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Hockaday

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(54) **MICRO-FUEL CELL POWER DEVICES**

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(58) **Field of Search** **429/34, 30, 37, 429/91, 38, 39, 26, 127, 27; 427/115, 105**

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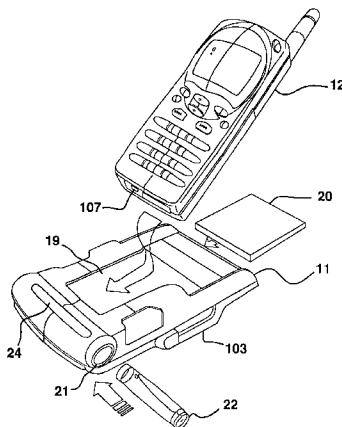
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(57) **ABSTRACT**

Coupling miniature liquid fueled fuel cells with portable electrical devices, with or without rechargeable batteries, lead to new appliance configurations: charging holster, piggyback charger, fuel cell integral with rechargeable battery, fuel cell with voltage regulating electronics, supplying fuel through a tube with a valve or pump, and supplying power through an electric cable between the fuel cell and the electronic device and the fuel cell power pack having independent communication and functions from the portable electrical devices. In all of these configurations there may be a window showing the fuel level of a disposable fuel ampoule or refillable fuel tank. Fuel is distributed through disposable fuel ampoules in blister packages, or refueling bottles. Adjustable moisture and thermal internal insulation allows fuel cells to run at elevated temperatures. These design features permit greater performance, workability, and convenience to the user of these portable electronics. Additionally, these MICRO-FUEL CELL arrays, which pack more energy into a small space, may be mass produced on a plastic film in a reel-to-reel process.

32 Claims, 11 Drawing Sheets



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FIG. 1A

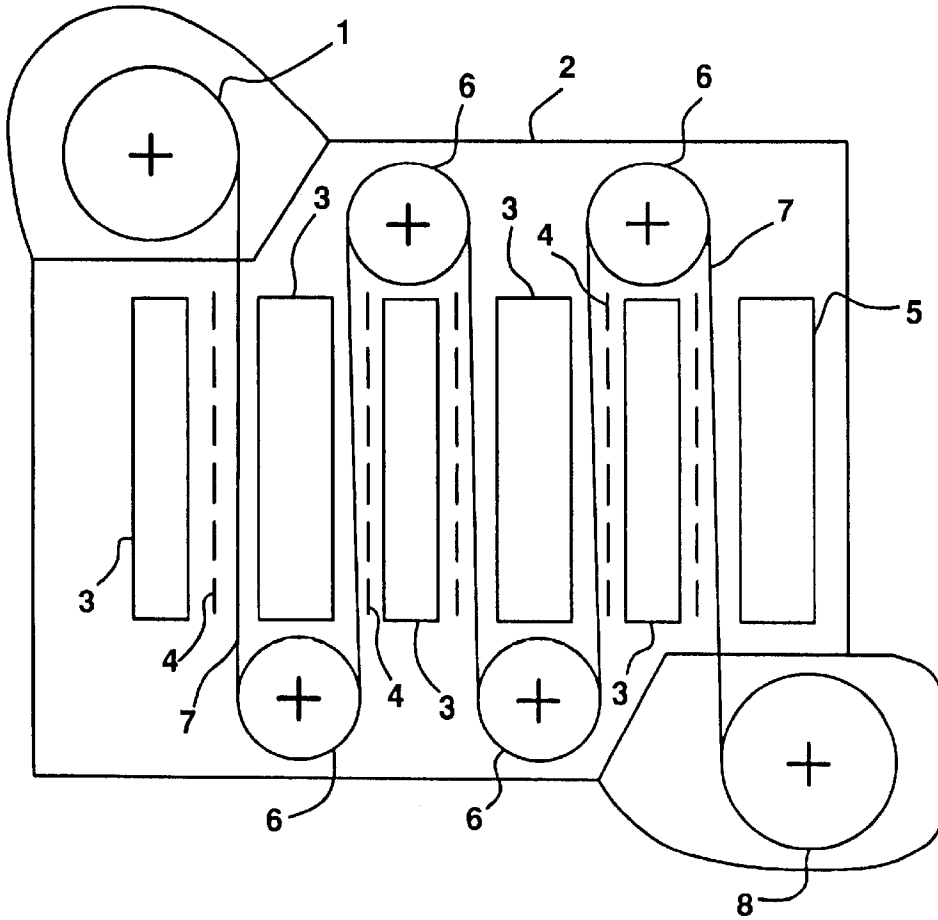
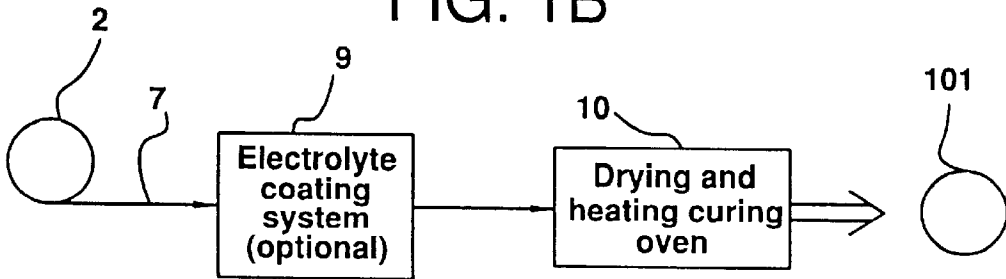


FIG. 1B



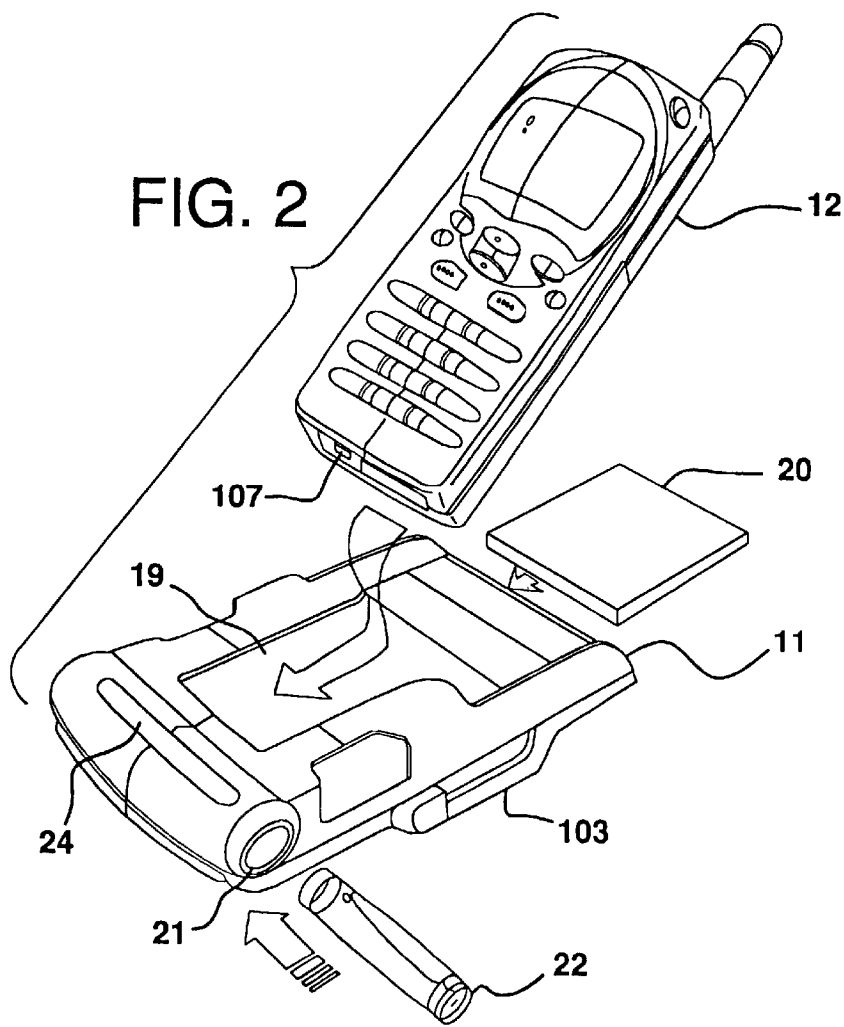


FIG. 3A

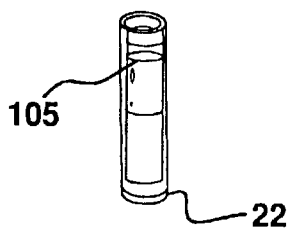


FIG. 3B

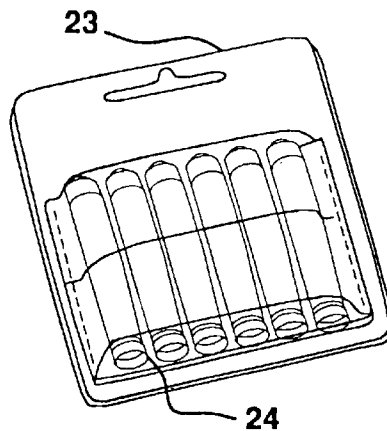


FIG. 4A

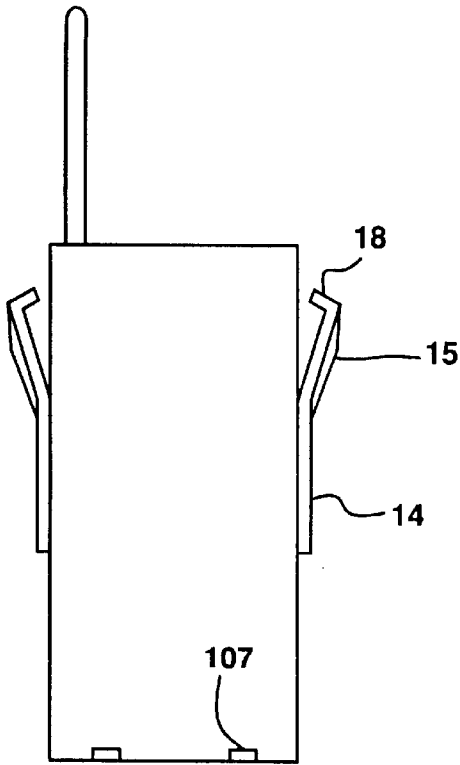


FIG. 4B

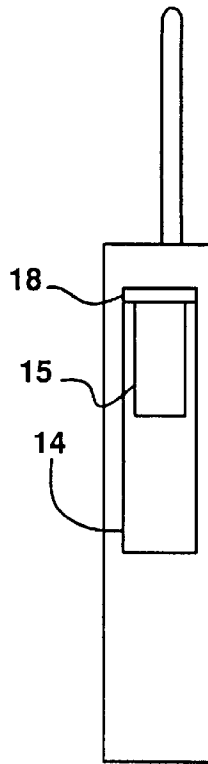


FIG. 4C

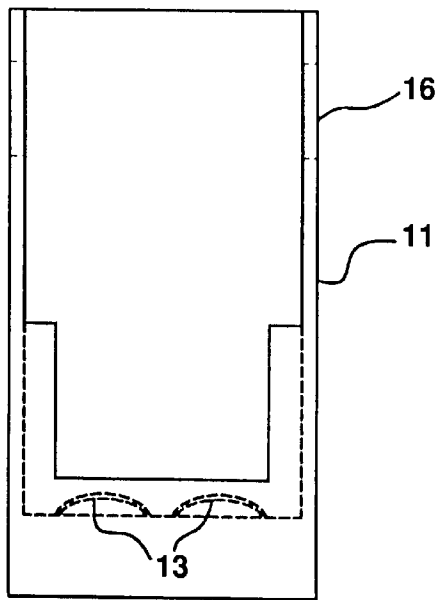
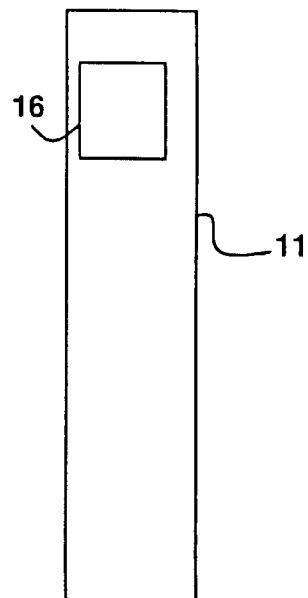


FIG. 4D



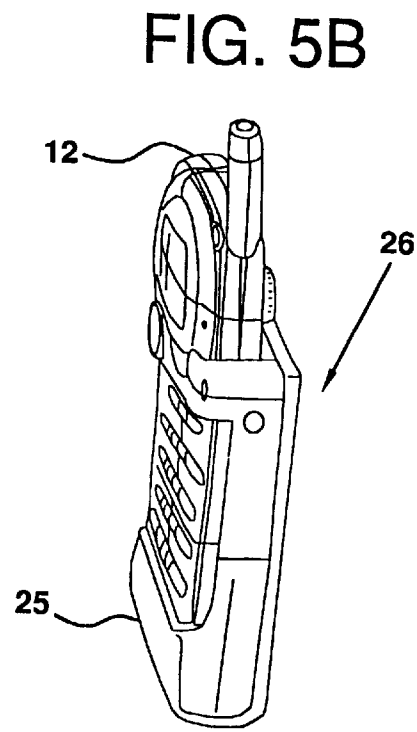
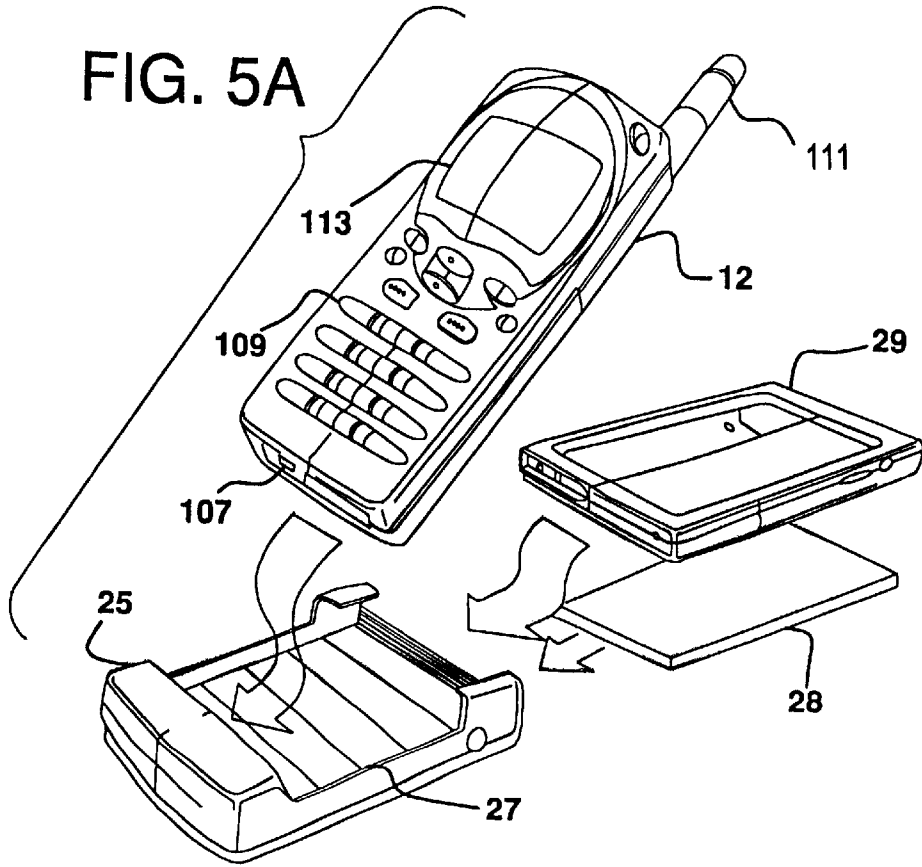


FIG. 6A

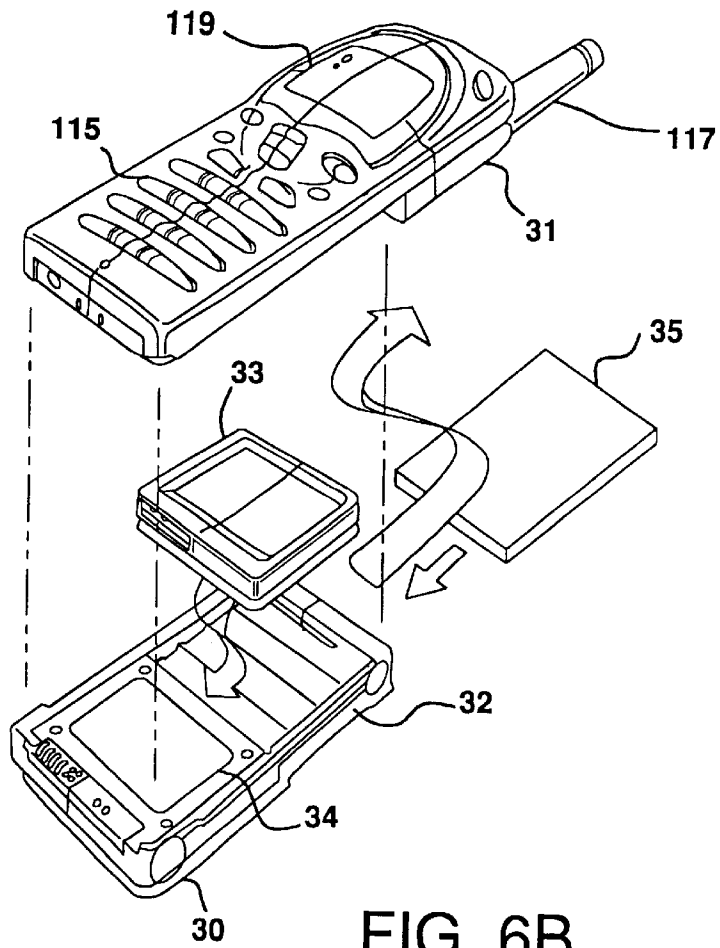


FIG. 6B

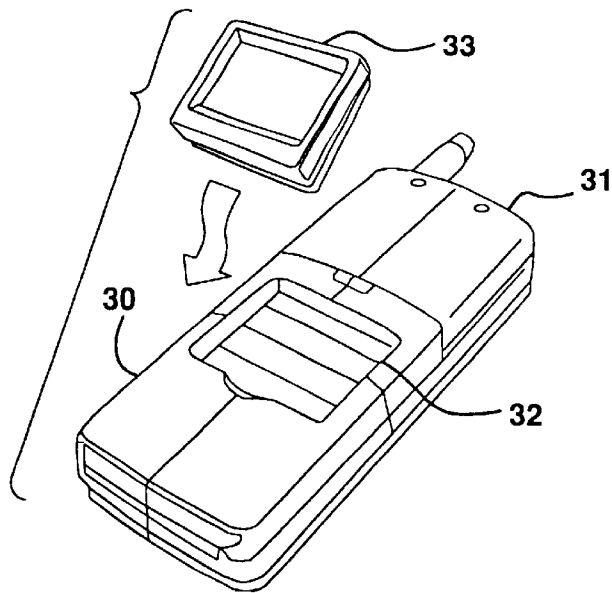


FIG. 7A

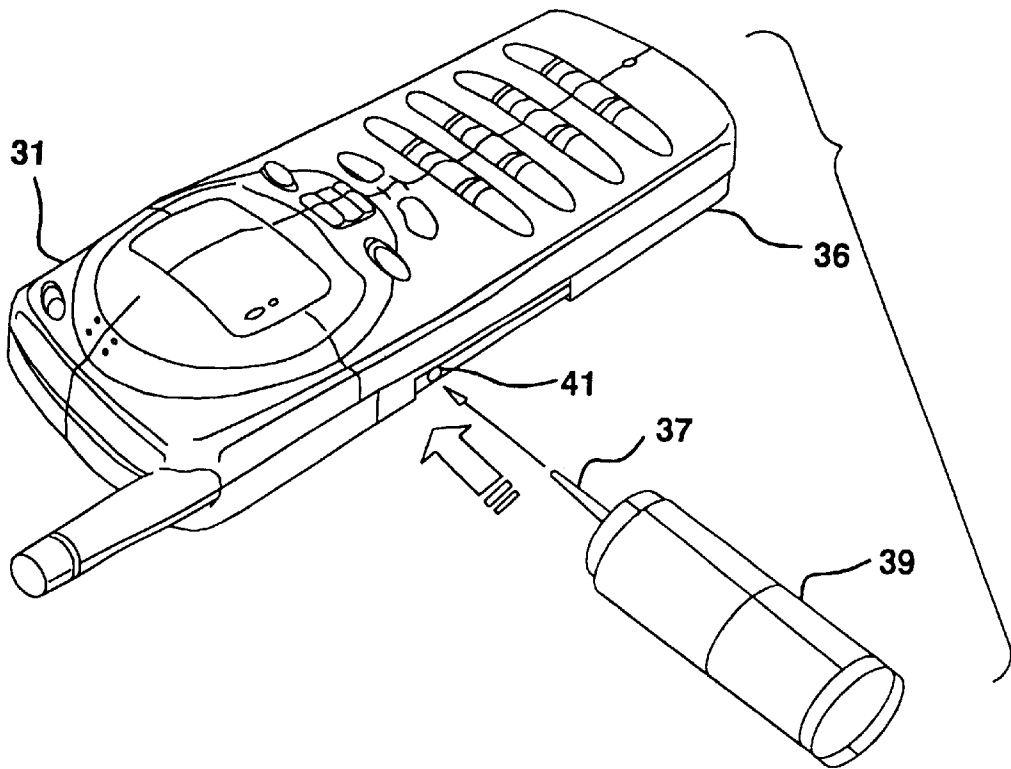


FIG. 7B

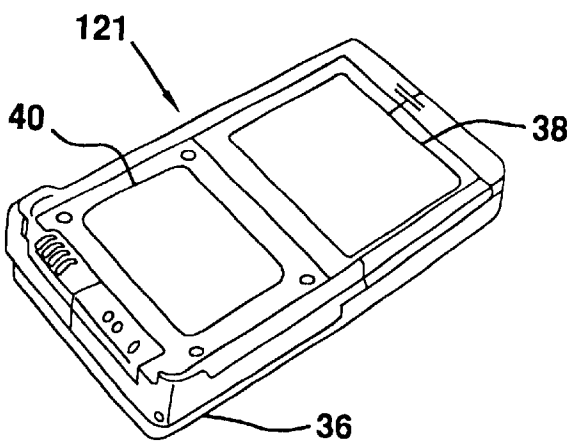


FIG. 8A

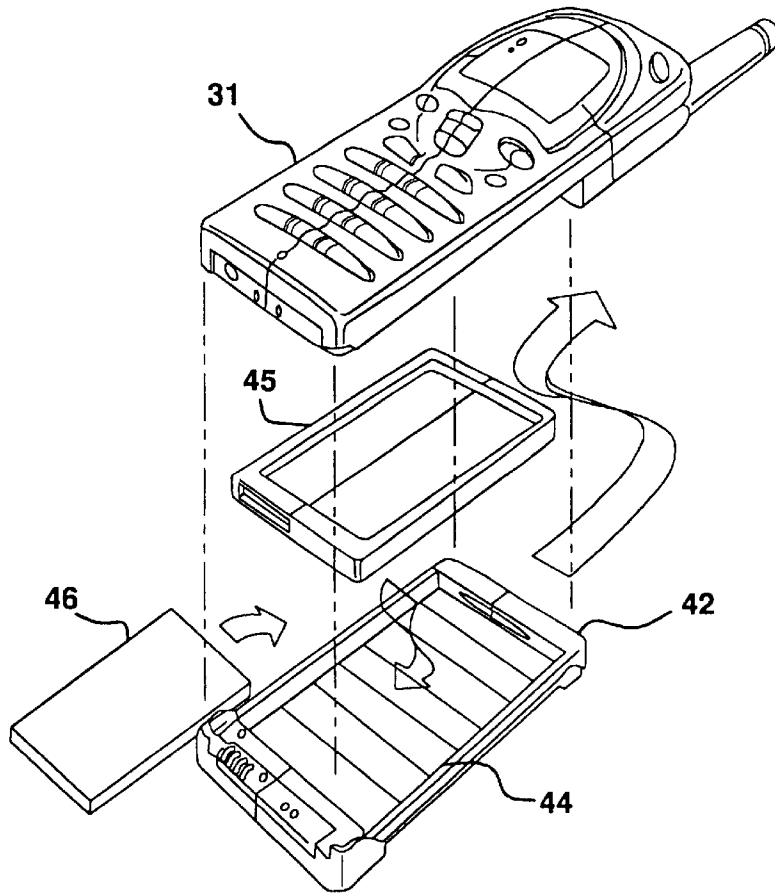


FIG. 8B

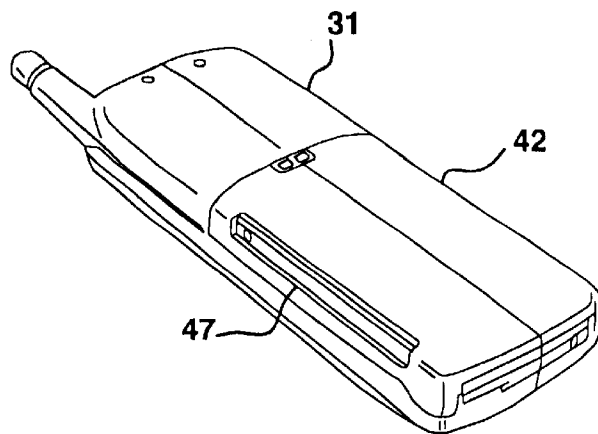


FIG. 9

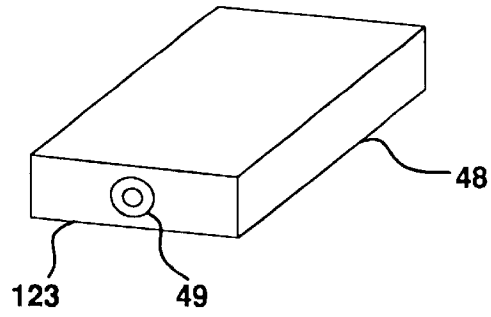


FIG. 10

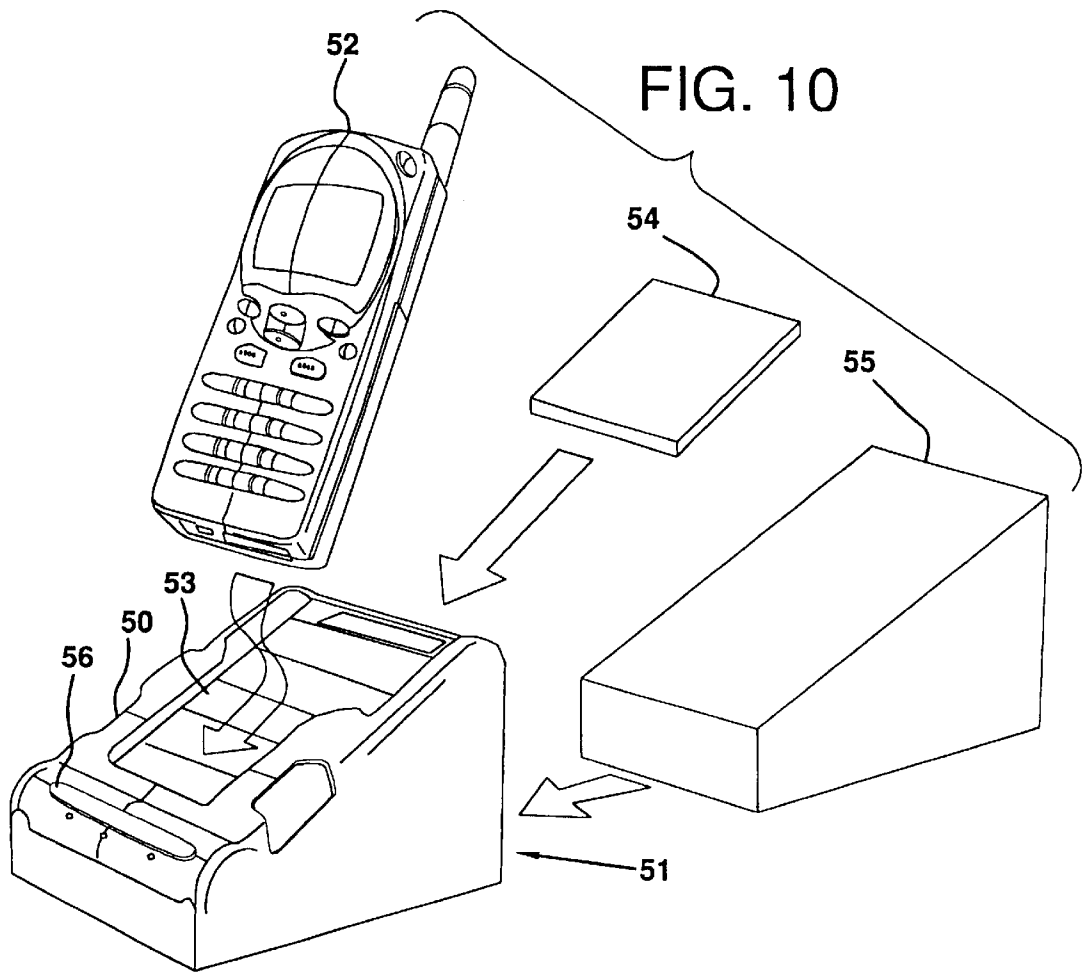


FIG. 11

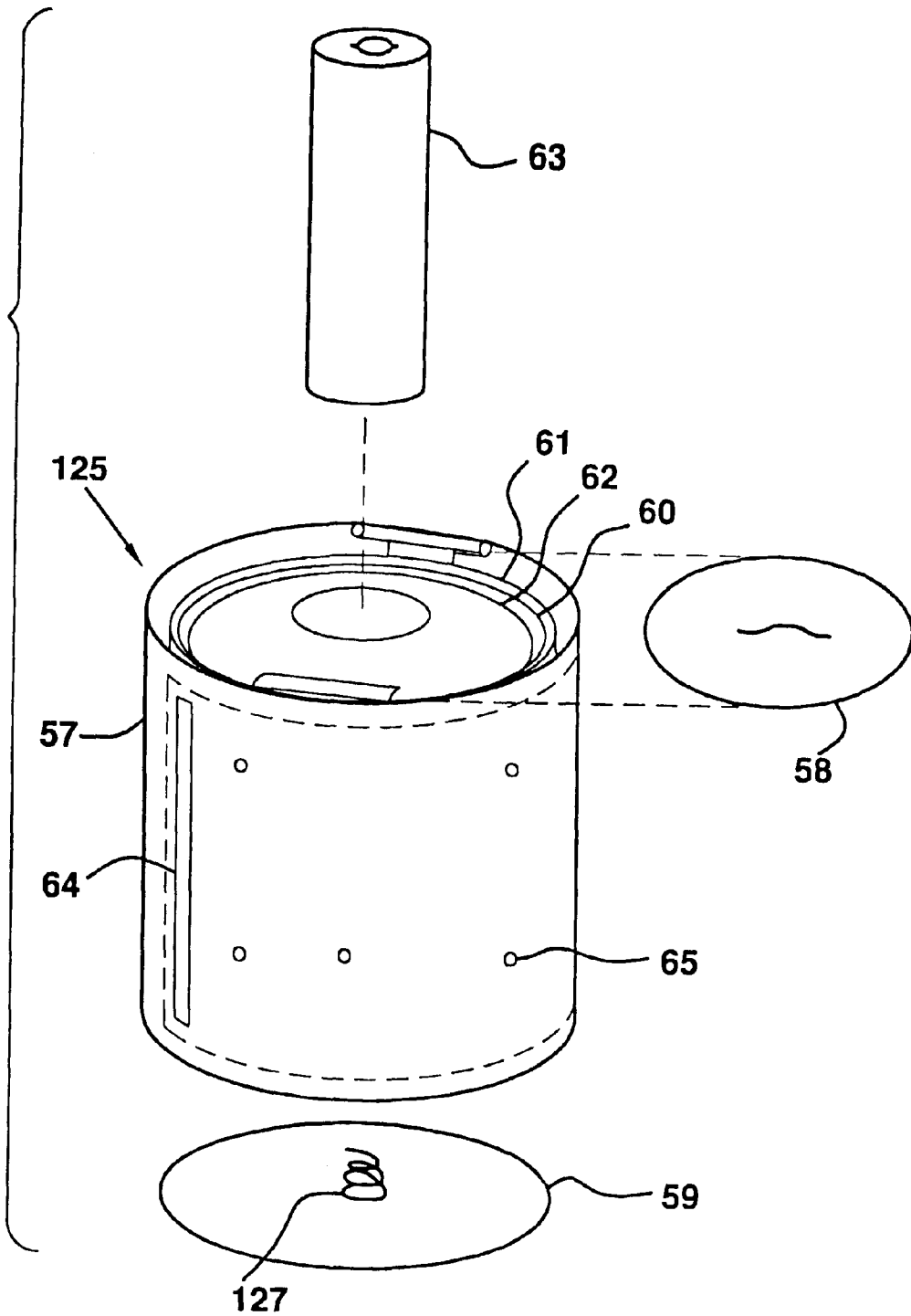


FIG. 12

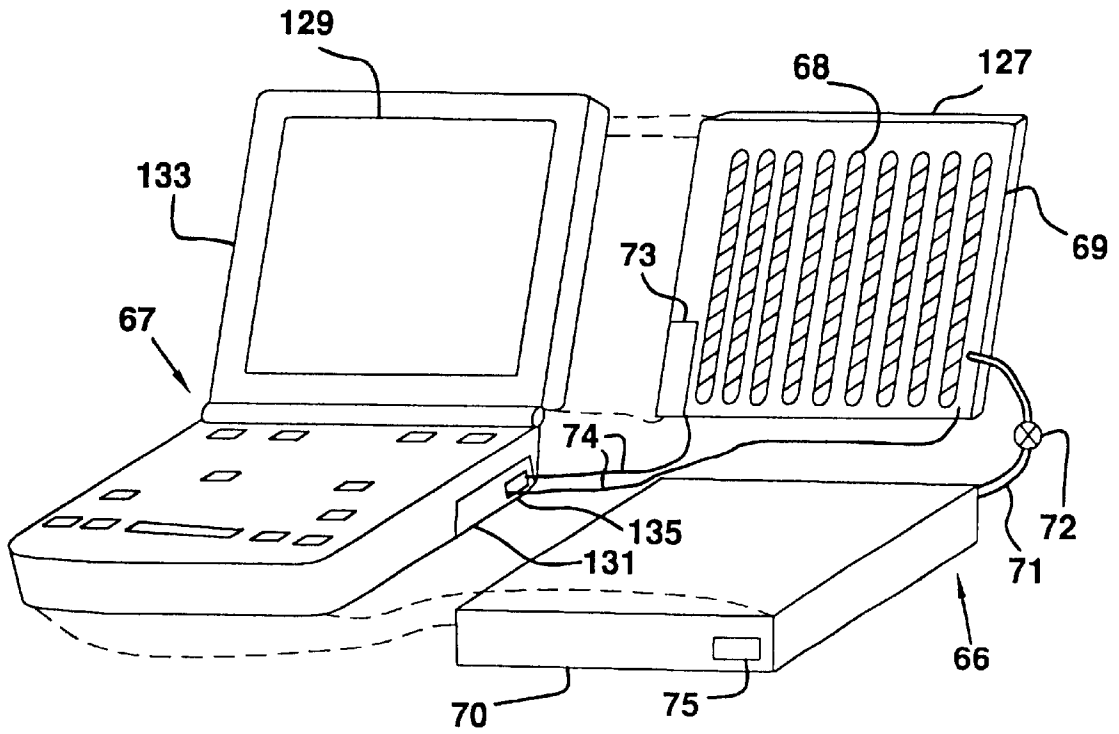


FIG. 13

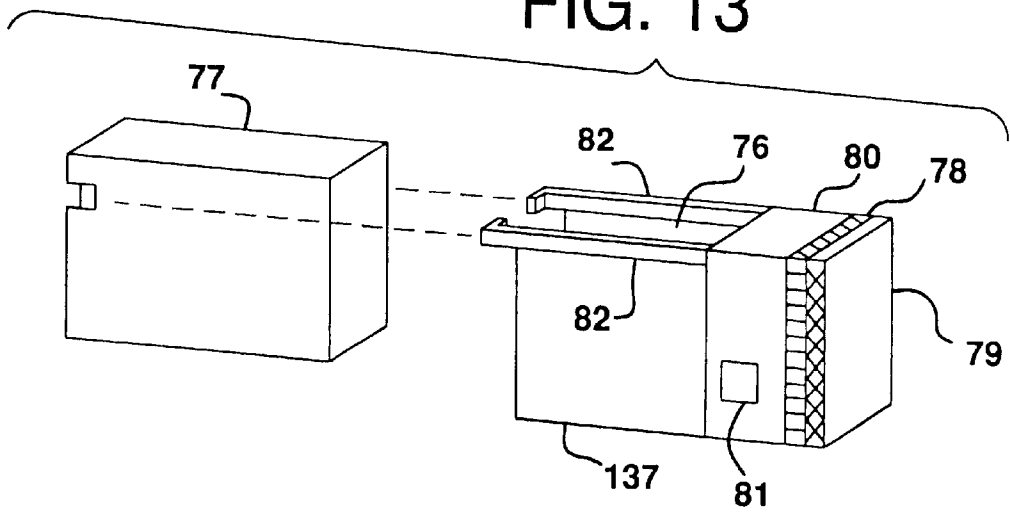
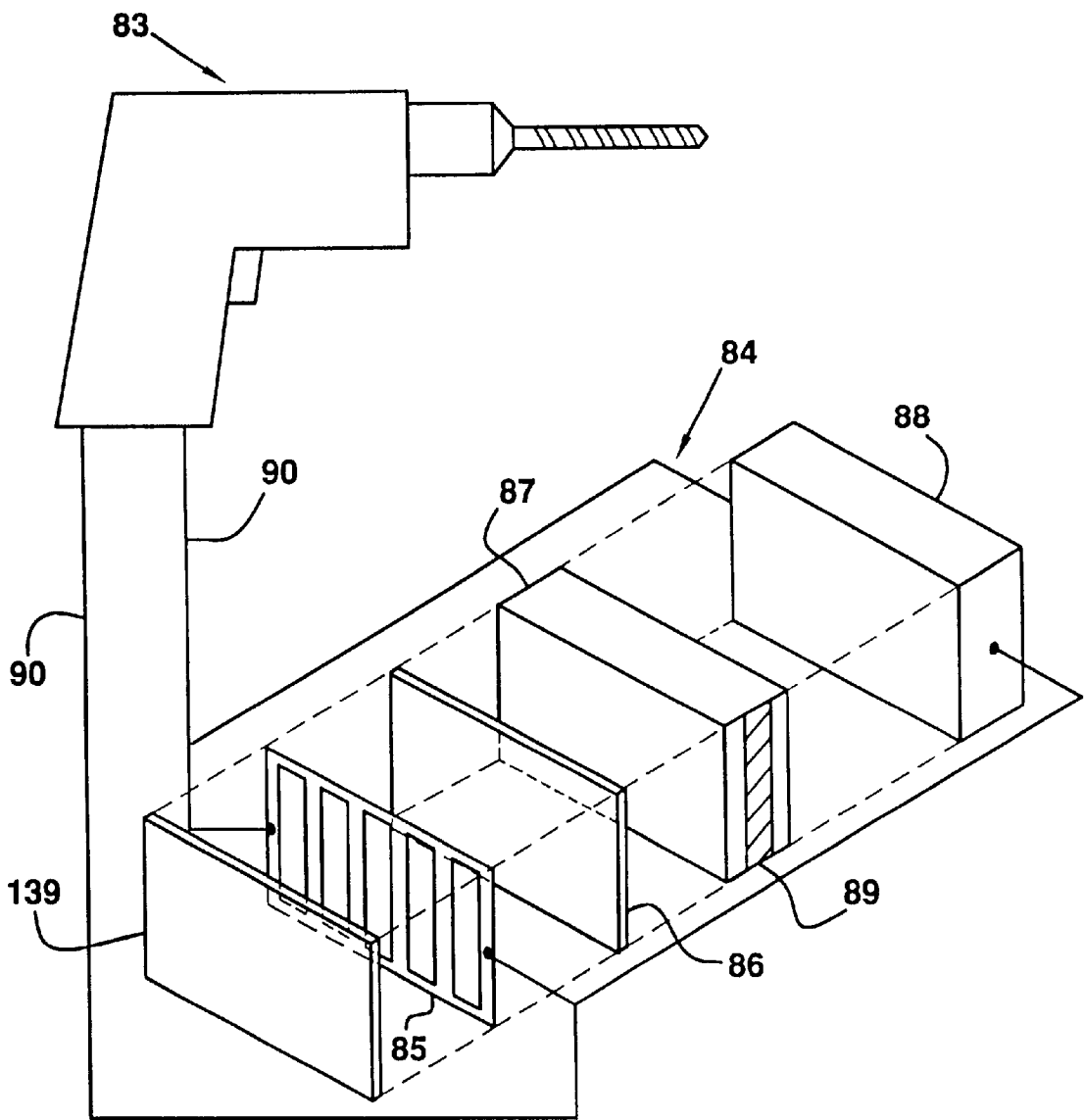


FIG. 14



MICRO-FUEL CELL POWER DEVICES**BACKGROUND OF THE INVENTION**

The present invention relates generally to fuel cell devices, and more specifically to the manufacturing process for MICRO-FUEL CELL™ power devices and to their application configurations.

A number of miniature fuel cells suitable for use with portable electronic products are becoming available today, but less attention has been shown to the low-cost mass production and device packaging of these fuel cells for varied applications. There is limited information in the literature concerning such things as the coupling of these miniature cells to the various applications, methods for refueling the cells in a low-cost and efficient manner, or any type of thermal insulation to elevate the temperature of the cell for higher efficiency in various environmental conditions. Another problem with portable electronic appliances is that they need to be kept in a ready position that is secure but easily accessible when needed. For example, cellular phone holsters may use clips and gravity securing devices to keep the phone from dropping when jostled. Another problem with portable electronics is that they can easily be misplaced.

Representative prior inventions of this general type include U.S. Pat. Nos. 5,364,711 and 5,432,023, which describe miniature fuel cells that run on methanol and are used to run electronics, and U.S. Pat. Nos. 4,673,624 ("Fuel Cell") and 5,631,099 ("Surface Replica Fuel Cell"), which describe methods of forming fuel cells. None of those patents describe how to package the fuel cell to efficiently run the electronics applications. U.S. Pat. No. 5,759,712 ("Surface Replica Fuel Cell for Micro Fuel Cell Electrical Power Pack") describes how a fuel cell can be packaged in a general hybrid systems power pack which may be comprised of a fuel cell and other energy sources, such as a battery, flywheel, or solar cells. It mentions cellular phones in particular, but does not appear to describe the coupling configurations or refueling systems for these electrical applications. In this application, the porous gas manifolds and air gaps in the case of the power packs acts as both insulation and water control mechanism. None of those patents mentioned using exchangeable insulation to compensate for different environmental temperature conditions. However, none of those patents discloses or suggests the novel features of the present invention.

SUMMARY OF THE INVENTION

The present invention applies the fuel cells described in this inventor's U.S. Pat. Nos., 4,673,624, 5,631,099, and 5,759,712, to numerous electrical devices. Examples of devices that realize a significant advantage from such power systems include, but are not limited to, portable electronics and power tools; such as cellular phones, pagers, video camcorders, portable tools, portable PCs, portable toilets, smoke detectors, hearing aids, portable stereos, portable TVs, portable radios, night vision goggles, portable lighting, toys, computer peripherals, and portable vacuum cleaners.

The critical component in this invention is a fuel cell that is formed on a plastic sheet, including a number of fuel cells described in "Surface Replica Fuel Cell", U.S. Pat. No. 5,631,099, U.S. Pat. No. 4,673,624, and U.S. Pat. No. 5,759,712. These fuel cells pack more energy in a smaller space than conventional rechargeable batteries by utilizing liquid methanol and water fuel. The methanol fuel has effectively 5 to 13 Whr per cubic inch (20% to 50%

efficiency) energy density. This is 3 to 9 times the energy density of today's best nickel cadmium batteries, and 40 to 120 times that of standard cellular phone battery packs. These micro-fuel cells are lighter than conventional rechargeable batteries. The methanol fuel has effectively 1200 to 3000 Whr per kg energy per unit mass (20% to 50% efficiency). This is 2 to 5 times the 600 Whr per kg quoted for the latest rechargeable lithium ion batteries (Science News, Mar. 25, 1995).

Our first micro-fuel cell is designed to replace the standard cellular phone battery packs. Conventional cell phones usually have a warning alert signal when the battery is low, but the accuracy and dependability of these indicators often leave much room for improvement. Determining the remaining energy capacity from a rechargeable battery typically uses the voltage output level as an indicator of charge but does not measure the capacity. Therefore, history of the discharge is used to assess the future of the remaining output. This electronic assessment of remaining energy capacity is complex, requires diagnostic electronics and is prone to errors. The liquid fueled fuel cell eliminates this uncertainty. Checking the fuel supply is as simple as looking at the liquid level in the fuel tank. The amount of fuel remaining compared to the total fuel tank capacity is the fraction of the total energy. Refueling also provides instant recovery. Components of these micro-fuel cells are inexpensive. Manufacturing and assembly cost are low. The production techniques allow the fuel-cells and power supply systems to be manufactured at costs similar to rechargeable batteries. The production techniques enable the fuel cells to be produced in a roll-to-roll manufacturing method, similar to printing press processes. The production is envisioned as taking place in a vacuum system in which the metal electrodes and catalysts are deposited onto a reeled plastic web. The electrolytes may also be deposited by means of a reeled vacuum deposition system or dip tank. The individual fuel cell devices would be cut off the rolls of fuel cells and assembled. The edge seals are expected to be heat seals, with the cutting operation and heat seal operation envisioned as one and the same. The MICRO-FUEL CELL is the "green" (environmentally clean) solution to energy needs. It is never thrown away, but rather refueled with common ethanol or methanol, an abundant and renewable energy source. The production process and the disposal of manufacturing by-products do not present toxic waste problems. The plastic fuel tanks when empty can be disposed of as common food packaging.

One aspect of this invention addresses the fact that small portable fuel cells encounter a range of exterior environmental temperature and humidity. To compensate for this range and to optimize the performance of the fuel cells an adjustable moisture and thermal internal insulation barrier is used to allow fuel cells to run at elevated temperatures.

Current appliances that run on rechargeable batteries are recharged by "plugging in" to alternating current sources or DC electrical systems, such as found in a car or other vehicle. This source of energy may be inconvenient or unavailable for many users in remote locations. The present invention allows the fuel cell energy system of an appliance, the fuel cell itself, and the fuel supply packaging to all fit together in a convenient manner.

These and further and other objects and features of the invention are apparent in the disclosure, which includes the above and ongoing written specification, with the claims and the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1A is a schematic representation of the reel-to-reel web coating production process for the micro-fuel cells of this invention.

FIG. 1B is a flow chart of the back-end production process for the micro-fuel cells of this invention.

FIG. 2 is a perspective view of the cellular phone power holster of this invention.

FIGS. 3A and 3B are perspective views of a fuel tank and a blister pack of fuel tanks.

FIGS. 4A and 4B are front and side elevations of a cellular phone with a ratchet mechanism.

FIGS. 4C and 4D are front and side elevations of a holster for receiving a cellular phone with a ratchet mechanism.

FIGS. 5A and 5B are perspective views of a piggyback charger.

FIGS. 6A and 6B are an exploded view of a trickle charger and a perspective view of a trickle charger.

FIGS. 7A and 7B are perspective views of refilling a trickle charger and a refillable trickle charger battery.

FIGS. 8A and 8B are an exploded view of a cellular phone with a fuel cell and a perspective view of a cellular phone with a fuel cell in place.

FIG. 9 is a perspective view of a fuel ampoule.

FIG. 10 is an exploded view of a desk power charger.

FIG. 11 is an exploded view of a battery charger doughnut.

FIG. 12 is an exploded view of a portable computer fuel cell power supply.

FIG. 13 is an exploded view of a portable camcorder piggyback fuel-cell power supply.

FIG. 14 is an exploded view of an external fuel-cell power supply for a portable battery-powered device.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1A shows a preferred embodiment of the production process for the MICRO-FUEL CELL of the present invention. The production line starts with a porous plastic substrate manufactured, as described in U.S. Pat. No. 5,631,099, in which the plastic is irradiated and etched to produce patterned porous plastic films. Alternatively manufactured porous plastic films may be used where selective areas of pores are filled to produce non-conductive regions in the MICRO-FUEL CELL arrays. The porous plastic web 7 is rolled onto a source reel 1 (spool) and inserted into the web coating vacuum chamber 2. Several loading schemes are available. The plastic web 7 may be reeled into the vacuum chamber 2 though a differential pumped seal, inserted through a load lock, or inserted into the coating chamber in an air environment and then evacuated. The plastic web 7 is reeled past the sputter sources and evaporation sources (guns) 3, as shown, where deposition patterns are deposited in any one of a variety of ways, as follows:

- i) the first scheme, shown here, is to sputter through proximity sputter masks 4;
- ii) the second scheme is to raster an atomic beam of the deposit material; or
- iii) the third way is to use self masking patterns on the porous plastic substrate and a deposition source which has angle of incidence and collimation control.

An analogous system of deposition in air or liquid includes spray painting, ink jet printing, proximity electroplating, Xerography, photolithography, chemical vapor deposition and auto electroplating, which all may be used in a reeled web system, under vacuum, controlled atmosphere, or in air as appropriate to the deposition requirements. All these deposition techniques are mentioned

in U.S. Pat. No. 5,759,712. In the vacuum deposition system, a variety of sputter sources 3 and heat sinks 5 may be arranged parallel to the porous plastic web 7. The production output rate of this sputter system is critically dependent upon the maximum temperature at which the materials are deposited onto the plastic substrate, and the rate at which heat is removed by means of strategically placed heat sinks 5. The heat removal from the plastic substrate in the vacuum system is proportional to the forth power of the absolute temperature and it's emissivity. The sputter sources 3 remove all excess heat transfer to the plastic substrates, but the essential heat input will come from the heat of condensation of the deposit material. Thus, the heat input to the plastic substrate is essentially proportional to the rate at which material is deposited. The deposition dwell time for a coating is proportional to the thickness of the film and the material condensation enthalpy divided by the desired substrate temperature to the forth power. The porous plastic web 7 may be moved into position using encoded motors on the position rollers 6. The fundamental motions are to:

- i) advance the plastic film;
- ii) fine adjust the position; and then
- iii) dwell for the deposit.

The positioning of the plastic web is coordinated through optical sensors to marks on the porous plastic or to the first deposit pattern. Slack in the plastic film between sputter deposits can be compensated for by translator controlled take-up reels. The first step in the material deposit is an oxygen ion milling of the surface of the plastic. Surface texturing may also take place in this step. Examples of material deposited in order are:

For the fuel side of membrane:

- i) high pressure sputter Pt/Ru to form porous deposits;
- ii) low pressure sputtered Pd; and
- iii) high pressure sputtered Pt/Ru.

For the air side of the membrane:

- iv) low pressure Au; and
- v) high pressure Pt/Ru.

Thus, in this example, five sputter guns 3 and deposits would be used to deposit the electrodes. The porous plastic web 7 is taken up on a take-up reel 8 which is aft of the sputter guns 3. The plastic film 7 may exit from the sputter chamber 2 by any one of the methods as previously mentioned to insert the plastic film.

FIG. 1B shows the back-end process for manufacturing the MICRO-FUEL CELLS. From the coating chamber 2, the plastic film 7 is loaded into an electrolyte coating system 9 (unless the electrolyte was already deposited in the vacuum chamber since some electrolytes can be deposited in vacuum.) The plastic web 7 is next reeled through an electrolyte solution, such as 5% Nafion® solution (perfluorinated ion exchange polymer alcohol solution made by Solution Technology Inc, PO Box 171 Mendenhall, Pa. 19357), and then is drawn up through a drying and heat curing oven 10 to provide the finished plastic web 101. Finally, the plastic web is then assembled with the gas manifolds, as in U.S. Pat. No. 5,759,712. The gas manifolds and a diffusion membrane or a second fuel cell array sub-assembly may be assembled and heat sealed, ultrasonic welded, or glued around the rim in place on the plastic web. These assembled MICRO-FUEL CELL arrays are then reeled onto spools which can be shipped to separate locations or cut out of the plastic web immediately. Laser cutting, shear cutting or die cutting are used to slice out the fuel cell arrays from the plastic web. The cutout fuel cell

arrays are placed in the fuel cell assemblies as described in U.S. Pat. No. 5,759,712 and the remainder of this patent. The fuel cell power supply assemblies then undergo an electronic performance check after they are assembled.

FIG. 2 shows a power holster **11** that is formed with a polycarbonate plastic housing to fit snugly around a cellular phone **12**. The cellular phone **12** needs to fit such as to maintain positive pressure between its electrical contacts and those in the power holster through gravity and the vertical mounting of the cellular phone. Alternatives to using gravity pressure is to have the phone press against electrical spring contacts **13** or to snap-in with a ratchet mechanism **14**, as shown in FIGS. 4A, 4B, 4C and 4D. The ratchet **14** is released by applying pressure simultaneously to the finger buttons **15**, located in the ratchet holes **16** on each side of the fuel cell holster **11**.

Alternatively, the mechanism's ratchet teeth **18** may be designed with a slope on both sides, so that the phone is removable from the holster by means of a firm pull. Velcro attached at the bottom of the holster is another securing mechanism working with the springy electrical contacts **13**. To provide a means of attaching the power holster to clothing, a clip **103** may be formed in the power holster plastic housing **11**. An alternative is to form a belt loop to permit a belt or purse strap to be threaded through.

Referring back to FIG. 2, the MICRO-FUEL CELL array **19** is placed along the length of the polycarbonate plastics housing **11**. A gas diffusion mat **20**, made from polyester fiber paper to serve as a protective cover, is placed over the MICRO-FUEL CELL array **19**. The gas diffusion mat **20** also serves as a thermal insulation layer. In cold environments it may be made thicker and in hot environments it may be thinner to maintain an optimum elevated operating temperature of the fuel cell array **19**. The power holster **11** has a fuel cavity **21** designed to accept the fuel tanks **22**, shown in FIG. 3A. The fuel tanks **22** are made from polyethylene plastic and filled with 1:1 molecular ratio of methanol to water mixture. The fuel tanks **22** are inserted into the fuel cavity **21** and are impaled on the fueling needle (not shown) to start fueling. The fuel is then wicked from the needle to the MICRO-FUEL CELL fuel manifold. The fuel tanks **22** may be sold in blister packages **23**, as shown in FIG. 3B. To allow observation of the fuel level **105** in the fuel tank **22** while mounted in the power holster **11**, a window **24** is included in the plastic housing over the fuel tank. Other methods of measuring fuel level include:

- i) a weight monitoring system correlated to fuel quantity based on the fact that the device will get lighter as the fuel is depleted is a viable alternative;
- ii) measuring the electronic capacitance of the fuel tank by placing electrodes in close proximity to the tank;
- iii) adding a chemical colorant that changes color or opacity as the fuel is depleted;
- iv) a fuel immobilizer matrix in the fuel tank, such that when fuel is replaced with gas it's opacity will change; and
- v) in larger systems, a float indicator such as fuel gauge systems in vehicles.

Electric power from the MICRO-FUEL CELL **22** is delivered to the electrical contacts **107** on the cellular phone through two gold coated beryllium copper contact leaf springs **13** that make contact with the MICRO-FUEL CELL **22** through rivet or other electrical connections. Additional electronic functions and features that may be incorporated into the holster **11** include:

- i) a locator device, consisting of a receiver/transmitter being added to the holster so that when the cell phone

is misplaced it may be located by means of a directional antenna or by simply stimulating the ringer on the phone;

- ii) a pager feature from the holster to the phone could be added;
- iii) a portable computer that can use the portable phone or electronic device as its communication relay;
- iv) a radio communications relay transmitter for a portable communication device which thereby reduces the weight and mass of the portable communication device; and
- v) such a portable communication device has the potential to be reduced to the size of a wristwatch, two-way hearing aid (bone conduction microphone), credit card or broach, so as to be located in a purse; pocket, attached to the belt, shoes, or inside the body as long as it can receive sufficient oxygen.

The piggyback charger **26** is formed with a polycarbonate plastic housing **25** to fit snugly and have a positive gripping hold around a cellular phone **12**, as shown in FIGS. 5A and 5B. A positive grip on the phone **12** may be accomplished in a number of ways, including:

- i) using Velcro foam backed strips in the well of the plastic housing;
- ii) by rubber ratchets on the inside of the plastic housing and a foam pad in the well of the housing; and
- iii) with ratchets that extend around the end of the phone.

The MICRO-FUEL CELL array **27** is placed along the length of the polycarbonate plastics housing **25**, as shown. A gas diffusion mat **28**, made from polyester fiber paper to serve as a protective cover, is placed over the MICRO-FUEL CELL array **27**. The gas diffusion mat **28** also serves as a thermal insulation layer. In cold environments it may be made thicker and in hot environments it may be made thinner to maintain an optimum elevated operating temperature of the fuel cell array **27**. The mat **28** or matrix may be wetted or coated with a wetting agent that causes water to be wicked into the fuel cell **27** to maintain an optimum humidity on the fuel cell. The surface energy or wetting coatings may be varied though the thickness of the matrix to draw water back into the fuel cell **27**. One alternative is to use hollow fibers in the matrix and by capillary action draw condensed water into the fuel cell **27**. For applications where there is excessive heat and water production, this same wicking system may be used to remove the excessive heat and water. The vaporization of water and liquid return cycle acts as an additional cooling mechanism for the removal of heat. If there is condensed water in the matrix, it increases the thermal conductivity, which reduces the thermal insulating property of the matrix, and raises the outer temperature of the matrix, thereby vaporizing more water to the outside air. The piggyback charger **26** has a fuel cavity designed to accept the low profile sealed fuel tank ampoule **29** between the insulating mat **28** and the cellular phone **12**. The fuel tanks **29** are shaped to fit the tank cavity and are made from polyethylene plastic and filled with 1:1 molecular ratio of methanol to water mixture. Other fuel mixtures of methanol and water may be used, as well as other types of alcohols, hydrocarbons and hydrogen bearing compounds. The fuel tanks **29** are inserted into the fuel cavity and are impaled onto the fueling needle to start fueling. The fuel is then wicked from the needle to the MICRO-FUEL CELL fuel manifold. The fuel tanks **29** may be sold individually or in volume packages. To allow observation of the fuel quantity while the tank is in the piggyback charger **26**, a transparent window over the fuel tank is included in the

plastic housing **25** for direct viewing of the fuel level. The electric power from the fuel cell **27** is delivered to the charging contacts **107** on the cellular phone through two gold coated beryllium copper contact leaf spring contacts (not shown). These contact springs make contact with the MICRO-FUEL CELL **27** through rivet or other electrical connections. The piggyback charger **26** is designed to be carried as an integral part of the phone so as to continuously charge the cell phone's battery. The cell phone **12** is fully functional at all times, even with the piggyback charger **26** in place. The piggyback charger **26** may have an outer porous cover to permit moisture from the fuel cell **27** and the user's hand to evaporate. The porous cover may also enhance the user's grip on the phone and make it more comfortable to use. The piggyback charger **26** does not cover any of the cellular phone function buttons **109**, antenna **111**, or displays **113**.

As shown in FIGS. **6A** and **6B**, the trickle charger **30** is formed with polycarbonate plastic housing to fit in the position designed for batteries in a typical cellular phone **31**. The trickle charger **30**, which replaces the standard battery pack in a cell phone **31**, has four primary components:

- i) a fuel cell **32**;
- ii) a fuel tank **33**;
- iii) a battery **34** (shown in this example as a lithium battery); and
- iv) an insulation mat **35**.

The MICRO-FUEL CELL array **32** is placed along the length of the polycarbonate plastics housing, as shown, and used to provide a continuous trickle charge to the battery **34**. A gas diffusion mat **35**, made from a matrix material such as polyester fiber paper to serve as a protective cover, is placed over the MICRO-FUEL CELL array **32**. The gas diffusion mat **35** also serves as a thermal insulation layer. In cold environments it may be made thicker and in hot environments it may be made thinner to maintain an optimum elevated operating temperature of the fuel cell array **32**. The heat from the fuel cell **32** warms the trickle charger **30** and maintains a higher operating temperature on the battery. For very cold environments the gas diffusion mat insulation **35** covers both the battery **34** and the fuel cell **32** to keep the battery at an elevated temperature from the surroundings. For warm environments the fuel cell **32** may be insulated from the battery **34**, and both the battery and fuel cell have minimal insulation to the exterior of the case. A material that is commercially available to do this function is called CoolMax® (made by Bush Associates P.O. Box 3043, Newport, Calif. 92663). To enable the fuel cell **32** to handle a range of temperature conditions the insulation may have a different thickness across each of the fuel cells in the array **32**. When the fuel cell array **32** is idling, the well insulated portion of the array is operating at optimum temperature and humidity while the less insulated portion of the fuel cells are cooler and at sub-optimum temperature. When the MICRO-FUEL CELL **32** is under load or in higher environmental temperatures, the insulated portion of the array is dehydrated and sub-optimum and the less insulated portion is at optimum temperature and humidity. The fuel cavity is designed to accept sealed fuel tanks (ampoules) **33** inserted between the cellular phone and the trickle charger **30**. In another embodiment, shown in FIG. **6B**, the fuel ampoule **33** is snapped into the back of the trickle charger **30** while it is attached to the cellular phone **31**. The fuel tanks **33** are shaped to fit the tank cavity and are made from polyethylene plastic and filled with 1:1 molecular ratio of methanol to water mixture. As the fuel tanks **33** are inserted into the fuel cavity they are impaled onto the fueling needle (not shown)

to start fueling. The fuel is then wicked from the needle to the MICRO-FUEL CELL fuel manifold. A ratcheting, positive clamping, snap-in, or other containment of the fuel tank **33** is provided between the trickle charger **30** and the fuel tank. The fuel tanks **33** may be distributed individually or in volume quantities. To allow observation of the fuel level in the fuel tank **33** while attached to the trickle charger **30**, a transparent window (not shown) over the fuel tank is included in the plastic housing for direct viewing of the fuel level. Electric power from the fuel cell is delivered to the charging contacts on the cellular phone through two gold coated beryllium copper contact leaf spring contacts (not shown). These contact springs make contact with the MICRO-FUEL CELL **32** through rivet or other electrical connections. The trickle charger **30** is carried as an integral part of the phone **31**, making the phone fully functional at all times. The trickle charger **30** may have an outer porous cover to permit moisture from the fuel cell **32** and the user's hand to evaporate. The porous cover enhances the user's grip on the phone and makes it more comfortable to use. The trickle charger **30** does not cover any of the cellular phone function buttons **115**, antenna **117**, or displays **119**.

The refillable trickle charger **121**, shown in FIGS. **7A** and **7B**, is formed with polycarbonate plastic housing **36** to fit in the position designed for batteries in the cellular phone **31**. The refillable trickle charger **121** has four primary components:

- i) a fuel cell (not shown);
- ii) a molded in fuel tank **38**;
- iii) a refueling tank or dispenser **39**; and
- iv) a battery **40** (shown in this example as a lithium battery).

The MICRO-FUEL CELL array (not shown) is placed along the length of the polycarbonate plastics housing **36**. A gas diffusion mat (not shown), made from polyester fiber paper to serve as a protective cover, is placed over the MICRO-FUEL CELL array. The gas diffusion mat also serves also a thermal insulation layer. In cold environments it may be made thicker and in hot environments it may be made thinner to maintain an optimum elevated operating temperature of the fuel cell array for maximum efficiency. The heat from the fuel cell warms the trickle charger **121** and maintains a higher operating temperature on the battery **40**. For very cold environments, in addition to the gas diffusion mat, both the battery **40** and the fuel cell provide more insulation to help keep the battery at an elevated temperature from the surroundings. On the other hand, for warm environments the fuel cell may be insulated from the battery and both the battery and fuel cell may have minimal insulation to the exterior of the case. The fuel cavity is designed to have the fuel tank **38** molded in between the cellular phone **31** and the trickle charger **121**, as shown. The fuel tank **38** is shaped to fit the tank cavity and may be made from PET polyethylene terephthalate or a similar plastic. The fuel tank **38** is filled with 1:1 molecular ratio of methanol to water mixture from a fuel dispenser **39**. A refillable port **41**, with a built-in valve that opens for refueling, is located on the side of the trickle charger **121**. The valve may be a spring loaded type, such as a tire valve, or a mechanism such as a rubber seal in a basketball where filling is accomplished with a needle through the seal. The act of refueling may be an alternate squeezing and relief action that forces the fuel from the dispenser **39** into the tank **38**, while at the same time releasing gas pressure in the tank. The fuel dispenser **39** may have any one of a number of insertion tip features, including, but not limited to:

- i) it may seal to the valve on the trickle charger;
- ii) it may screw into the trickle charger;
- iii) it may twist-lock and seal into the trickle charger; and
- iv) in a dual flow manner, it may provide an exit route for gas in the fuel tank as fuel is flowing in.

In refueling, the fuel is wicked from the needle 37 to the MICRO-FUEL CELL fuel manifold. The fuel dispensers 39 may be distributed individually or in blister packages, or they may be refillable through a screw cap from larger bottles of fuel. To allow observation of the fuel level in the fuel tank 38, a transparent window (not shown) is included over the fuel tank and built into the side of the plastic trickle charge refill housing 36. The electric power from the fuel cell is delivered to the charging contacts on the cellular phones through two gold coated beryllium copper contact leaf spring contacts. These contact springs make contact with the MICRO-FUEL CELL through rivet or other electrical connections. The trickle charge refill 121 is designed to be carried as an integral part of the phone. The trickle charger refill 121 may have an outer porous cover to permit moisture from the fuel cell and the user's hand to evaporate. The porous cover enhances the user's grip on the phone and makes it more comfortable to use.

Referring to FIGS. 8A and 8B, the fuel cell only power supply is formed with a polycarbonate plastic module 42 to fit in the position designed for batteries in the cellular phone 31. The fuel cell has four primary components:

- i) a fuel cell 44;
- ii) a large capacity fuel tank 45;
- iii) an insulation and diffusion mat 46; and
- iv) voltage regulating electronics (not shown).

The MICRO-FUEL CELL array 44 is placed along the length of the polycarbonate plastic module's housing 42, as shown in FIG. 8A. A gas diffusion mat 46, made from polyester fiber paper to serve as a protective cover, is placed over the MICRO-FUEL CELL array 44. The gas diffusion mat 46 also serves as a thermal insulation layer. In cold environments it may be made thicker and in hot environments it may be made thinner to maintain an optimum elevated operating temperature of the MICRO-FUEL CELL array. The fuel cavity is designed to have fuel tank 45 between the cellular phone 31 and the plastic housing 42, as shown. The fuel tanks 45 are shaped to fit the tank cavity and are made from polyethylene plastic and filled with 1:1 molecular ratio of methanol to water mixture. The fuel tanks are inserted into the fuel cavity and are impaled onto the fueling needle (not shown) to start fueling. The fuel is then wicked from the needle to the MICRO-FUEL CELL fuel manifold. The fuel tanks 45 may be sold individually or packaged in volume quantities. The fuel tanks may also be refilled from a larger container of fuel by means of screw cap. To allow observation of the fuel level, a fuel level indicator window 47 is included in the side of the fuel cell module's plastic housing 42. Electric power from the fuel cell is delivered to the charging contacts on the cellular phone through two gold coated beryllium copper contact leaf spring contacts. These contact springs make contact with the MICRO-FUEL CELL through rivet or other electrical connections.

The fuel-cell-only is designed to be carried as an integral part of the cell phone. The fuel-cell-only may have an outer porous cover to permit moisture from the fuel cell and the user's hand to evaporate. The porous cover enhances the user's grip on the phone and makes it more comfortable to use.

The fuel tanks or ampoules 48 are sealed polyethylene containers filled with a 1:1 molecular mixture of methanol

and water, as shown in FIG. 9. The container wall material and properties are chosen to retain the fuel mixture at least five (5) years with less than a 10% loss of fuel. A dimple 49 which may be punctured with a needle is included for fueling the ampoule 48. The surface 123 where the sealing dimple is located needs to be smooth and impermeable enough to permit an o-ring or other type seal to fit tightly around the fueling needle, or mechanism. Other than the dimples, the container may have ridges or protrusions that allow it to fit into the particular fuel cell device and maintain structural integrity to assure a reliable seal with the fueling needle from full to empty. The fuel ampoules 48 may have shapes and forms that allow them to fit snugly and fill the available space in the power supply cavity of a product. The fuel ampoules 48 may be filled with a fuel permeable material that allows the fueling needle to make wicking contact with the fuel regardless as to the orientation of the fuel tank. The tank filler may also have the property that as the fuel is removed from the fuel tank the filler becomes opaque to light or changes color. The fuel tank filler may also act as a flow retardant to minimize fuel leakage in the event of a fuel tank rupture.

As shown in FIG. 10, the desk power charger 51 is used to charge the batteries in a cellular phone 52 when the phone is not in use. This desk power charger 51 is formed with polycarbonate plastic or ABS plastic (terpolymer of acrylonitrile, butadiene, and styrene) into a housing 50 that accepts the cellular phone 52 and holds it snugly in place, as shown in FIG. 10. The cellular phone 52 maintains a positive pressure on the electrical contacts in the desk power charger 51 through gravity and/or the vertical mounting of the cellular phone. Alternatives to using gravity pressure is to have the cell phone press against electrical spring contacts and snap-in with a ratchet mechanism, which may be released with a mechanism requiring double pressure on the sides of the charger, or by means of a firm pull on the phone if the ratchet is designed with a slope on both sides of the teeth as discussed earlier with the holster release of FIG. 4A. Velcro, screws, or sticky foam tape may be included on the bottom of the power charger 51 to allow it to be attached to a desk, etc.

The MICRO-FUEL CELL array 53 is placed along the length of the polycarbonate plastic housing 50. A gas diffusion mat 54, made from polyester plastic fiber paper to serve as a protective cover, is placed over the MICRO-FUEL CELL array 53. The gas diffusion mat 54 also serves as a thermal insulation layer. In cold environments it may be made thicker and in hot environments it may be made thinner to maintain an optimum elevated operating temperature of the fuel cell array 53. The desk charger 51 has a large fuel cavity designed underneath to accept the fuel tank (ampoule) 55. The fuel tank 55 is made from polyethylene plastic and filled with 1:1 molecular ratio of methanol to water mixture. As the fuel tank 55 is inserted into the fuel cavity, it is impaled on the fueling needle (not shown) to start fueling. The fuel is then wicked from the needle to the MICRO-FUEL CELL fuel manifold. This larger fuel tank will generally be sold individually or packaged for volume distribution. To allow observation of the fuel level in the fuel tank, a transparent fuel level window 56 is built into the plastic housing 50 of the desk power charger 51.

Electric power from the fuel cell 53 is delivered to the electrical contacts on the cellular phones through two gold coated beryllium copper contact leaf spring contacts. These contact springs make contact with the MICRO-FUEL CELL 53 through rivets or other electrical connections.

The battery charger doughnut or ring 125, shown in FIG. 11, is formed with polycarbonate plastic housing 57 to fit

snugly with a positive gripping hold around a rechargeable battery **63**, as shown in FIG. **11**. The positive grip on the battery **63** may be accomplished using springy sliding end caps **58** and **59** that also make the electrical connection between the fuel cell **60** and the battery **63**. The MICRO-FUEL CELL array **60** is placed along the exterior periphery of the fuel tank **62**. A gas diffusion mat **61**, made from polyester fiber paper to serve as a protective cover, is placed around the MICRO-FUEL CELL array **60**. The gas diffusion mat **61** also serves also a thermal insulation layer. Gas diffusion **61** mats may be placed on both the exterior and interior sides of the MICRO-FUEL CELL array **60**. In cold environments it may be made thicker and in hot environments it may be made thinner to maintain an optimum elevated operating temperature of the fuel cell array **60**.

The battery charger doughnut **125** has a fuel cavity which is designed to accept a sealed fuel tank **62** in between the gas MICRO-FUEL CELL array **60** with diffusion mat **61** and a standard battery **63**. The fuel tanks **62** are shaped to fit the tank cavity of the charger **57** and have a cylindrical hole in the center to accept a standard rechargeable battery **63**. The tanks **62** are made from polyethylene plastic and filled with 1:1 molecular ratio of methanol to water mixture. The fuel tanks are inserted into the fuel cavity and are impaled onto the fueling needle (not shown) to start fueling. The fuel tanks **62** are held in the polycarbonate plastic housing **57** by the electrical end caps **58** and **59** and the polycarbonate housing. The fuel is wicked from the needle to the MICRO-FUEL CELL fuel manifold. The fuel tanks may be sold individually or packaged for volume distribution. To allow observation of the fuel level in the fuel tank **62**, a viewing slot **64** is built into the battery charger housing **57**. The electric power from the fuel cell **60** is delivered to the charging contacts on the battery **63** through two gold coated beryllium copper contact leaf spring contacts **127** located on the upper **58** and lower **59** end caps. These contact springs **127** make contact with the MICRO-FUEL CELL through rivets or other electrical connections. The battery charger ring **125** is designed to have an external profile that matches the battery space available in an electrical application. The outer surface of the battery charger ring **127** is porous with ventilation holes **65** to permit moisture and carbon dioxide from the fuel cell to diffuse out and oxygen to diffuse in. The porous cover can be energy absorbing to enhance the mechanical shock absorbing performance of the power supply in the electrical application.

A portable computer fuel cell power supply **66** is formed with ABS plastic housing **127** to fit and attach onto the exterior surfaces of a portable computer **67**, as shown in FIG. **12**. The fuel cell power supply **66** has seven (7) primary components:

- i) a fuel cell array **68**;
- ii) a diffusion and insulation mat **69**;
- iii) a fuel tank **70**;
- iv) a fuel tube **71**;
- v) a valve **72**;
- vi) voltage regulating electronics **73**; and
- vii) the electrical cable **74** connection to the portable computer **67**.

The fuel cell power supply **66** may also be used to charge a battery **131** located in the portable computer **67**. The fuel cell array **68** is placed along the back of the display screen **129** of the personal computer **67** and is protected by the ABS plastic housing **127**, as shown. The fuel cell **66** is placed at this location to take advantage of the heat generated by the display screen **129** to elevate the operating temperature of

the fuel cell and keep the heat and moisture generated by the fuel cell connected away from the user. A gas diffusion mat **69**, made from polyester fiber paper to serve as a protective cover, is placed over the MICRO-FUEL CELL array **68** inside the ABS plastic housing **127**. The gas diffusion mat **69** also serves as a thermal insulation layer. In cold environments it may be made thicker and in hot environments it may be made thinner to maintain an optimum elevated operating temperature of the MICRO-FUEL CELL array **68**.

The fuel cavity is designed to have the fuel tank **70** underneath the portable computer, as shown in FIG. **12**. The fuel tank **70** may be protected by an ABS plastic cover, or it may be made robust enough that a cover is not needed. This places the majority of the mass of the fuel cell power supply **66** as low as possible on the portable computer **67** to maintain a low center of gravity. The fuel tank **70** also provides good thermal conductivity to dissipate heat generated by the computer. The fuel tank **70**, which is shaped to fit and grip the underside of the portable computer, is made from polyethylene plastic or polycarbonate plastic and filled with 1:1 molecular ratio of methanol to water mixture. The fuel tank **70** is made to be snapped to the underside of the portable computer **67** or to attach with other possible attachment mechanisms, such as Velcro, foam tape, slide-on, or screws. Fuel tanks **70** may be sold individually for replacement or may be refilled from a larger container of fuel. New fuel tanks **70** may have a membrane seal to ensure that no fuel leaks through the coupling before use.

Fueling is done by connecting the fuel tube **71** to the fuel tank **70**. This fitting may be a screw on to a valve stem, a "quick connect", or a fuel needle insert type similar to a basketball rubber seal that seals on the shaft of the needle. The fuel is wicked, flowed or pumped from the needle or fuel connection to the MICRO-FUEL CELL fuel manifold. To allow observation of the fuel level in the fuel tank **70**, a clear window **75** is built into the plastic housing **127**. If a porous filler is used in the fuel tank, a change in the filler from transparent to opaque may be used to indicate the fuel level in the fuel tank. A dimpled area of the fuel tank **70** may be provided to pump the fuel to the fuel tube by alternately compressing and relieving pressure on the dimple. Since the portable computer power supply **66** is expected to run for periods of many hours before being shut down, a valve **72**, which is connected to the fuel tube **71**, is provided to shut off the fuel cell and save fuel from diffusion leakage through the fuel cell array **68**. The fuel valve **72** may be opened and closed when the screen **133** of the computer **67** is opened and closed. The valve **72** may include capillaries to allow the fuel to wick through the valve. In another embodiment, the fuel tube **71** is made out of a rubber or plastic such that when the display screen **133** is opened or shut, the capillaries are squeezed on and off, respectively. If one-way valves are used, simple pumping of the fuel may be achieved by opening and closing the display screen **133**, or possibly by simply squeezing the fuel tube **71**. The electric power from the fuel cell is delivered through voltage regulating circuitry **73** which is located next to the fuel cell array **68** or in the conventional battery cavity of the portable computer **67**. Current flows from the fuel cell array **68** to the battery input connection **135** on the portable computer **67** through an electric cable **74**. If a rechargeable battery is used, the electrical input may be at the common connection of the battery and the portable computer. The contact with the MICRO-FUEL CELL **68** can be made with rivet or other electrical connections. The fuel cell power supply **66** is carried as an integral part of the portable computer **67**. It may have an outer porous cover to permit moisture from the

fuel cell and the user's body to evaporate. The porous cover enhances the user's grip on the portable computer and makes it more comfortable to use.

The fuel cell power supply **76** is formed with ABS plastic housing **137** to fit and attach onto the exterior surfaces of a video camcorder or portable power tool battery **77**, as shown in FIG. **13**. The fuel cell output is electrically connected in parallel to the rechargeable battery located in the camcorder or tool. The battery **77** may be a lead acid, nickel metal hydride or a lithium ion battery. With all those batteries, voltage regulation of the output may be used. For a lithium ion battery, the voltage regulation and charging circuit may automatically regulate the charging. The video camcorder or portable power tools are used for short periods of time, and then are idled for a period of time that ranges from hours to days. Thus, the fuel cell **76** trickle charges the battery **77** during the idle periods. The fuel cell array **78** is snapped along the back of the tool's battery **77**, or surrounds a smaller than usual battery, to allow this hybrid power supply to fit the docking cavity or arrangement on the video camcorder or portable power tool. The housing **137** of this hybrid power supply is made of ABS plastic. The fuel cell **76** is placed at this location to release the heat and moisture generated by the fuel cell **76** away from the video camcorder or portable power tool. A gas diffusion mat **79**, made from polyester fiber paper to serve as a protective cover, is placed over the MICRO-FUEL CELL array **78** inside the ABS plastic housing **137**. The gas diffusion mat **79** also serves as a thermal insulation layer. In cold environments it may be made thicker and in hot environments it may be made thinner to maintain an optimum elevated operating temperature of the fuel cell array **78**. The fuel tank **80** is shaped to fit inside the power supply between the battery **77** and the diffusion mat **79**. The fuel tank **80** is made from polyethylene plastic or polycarbonate plastic and filled with 1:1 molecular ratio of methanol to water mixture.

Fueling may be accomplished by snapping open the fuel cell power supply **76** from the battery **77**, inserting the fuel tank **80**, and closing the power supply assembly back over the battery. The fuel tank **80** is punctured by a fueling needle as the cover slides over the battery or could have screw on caps and screw onto the fuel cell. The fuel is then wicked from the needle or fuel connection to the fuel cell fuel manifold. The fuel tanks **80** may be sold individually or refilled by the user from a larger container of fuel. The fuel tanks **80** may also have a membrane seal to insure no fuel leakage through the coupling before use.

To allow observation of the fuel level in the fuel tank **80**, the tank could be made clear with a window **81** in the plastic housing **137** for viewing. If a porous filler is used in the fuel tank, the change from transparent to opaque may also be the indicator of fuel quantity in the fuel tank **80**. Electric power from the fuel cell is delivered through voltage regulating circuitry (not shown). Current flows from the fuel cell array **78** to the video camcorder or portable power tool through two sheet metal contact strips **82**, or by other electrical means, that form the common connection between the battery and video camcorder/power tool. Electrical contact with the MICRO-FUEL CELL **78** is made through rivets or other electrical connections. The fuel cell to portable video camcorder or power tool power supply is carried as an integral part of the appliance. It may have an outer porous cover to permit moisture from the fuel cell and the user's body to evaporate. The porous cover enhances the user's grip on the appliance and makes it more comfortable to use.

A substitute for a piggy back charging scheme for video camcorders and portable power tools **83** is the separate fuel

cell power supply **84**, which is connected to the camcorder or tool through an electrical power cord, as illustrated in FIG. **14**. This permits a wide range of devices to be powered by the fuel cell **84**, lightens the weight of the tool **83**, and dissipates the heat of the fuel cell **84** away from the appliance **83**. The fuel cell **84** may be carried as a strap-on or a clip-on by the user. The fuel cell output is electrically connected in parallel to the rechargeable battery **88**, or is voltage regulated through electronics. The battery **88** may be a lead acid battery, nickel metal hydride or a lithium ion battery. With all of these battery chargings, voltage regulation of the output may be used. Especially if a lithium ion battery is used, the voltage regulation and charging circuit may regulate the charging. The video camcorder or portable power tools **83** are to run for short periods of time, and then are idled for hours to days. Thus, the fuel cell **84** trickle charges the battery during the idle periods. The housing of this power supply is made of ABS plastic. The fuel cell array **85** is placed at the outer surface to permit the intake of oxygen and the release of carbon dioxide, heat, and moisture generated by the fuel cell **84**. Gas diffusion mats **86** and **139**, made from polyester fiber paper to serve as a protective covers, are placed around the fuel cell array **85** inside the ABS plastic housing. The gas diffusion mats **86** and **139** also serve as a thermal insulation layer. In cold environments it may be thickened, and in hot environments it may be thinned to maintain an optimum elevated operating temperature of the fuel cell array **85**. The fuel tank **87** is shaped to fit inside the power supply assembly between the battery **88** and the inner diffusion mat **86**. The outer diffusion mat **139** may be removed or changed. The fuel tanks **87** are made from polyethylene plastic or polycarbonate plastic and filled with 1:1 molecular ratio of methanol to water mixture. Fueling is done by snapping open the fuel cell from the assembly, inserting the fuel tank, and closing the fuel cell back over the assembly. The fuel tank is punctured on a fueling needle as the cover closes over the assembly. The fuel is then wicked, from the needle or fuel connection to the fuel cell fuel manifold. These large fuel tanks **87**, which have a membrane seal to insure no fuel leakage through the coupling before use, may be sold individually or may be refilled by the user from a larger container of fuel. An alternative to the membrane seal might be to have a removable screw on cap that may be removed for attaching the fuel tank **87** to the fuel cell **85**. To allow observation of the fuel quantity in the fuel tank **87**, a clear window **89** or opening is provided to allow the fuel level to be viewed. If a porous filler is used in the fuel tank, the change from transparent to opaque indicates the fuel quantity in the fuel tank **87**. Electric power from the fuel cell is delivered through a voltage regulating circuit next to the fuel cell. The current flows from the fuel cell array **85** to the video camcorder or portable power tool **83** through the electrical cable **90**. The electrical contact with the fuel cell is made through rivets or other electrical connections.

The fuel cell to portable video recorder, or power tool power supply, is carried separate from the appliance. It may have an outer porous cover to permit moisture from the fuel cell and the user's body to evaporate. The porous cover enhances the user's grip on the power supply and makes it more comfortable to use.

While this invention has been described in the context of a series of preferred embodiments, it will be apparent to those skilled in the art that the present invention may be modified in numerous ways and may assume many embodiments other than those specifically set out and described above. Accordingly, it is intended by the appended claims to cover all modifications of the invention which fall within the true spirit and scope of this invention.

We claim:

1. An apparatus having a power source for a battery powered device comprising an energy source, a fuel cell array consisting of at least one rechargeable fuel cell array sub-assembly having a plastic web comprising a patterned porous plastic substrate, electrolyte coating on the substrate, diffusion membrane, and gas manifolds for receiving fuel from the energy source and converting to power supply for the device, a thermal insulation and gas diffusion mat positioned on the fuel cell array, the gas diffusion mat having a water distribution matrix for removing and/or supplying water to the fuel cell array, and fuel manifolds in the fuel cell array, and a holder for receiving the battery powered device, the energy source, the thermal insulation and gas diffusion mat, and the fuel cell array.
2. The apparatus of claim 1, wherein the holder is of a plastic material.
3. The apparatus of claim 1, wherein the energy source is a fuel tank.
4. The apparatus of claim 3, wherein the fuel tank contains fuel that has a 1:1 molecular ratio of methanol to water.
5. The apparatus of claim 3, wherein the fuel tank is replaceable.
6. The apparatus of claim 3, further comprising a cavity in the holder for receiving the fuel tank.
7. The apparatus of claim 3, further comprising a fuel level indicator window in the holder for viewing the level of fuel in the fuel tank.
8. The apparatus of claim 1, further comprising a location in the holder for locating the portable battery charger and battery powered device.
9. The apparatus of claim 1, further comprising power connecting electronics in the holder.
10. The apparatus of claim 1, further comprising a clip on the holder for attaching the holder to a user's clothing.
11. The apparatus of claim 1, further comprising a ratchet mechanism for releasably securing the battery powered device to the holder.
12. The apparatus of claim 1, wherein the diffusion mat has a thickness that varies across the fuel cell array.
13. The apparatus of claim 1, further comprising a cover for covering the holder.
14. The apparatus of claim 1, wherein the fuel cell array is a surface replica fuel cell power source.
15. The apparatus of claim 5, further comprising a package having a plurality of fuel tanks for replacing spent fuel tanks.
16. The apparatus of claim 3, wherein the fuel tank contains fuel having a hydrogen bearing compound.

17. The apparatus of claim 16, wherein the fuel is selected from a group consisting of alcohol and hydrocarbon bearing compounds.
18. A portable fuel cell power supply apparatus comprising an energy source, a fuel cell array consisting of at least one rechargeable fuel cell array sub-assembly having a plastic web comprising a patterned porous plastic substrate, electrolyte coating on the substrate, diffusion membrane, and gas manifolds for receiving fuel from the energy source, a thermal insulation and gas diffusion mat positioned on the fuel cell array, the gas diffusion mat having a water distribution matrix for removing and/or supplying water to the fuel cell array, a battery for receiving a continuous charge from the fuel cell array, and a holder for receiving the energy source, the fuel cell array, the diffusion mat and the battery.
19. The apparatus of claim 18, wherein the energy source is a fuel tank.
20. The apparatus of claim 19, wherein the fuel tank contains fuel that has a 1:1 molecular ratio of methanol to water.
21. The apparatus of claim 19, wherein the fuel tank is refillable.
22. The apparatus of claim 18, wherein the holder fits into the battery cavity of a cellular phone.
23. The apparatus of claim 18, wherein the holder is of a plastic material.
24. The apparatus of claim 19, further comprising a cavity in the holder for receiving the fuel tank.
25. The apparatus of claim 19, further comprising a fuel level indicator window in the holder for viewing the level of fuel in the fuel tank.
26. The apparatus of claim 18, wherein the diffusion mat has a thickness that varies across the fuel cell array.
27. The apparatus of claim 18, further comprising a cover for covering the holder.
28. The apparatus of claim 21, further comprising a refill port in the holder for adding fuel to the fuel tank.
29. The apparatus of claim 28, further comprising a fuel dispenser for adding fuel to the fuel tank through the refill port.
30. The apparatus of claim 18, wherein the fuel cell array is a surface replica fuel cell power source.
31. The apparatus of claim 21, wherein the fuel tank is replaceable.
32. The apparatus of claim 31, further comprising a kit having a plurality of fuel tanks for replacing spent fuel tanks.

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UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 6,326,097 B1

Page 1 of 1

DATED : December 4, 2001

INVENTOR(S) : Robert G. Hockaday, Patrick S. Turner, Marvin Maslow and Martin Cooper

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Title page,

Item [75], add the following inventors:

Patrick S. Turner, Los Alamos, NM (US)

Marvin Maslow, New York, NY (US)

Martin Cooper, Del Mar, CA (US)

Signed and Sealed this

Sixteenth Day of April, 2002

Attest:

A handwritten signature in black ink, appearing to read "James E. Rogan", written over a horizontal line.

Attesting Officer

JAMES E. ROGAN
Director of the United States Patent and Trademark Office