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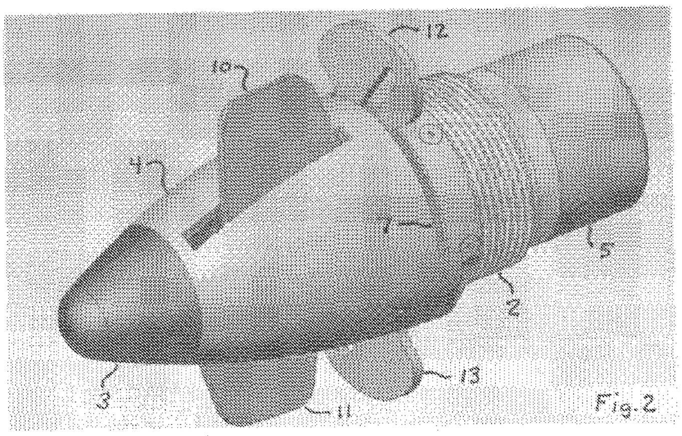

(57) Abstract: A course correcting fuze for use in artillery warheads or other military projectiles. Mechanisms are provided whereby air brake fins and spin control fins can be deployed and retracted under computer control during projectile flight to improve targeting accuracy. Power is supplied by an innovative fuel cell module that allows for long term storage of the fuze, rapid activated during launch of the artillery shell, and sufficient power for use by the electronics and actuator motors during operation.

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SPECIFICATION

TITLE

"COURSE CORRECTING FUZE"

CROSS-REFERENCE TO RELATED APPLICATION

This application claims the benefit of U.S. Provisional Patent Application Serial No. 60/873,478, filed December 7, 2006, which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates generally to a course correcting fuze for use in artillery warheads or other military projectiles.

SUMMARY OF THE INVENTION

A course correcting fuze for use in artillery warheads or other military projectiles. Mechanisms are provided whereby air brake fins and spin control fins can be deployed and retracted under computer control during projectile flight to improve targeting accuracy. Power is supplied by an innovative fuel cell module that allows for long term storage of the fuze, rapid activated during launch of the artillery shell, and sufficient power for use by the electronics and actuator motors during operation.

In one embodiment, this invention provides an improved course correcting fuze for use in artillery warheads or other military projectiles using air brake fins and spin control fins to obtain course correction control during flight.

Another embodiment provides a Global Positioning System (GPS) guidance system and related controls to determine course corrections and to use the information to adjust the air brake fins and spin control fins to land on target.

In a further embodiment, this invention provides an electro-mechanical air brake fin and spin control fin adjustment mechanism that can withstand the initial high G-force acceleration of an artillery firing and also meet all other military specifications.

Another embodiment provides a fully adjustable electro-mechanical air brake fin and spin control fin mechanism that is capable of both extending and retracting from the body of the shell during flight under command of its controlling mechanism and programming.

Yet a further embodiment provides an air brake fin and spin control fin mechanism that is compatible with a fuel cell electricity power supply.

An embodiment of this invention provides a unique fuel cell power supply that replaces generic battery packs and simplifies the fuze design thus increasing its reliability.

A further embodiment of this invention is to provide a unique fuel cell activation mechanism that allows the fuel cell to remain dormant during long periods of storage while at the same time allowing the fuel cell to be quickly activated in the gun barrel during launch of the artillery shell and is fuze.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is an isometric drawing of the fuze mechanism in its launch position in its preferred embodiment.

Figure 2 is a second isometric external view of the fuze mechanism in its fully deployed mode.

Figure 3 is an isometric view of the entire fuze including the electronics module, the fin section, the threaded section containing the fuel cell, and the tail section containing the safe and arm mechanism and the booster charge.

Figure 4 is an isometric view of the fuze with the outer housing completely removed from section 4, and the electronics nose cone removed.

Figure 5 is an isometric view with the outer housing and the electronics section completely removed revealing the spin brake mechanism.

Figure 6 is an isometric view with both the outer housing and the electronics completely removed showing both the spin brake fins and air brake fins completely deployed.

Figure 7 is a cut-away view of the entire course correcting fuze of this invention with the cut being taken so as to pass through the centers of the two electric motor assemblies.

Figure 8 is an isometric cut-away view of the entire course correcting fuze of this invention with the cut being taken so as to pass through the centers of the two electric motor assemblies.

Figure 9 is a cut-away view of the entire course correcting fuze of this invention with the cut being taken between the two electric motor assemblies so that only the top part of motor assembly can be seen.

Figure 10 is a perspective overview of the fuze fuel cell reserve battery assembly.

Figures 11 and 12 are cut-away views of the fuel cell assembly passing through the two activation arms.

Figure 13 is a cross-sectional view of the fuel cell portion of the course correction fuze of this invention.

Figure 14 is an isometric view of the fuel cell with top plate removed and with activation arms in their initial storage positions.

Figure 15 is a three dimensional perspective view of the outer wall portion of the fuel cell assembly including a flange, an outer threaded wall, and lower fuel cell rim.

Figure 16 is a perspective cut-away view of the fuel cell assembly without its outer shell.

Figure 17 is a perspective view of the fuel cell assembly without the outer shell.

Figure 18 is an up-side-down perspective view of the fuel cell assembly without the outer shell.

Figure 19 is a perspective view of the fuel cell gas diffuzer stack and catalytic membrane assembly, which is housed in the fuel cell reaction chamber.

Figure 20 is a perspective view of the fuel cell gas diffuzer stack and current collector assembly, which is housed in the fuel cell reaction chamber.

Figure 21 is a perspective view of the fuel cell current collector assembly.

Figure 22 shows two gas diffuzers and support elements in perspective view with a portion of catalytic membrane between them.

Figure 23 shows two gas diffuzer and support elements in perspective view with a portion of a catalytic membrane between them.

Figure 24 is an isometric view of the spin brake fin mechanism in its retracted state.

Figure 25 is a view of the spin brake fin mechanism in its fully deployed state.

Figure 26 is an isometric view of the air brake fin mechanism in its retracted state.

Figure 27 is a view of the air brake fin mechanism in its fully deployed state.

Figure 28 is an isometric view of the fuze nose cone electronics module.

Figure 29 is a finished perspective rendering of the course correcting fuze, as it would appear with both sets of fins fully deployed.

Figure 30 is a functional block schematic for the principal components contained within the fuze electronics module.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In the preferred embodiment shown in the drawings, the fuze is applied for use in controlling the trajectory and detonating an artillery shell projectile. The same mechanism, adjusted in scale, could be used in precision guided mortar rounds. Similar mechanisms may be employed to control the trajectory of a rocket, missile, torpedo, bomb, or the like. Using suitable precautions, the mechanism may be used in an air or water environment. Portions of this invention may be employed in other mechanisms. For example the air brake mechanism may be employed on a drill head to fix the head at a certain position along a pre-drilled shaft by acting as a mechanical break.

The unique fuel cell design innovations of this invention have application to other smart munitions whereby electric power is only needed for a short period during launch of the munitions including artillery shells, rockets, missiles, torpedoes, bombs, and the like. Batteries that remain inactive for long storage periods and then need to be quickly activated for one time use would find many applications in emergency equipment, such as: emergency lighting, lost-at-sea emergency radio gear, fire activated radio or water activated emergency signaling or lighting gear, automotive emergency lights, power outage lighting, or the like. Other one time electric power requirements may occur in construction, boat launch or docking, aircraft and spacecraft launch or landing, sports or recreational applications, and the like.

Figure 1 provides an isometric drawing of the fuze mechanism in its launch position in its preferred embodiment. The fuze mechanism 1 mates to the top warhead portion of an artillery shell (not shown) by means of the threaded collar 2. The top section of the fuze 3 contains the electronics for the fuze. The next section 4 contains the course correcting air brake fins and spin control fins and associated electro-mechanical mechanisms. The next section 2, behind the threaded collar, houses the fuel cell battery, its fuel supply, and associated mechanical activation mechanisms. The lowest section of the fuze 5 houses the safe and arm mechanism and the booster charge. Of importance is that section 2 and section 5 are both designed to be fully compatible with the existing inventory of military artillery rounds be they high explosive (HE) or cargo rounds.

The vertical slot 6 in the fuze housing, and a corresponding horizontal slot on the opposite side of the fuze (not shown) provides egress for the spin brake fins by an electro-mechanical mechanism within the housing. The horizontal slot 7, and a corresponding horizontal slot on the opposite side of the fuze (not shown) provides egress for the air brake fins by a second electro-mechanical mechanism within the housing. The circular marks 8 on the outer shell of the fuze are a type of flush fasteners used in the assembly of the fuze. Not shown in these drawings is a plastic dust seal that would cover the vertical slot 6 and horizontal slot 7 and their corresponding slots on the other side of the fuze during storage and handling prior to use. These dust covers would be popped off the slots for both the horizontal and vertical fins when the fins are activated.

Figure 2 provides a second isometric external view of the fuze mechanism in its fully deployed mode. As before, the first section 3 contains the control electronics, the second section 4 contains the fin deployment mechanism, the threaded section 2 contains within it the fuel cell, and the bottom of the fuze 5 contains the safe and arm mechanism and the booster charge. In this drawing the vertical slot 6 provides an opening for one of the spin brake fins 10, shown fully deployed. The other spin brake fin 11 is shown at the bottom of the drawing and partially eclipsed by the body of the fuze in this isometric view. Likewise the air brake fin 12 is shown fully emerged from its horizontal slot 7 at the top of the drawing. The other air brake fin 13 is shown at the bottom of the drawing and is also partially eclipsed by the fuze body.

Figures 1 and 2 show the method of this invention, whereby an artillery projectile is initially hurdled through the air along its trajectory towards a point beyond and to the right (or left) of the intended target and whereby the projectile is given an initial spin by the rifling of the gun barrel. The velocity and spin of the projectile is proportional to the charge used to fire the round. Data from a Global Positioning System (GPS) within the fuze electronics is combined with targeting information to determine when to deploy the air brake fins to slow the projectile sufficiently to drop exactly onto the correct range of the target. The spin of the projectile normally causes the shell to arc to the right or left depending on whether the spin is clockwise or counter clockwise. The spin brake is then deployed to reduce the spin, causing less of a twist to the right (or left), and thus correcting for the right (or left) overshoot.

Previous to this invention, the spin brake fins and the air brake fins were normally deployed once during the flight of the projectile, and remained deployed until impact or detonation. This old "one time" method created a very critical activation point that could be difficult to determine. This invention allows further refinement of this approach by providing a means of both extending and retracting the spin brake fins and the air brake fins during the flight of the projectile. This allows for a complete feedback between projected flight path and actual flight path whereby course correction can take place continuously until impact or detonation. This invention thus allows for the flight path correction for wind and atmospheric variations, target movement, and even some countermeasures that may be used against the incoming projectile.

Figure 3 provides an isometric view of the entire fuze including the electronics module 3, the fin section 4, the threaded section 2 containing the fuel cell, and the tail section 5 containing the safe and arm mechanism and the booster charge. The outer housing is partially removed from the fin section 4 in this drawing. The spin brake fins 10 and 11 and the air brake fins 12 and 13 (not seen in this view) are shown in their fully retracted position. The top motor assembly 20, used to deploy the air brake fins, is partially exposed in this drawing. The motor mount support 24 can be partially seen at the top of this view. The two sets of gears used to deploy the two sets of fins can be partly seen between the undeployed spin brake fin 10 and the lower threaded section 2. Note here that the electronic section 3 has cuts and cutouts to allow clearance for portions of the fin assembly.

Figure 4 provides an isometric view of the fuze with the outer housing completely removed from section 4, and the electronics nose cone removed, so that the spin brake fin and the air brake fin mechanisms are completely exposed. Both sets of fins are completely retracted in this drawing. The air brake deployment motor assembly 20 and the spin brake motor assembly 21 can be clearly seen in this isometric view along with portions of their mutual motor mount support 24. The spin brake fins 10 and 11 can be seen in their retracted position, and only the edge of one spin brake fin 12 can be seen in this drawing. The threaded section 2 containing the fuel cell, and the bottom section 5 containing the safe and arm mechanism and the booster charge, are seen below the fin section 4.

Note here that the spin brake fins 10 and 11 are shaped to fit into space available within the fuze housing; the only aerodynamic consideration given the shape of the fins is the requirement that they provide a symmetric impediment to the air flow so that the projectile doesn't begin to wobble or tumble in its flight.

Figure 5 provides an isometric view with the outer housing of section 4 and the electronics section completely removed revealing the spin brake mechanism. The threaded section 2 containing the fuel cell, and the tail section 5 containing the safe and arm mechanism and the booster charge are shown below the fin section. The air brake motor assembly 20 and the spin brake motor assembly 21 can be seen in this view along with their motor mount support 24. Only the edge of one air brake fin 12 can be seen in this view. In this view the worm gear 32, the carriage bar 33, the cam guide 34, and other parts of the spin brake deployment mechanism can be seen in the spin brake fin deployed condition.

Of particular note here is that the spin brake fins do not emerge radially from the spin axis of the fuze. Instead the spin brake fins emerge tangent to the threaded carriage 33 and the cam guides 34. In a plane cut through the spin brake fins and perpendicular to the fuze spin axis the spin brake fins would form an "S" shaped geometry, so that the spin air drag is different for the clockwise and the counter clockwise projectile rotations. Performance characteristics will determine which of the two possible configurations is optimum. Also, the entire spin brake mechanism can be designed as a mirror image to that shown in this embodiment to give more drag in the opposite spin direction.

Figure 6 provides an isometric view with both the outer housing of section 4 and the electronics completely removed showing both the spin brake fins 10 and 11 and air brake fins 12 and 13 completely deployed. The threaded section 2 containing the fuel cell, and the tail section 5 containing the safe and arm mechanism and the booster charge are shown below the fin section. The air brake motor assembly 20 and the spin brake motor assembly 21 can be seen in this view along with their motor mount support 24. The worm gear 32, the carriage bar 33, the cam guide 34, and other parts of the spin brake deployment mechanism can be seen in the spin brake fin deployed condition.

Figure 6, and other drawings show that the shape of the fins, particularly the air brake fin, are irregular in appearance. Since the purpose of the fins is to create drag the shape of the fins are not critical. Some shapes would create more drag than others but most shapes would create sufficient drag to carry out their function. The fin shapes are therefore determined for the most part by packaging considerations, i.e., space constraints within the fuze housing determine the shape of the fins. The only necessary constraint on the spin fin shape or air brake fin shape is that they are symmetrical for balance and are deployed simultaneously. In general they are shaped to fit in the housing 4 and present the greatest possible area to the air flow through which the projectile is flying in the fully deployed mode.

Figure 7 provides a cut-away view of the entire course correcting fuze (CCFuze) of this invention with the cut being taken so as to pass through the centers of the two electric motor assemblies 20 and 21. As before, this drawing shows the four main sections of the fuze: the electronics nose cone 3, the fin deployment section 4, the fuel cell battery section 2, and the combined section 5 containing the safe and arm mechanism 82 and the booster charge 83. In this view, portions of the air brake fins 12 and 13 and one partial face of the spin brake fin 11 are shown in their fully retracted state. (Spin brake fin 10 does not appear in this drawing; it is entirely contained in the eliminated portion of this drawing.) The shaft of the upper motor assembly 21 is affixed to spur gear 30, which is used to rotate worm gear 32. The worm gear 32 moves the threaded carriage 33 which in turn deploys the two spin brake fins 10 and 11 (shown here in their fully retracted state) through a cam and pin system. The lower motor assembly 20 has its shaft affixed to spur gear 50 which meshes with internal gear 51. Internal gear 51 causes the deployment of air brake fins 12 and 13 by means of a cam and pin system (not seen in this view).

Figure 8 provides an isometric cut-away view of the entire course correcting fuze (CCFuze) of this invention with the cut being taken so as to pass through the centers of the two electric motor assemblies 20 and 21. This drawing shows the four main sections of the fuze: the electronics nose cone 3, the fin deployment section 4, the fuel cell battery section 2, and the combined section 5 containing the safe and arm mechanism 82 and the booster charge 83. In this view the air brake fins 12 and 13 and the spin brake fin 11 are shown in their fully deployed state. (Spin brake fin 10 does not appear in this drawing; it is entirely contained in the eliminated portion of this drawing.) The shaft of upper motor assembly 21 is affixed to spur gear 30 which is used to rotate worm gear 32. The worm gear 32 moves the threaded carriage 33 which in turn deploys the two spin brake fins 10 and 11 (shown here in their fully deployed state). The lower motor assembly 20 has its shaft affixed to spur gear 50 which meshes with internal gear 51. Internal gear 51 causes the deployment of air brake fins 12 and 13 by means of a cam and pin system (not seen in this view).

Figure 9 provides cut-away view of the entire course correcting fuze (CCFuze) of this invention with the cut being taken between the two electric motor assemblies so that only the top part of motor assembly 20 can be seen in this drawing. This drawing also shows the four main sections of the fuze: the electronics nose cone 3, the fin deployment section 4, the fuel cell battery section 2, and the combined section 5 containing the safe and arm mechanism 82 and the booster charge 83. In this view the spin brake fins 10 and 11 are seen edge on in their fully retracted states. The drawing cuts through the center of the pivot holes 38 of the two air brake fins. The air brake fins are seen edge-on in the slot section 88. Motor assembly 21 (not seen in this view) rotates worm gear 32 by means of a spur gear (not seen in this view). The worm gear 32 deploys the spin brake fins by moving carriage 33 up the worm gear. A cam and pin arrangement (not seen in this view) then rotates the spin brake fins 10 and 11 around pivot points 38 and into the air stream. In this embodiment the two motor assemblies 20 and 21 are show to be DC motors with encoders attached. DC Servo motors could also be used to the same effect. The encoders or the use of a servomotor are to allow the logic in the electronics package to “know” the position of either the spin brake or air brake fins without the use of a complicated switch system.

Special Features of Figures 7, 8 and 9

Of particular note in the cut-away drawings of **Figures 7, 8 and 9** is the channel 84 extending through the center of worm gear 32. This opening continues through a rectangular passage 85 and circular passage 86 in the fuel cell section, and it further extends as a circular hole 87 through the safe and arm section 82. (The detonator, not shown, is a long cylindrical object occupying the circular passage 86 and 87.) This straight passage provides a wire channel between the electronics module 3 and the lower sections of the fuze and is a unique feature of this invention. In the previous art, the electric wires were wrapped around the batteries in section 2 and otherwise followed a contorted path through the fuze assembly thus being subjected to possible cutting, disconnection, and other high-g stress related failures during the firing of the shell. The straight channel through this fuze design thus prevents a number of possible failure modes.

Figure 10 provides a perspective overview of the fuze fuel cell reserve battery assembly 100. The top plate 101 covers the top of the fuel cell and is sealed to the fuel cell shell 102 with counter sunk screws, around the circumference. A gasket or "O" ring would be used between the two pieces here for sealing. The fuel cell shell 102 includes a threaded section 103 and a lower collar 104 with internal threads. The fuel cell shell 102 also forms the outer surface of the fuze assembly referred to as 2 in other drawings. The two mounting posts 106 emerging from opposite sides of top plate 101 have no functional importance other than serving as mounting and assembly means for the top section of the fuze. The circular hole 107 forms part of the primary axial wire channel between the electronics module at the top of the fuze and the booster charge chamber at the bottom of the fuze, and is seen in side views as 84, 85, 86, and 87 in other drawings. A slot 108 in the top plate 101 forms a second wire channel between the positive terminal of the fuel cell membranes and the primary axial wire channel at position 107. Wire channel 108 allows wires to be connected between the fuel cell membranes and the fuel cell electronics at the top of the fuze. The other unlabeled holes in the top plate 101 serve as gas fill ports and mounting means. The negative terminal of the fuel cell is grounded to the case of the fuze and requires no wiring.

Of particular note is that the main fuel cell components 101, 102, 103, and 104 also forms the outer wall 2 of the entire fuze assembly. The fuel cell is thus a custom design exactly suited for this application unlike previous fuze designs that used either custom or off-the-shelf batteries placed in a special compartment. This custom design allows the battery walls to also serve as the fuze outer wall thus saving space and weight. The custom fuel cell design also provides for a primary axial wire channel that increases the reliability of the fuze. The fuel cell also includes a number of unique activation, storage, and operational features specially designed for artillery shell fuze applications. Taken together this novel and unique fuze design provides longer storage life, greater reliability, and extended functionality over the previous art.

Figures 11 and 12 provide a cut-away view of the fuel cell assembly passing through the two activation arms 110 and 111. The top plate 101 covering the top of the fuel cell and the fuel cell shell 102 are shown in this cut-away. The threaded outer portion of the shell 103 and the collar 104 are shown in cross-section. One of the mounting posts 106 is shown on the left side of the cut-away, and the axial wire channel 107, 85 and 86 is seen passing through the center of the fuel cell.

In these two views the chamber 122 on the left is filled with oxygen gas under pressure and the chamber 120 on the right is filled with hydrogen gas under pressure. When the fuel cell is activated, oxygen gas flows through the hole 125 into reaction chamber 129 on the left side and the hydrogen gas flows through hole 126 into reaction chamber 129 on the right side of the drawing. The reaction chamber 129 is a toroidal volume formed between the inner wall 131 and the outer wall 103. The oxygen in reservoir 122 is separated from the reaction chamber 129 by a thin portion of the metal wall 127 which can be pierced by a sharp projection portion of the fuel cell activation arm 110. A similar arrangement exists on the hydrogen side where the hydrogen reservoir 120 is separated from the reaction chamber 129 by a thin portion of the metal wall 128 which can be pierced by a sharp projection of the fuel cell activation arm 111. The fuel cell activation arms 110 and 111 are free to pivot around their respective pins 112 and 113 and are held in the upward positions shown in **Figure 11** by thin metal wires (not shown).

When the artillery shell is fired, the high acceleration causes a high G-force in the downward direction. These forces can easily exceed 20,000 G. This high G-force pulls on the center of mass (c.g.) of the activation arms 110 and 111 causing them to swing downward against thin retaining wires (not shown) and snap these wires, thus causing the arms to continue swinging around their respective pivots 112 and 113. The activation arms then rotate down and towards the outer walls as they are pulled downward by the high G-force and also pulled towards the walls by the high centrifugal forces. The centrifugal forces are generated by the high speed spin of the projectile caused by the rifling along the gun barrel. The spin can reach up to 300 revolutions per seconds (RPS) in some artillery pieces. Sharp projections 132 and 133 on the pivot arms then puncture the thin metal walls 127 and 128 as shown in **Figure 12** allowing the oxygen and hydrogen to enter the reaction chamber 129 where the two gases react to produce electricity. This arrangement of keeping the gases separated until the artillery shell is fired allows the fuze to be stored for long periods of time without degradation of performance capability, unlike conventional batteries which slowly degrade with time even when not in use. This invention is referred to as a fuel cell "reserve" battery to point out this long-term storage feature of this invention.

Prior to firing the shell the reaction chamber 129 is filled with a vacuum. During manufacture air is extracted from the reaction chamber 129 through a vacuum fill hole 130, after which the fill hole is sealed to retain the vacuum in the reaction chamber. Once the thin metal walls 127 and 128 are punctured the initial vacuum allows the oxygen and hydrogen to enter the reaction chamber 129 quicker and without being diluted by residue air in the chamber.

Figure 13 provides a cross-sectional view of the fuel cell portion of the course correction fuze of this invention. The cut-away is taken at the flange portion 102 of the fuel cell's outer shell. The inner portion of the fuel cell 131 (shown in light gray in this drawing) is a gas storage tank consisting of four-chambers, 120, 121, 122 and 123. The four chambers are separated by radial walls 142 with element 131 forming the outer wall. This wall configuration is required by the very high spin of the artillery projectile and maintains the balance of the round. There are two small slots or holes placed in two of the walls to join three of the compartments effectively into one larger compartment. Top plate 101 forms the top to all the gas chambers and bottom plate 142 seals the gas chambers on the bottom. The hydrogen and oxygen are converted to water (H2O) by a catalytic membrane in the ratio 2:1 so chamber 122 contains oxygen gas under pressure and chambers 120, 121 and 123 contain hydrogen gas under pressure arranged so as to maintain a volume ratio of 2:1. The vacuum fill hole 130, the oxygen fill hole 147, the hydrogen fill holes 148, and the axial wire channel holes 107, are seen at the point where they enter the fuel cell top plate 101. The fuel cell activation arms 110 and 111 are seen from the top looking down where the arms are seen to be arrow-shaped. The head of these arms act as additional inertial mass that is acted on by G-forces to initiate arm movement during shell firing.

The toroidal fuel cell reaction chamber 129 occupies the volume between the inner support wall 131, the fuel cell shell 102, and the fuel cell top plate 101 and bottom plate 142. This volume is packed with two rings of wedge-shaped gas diffuzer and support elements 139 and 140 made of a fibrous porous polymer material. This material is designed to give a specific gas flow rate to the fuel cells. A very thin catalytic membrane 141 is squeezed between the two layers of fibrous polymer material and has a saw-tooth cross-section in this cut-away view to increase its surface area. Oxygen gas from gas chamber 122 feeds through hole 125 into the outer ring of gas diffuzer and support elements, while hydrogen gas flows through opening 126 and into the inner ring of gas diffuzer and support elements. Oxygen gas thereby approaches the catalytic membrane 141 from the outside and hydrogen gas approaches the membrane from the inside surface. This toroidal design serves another purpose. By placing the oxygen gas on the outside and the hydrogen gas on the inside, the water of the reaction forms in the outer chamber. Then because the artillery shell is spinning, the water formed on the catalyst layer will be spun off toward the outer shell of the fuel cell. This eliminates any need water removal which is a critical factor in normal fuel cell stack design.

The catalytic membrane 141 normally called an MEA consists of a thin polymer film that is porous to proton diffusion but acts as a barrier to the passage of O2 or H2 gases and is an electrical insulator. Each side of the membrane is coated with a conductive layer of carbon black and platinum in various ratios. Hydrogen gas approaching the catalytic membrane 141 is broken down to free electrons, which pass along the hydrogen surface and form the anode portion of the fuel cell, and protons, which pass through the polymer film to the oxygen side of the membrane. On the oxygen side of the catalytic membrane 141, the oxygen molecules are broken down to oxygen ions, which then combine with protons and electrons (from the anode side and conducted out of the cell as a source of power and returned here) to form water. The extra electron is required to complete the process, which makes the oxygen side of the membrane the cathode side of the fuel cell. Wires are connected to the cathode and anode sides of the fuel cell (not shown) and are used to meet the power requirements of the course correction fuze of this invention.

Figure 14 provides an isometric view of the fuel cell with top plate 101 removed and with activation arms 110 and 111 in their initial storage positions. The outer shell is shown consisting of flange 102, outer threaded wall 103, and lower fuel cell rim 104. In this view the quad chambered high pressure tank assembly 146 can be clearly seen including the oxygen storage chamber 122 and the three hydrogen storage chambers 120, 121 and 123. Note that chambers 121 and 123 each occupy 60° of real estate around the circumference of the gas storage tank 146 and chambers 120 and 122 each occupy 120° of real estate. The volume of chambers 120 and 122 is roughly twice the volumes of chambers 121 and 123 (less corrections for wall thickness). Chambers 120, 121 and 123 together contain twice the volume of chamber 122 so that there is twice the volume of hydrogen as oxygen to meet the chemical requirements of water, i.e. H2O two parts hydrogen and one part oxygen. These tanks can be charged to any reasonable pressure, generally under 1,000 PSI in this application. The charge pressure determines the power or run time of the system.

The packing arrangement of the inner ring of gas diffuzer and support elements 139 and the outer ring of gas diffuzer and support elements 140 is seen here within the fuel cell reaction chamber 129. The wedge-shaped fibrous porous polymer material is seen to completely fill the available reaction chamber volume while squeezing the catalytic membrane 141 into a saw-tooth vertical arrangement that increases the surface area of the membrane material. The vacuum fill hole 130, the oxygen fill hole 147, the hydrogen fill holes 148, and the axial wire channel holes 107, are seen at the point where they enter the fuel cell top plate 101. The two fuel cell activation arms 110 and 111 are clearly seen suspended in their standby positions without their associated attachment means. There are many other arrangements of putting the cells into this type of configuration, for example the bend on each side could be eliminated and the fells just laid one on top the other. The novel portion of this design is that by constructing the fuel cell stack in this method, the collection of electrons and the flow of gas is much simpler to achieve as compared with other more conventional designs. There are also significantly fewer parts this way.

Figure 15 provides a three dimensional perspective view of the outer wall portion of the fuel cell assembly including flange 102, outer threaded wall 103, and lower fuel cell rim 104. This component is made from a single piece of metal and forms a portion of the outer wall of the course correcting fuze. Note that the bottom plate 142 seats against beveled edge 143. The flange 102 attached to top plate 101 by means of fasteners passing through fastener holes 144 and applies the sealing pressure for the bottom bevel.

Figure 16 provides a perspective cut-away view of the fuel cell assembly without its outer shell. In this drawing, the fuel cell assembly is positioned up-side-down with the vertical cut being made through the two fuel cell activation arms 110 and 111 and through the hydrogen gas chamber 120 and the oxygen gas chamber 122. The top plate 101 with one of the mounting post 106 attached is shown on the bottom of this drawing. In this view, half of the hydrogen activation arm support structure 151 and half of the oxygen activation arm support structure 152 is shown which allows attachment means for the two activation arm pivot pins (not shown). Passage through the center of the fuel cell is shown, including the cylindrical detonator containment hole 150 and 86, the rectangular wire passage channel 85, and the axial wire channel hole 107. Portions of the outer gas diffuzer and support elements 140, the catalytic membrane 141, and the inner gas diffuzer and support elements 139, are seen wrapped around the quad chambered high pressure tank assembly 146.

Figure 17 provides a perspective view of the fuel cell assembly without the outer shell 102. This view shows the top plate 101 with its two mounting posts 106 emerging from opposite sides of top plate. The circular hole 107 forms part of the primary axial wire channel between the electronics module at the top of the fuze and the cylindrical detonator containment hole at the bottom of the fuel cell. Wire channel 108 allows wires to be connected from the anode and cathode to other parts of the fuze assembly. The outer gas diffuzer and support elements 140 can be seen beneath the top plate 101. The oxygen flow through hole 125 exiting from the polymer separation element 160 and the outer gas passage offset 166 are clearly seen in this view. Only the outside surface of the anode 161 can be seen in this view.

Figure 18 provides an up-side-down perspective view of the fuel cell assembly without the outer shell. This view shows the bottom of the top plate 101 with its two mounting posts 106 emerging from opposite sides of top plate. The bottom of the top plate 142 is shown at the top of the drawing indicating the placement of the cylindrical detonator containment hole 150. The outer gas diffuzer and support elements 140 can be seen above the top plate 101. The oxygen flow through hole 125 exiting from the polymer separation element 160 and the outer gas passage offset 166 are can be seen in this view. Only the outside surface of the anode 161 can be seen in this drawing.

Figure 19 provides a perspective view of the fuel cell gas diffuzer stack and catalytic membrane assembly, which is housed in the fuel cell reaction chamber. This view shows the relative positions of the outer gas diffuzer and support elements 140, the catalytic membrane 141, the inner gas diffuzer and support elements 139, and the offsets 166 and 167. The first section of the catalytic membrane 170 is shown folded against the edge of the last outer gas diffuzer and support element 168. The catalytic membrane 141 is then seen to be pressed between the interlocking layers of inner and outer gas diffuzer and support elements 139 and 140 following a circular saw-tooth path to the opposite membrane edge 171, which is folded against an edge of the first inner gas diffuzer and support element 172.

Figure 20 provides a perspective view of the fuel cell gas diffuzer stack and current collector assembly, which is housed in the fuel cell reaction chamber 129. This view shows the relative positions of the outer gas diffuzer and support elements 140, the catalytic membrane 141, and the inner gas diffuzer and support elements 139 and their connection to the current collector assembly. The catalytic membrane 141 is first seen to wrap counter clockwise around the cathode 162 exposing its outer surface to the cathode; it then follows a circular saw-tooth path within the fibrous polymer gas diffusion elements around the reaction chamber; and it then tucks into a offset in the anode element 161 where its inner surface makes contact with the anode. The last outer gas diffuzer and support element 168 inserts into the offset of the anode 161 thus pressing the catalytic membrane 141 firmly against the anode. The cathode and anode are separated by a polymer separation element 160, which includes holes for vacuum fill and oxygen flow.

Of particular note in **Figure 20** is the offset 166 cut into all the outer gas diffuzer and support elements 140, and a similar offset 167 cut around the inside of the inner gas diffuzer and support elements 139. The thickness of the respective gas diffuzer and support elements above the offsets are slightly reduced to allow the rapid flow and distribution of oxygen gas from the input port 125 to all the gas diffuzer elements, and likewise the inner offset 167 allows for the rapid flow and distribution of hydrogen gas to all the inner gas diffuzer and support elements 139 from the hydrogen input port 126.

Figure 21 provides a perspective view of the fuel cell current collector assembly. This assembly provides termination for the two ends of the catalytic membrane 141. The inside catalytic membrane wraps around the last outer gas diffuzer and support element 168 thus exposing its inside surface to full contact with the negative current collector element (anode) 161 which is made of a conductive metal. Likewise the outside surface of the catalytic membrane 141 wraps around the positive current collector element (cathode) 162 which is also made of a conductive metal. The cathode 162 has a cathode pin insertion hole 163 where a conductive metal pin (not shown) is inserted to allow current flow to elements outside of the fuel cell. Vacuum fill hole 130 and its horizontal extension 165, and the oxygen flow through hole 125, and the gas passage offset 166 is cut into the polymer separation element 160.

Figure 22 shows two gas diffuzers and support elements 139 and 140 in perspective view with a portion of catalytic membrane 141 between them. The end outer gas diffuzer and support element 168 is shown with the anode end section of catalytic membrane 170 folded around its edge. This view clearly shows a reduction in gas diffuzer and support element thickness above the outer gas passage offset 166 and likewise the drawing shows a corresponding reduction in support element thickness above the inner gas passage offset 167.

Figure 23 shows two gas diffuzer and support elements 139 and 140 in perspective view with a portion of catalytic membrane 141 between them. The end outer gas diffuzer and support element 168 is shown with the anode end section of catalytic membrane 170 folded around its edge. The reduction in gas diffuzer and support element thickness is clearly shown above the offsets 166 and 167 on the outer and inner sections of gas diffuzer and support elements. In particular this view shows how the individual gas diffuzer and support panels are interlinked together with the catalytic membrane 141 pressed between them. The gas diffuzer and support element are made of a very fibrous and very porous polymer that allows the gases to be quickly and uniformity distributed to all parts and both sides of the catalytic membrane 141. It also acts to reduce the shock of activation as the gas membranes are ruptured causing a high-pressure shock wave to travel into the fuel cell compartment.

Figure 24 provides an isometric view of the spin brake fin mechanism in its retracted state and **Figure 25** provides a view of the spin brake fin mechanism in its fully deployed state. (Note that the mechanism in **Figure 25** is shown turned around from its position in **Figure 24** to better show the gear mechanism.) This mechanism consists of an electric motor 21 with its associated spur gear 30 which meshes with spur gear 31. Spur gear 31 is affixed along a common shaft to worm gear 43 so that the two components rotate together. A threaded carriage bar 33 slides along the worm gear 32 as the worm gear is rotated. Cam guides 34 are attached on both ends of the carriage bar 33. Bearing surfaces 40, 41, 42, and 43 allow the motor shaft and worm gear shafts to rotate freely and with reduced friction.

The spin break fin 10 has a pivot hole 38 and a cam pinhole 37 with similar features and structures on spin break fin 11. A pin (not shown), having one end attached to the fuze housing, is inserted through pivot hole 38 to tie one corner of the spin break fin to secure the fin to a fixed position in the fuze housing while still allowing it to rotate around the pin. A cam pin (not shown) is inserted through the cam pinhole 37 and extends through cam slot 35; the portion of the cam pin in hole 37 is firmly attached to the fin, while the portion extending into the cam slot is not attached to the cam guide 34.

Now, beginning from its position in **Figure 24** with the spin break fins undeployed, the activation of the electric motor 21 serves to rotate the worm gear 32 moving the carriage bar 33 away from the gears as shown in **Figure 25**. The cam pin in hole 37 is guided by the cam slot 35 as the carriage moves along the worm gear forcing the spin brake fin to rotate around pivot pin 38. This action rotates a portion of the fin out of the fuze housing and into the air stream exterior to the fuze housing. The extended fins shown in **Figure 25** extend parallel to the forward airflow and thus adding little drag to forward motion of the projectile. These air brake fins extend perpendicular to the rotational air flow thus adding considerable drag to the rotational motion of the projectile which in turn causes a decrease in the projectile spin.

Figure 26 provides an isometric view of the air brake fin mechanism in its retracted state and **Figure 27** provides a view of the air brake fin mechanism in its fully deployed state. This mechanism consist of an electric motor 20 with its associated spur gear 50 which meshes with inside diameter (ID) spur gear 51 and causes it to rotate around a shaft inserted in hole 56 at a reduced angular speed. Two cam pins 52 and 53 are rigidly affixed to ID spur gear 51 and extend into cam slots 54 and 55 in air brake fins 12 and 13. (Note that the cam pins are mounted on the backside of the ID spur gear as pictured in these drawings. Only a portion of pin 52 can be seen in **Figure 27** and pin 53 cannot be seen in either drawing.)

As the ID spur gear 51 is rotated, the cam pins 52 and 53 engage the cam slots 54 and 55 causing the air brake fins 12 and 13 to rotate around their respective pivots at 60 and 61 and swing outward into the external air stream through slot 7 in the fuze housing and its counterpart. (Note that pivot hole 60 is partially eclipsed by the ID spur gear 51 and that pivot hole 61 is completely eclipsed by the ID spur gear 51. The pivot holes rotate around pins fixed to the fuze housing, not shown in these drawings.) Cut-outs 57 and 58 serve to reduce the weight of metal used in the ID spur gear and otherwise do not serve a mechanical function. Cylindrical surface 59 is a bearing surface.

In the extended position shown in **Figure 27**, the plane of the air brake fins lies perpendicular to the forward airflow and parallel to the rotational airflow. The air brake fins, when deployed, cause a drag in the forward movement of the projectile while at the same time having little effect on the rate of spin. The air brake fins can thus be used to reduce the range at which the shell will impact. In practice, the shell is launched to over-shoot its target. The air brake fins are then deployed at the appropriate position along its trajectory to cause it to decrease its range in accordance with environmental conditions during the time of flight and fall exactly on the intended target.

In general for **Figures 23 through 27**, the electric motors 20 and 21 are geared down DC motors with encoders or the like, that can rotate in either the clockwise or counter-clockwise direction depending on the polarity of the electric current. The encoder portion of the motor assembly sends pulses back to the controlling electronics at the rate of 16 pulses per rotation. This feature allows the spin brake fins and air brake fins to be either extended or retracted by the mechanism shown in **Figures 23, 24, 26, 27**, and other drawings. Electric power distributed by the fuze electronics to the motors determines the direction of motor rotation and thus controls whether the fins are extended, retracted, or remain in their current position. The encoder pulses sent back to the controller electronics allow the computer to calculate how far the fins have deployed. By this invention the amount of spin and air braking can be determined moment by moment during the projectile flight to correct for wind gust and other environmental factors, unlike existing projectile brake mechanisms which are deployed once and remain deployed until impact or detonation.

Note that all components of the spin and air brake systems are ruggedized to withstand the 20,000 g's of initial shell launch force. Once the mechanisms are in-flight, only a portion of the fins are immersed in the air stream where they are subject to the tremendous force of the airflow. Also, the fins are extended slowly (relatively speaking) into the air stream minimizing the stress on the fin securing means. This is in contrast to current methods of quick releasing a flower-pedal opening of the top of the fuze housing, which is prone to failure by breakage at the hinges. The motors used in fin deployment are rugged industrial motors capable of withstanding drop tests onto a hard surface, which induces g-forces similar to those encountered in artillery launch.

Figure 28 provides an isometric view of the fuze nose cone electronics module. Note that the solid object 70 does not necessarily represent the actual appearance of the electronics module. 70 represents the volume available to house the control electronics, which includes the major electronic elements shown in the schematic of **Figure 30**. This module includes a Global Positioning System (GPS) sub-module, a targeting information receiver, computer processor, a PROM memory chip, and high power circuits to control the fin motors. These components; and related circuitry, wires, and connectors; are mounted on customized circuit boards designed to fit in the volume 70. The volume also includes the external surface of the tip of the fuze nose cone; internal struts, brackets, and supports; related fasteners; and other housing features as necessary. The housing may be a solid integrated component, or it may be made of discrete elements, or a combination of the two. The volume 70 includes cutouts 71 for the tips of the spin brake fins and cutouts and voids for other fuze elements that mate with this module.

Figure 29 provides a finished perspective rendering of the course correcting fuze, as it would appear to the eye with both sets of fins fully deployed. This view is similar to **Figure 2**, but rotated about 15° counter-clockwise. As before, the nose cone tip 3 houses the electronics module, the body 4 houses the fin deployment mechanisms, the threaded section 2 contains the fuel cell, and the tail section 5 houses the booster charge and safe and arm mechanism. The spin brake fins 10 and 11, and the air brake fins 12 and 13 are shown in their deployed position with the protective caps removed.

Figure 30 provides a functional block schematic for the principal components contained within the fuze electronics module 3. The major components are labeled. The arrows indicate flows of information and electric power. The fuel cell and motor components are not contained in the electronics module but are shown here for completeness. Each motor includes an encoder 81 that indicates shaft position by sending a digital pulse to the computer when the output shaft has rotated another 22.5° (i.e. 16 pulses per rotation). The PROM memory component stores programming and targeting data for access by the computer.

Just before firing of the artillery shell a special magnetic encoder unit (not shown) is placed over the electronic module portion of the fuze where an antenna 83 picks up encoded targeting information and stores it in the PROM memory. During launch out of the gun barrel, the fuel cell is activated and sends electric power to the computer processor, which is thereby activated. Shortly after leaving the gun barrel the Global Positioning System (GPS) antenna 84 acquires and receives satellite positioning signals, which are interpreted by the GPS module and sent to the computer. Using stored programming and data tables the computer uses the GPS data to determine the current speed and trajectory of the artillery projectile. The trajectory information is then compared to the target information and the probable impact point is quickly determined. The computer then calculates the spin and air brake fin deployment requirements to reach the target. The artillery shell will be fired slightly "off target" to give the shell and its guidance system room to adjust the projected impact point.

At a calculated point in the trajectory power is sent to the air brake motor and/or the spin brake motor to deploy the respective sets of fins. (Note, the air brake fins and spin brake fins are not necessarily deployed at the same point along the trajectory, and they may be fully deployed or partly deployed.) As the motors rotate, their attached encoders send pulses to the computer at each 22.5° of shaft rotation angle which in turn tells the computer how far the corresponding set of fins have deployed. When the fins have been deployed by the proper amount, the computer stops sending power to the motors and the deployment ceases.

The computer then takes another set of GPS position readings and makes further calculations to determine if corrections are needed to be made to the previous deployment settings. If course corrections are needed, the computer sends power to the motors to either further deploy a particular set of fins or to retract a particular set of fins. This feedback process continues until the projectile is detonated. Note that in this invention, unlike previous fin control mechanisms, the fins may be partially deployed, fully deployed, or they may be retracted during flight. This allows course correction refinements to be made continuously during the flight and thus provides a more accurate target interdiction.

The present invention also provides a battery power supply or other power supply that powers a course correcting fuze, for example, of the type described and shown herein. One such battery or power supply has a port extending through the battery or power supply through which communication leads and power leads extend.

Thus, there is provided a course correcting fuze including an artillery component; at least one fin in the artillery component, the at least one fin being selectively deployable; a fin deployment drive in said artillery component connected and operable to effect deployment of the at least one fin; a deployment control connected to the fin deployment drive; and a fuel cell module in said artillery component connected to the fin deployment drive and the deployment control.

There is also provided a method of building an artillery fuze, including installing at least one miniature motor in a housing of the artillery fuze; connecting the at least one miniature motor to a controllable surface of the artillery fuze; and powering the at least one miniature motor by at least one of a fuel cell power source, a battery and a power supply to provide course correction to an artillery round. The method may also include dynamically controlling the controllable surface using in flight GPS guidance for the artillery fuze.

In a further embodiment, a method of guiding an artillery apparatus is provided including mounting at least one fin in at housing of the artillery apparatus at an opening; extending the at least one fin through the opening using a reversible motor so that the at least one fin acts as an air brake to slow the artillery apparatus by an amount depending on an extent to which the at least one fin extends from the artillery apparatus; and powering the extending of the at least one fin with at least one of fuel cell and a battery and a power supply in the artillery apparatus. The method may include spinning the artillery apparatus during travel; and slowing spin of the artillery apparatus using at least one spin brake fin configured as a spin brake that slows the spin of the artillery apparatus when extended from the housing of the artillery apparatus; extending the at least one spin brake fin from the housing using a reversible motor so that the at least one spin brake fin brake by extending from the artillery apparatus to act as a spin brake to slow the spin by an amount dependent on the extension of the at least one spin brake fin from the housing. The method may include controlling extending of the at least one fin of using the at least one of the fuel cell and battery and power supply to power a GPS apparatus, on board electronics and actuation motors. In some embodiments, the at least one of the fuel cell and the battery and the power supply has a port extending through it through which passes communications and power leads. Charging the at least one of the fuel cell and the battery and the power supply can be provided in an initiation charge using the port. At least one of the fuel cell and the battery and the power supply may serve as a base of a fuze apparatus. As a further embodiment, a booster charge is provided to the artillery apparatus.

According to aspects of the invention an arrowhead shape on the inertial arms may be provided to maximize the kinetic energy available for wall piercing. Another aspect provides offsetting the punch point toward the pivot on the inertial arm to maximize the punch force by use of leverage.

The fins may be moved between a retracted position and extended position using a screw mechanism to move the fins. Alternatively, the fins may be moved using gears. Miniature servo motors may be used to control the fin position. Encoders may be used to determine the fin position. Miniature mechanical of electronic switches may be used to control fin position. In a preferred embodiment, gas channels are provided in the fuel cell support structure that aid in gas flow during operation.

A fin actuation screw may act as a wire guide by having a hole through the center of it. A machined outer case and a brazed or otherwise welded gas tank center may be provided to be bolted or screwed together such that a mechanical seal isolates the fuel cell compartment from the rest of the battery and fuze. In a preferred embodiment, machining the fuze shell to act as support for some of the critical items on the inside thereby freeing up other inside space for the actuation mechanism. The fuze and power supply may be provided as a single device rather than a series of components thereby making better use of the available space by combining functions.

Although other modifications and changes may be suggested by those skilled in the art, it is the intention of the inventors to embody within the patent warranted hereon all changes and modifications as reasonably and properly come within the scope of their contribution to the art.

I CLAIM:

1. A course correcting fuze, comprising:
an artillery component;
at least one fin in said artillery component, said at least one fin being selectively deployable;
a fin deployment drive in said artillery component connected and operable to effect deployment of said at least one fin;
a deployment control connected to said fin deployment drive; and
a fuel cell module in said artillery component connected to said fin deployment drive and said deployment control.

2. A method of building an artillery fuze, comprising the steps of:
installing at least one miniature motor in a housing of the artillery fuze;
connecting the at least one miniature motor to a controllable surface of the artillery fuze; and
powering the at least one miniature motor by at least one of a fuel cell power source, a battery and a power supply to provide course correction to an artillery round.

3. A method as claimed in claim 2, further comprising the step of:
dynamically controlling the controllable surface using in flight GPS guidance for the artillery fuze.

4. A method of guiding an artillery apparatus, comprising the steps of:
mounting at least one fin in at housing of the artillery apparatus at an opening;
extending the at least one fin through the opening using a reversible motor so that the at least one fin acts as an air brake to slow the artillery apparatus by an amount depending on an extent to which the at least one fin extends from the artillery apparatus; and
powering the extending of the at least one fin with at least one of fuel cell and a battery and a power supply in the artillery apparatus.

5. A method as claimed in claim 4, wherein the artillery apparatus spins during travel; and further comprising the steps of:
slowing spin of the artillery apparatus using at least one spin brake fin configured as a spin brake that slows the spin of the artillery apparatus when extended from the housing of the artillery apparatus;
extending the at least one spin brake fin from the housing using a reversible motor so that the at least one spin brake fin brake by extending from the artillery apparatus to act as a spin brake to slow the spin by an amount dependent on the extension of the at least one spin brake fin from the housing.

6. A method as claimed in claim 4, comprising the step of: controlling extending of the at least one fin of using the at least one of the fuel cell and battery and power supply to power a GPS apparatus, on board electronics and actuation motors.

7. A method as claimed in claim 4, wherein the at least one of the fuel cell and the battery and the power supply has a port extending through it through which passes communications and power leads.

8. A method as claimed in claim 7, further comprising the step of: charging the at least one of the fuel cell and the battery and the power supply in an initiation charge using the port.

9. A method as claimed in claim 4, wherein the at least one of the fuel cell and the battery and the power supply serve as a base of a fuze apparatus.

10. A method as claimed in claim 4, further comprising the step of:
providing a booster charge to the artillery apparatus.

11. A method as claimed in claim 2, further comprising the step of: using an arrowhead shape on inertial arms to provide kinetic energy available for a wall pierce.

12. A method as claimed in claim 2, further comprising the step of: offsetting a punch point toward a pivot on an inertial arm to provide punch force by use of leverage.

13. A method as claimed in claim 4, further comprising the step of: moving at least one fin from a retracted position to an extended position using a screw mechanism.

14. A method as claimed in claim 4, further comprising the step of: moving at least one fin from a retracted position to an extended position using gears.

15. A method as claimed in claim 2, further comprising the step of: channeling gas flow through gas channels in a fuel cell support structure during operation of the fuel cell.

16. A method as claimed in claim 2, wherein the fin position is controlled using miniature servo motors.

17. A method as claimed in claim 2, wherein the fin position is determined using encoders.

18. A method as claimed in claim 2, wherein fin position is changed using miniature mechanical or electronic switches.

19. A method as claimed in claim 2, further comprising the step of: guiding a wire using a fin actuation screw as a wire guide by providing a hole through a center of the screw.

20. A method as claimed in claim 2, wherein the housing includes a machined outer case and a brazed or otherwise welded gas tank center threadably fastened together such that a mechanical seal isolates a fuel cell compartment from a rest of the battery and fuze.

21. A method as claimed in claim 2, further comprising the step of: machining a fuze shell to act as support for items on the inside the shell.

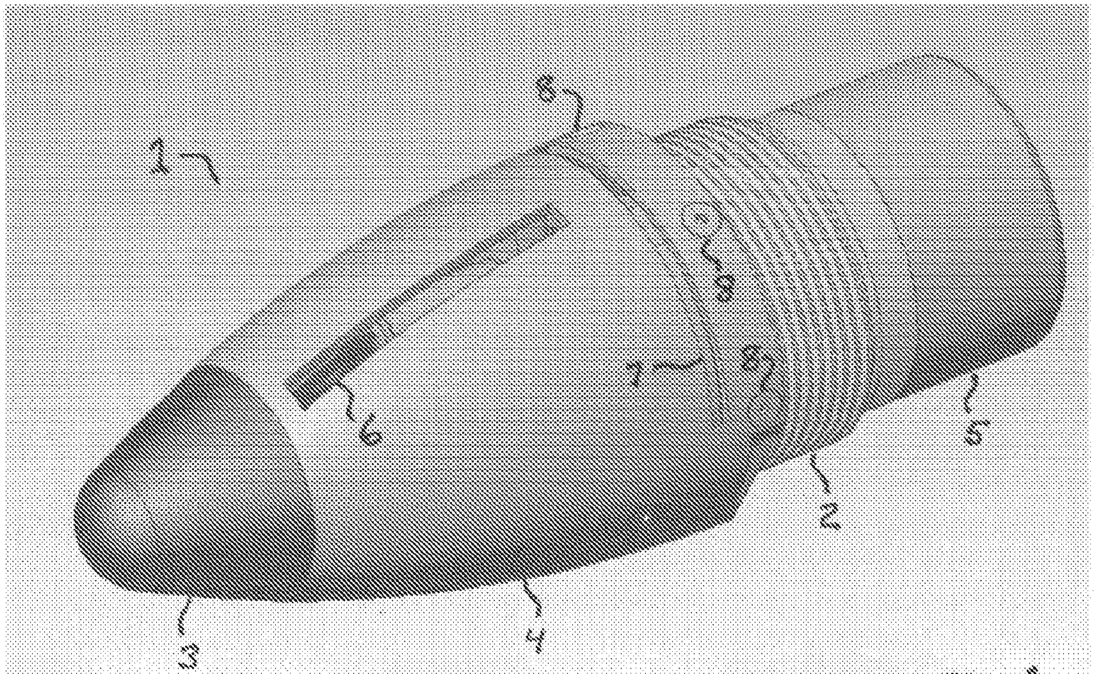


Fig. 1

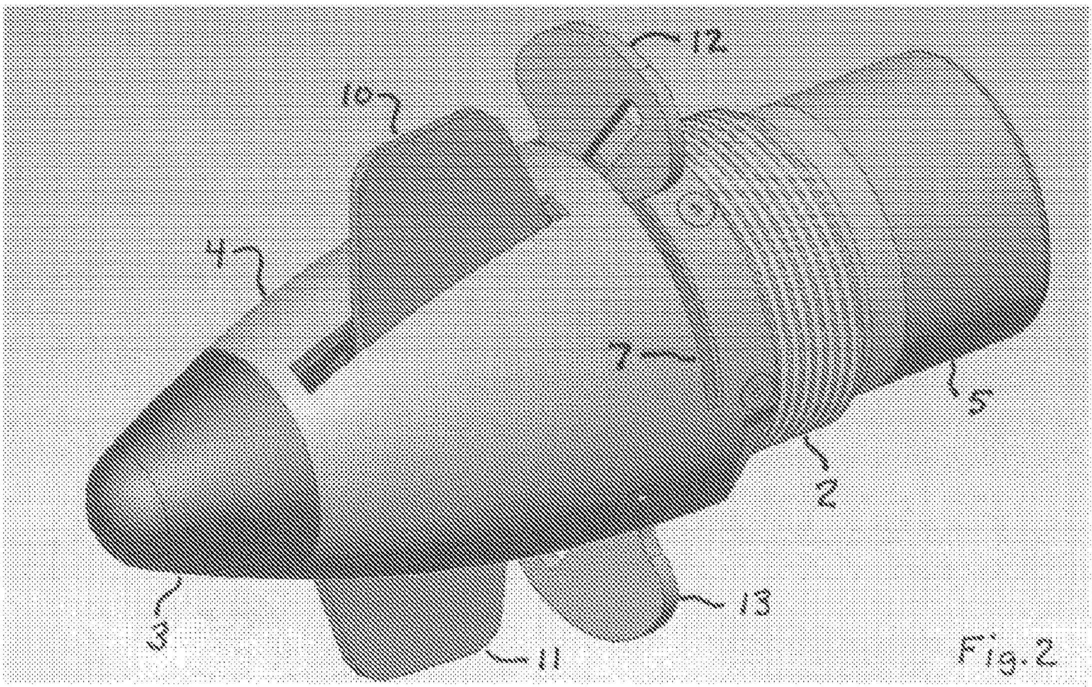


Fig. 2

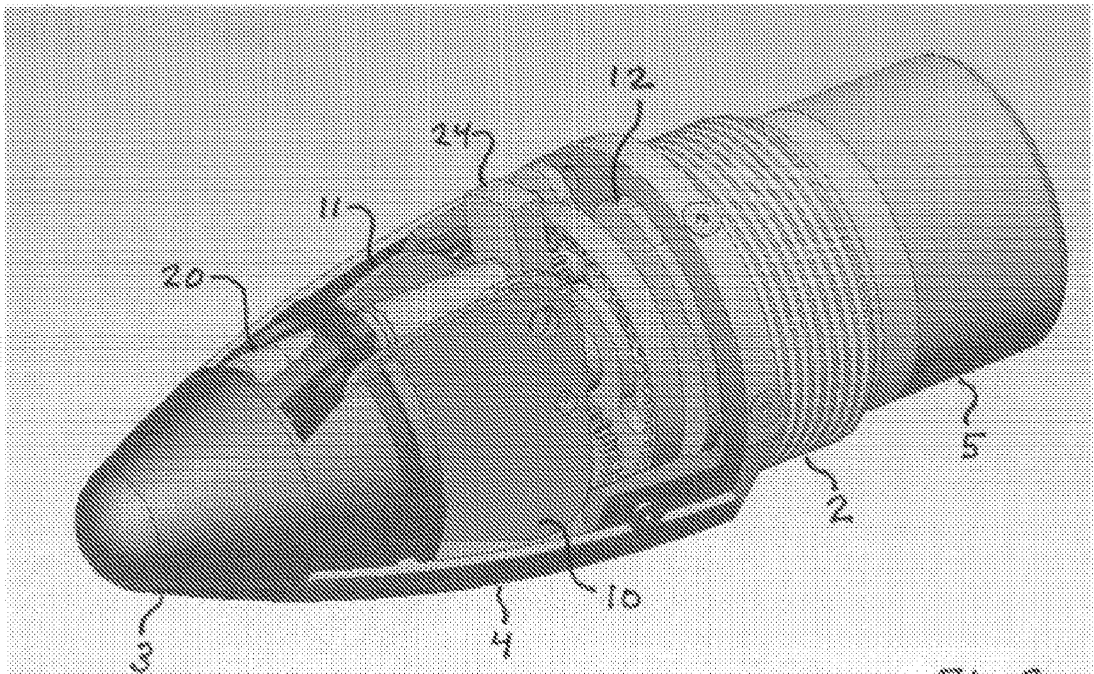


Fig. 3

Fig. 4 Fuze shown with nose and cover removed all brakes retracted

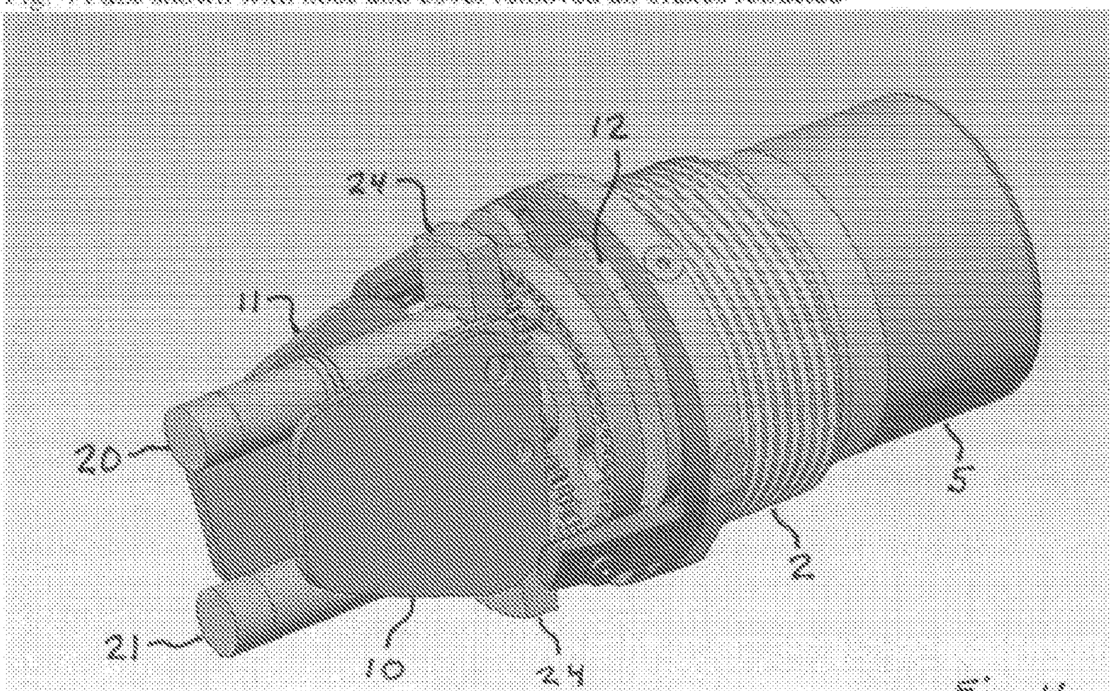


Fig. 4

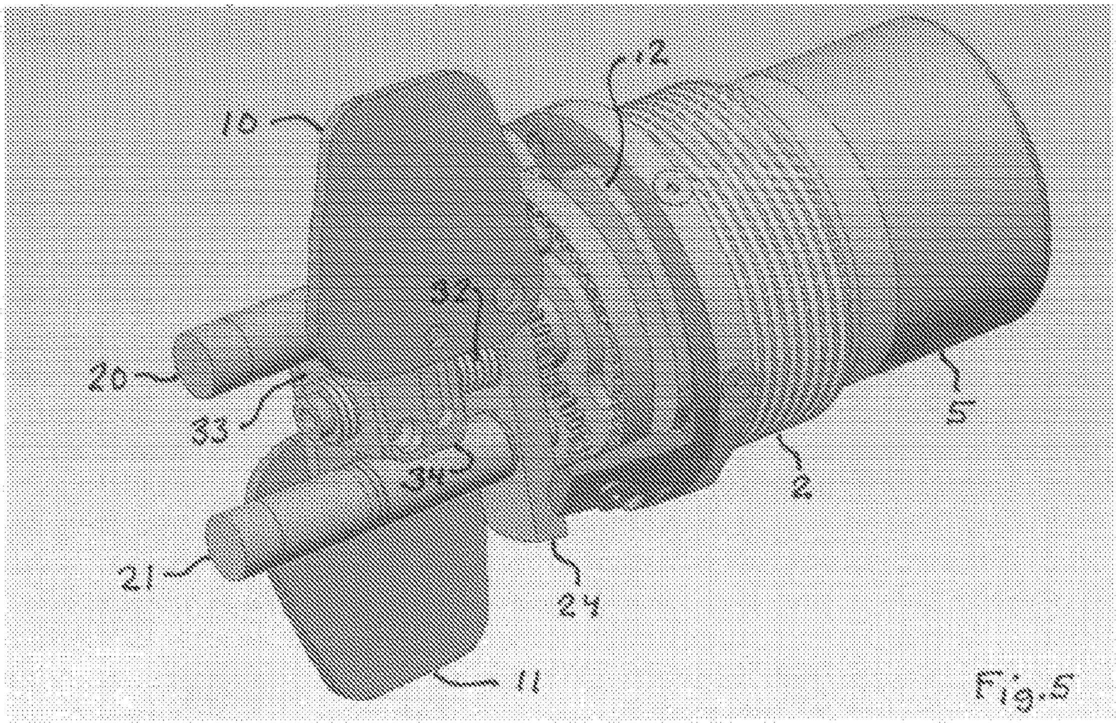


Fig.5

Fig. 6 Fuze with spin and air break fins deployed

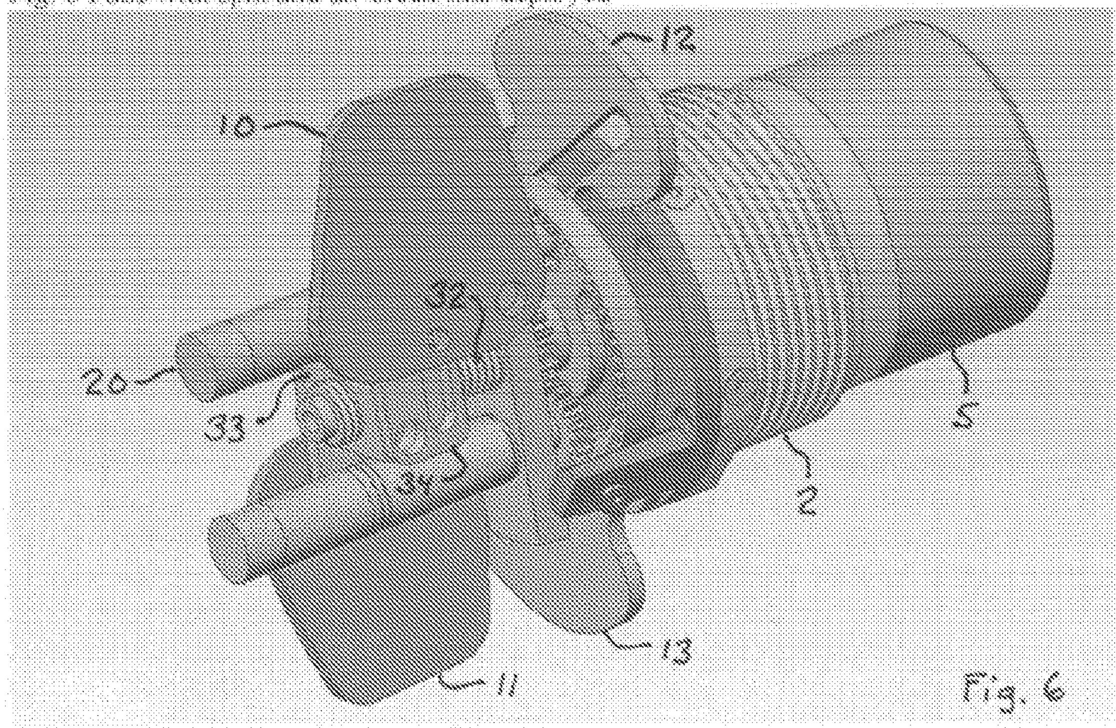


Fig. 6

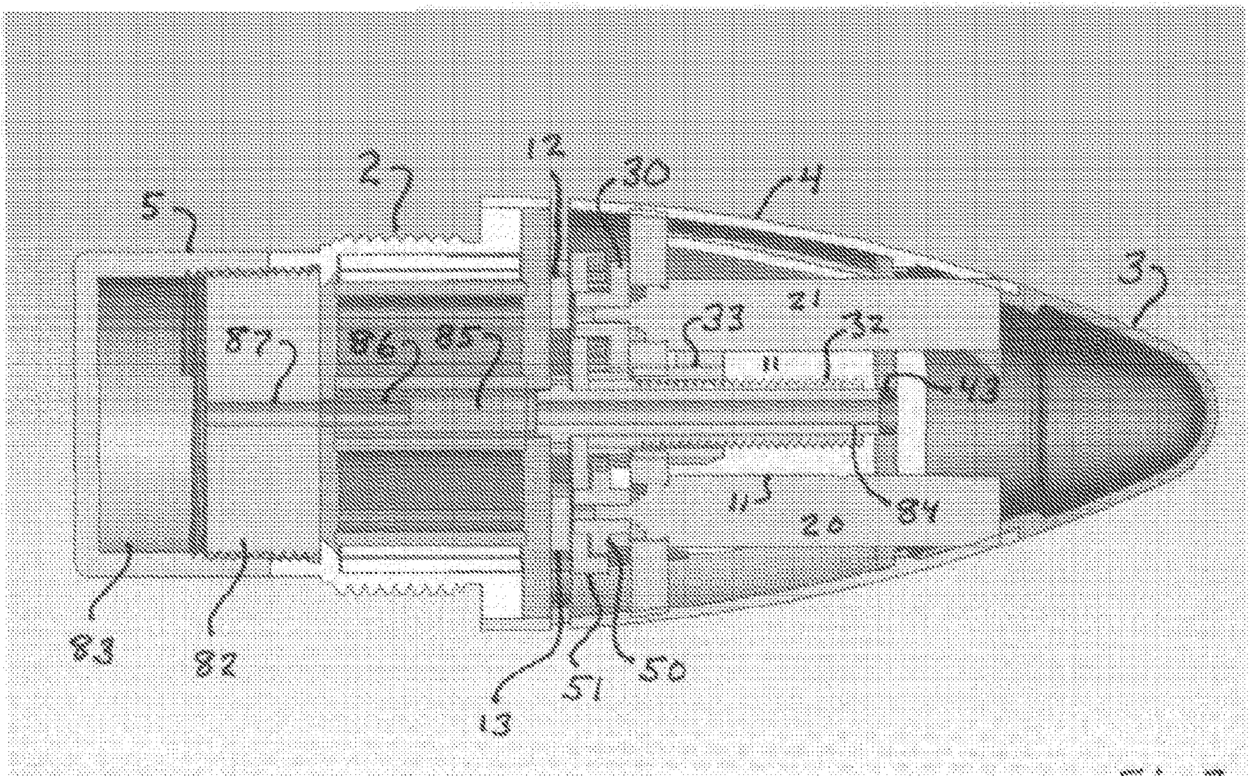


Fig. 7

Fig. 8 Pass-out awa isometric with brake fins deployed

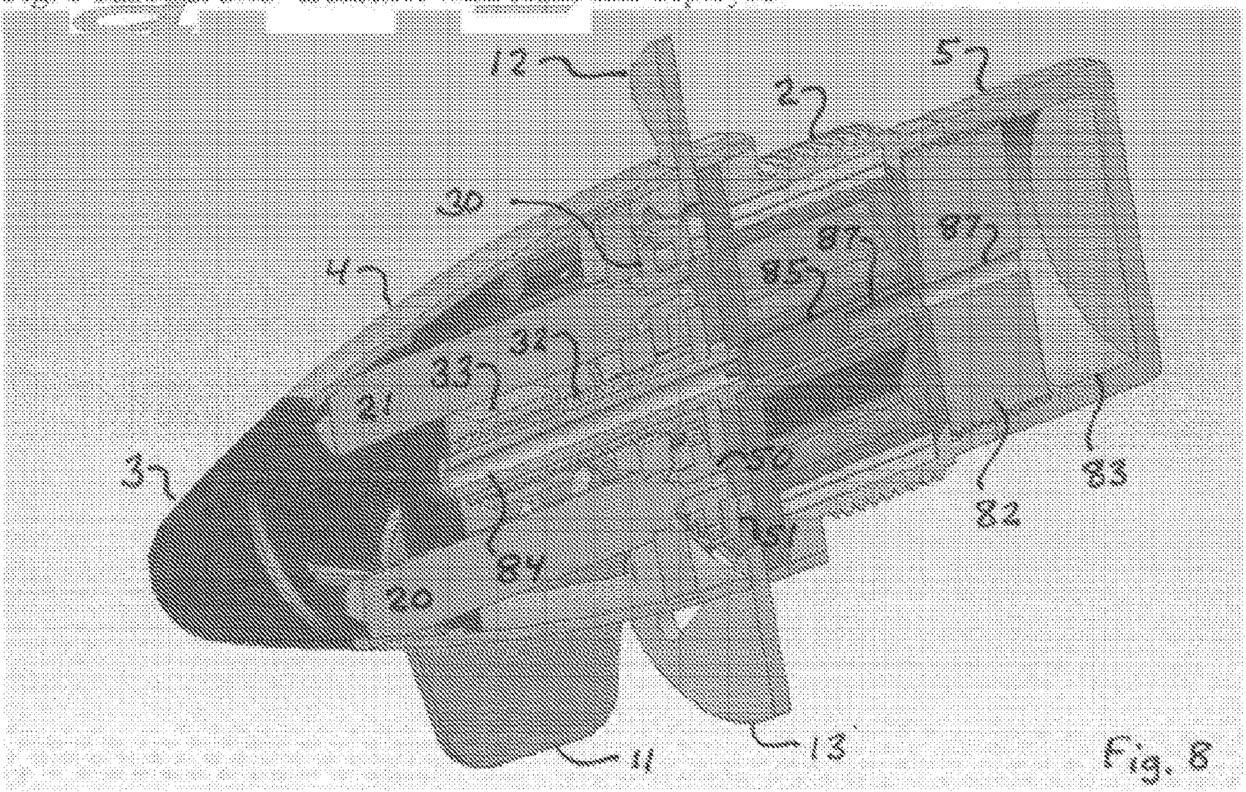


Fig. 8

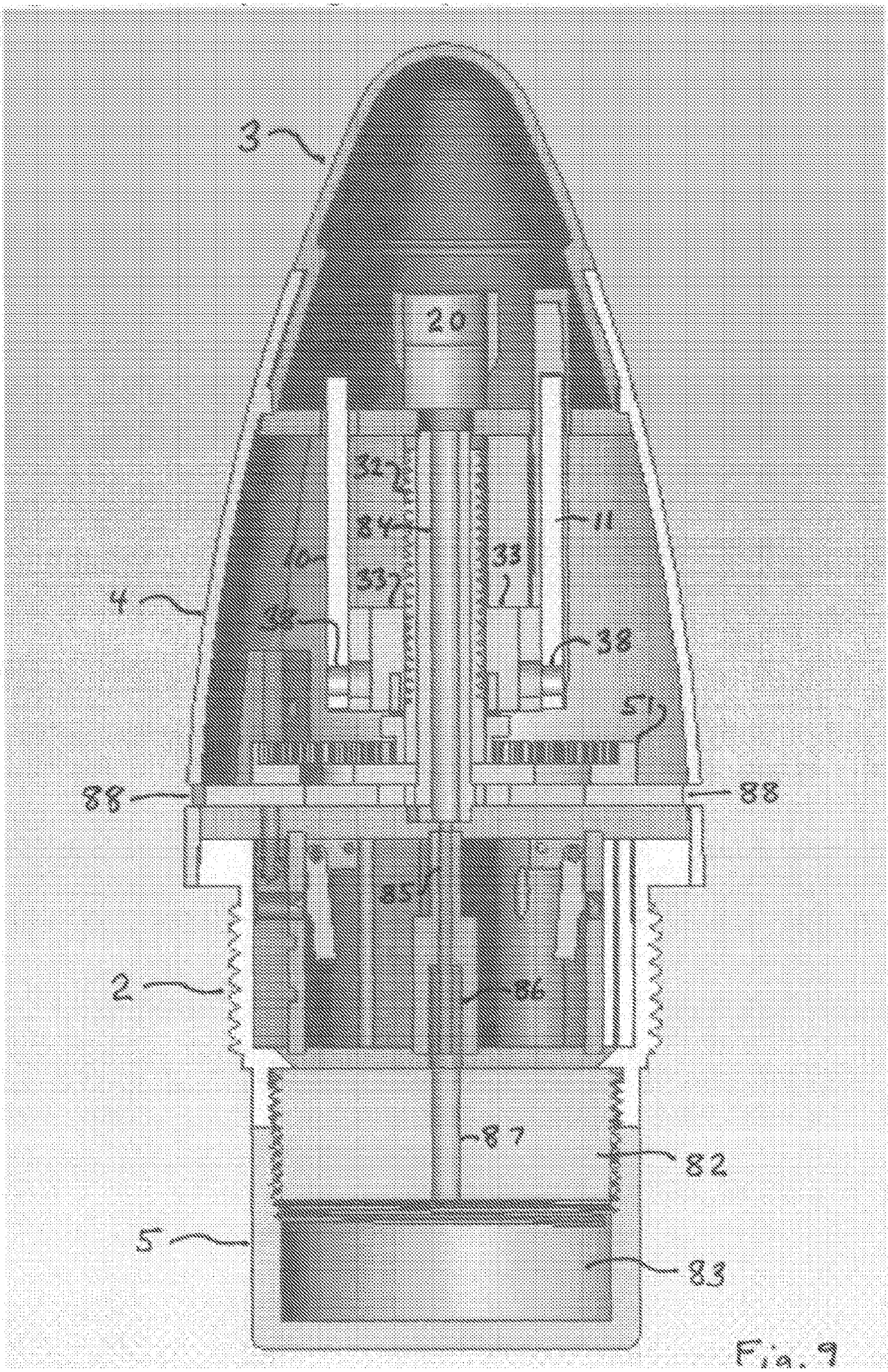


Fig. 9

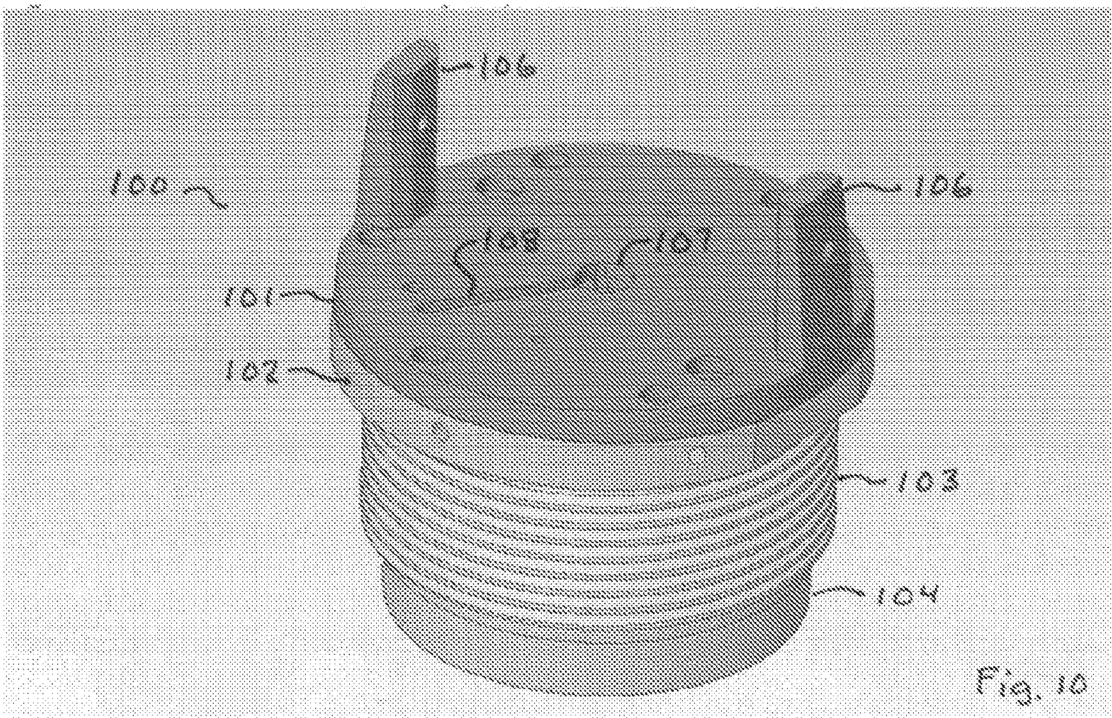


Fig. 10

Fig. 11 Fuze fuel cell battery activation arms up

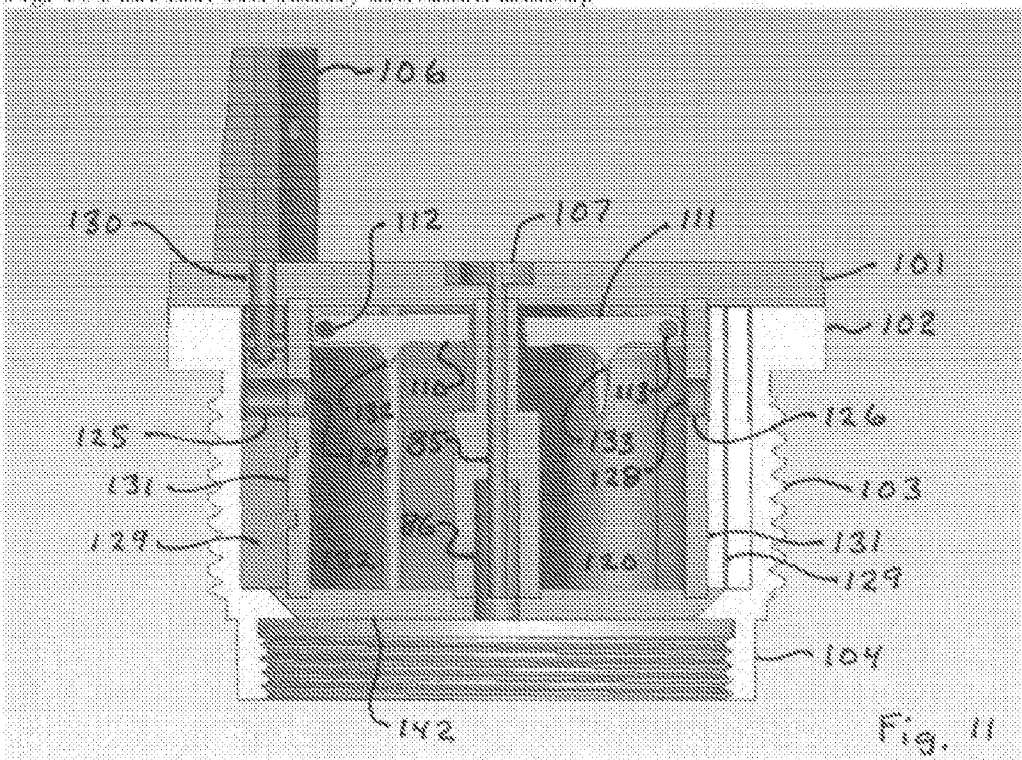


Fig. 11

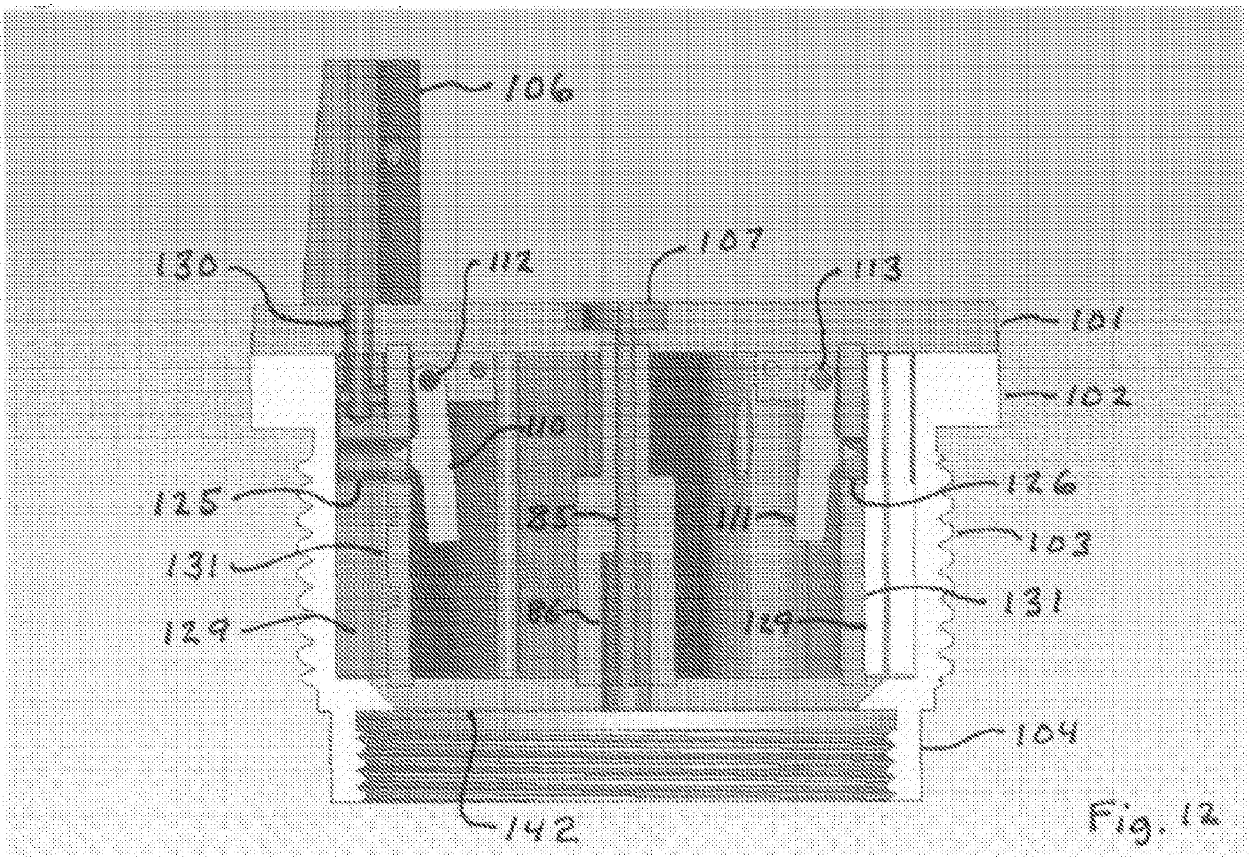
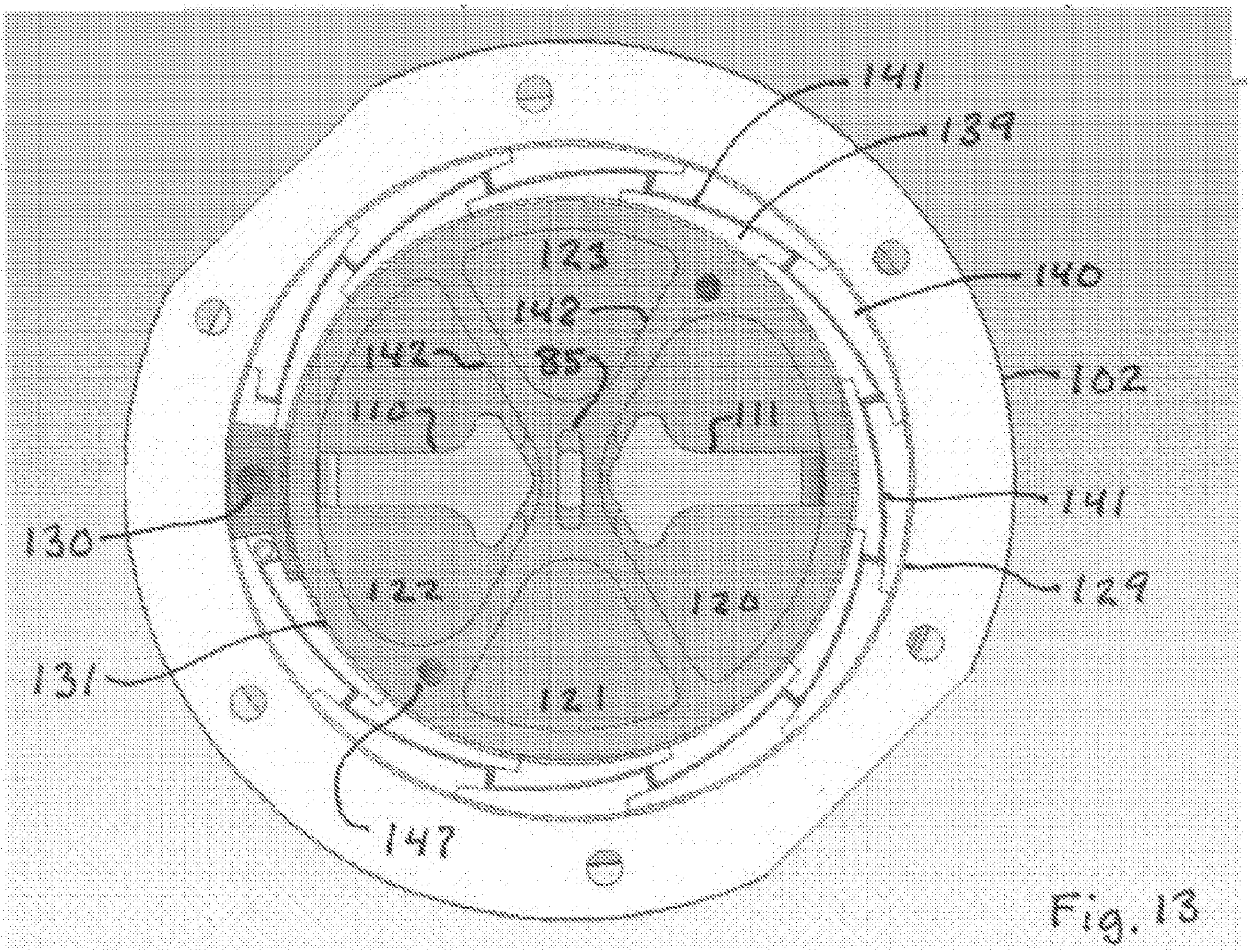

106
107
130
112
113
101
102
110
125
126
85
111
103
131
131
129
86
129
104
142

Fig. 12


141
139
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140
142
142
85
102
110
111
141
130
129
122
120
131
121
147

Fig. 13

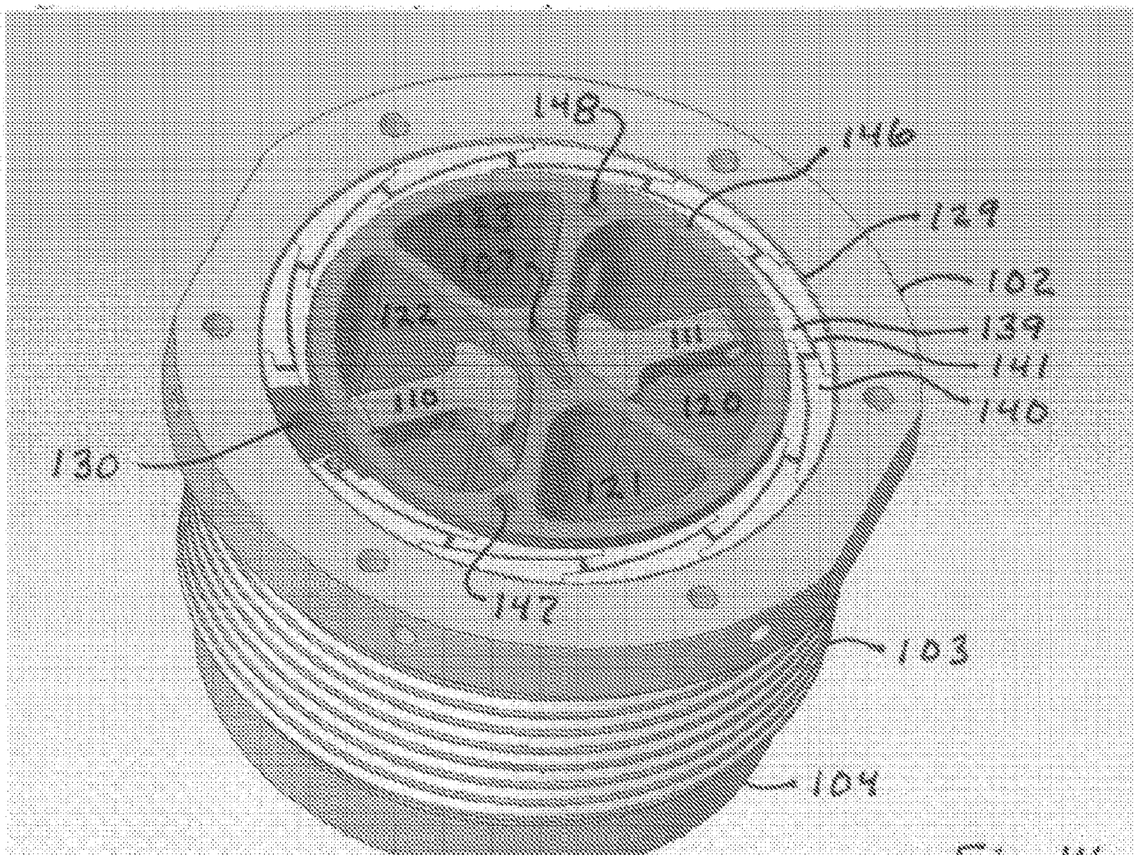

Fig. 14

Fig. 15 Fuze fuel cell battery outer shell only

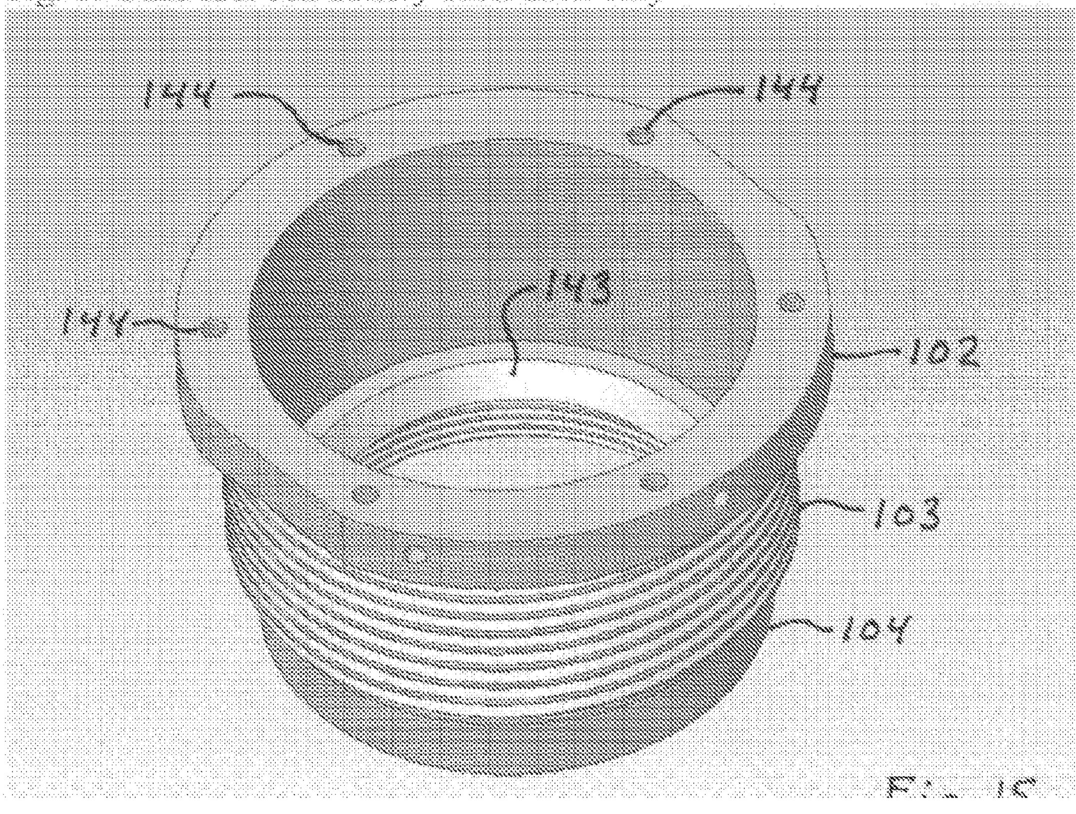

Fig. 15

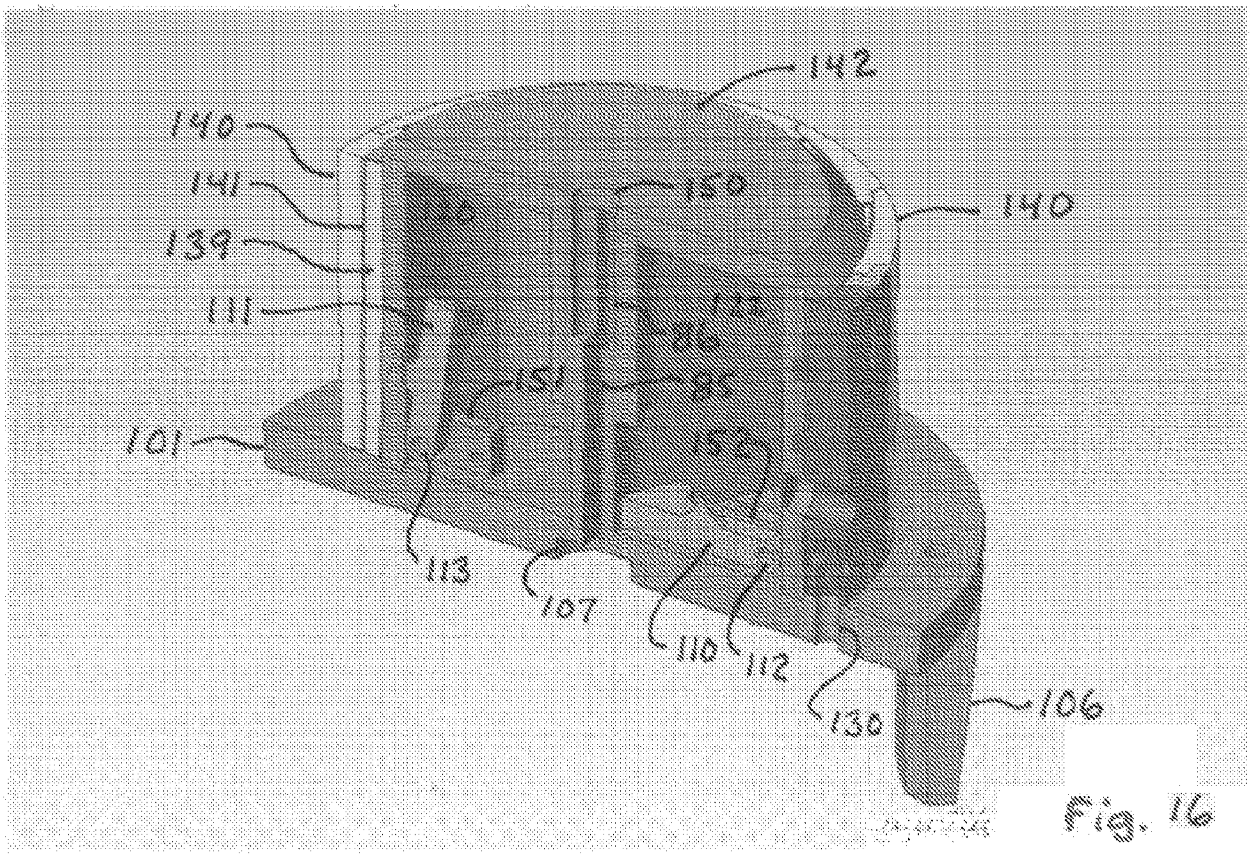
142
140
141
139
111
150
140
86
151
85
101
152
113
107
110
112
130
106

Fig. 16

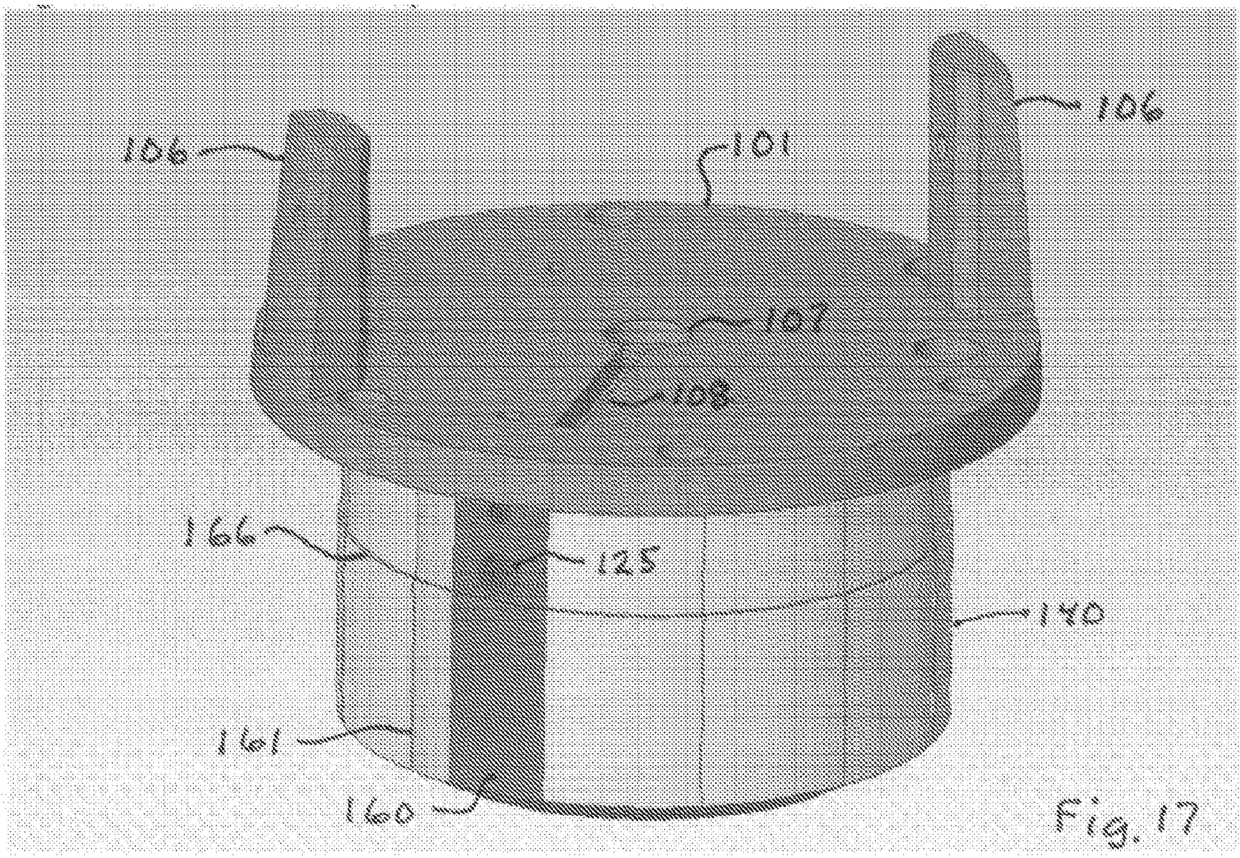

Fig. 17

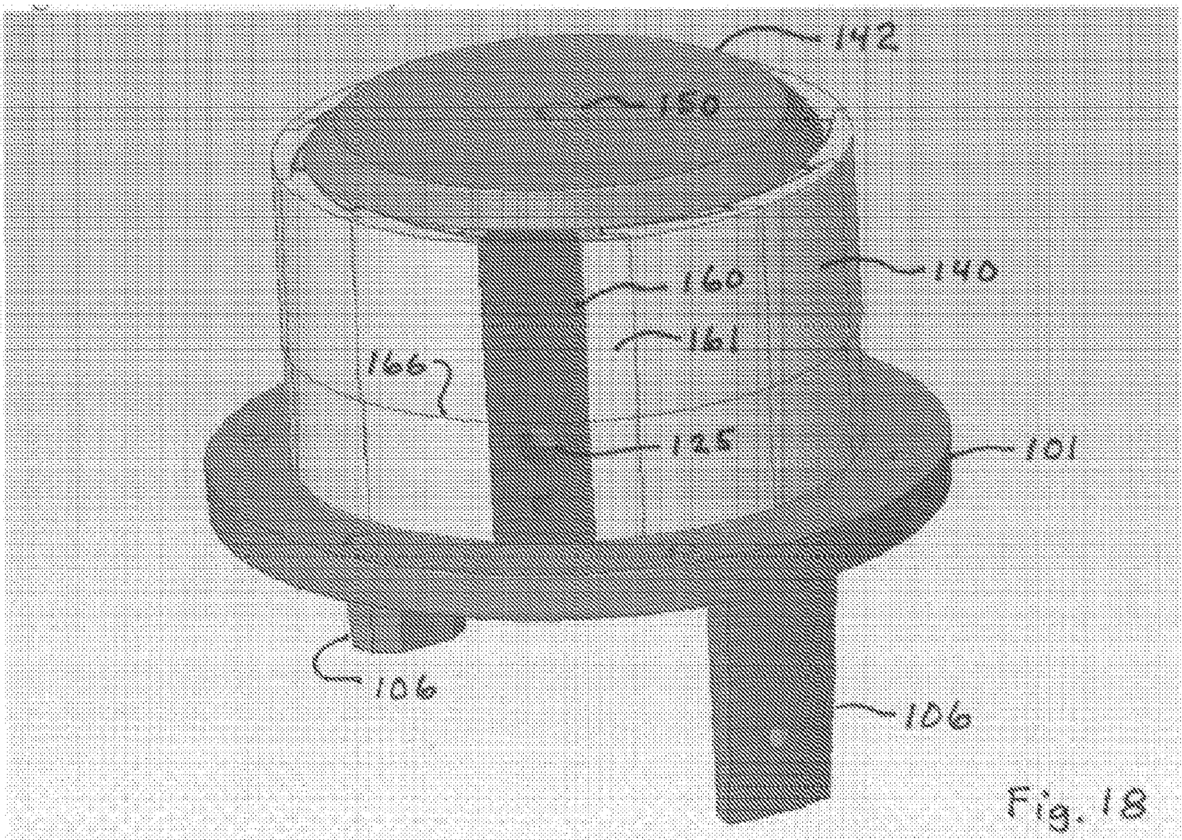

Fig. 18

Fig. 19 Fuze fuel cell stack assembly only

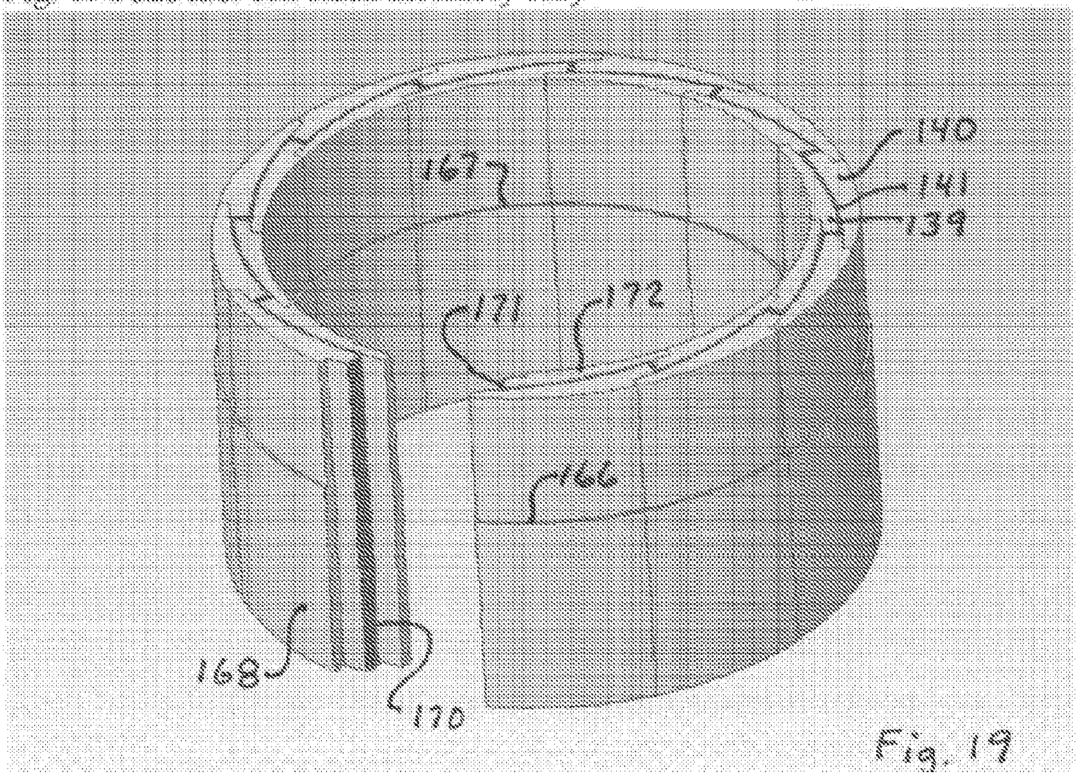

Fig. 19

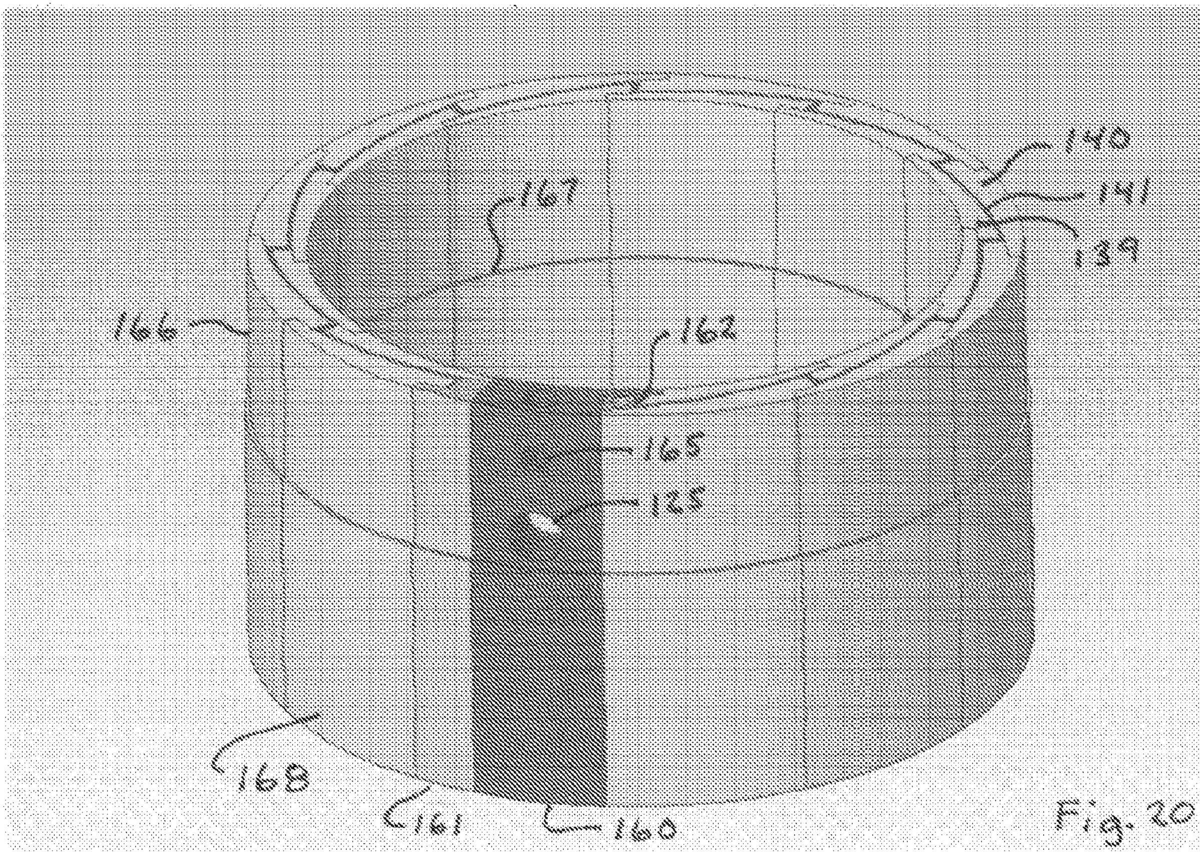

Fig. 20

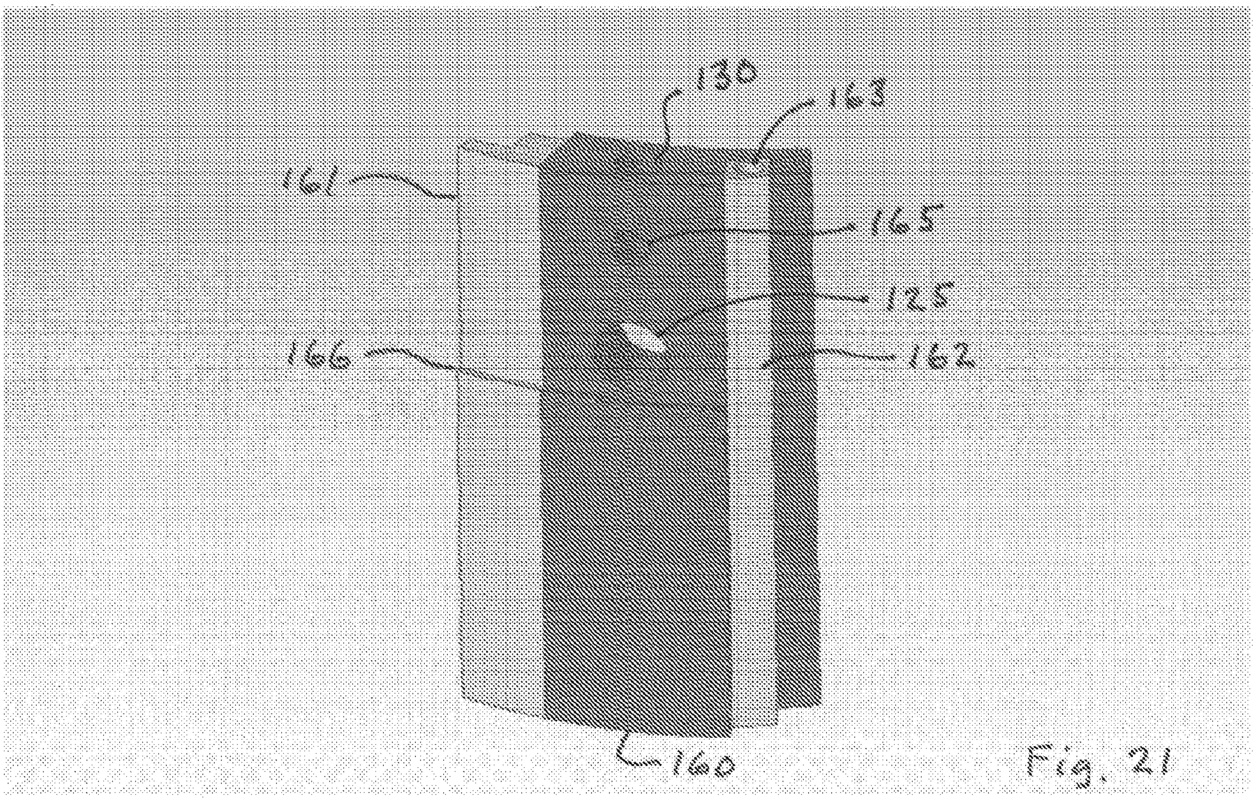

Fig. 21

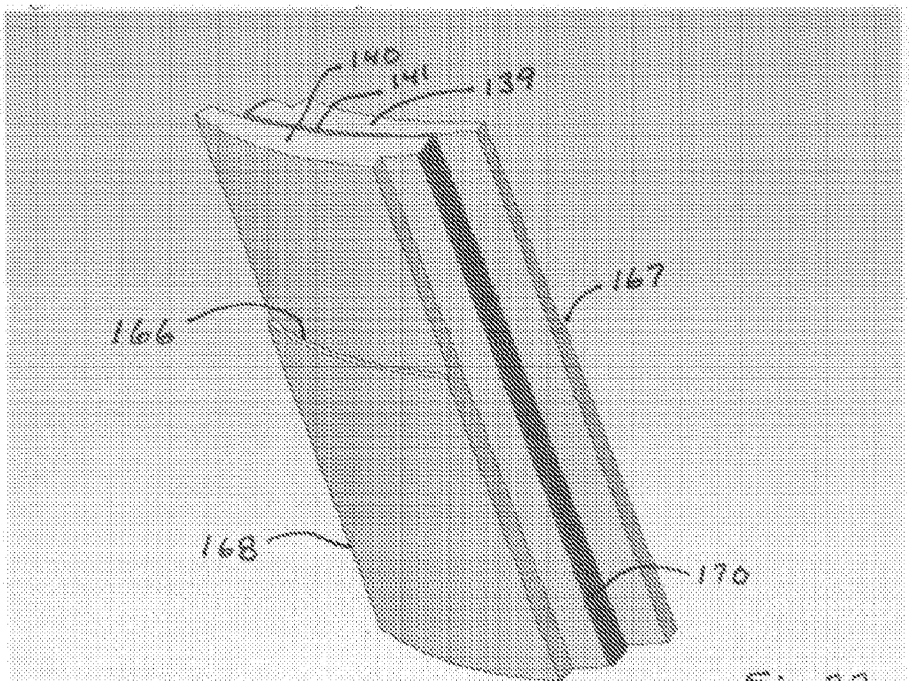

Fig. 22

Fig. 23 Fuze fuel cell with interlinked assembly shown

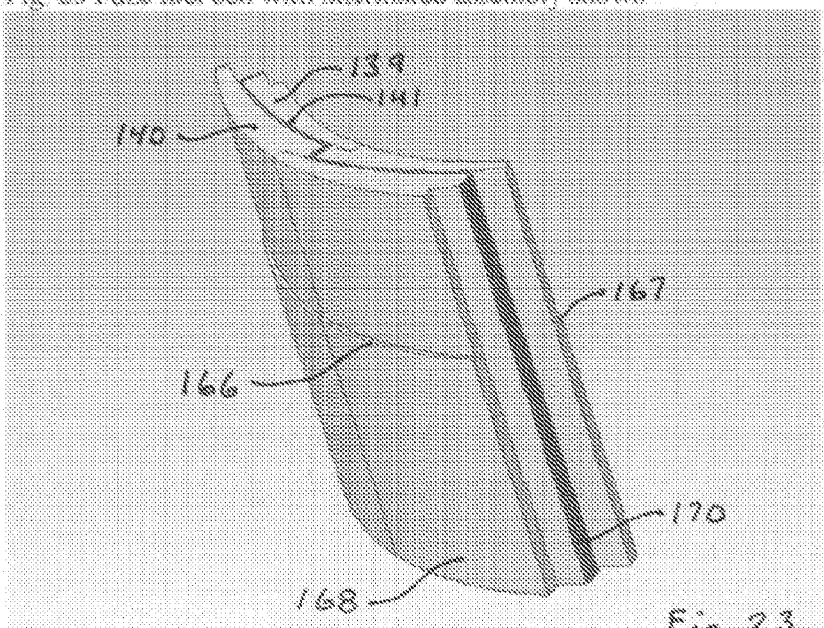

Fig. 23

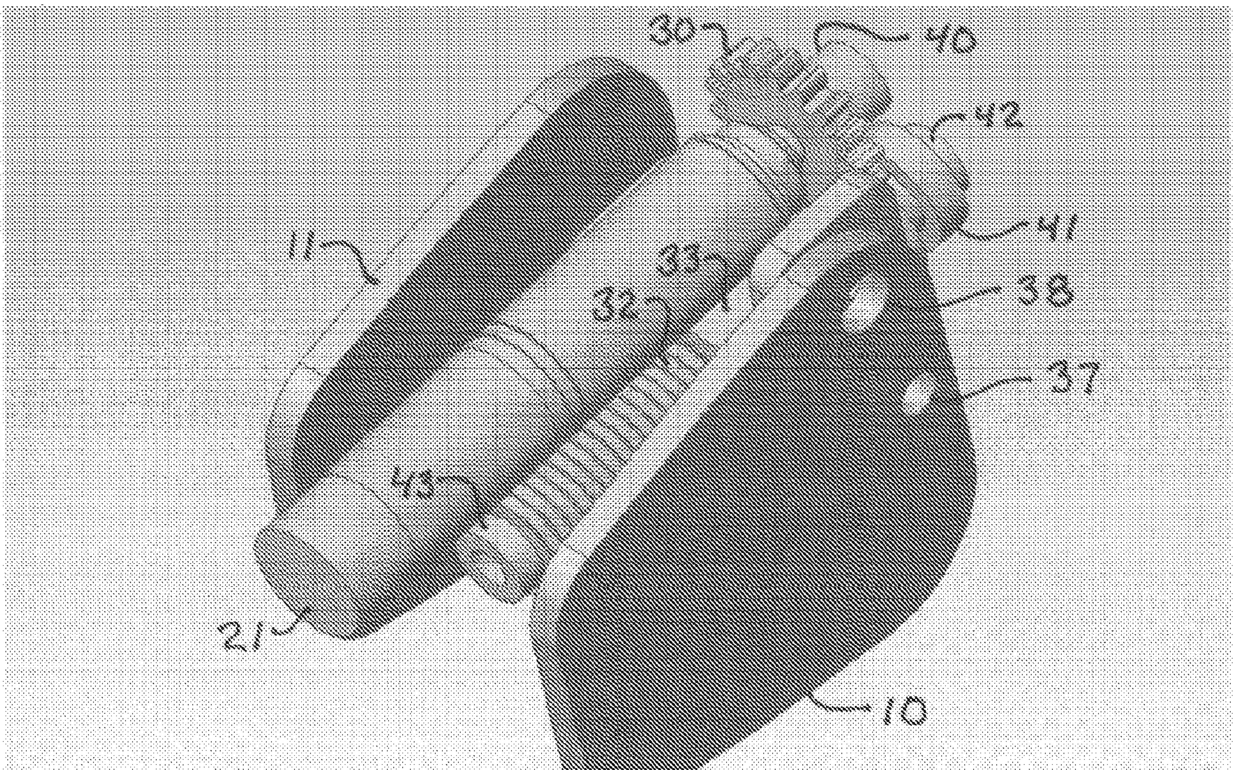

Fig. 24

Fig. 25 Fuze spin brake fins deployed

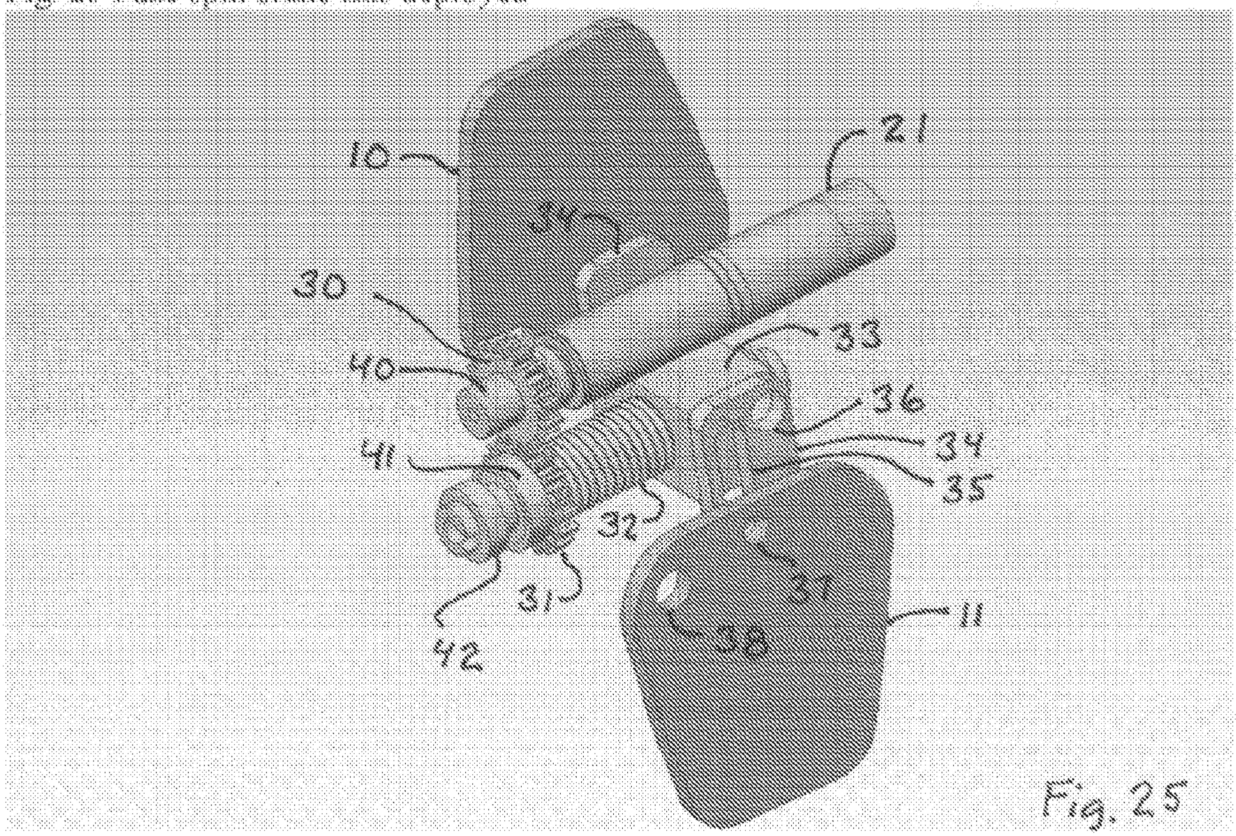

Fig. 25

18/22

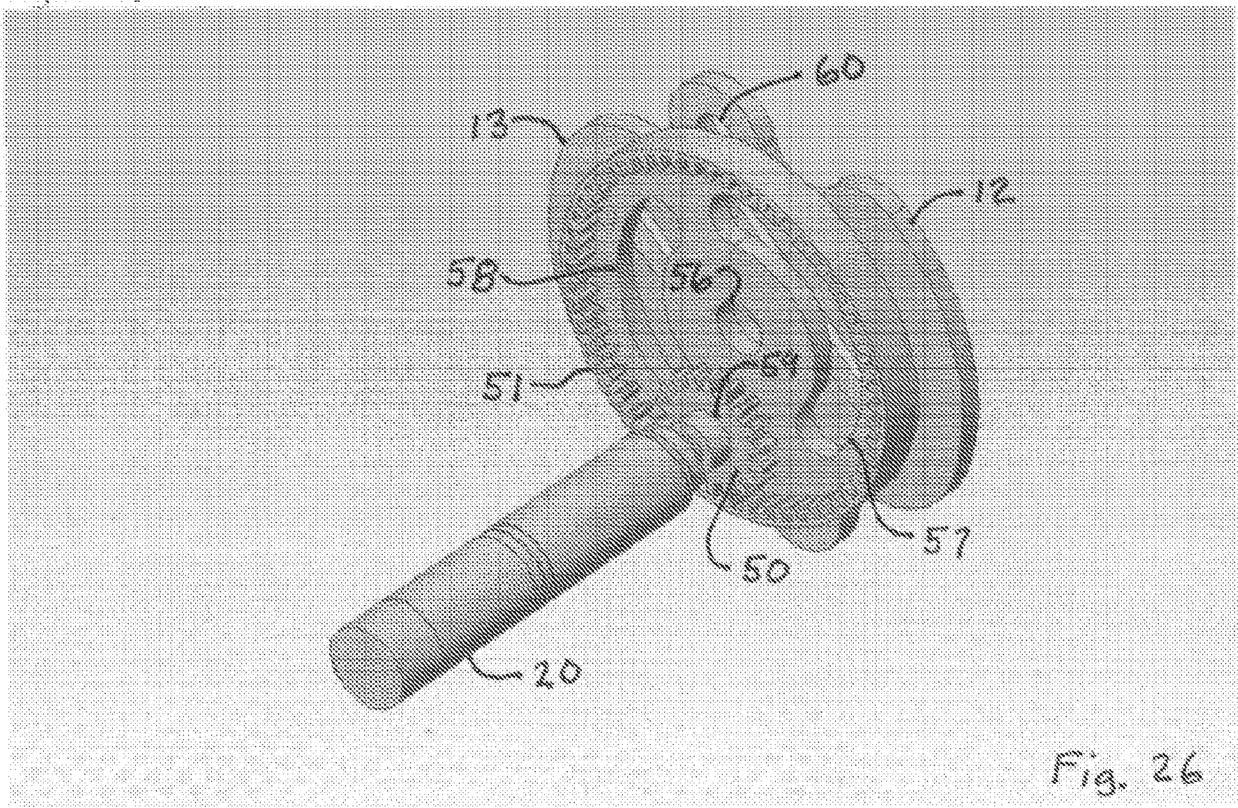

Fig. 26

Fig. 27 Fuze speed brake fins deployed

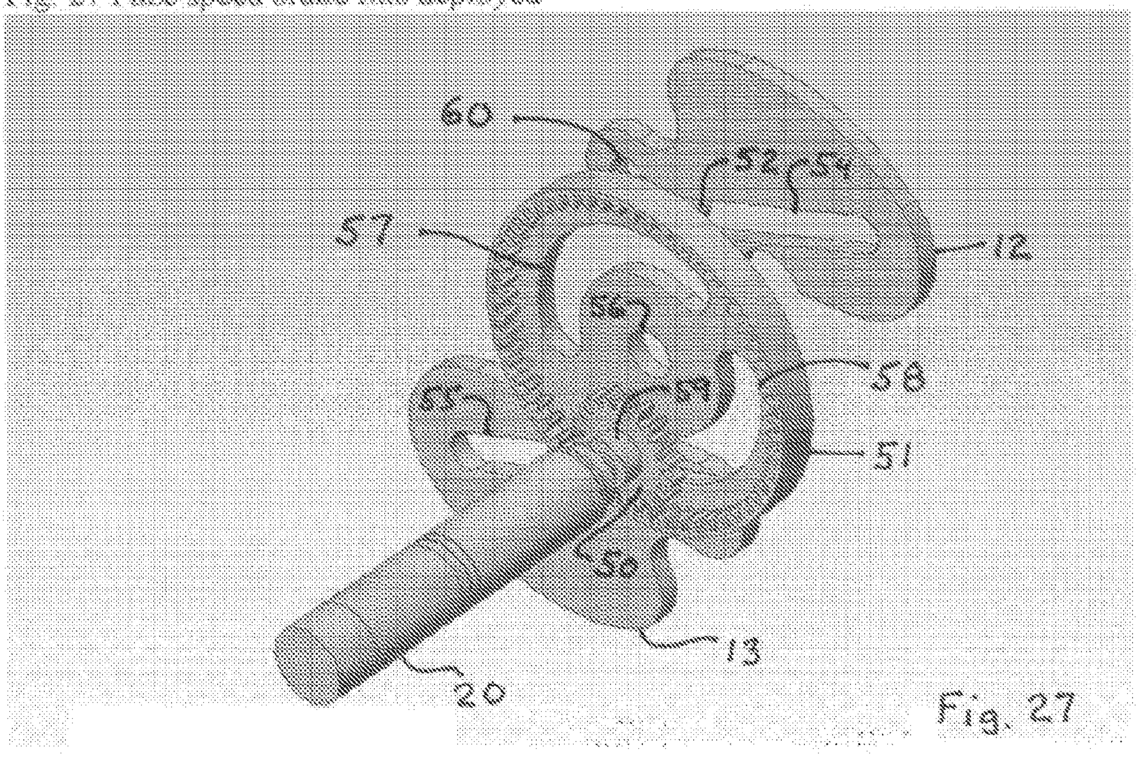

Fig. 27

19/22

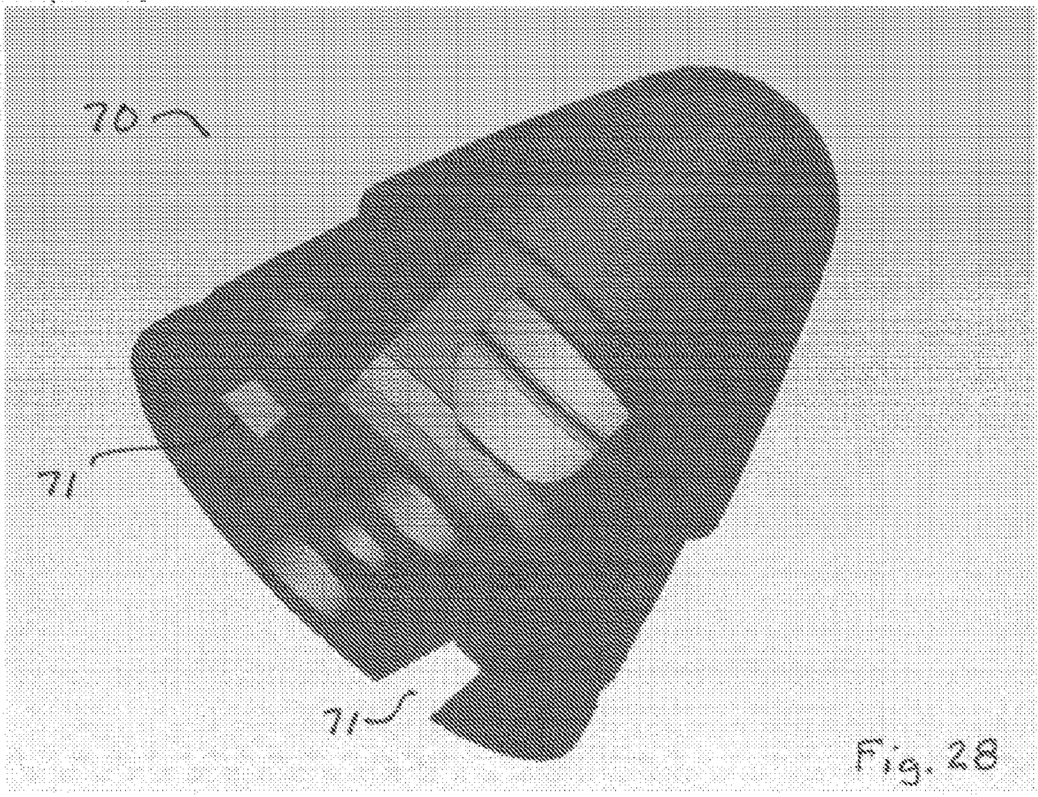

Fig. 28

Fig. 29 PEMERY COURSE CORRECTING FUZE

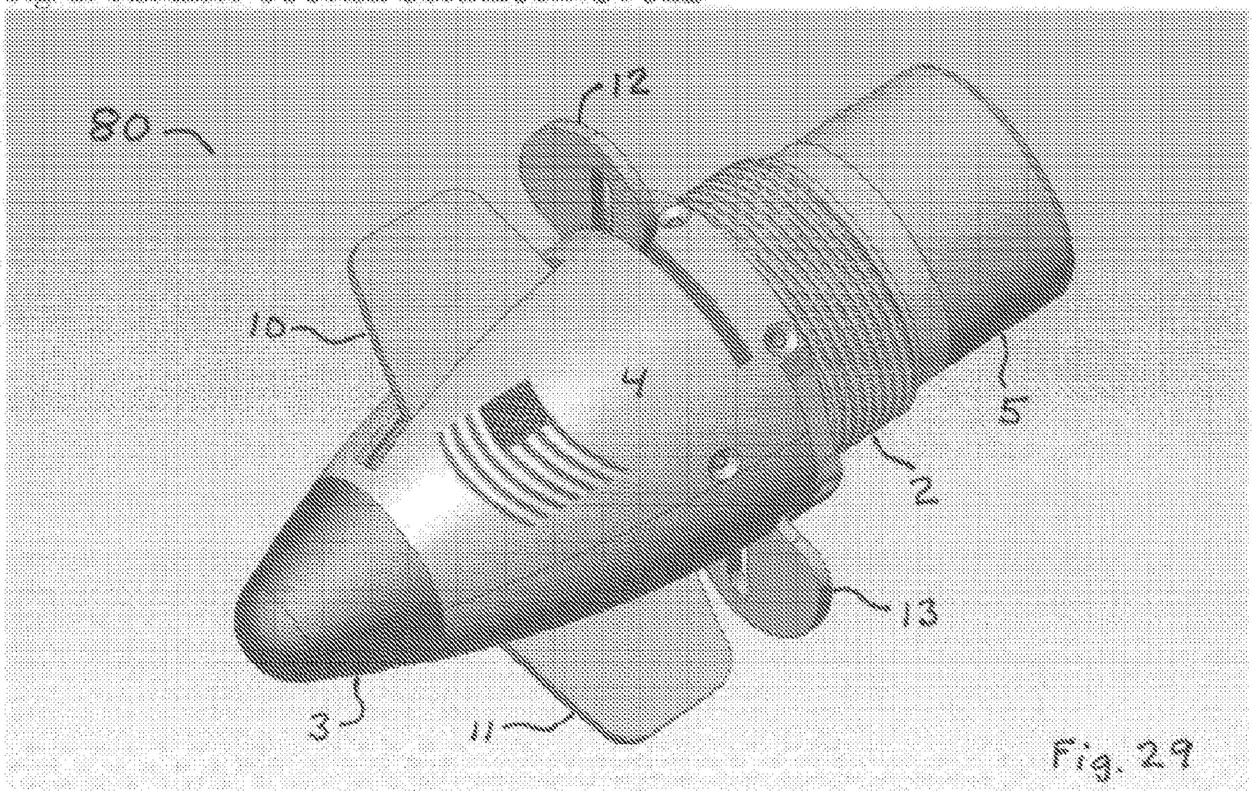

Fig. 29

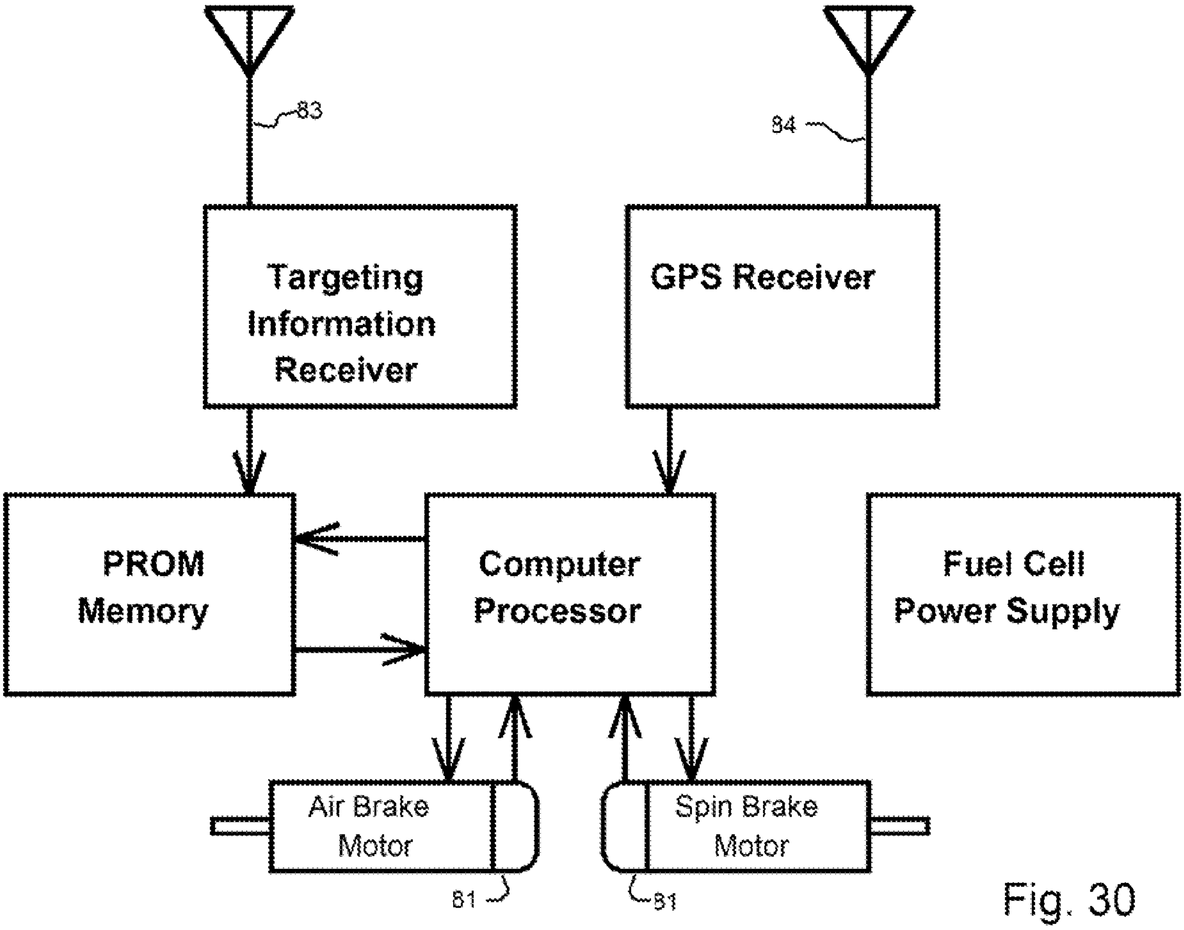
83
84
Targeting Information Receiver
GPS Receiver
PROM Memory
Computer Processor
Fuel Cell Power Supply
Air Brake Motor
Spin Brake Motor
81
81

Fig. 30