606
306
610
602
28Vrtn

FIG. 6

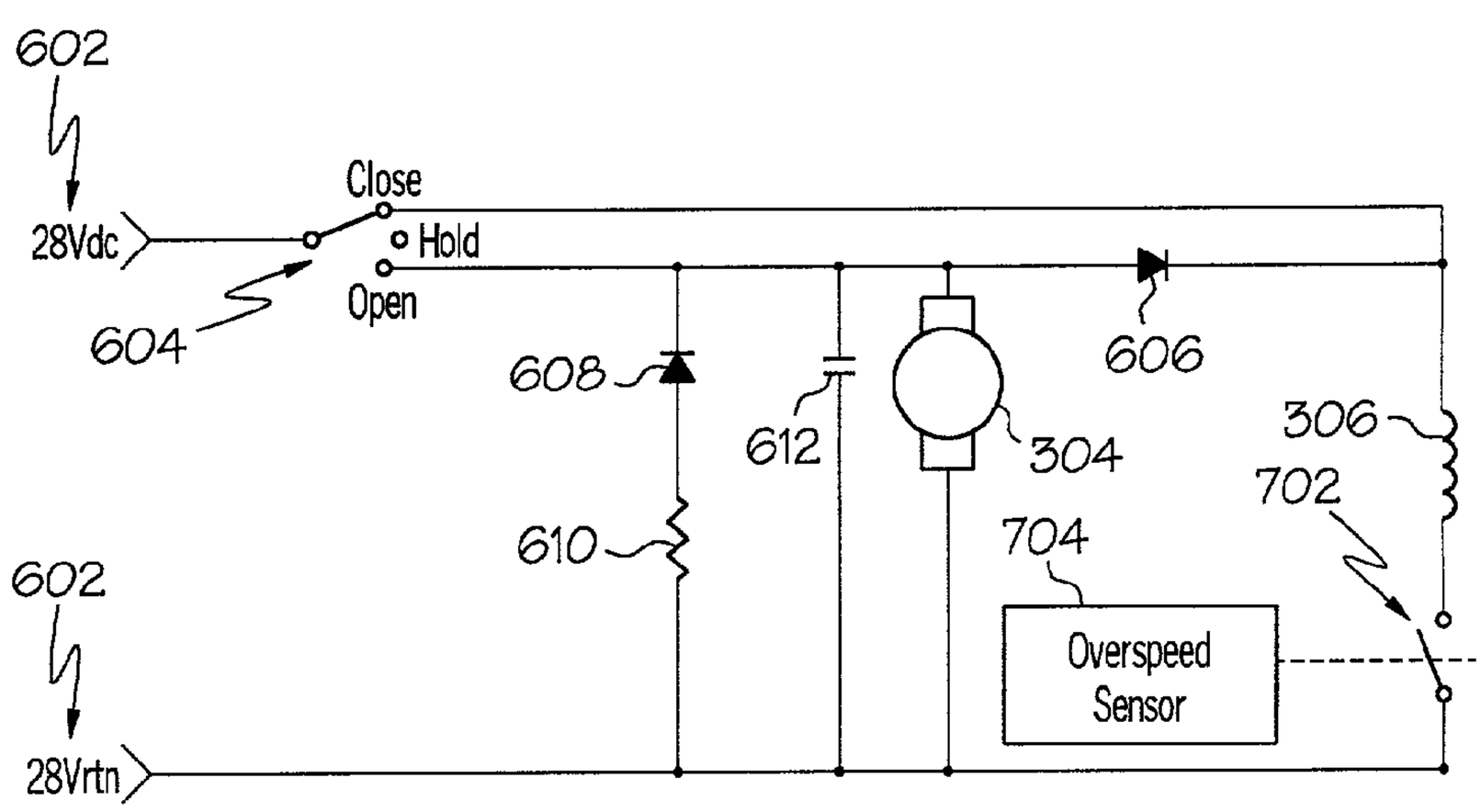

602
Close
28Vdc
Hold
Open
604
608
612
304
606
306
702
610
704
602
Overspeed
Sensor
28Vrtn

FIG. 7

SYSTEM AND METHOD FOR CONTROLLING THE MOVEMENT OF AN AIRCRAFT ENGINE COWL DOOR

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The present invention relates to a system and method for moving one or more aircraft engine cowl doors and, more particularly, to a system and method for controlling the movement of one or more engine cowl doors using an electric control system.

[0003] 2. Description of Related Art

[0004] The engines installed on many aircraft are housed within a nacelle. Typically, the engine nacelle includes one or more cowl doors. The cowl doors allow maintenance personnel to access the interior of the nacelle to repair and maintain the engine.

[0005] The movement of the cowl doors between the open and closed positions has, in the past, been accomplished via hydraulic or pneumatic actuation systems. Hydraulic systems may include one or more hydraulic controllers and hydraulic lines coupled to the aircraft's hydraulic system, and hydraulic actuators connected to the doors. Pneumatic systems may include one or more controllers coupled to one or more pneumatic motors that are coupled to the cowl doors via actuators. These hydraulic and pneumatic control systems are generally satisfactory, but can be complex, bulky, and heavy.

[0006] Hence, there is a need for an improved system that can control the movement of the engine cowl doors, that is safe, simple, reliable, less expensive, and light in weight as compared to hydraulic or pneumatic control systems. The present invention addresses one or more of these needs.

SUMMARY OF THE INVENTION

[0007] The present invention provides a comparatively simple, reliable, and lightweight system and method for controlling movement of a jet engine cowl door.

[0008] In one embodiment of the present invention, and by way of example only, a system for controlling movement of a jet engine cowl door between an open position and a close position includes an electric motor, at least one actuator, an electrically operated brake assembly, and a first switch. The actuator is coupled to the motor and is operable to move the cowl door to the open position. The electrically operated brake assembly is electrically coupled in parallel with the motor and is operable to allow motor rotation when energized and stop motor rotation when de-energized. The first switch is coupled to a power source and has at least a first position and a second position, the first switch is operable to couple the power source to the motor and the brake assembly when in the first position and remove the power source from the motor and couple the power source to the brake assembly when in the second position.

[0009] In another exemplary embodiment, an aircraft engine nacelle includes a nacelle housing with at least one cowl door, a gas turbine engine, and a system for moving the cowl door. The nacelle housing cowl door is moveable between an open position and a closed position. The gas turbine engine is mounted in the nacelle. The system for moving the cowl door includes an electric motor, at least one actuator, an electrically operated brake assembly, and a first switch. The actuator is coupled to the motor and is operable to move the cowl door to the open position. The electrically operated brake assembly is electrically coupled in parallel with the motor and is operable to allow motor rotation when energized and stop motor rotation when de-energized. The first switch is coupled to a power source and has at least a first position and a second position, the first switch is operable to couple the power source to the motor and the brake assembly when in the first position and remove the power source from the motor and couple the power source to the brake assembly when in the second position.

[0010] In still another exemplary embodiment, a method of controlling movement of the cowl door between closed and opened positions includes releasing a brake assembly to allow rotation of the electric motor, energizing the electric motor to thereby rotate the motor in a first predetermined direction to move the cowl door to the opened position, and de-energizing the motor to allow the cowl door to move to the closed position under gravitational force.

[0011] Other independent features and advantages of the preferred cowl door operating system and method will become apparent from the following detailed description, taken in conjunction with the accompanying drawings which illustrate, by way of example, the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] **FIG. 1** illustrates a front view of a jet engine with at least one set of cowl doors open;

[0013] **FIG. 2** is a perspective schematic view of an exemplary embodiment of a cowl door control system according to the present invention that depicts one physical arrangement of the actuator assemblies within the engine nacelle;

[0014] **FIG. 3** is a partial cross-section view of an actuator assembly depicted in **FIG. 2** that may be used to move the cowl doors depicted in **FIG. 1**;

[0015] **FIGS. 4 and 5** are alternate configurations of the actuator assembly depicted in **FIG. 3**;

[0016] **FIG. 6** is a schematic diagram of a controller circuit used to control the actuator assemblies depicted in FIGS. **3-5**; and

[0017] **FIG. 7** is a schematic diagram of an alternative embodiment of the controller circuit depicted in **FIG. 6**.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0018] An engine **100**, such as the gas turbine engine depicted in **FIG. 1**, includes at least a fan section and a turbine section that are housed within an engine nacelle **102**. The nacelle **102** includes one or more sets of cowl doors that may be opened to provide access to various portions of the engine. For example, the nacelle **102** may include fan cowl doors **104** (shown in the closed position), one on each side of the engine nacelle **102**, that may be opened to provide access to the engine fan section, and engine cowl doors **106** (shown in the opened position), one on each side of the engine nacelle **102**, that may be opened to provide access to the turbine engine section. It will be appreciated that the jet

engine **100**, depending upon its configuration, may include additional cowl doors beyond those explicitly depicted and described. As **FIG. 1** additionally depicts, one or more holding tubes **108** may be mounted on the inner portion of the cowl doors **104** and **106** to assist in holding the cowl doors **104** and **106** open.

[**0019**] The cowl doors **104** and **106** are each moved between the open and close positions using a cowl door operating control system **200**. An exemplary embodiment of the control system is depicted in **FIG. 2**, in perspective schematic form. The control system **200** includes a plurality of actuator assemblies and one or more controllers. In the depicted embodiment, the control system **200** includes first and second fan cowl door actuators **202** and **204**, and first and second engine cowl door actuators **206** and **208**. The first **202** and second **204** fan cowl door actuators are each coupled to one of the fan cowl doors **102** and, likewise, the first **206** and second **208** engine cowl door actuators are each coupled to one of the engine cowl doors **104**. For the sake of clarity, only a single engine cowl door **106** is depicted in **FIG. 2**.

[**0020**] A first controller **210** is electrically coupled to the first fan cowl door actuator **202** and to the first engine cowl door actuator **206**, and a second controller **212** is electrically coupled to the second fan cowl door actuator **204** and to the second engine cowl door actuator **208**. As will be discussed below, the first **210** and second **212** controllers control the movement of the actuators **202-208**, thereby controlling the movement of the cowl doors **104** and **106**.

[**0021**] In a preferred embodiment, each controller **212** and **214** is operable to separately control the movement of each of the actuator assemblies to which it is coupled. It will be appreciated, however, that the controllers **212** and **214** could be configured to simultaneously control the movement of each actuator assembly. It will be further appreciated that although the depicted control system **200** includes two controllers **214** and **216**, one for the doors on each side of the engine **100**, the control system **200** could also be configured with individual controllers for each actuator assembly, or as a single controller that controls the movement of the actuator assemblies individually or collectively.

[**0022**] Turning now to **FIG. 3**, an exemplary preferred embodiment of an actuator assembly **300** that may be used as either a fan cowl door actuator **202** and **204** or an engine cowl door actuator **206** and **208** will be described. The actuator assembly **300** includes an actuator **302**, an electric motor **304**, and an electrically operated brake assembly **306**. In the depicted embodiment, the actuator **302** includes a gear box **308**, a ball screw shaft **310** and a ball nut **312**. The gear box **308** houses reduction gears (not illustrated) and mechanically couples the motor **304** to the ball screw shaft **310**. As **FIG. 3** further illustrates, the gear box **308** may also house a torque limiter **309** that is mechanically coupled between reduction gears and the ball screw shaft **310**. The torque limiter **309** is preferably a ball ramp type torque limiting clutch that limits the output force below the actuator load limit should a jam occur at any position along the stroke of the actuator assembly **300**. The torque limiter **309** also inhibits potential damage during manual operation of the actuator assembly **300**. The ball screw shaft **310** is rotationally mounted by a duplex bearing assembly **312** positioned proximate a first end **305** of the ball screw shaft **310**. The ball nut **312** is rotationally supported on the ball screw shaft **310** by a plurality of ball bearings **316** and is coupled, via an extension tube **318** and spherical bearing **320**, to one of the cowl doors (not illustrated in **FIG. 3**). An anti-rotation tang **322** prevents the ball nut **312** and extension tube **318** from rotating. Thus, rotation of the motor **304** causes rotation of the ball screw shaft **310**, which results in translation of the ball nut **312** and movement of the attached cowl door. A mechanical hard stop **324** is coupled to a second end **307** of the ball screw shaft **310** and stops translation of the ball nut **312**, and thus the cowl door, in the open direction. An electrical connector **326** provides the electrical interface to the cowl door operating controllers **210** and **212**. It is to be appreciated that although the actuators **300** depicted and described herein are ball screw type actuators, the depicted embodiment could use other types of actuator designs such as, for example, jack screw actuators and roller screw actuators.

[**0023**] The motor **304** is coupled to the actuator **302** via the reduction gears. The motor **304** is preferably a brush DC motor, though various DC motor designs may be used. Because the motor **304** is a DC motor, the polarity of the DC voltage applied to it determines its direction of rotation. Thus, as will be described below, the motor **304** is electrically connected so that when it is energized, it rotates in a direction that will cause the actuator **302** to move the cowl door to which it is coupled to the open position.

[**0024**] The DC motor **304** may also operate as a generator. Specifically, if a DC motor is rotated by an external power source, it will generate a DC output voltage. The magnitude of the generated DC voltage is directly proportional to the rotational speed. Thus, as a generating DC motor's rotational speed increases, the magnitude of the generated DC voltage also increases. Connecting an electrical load across the generating DC motor's output will load the generating motor, applying a torque resisting the DC motor's rotation, acting as a brake. The generating characteristic of the motor **304**, as is discussed further below, is used by the cowl door operating control system **200**.

[**0025**] The brake assembly **306** is preferably coupled to the motor **304** and may be any one of numerous known brake designs known in the art such as, for example, an electromagnetic brake assembly. No matter the particular design, the brake assembly **306** is preferably operable to apply a braking force to the motor **304** when power is removed from the brake assembly **306**, and to remove the braking force from the motor **304** when power is supplied to the brake assembly **306**. Thus, when the brake assembly **306** is de-energized, it substantially prevents rotation of the motor **304**, and when the brake assembly **306** is energized, it allows the motor **304** to rotate freely.

[**0026**] The actuator assembly **300** may be configured so that the motor **304** and brake assembly **306** are offset from, but in the same plane as, the actuator **302**, as depicted in **FIG. 3**, or the actuator assembly **300** may be configured as depicted in **FIGS. 4 and 5**, in which the motor **304** and brake assembly **306** are in line with the actuator **302** and perpendicular with the actuator, respectively. It will additionally be appreciated that in each of the described embodiments the motor **304** could be directly coupled to the actuator **302** without any intervening gears.

[**0027**] With reference now to **FIG. 6, a** detailed description of the cowl door operating controllers **210** and **212** will

be provided. The cowl door operating controllers **210** and **212** are each electrically coupled to a receive power from a power source **602**. This power source **602** may be the electrical system of the aircraft or by a ground power source, such as a ground cart. In a preferred embodiment, the power source **602** is a 28 volt direct current (VDC) power source, though it will be appreciated that DC power sources of other magnitudes, either higher or lower, may also be used. It will additionally be appreciated that the DC power may be derived from a rectified AC power source. Each controller **210** and **212** is electrically coupled to one of the motors **304** and one of the brake assemblies **306**, and includes a cowl position control switch **604** and various other circuit elements that are discussed in more detail below.

[**0028**] The cowl position control switch **604** is a multi-position switch, preferably having at least three positions such as, for example, OPEN, HOLD, and CLOSE positions. In the OPEN position, the position control switch **604** electrically couples both the motor **304** and the brake assembly **306** to the power source **602**. This causes the brake assembly **306** to release, and the motor **304** to rotate in the direction to open the cowl doors **104** and **106**. The motor **304** will continue to rotate in the open direction until the position control switch **604** is moved to the HOLD position, the CLOSE position, or until the cowl door **102**, **104** reaches its fill open position.

[**0029**] In the HOLD position, the position control switch **604** disconnects the power source **602** from both the motor **304** and the brake assembly **306**. This causes the motor **304** to stop rotating in the open direction (if it was rotating in that direction) and the brake assembly **306** to engage. As a result, the cowl doors **104** and **106** are held in place by the brake assembly **306**. For additional holding power, the holding tubes **108** may be extended into position, as indicated in **FIG. 1** above. It will be appreciated that other mechanisms may also be used to hold the cowl doors in the open position.

[**0030**] In the CLOSE position, the brake assembly **306** is electrically coupled to the power source **602**. However, a first diode **606** is electrically coupled in the circuitry such that it is reverse biased when the cowl position control switch **604** is in the CLOSE position, thereby removing power from the motor **304**. Thus, in the CLOSE position the motor **304** is de-energized and the brake assembly **306** is released. As a result, the cowl doors **104** and **106** will move toward the close position under the force of their own weight, and drive the motor **304** in a rotational direction that is opposite the normal opening direction.

[**0031**] As noted above, when the motor **304** is driven in this manner, it operates as a generator and generates a DC voltage. The polarity of the DC voltage generated by the motor **304** forward biases a second diode **608**, allowing current to flow through a load resistor **610**. The current flow through the load resistor **610** will generate a resisting torque on the generating motor **304** that will limit the closing speed of the cowl doors **104** and **106**.

[**0032**] As **FIG. 6** additionally depicts, the each controller **210** and **212** may additionally include a capacitive circuit element **612**. This capacitive circuit element **612** may be made up of one or more capacitors, and is included to reduce any electromagnetic interference (EMI) emissions generated by the motor **304**.

[**0033**] In an alternate embodiment, which is depicted in **FIG. 7**, the controllers **210** and **212** each include an over-speed switch **702**. The overspeed switch **702** is electrically coupled in series with the brake assembly **306** and is operable to selectively de-energize the brake assembly **306** when the rotational speed of the motor **304** is at or above a predetermined rotational speed magnitude. The overspeed switch **702** may be a centrifugal switch that opens when the motor's rotational speed is at or above the predetermined rotational speed magnitude. Alternately, as further depicted in **FIG. 7**, the controller **210** and **212** may include a motor speed sensor **704** that senses the motor's rotational speed and opens the overspeed switch **702** when the motor's rotational speed is at or above the predetermined rotational speed magnitude. The motor speed sensor **704** may be any one of numerous speed sensors known in the art, but in a preferred embodiment the motor speed sensor **704** determines the motor's rotational speed by sensing the voltage magnitude across the motor **304**. When the voltage magnitude across the motor **304** exceeds a predetermined voltage magnitude, the sensor **704** opens the overspeed switch **702** and de-energizes the brake assembly **306**.

[**0034**] While the invention has been described with reference to a preferred embodiment, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt to a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the appended claims.

We claim:

1. A system for controlling movement of an aircraft engine cowl door between an open position and a closed position, comprising:

an electric motor;

at least one actuator coupled to the motor and operable to move the cowl door to the open position;

an electrically operated brake assembly electrically coupled in parallel with the motor, the brake assembly operable to allow motor rotation when energized and stop motor rotation when de-energized; and

a first switch coupled to a power source and having at least a first position and a second position, the first switch operable to couple the power source to the motor and the brake assembly when in the first position and remove the power source from the motor and couple the power source to the brake assembly when in the second position.

2. The system of claim 1, wherein:

the first switch has a third position; and

the first switch is operable to remove power from the motor and from the brake assembly when in the third position.

3. The system of claim 1, further comprising a motor speed sensor operable to sense a rotational speed of the motor and to selectively energize and de-energize the brake assembly when the motor rotational speed is, respectively, at

or above a first predetermined rotational speed and at or below a second predetermined rotational speed.

4. The system of claim 1, further comprising:

a second switch electrically coupled in series with the brake assembly, the second switch having at least a close position and an open position and operable to move to the open position when the motor rotational speed is at or above a first predetermined rotational speed and move to the close position when the motor rotational speed is at or below a second predetermined rotational speed.

5. The system of claim 4, further comprising:

a motor speed sensor operable to sense a rotational speed of the motor and operable to move the second switch to the open position when the motor rotational speed is at or above a first predetermined rotational speed and move the second switch to the close position when the motor rotational speed is at or below a second predetermined rotational speed.

6. The system of claim 1, further comprising:

a load impedance electrically coupled in parallel with the motor.

7. The system of claim 6, further comprising:

a first rectifying circuit element electrically coupled in series between the motor and the load impedance.

8. The system of claim 1, further comprising:

an electromagnetic interference suppressing circuit element electrically coupled in parallel with the motor.

9. The system of claim 1, further comprising:

a second rectifying circuit element electrically coupled in series between the motor and the brake assembly.

10. The system of claim 1, further comprising:

a controller, the controller housing at least the first switch therein.

11. A system for controlling movement of an aircraft engine cowl door between an open position and a closed position, comprising:

an electric motor;

at least one actuator coupled to the motor and operable to move the cowl door to the open position;

an electrically operated brake assembly electrically coupled in parallel with the motor, the brake assembly operable to allow motor rotation when energized and stop motor rotation when de-energized; and

a first switch coupled to a power source and having at least a first position, a second position, and a third position, the first switch operable to couple the power source to the motor and the brake assembly when in the first position, remove the power source from the motor and the brake assembly when in the second position, and remove the power source from the motor and couple the power source to the brake assembly when in the second position.

12. The system of claim 11, further comprising a motor speed sensor operable to sense a rotational speed of the motor and to selectively energize and de-energize the brake assembly when the motor rotational speed is, respectively, at or above a first predetermined rotational speed and at or below a second predetermined rotational speed.

13. The system of claim 11, further comprising:

a second switch electrically coupled in series with the brake assembly, the second switch having at least a close position and an open position and operable to move to the open position when the motor rotational speed is at or above a first predetermined rotational speed and move to the close position when the motor rotational speed is at or below a second predetermined rotational speed.

14. The system of claim 13, further comprising:

a motor speed sensor operable to sense a rotational speed of the motor and operable to move the second switch to the open position when the motor rotational speed is at or above a first predetermined rotational speed and move the second switch to the close position when the motor rotational speed is at or below a second predetermined rotational speed.

15. The system of claim 11, further comprising:

a load impedance electrically coupled in parallel with the motor.

16. The system of claim 15, further comprising: a first rectifying circuit element electrically coupled in series between the motor and the load impedance.

17. The system of claim 11, further comprising:

an electromagnetic interference suppressing circuit element electrically coupled in parallel with the motor.

18. The system of claim 11, further comprising:

a second rectifying circuit element electrically coupled in series between the motor and the brake assembly.

19. The system of claim 11, further comprising:

a controller, the controller housing at least the first switch therein.

20. A system for controlling movement of an aircraft engine cowl door between an open position and a closed position, comprising:

an electric motor;

at least one actuator coupled to the motor and cowl door and operable to move the cowl door to the open position;

an electrically operated brake assembly electrically coupled in parallel with the motor, the brake assembly operable to allow motor rotation when energized and stop motor rotation when de-energized;

a first switch coupled to a power source and having at least a first position, a second position, and a third position, the first switch operable to couple the power source to the motor and the brake assembly when in the first position, remove the power source from the motor and the brake assembly when in the second position, and remove the power source from the motor and couple the power source to the brake assembly when in the second position; and

a second switch electrically coupled in series with the brake assembly, the second switch having at least a close position and an open position and operable to move to the open position when the motor rotational speed is at or above a first predetermined rotational

speed and move to the closed position when the motor rotational speed is at or below a second predetermined rotational speed.

21. The system of claim 20, further comprising:

a motor speed sensor operable to sense a rotational speed of the motor and operable to move the second switch to the open position when the motor rotational speed is at or above a first predetermined rotational speed and move the second switch to the close position when the motor rotational speed is at or below a second predetermined rotational speed.

22. The system of claim 20, further comprising:

a controller, the controller housing at least the first and second switches therein.

23. An aircraft engine nacelle, comprising:

a nacelle housing with at least one cowl door moveable between an open position and a closed position;

a gas turbine engine mounted in the nacelle; and

a system for moving the cowl door, including:

an electric motor,

at least one actuator coupled to the motor and operable to move the cowl door to the open position, an electrically operated brake assembly electrically coupled in parallel with the motor, the brake assembly operable to allow motor rotation when energized and stop motor rotation when de-energized, and

a first switch coupled to a power source and having at least a first position and a second position, the first switch operable to couple the power source to the motor and the brake assembly when in the first position and remove the power source from the motor and couple the power source to the brake assembly when in the second position.

24. In a jet engine cowl door operating system including an electric motor operatively coupled to the cowl door, a method of controlling movement of the cowl door between closed and opened positions, comprising:

releasing a brake assembly to allow rotation of the electric motor;

energizing the electric motor to thereby rotate the motor in a first predetermined direction to move the cowl door to the opened position; and

de-energizing the motor to allow the cowl door to move to the closed position under gravitational force.

25. The method of claim 24, further comprising:

de-energizing the motor; and

actuating the brake assembly to prevent rotation of the motor, whereby the cowl door is held in position.

26. The method of claim 25, wherein:

the brake assembly is electrically operated;

the brake assembly is released by supplying electrical power thereto; and

the brake assembly is actuated by removing electrical power therefrom.

27. The method of claim 24, wherein the cowl door rotates the motor in a second predetermined direction during cowl door movement toward the closed position, whereby the motor generates a voltage.

28. The method of claim 27, further comprising:

applying the voltage generated by the motor across a load impedance to limit the rotational speed of the motor.

29. The method of claim 24, further comprising:

limiting a rotational speed of the motor.

30. The method of claim 29, wherein limiting the motor rotational speed comprises:

determining the motor rotational speed;

actuating the brake assembly when the determined rotational speed is at or above a first predetermined rotational speed; and

releasing the brake assembly when the determined rotational speed is at or below a second predetermined rotational speed.

* * * * *