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(54) **POWER GENERATION FOR PROCESS DEVICES**

(75) Inventors: **Gregory C. Brown**, Chanhassen, MN (US); **Andrew J. Klosinski**, Chaska, MN (US); **Steven R. Trimble**, Prior Lake, MN (US); **Mark Fandrey**, Eden Prairie, MN (US)

(73) Assignee: **Rosemount Inc.**, Eden Prairie, MN (US)

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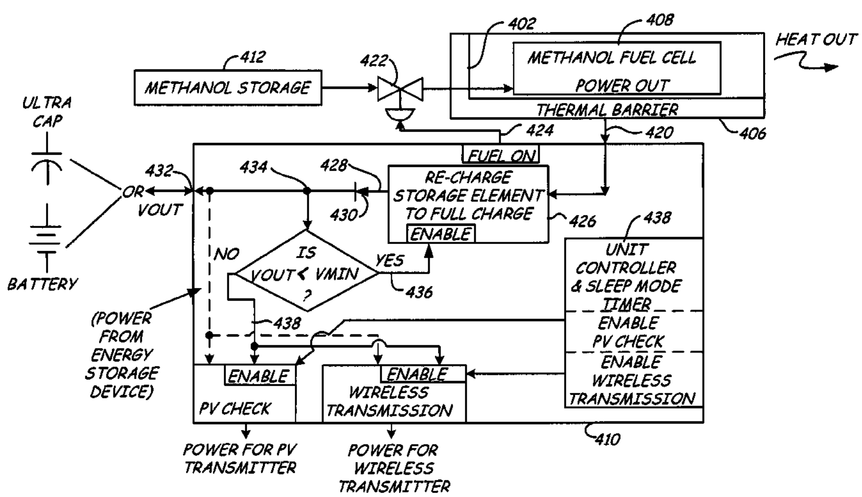
Primary Examiner — Albert DeCady
Assistant Examiner — Darrin Dunn
(74) *Attorney, Agent, or Firm* — Christopher R. Christenson; Westman, Champlin & Kelly, P.A.

(57) **ABSTRACT**

A process device includes a controller and a wireless communications module. The wireless communications module is coupled to the controller. A power generation module is provided to generate electricity for the process device. The power generator module can be disposed within the process device or it can be a separate unit coupled to the process device.

9 Claims, 11 Drawing Sheets



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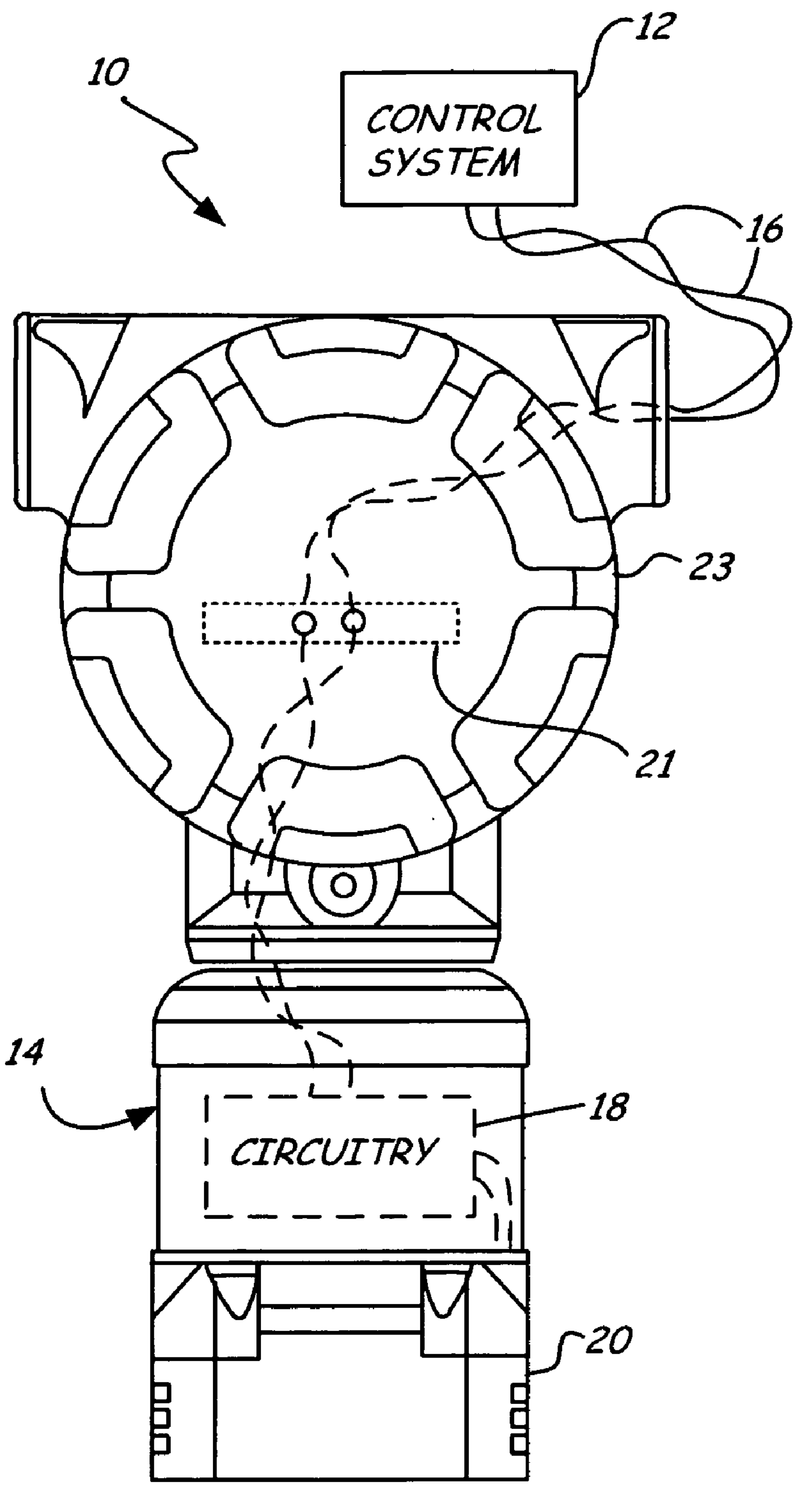


Fig. 1

(PRIOR ART)

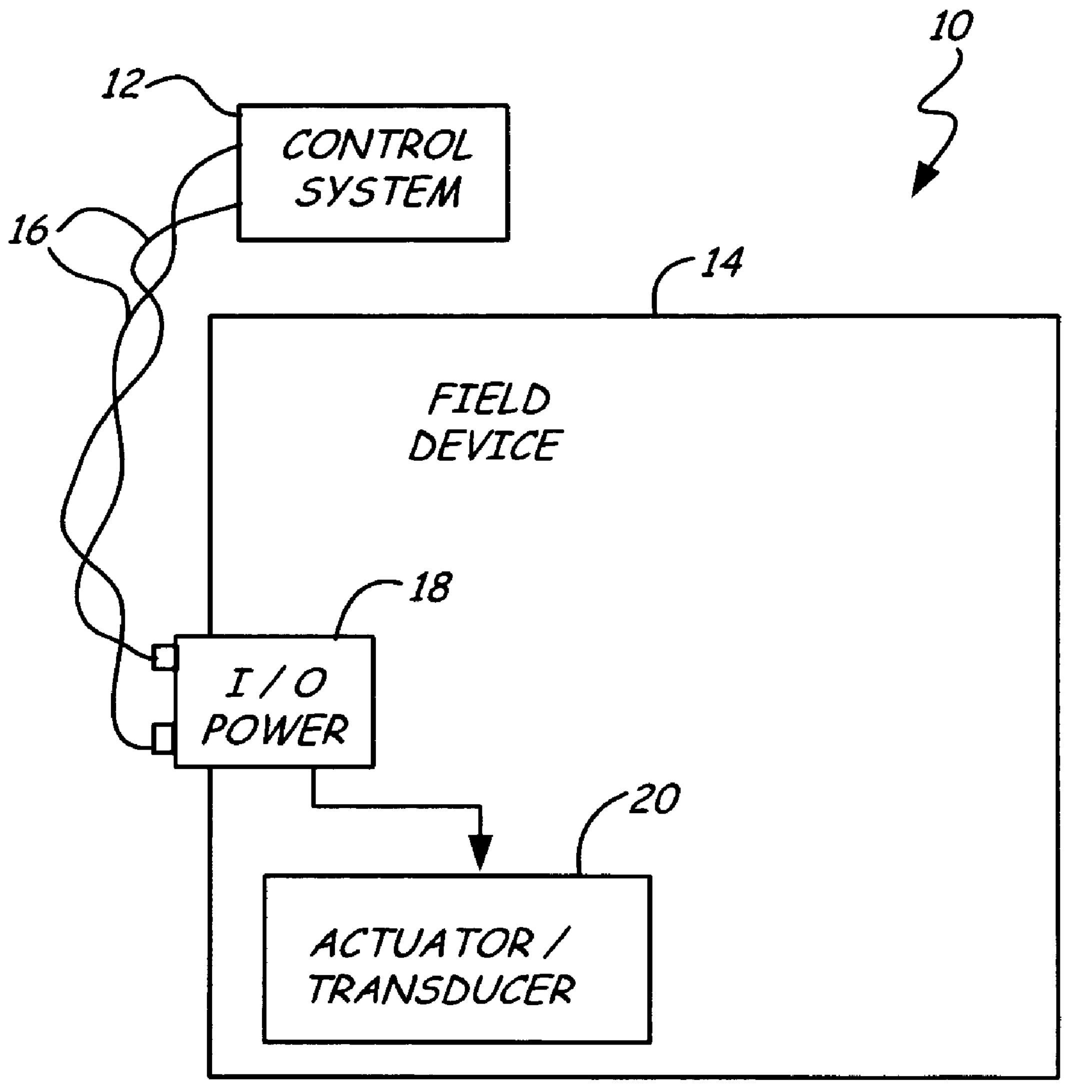
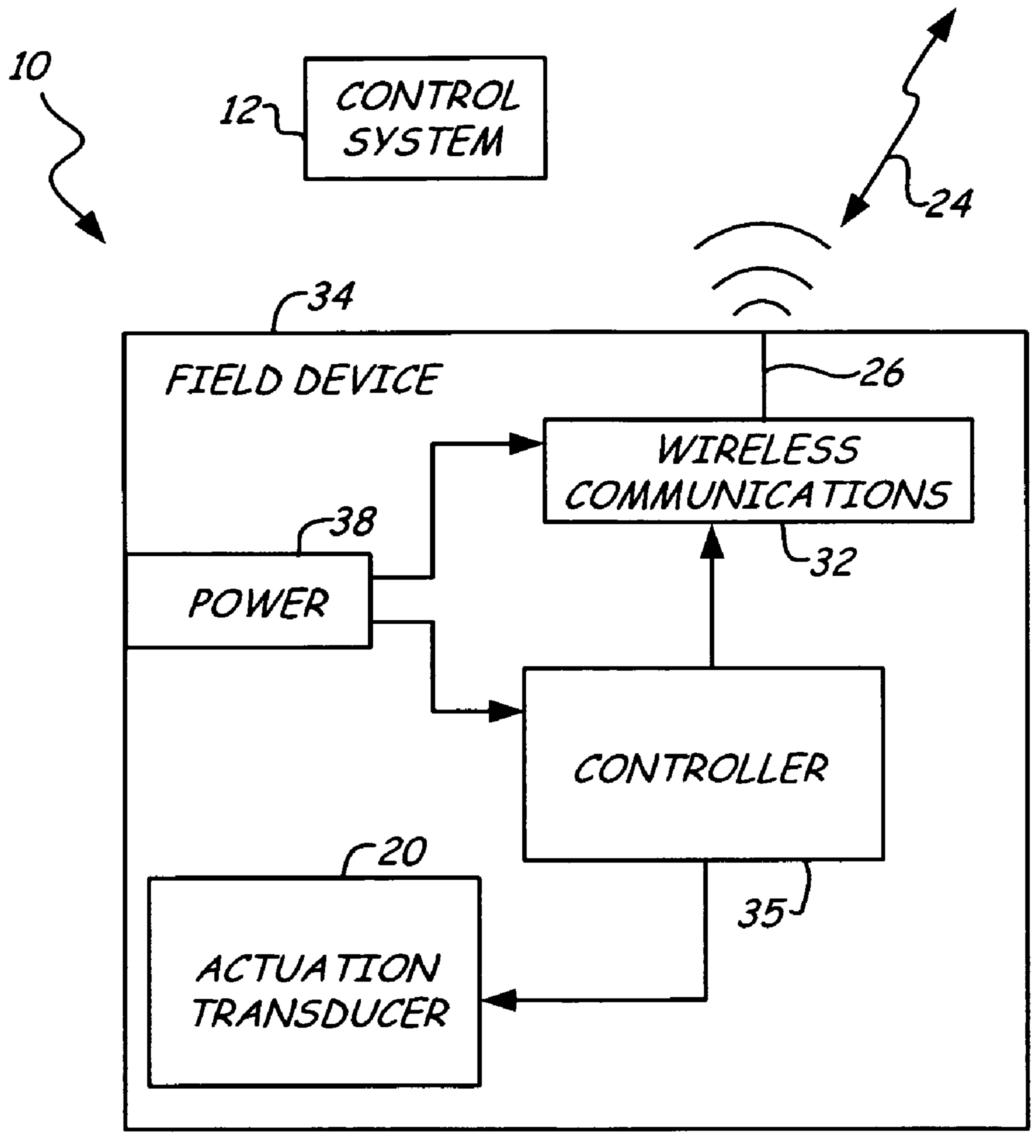


Fig. 2
(PRIOR ART)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12
CONTROL SYSTEM
24
34
FIELD DEVICE
26
WIRELESS COMMUNICATIONS
38
POWER
32
CONTROLLER
20
35
ACTUATION TRANSDUCER

Fig. 3

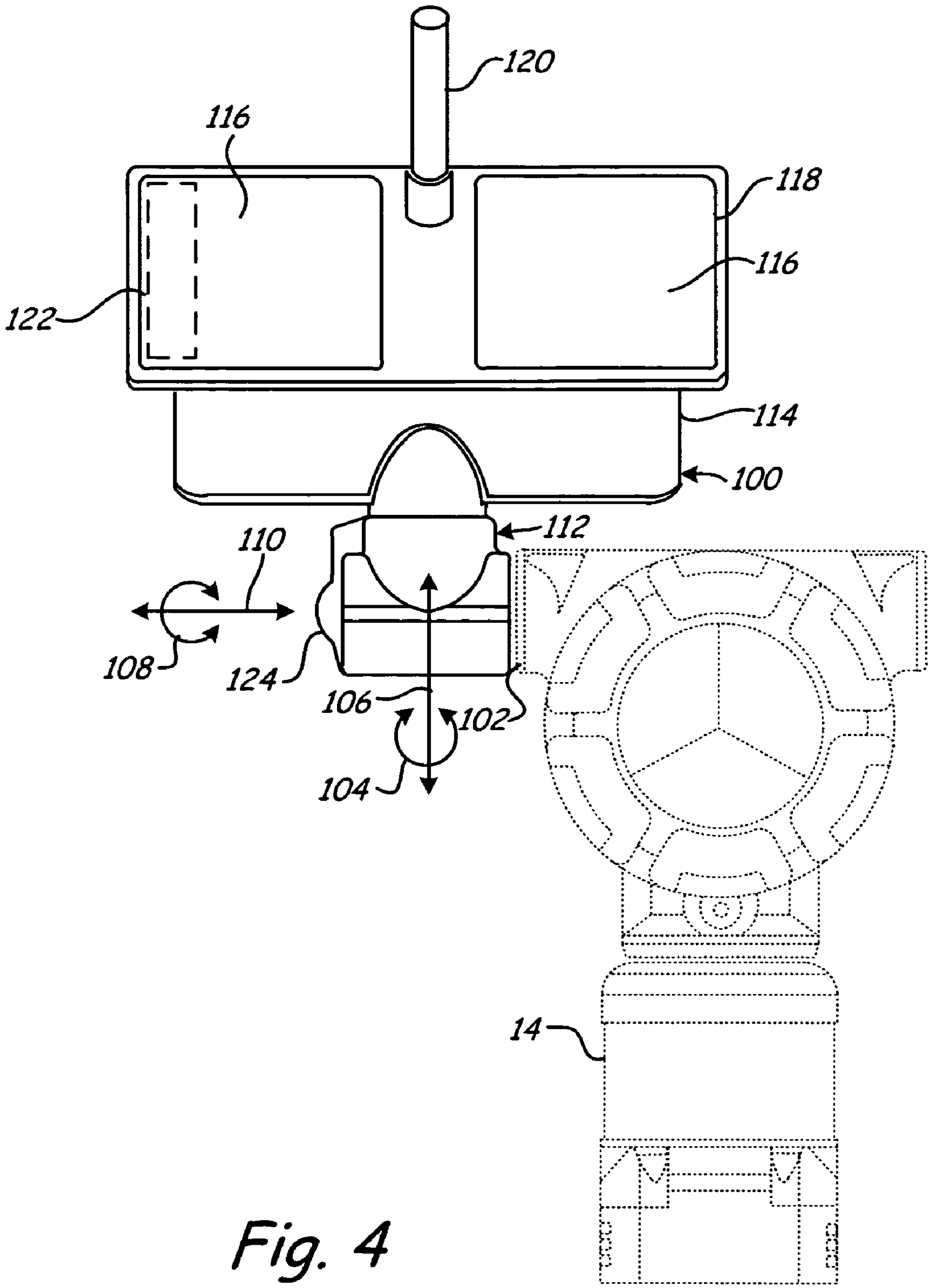


Fig. 4

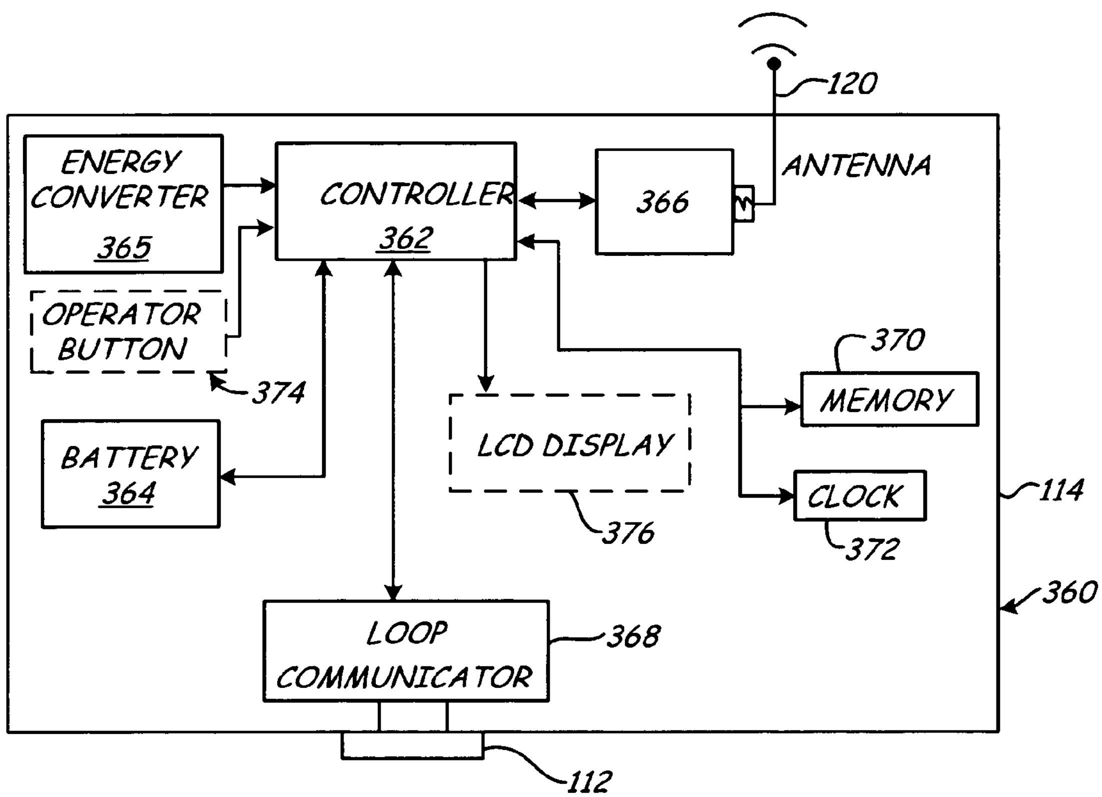
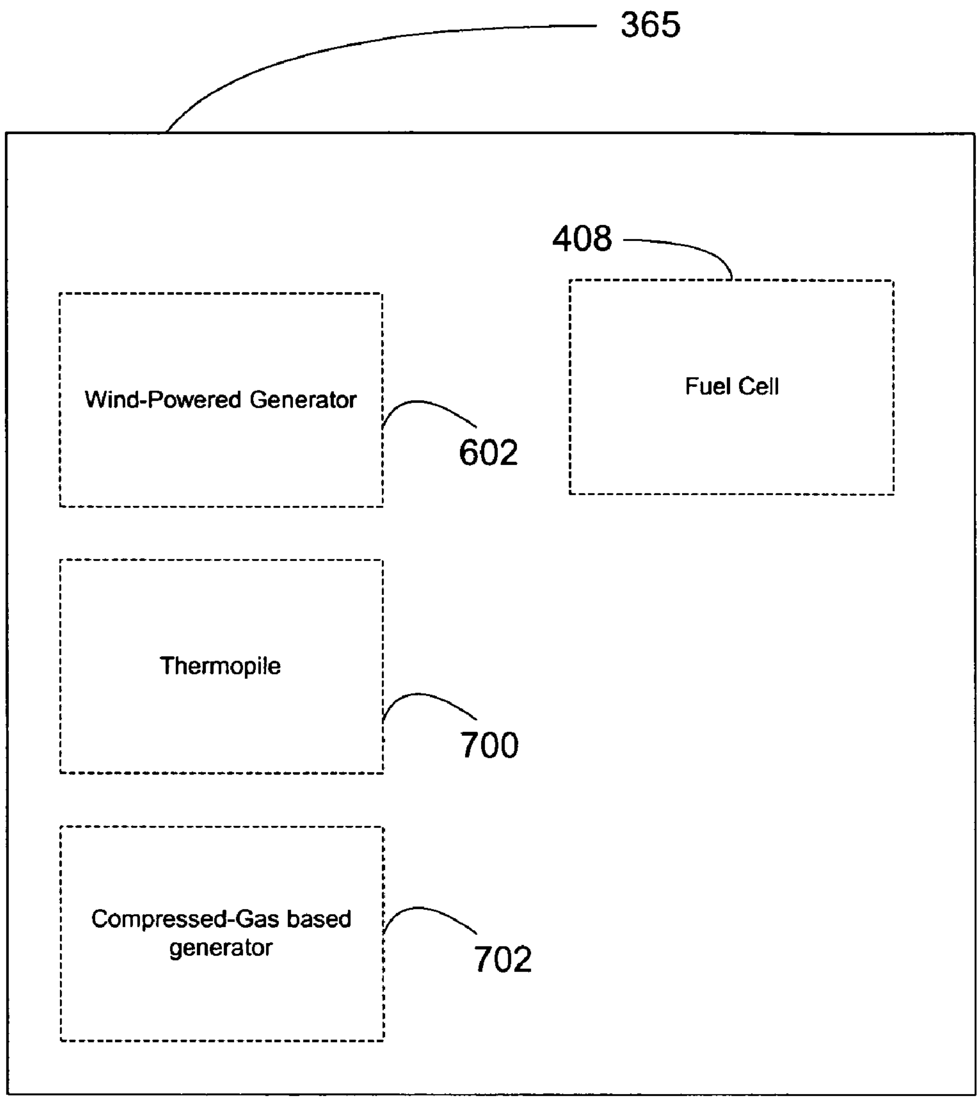

120
ANTENNA
ENERGY CONVERTER 365
CONTROLLER 362
366
OPERATOR BUTTON
374
BATTERY 364
370
MEMORY
LCD DISPLAY
CLOCK
114
376
372
360
LOOP COMMUNICATOR
368
112

Fig. 5A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408
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602
Fuel Cell
Thermopile
700
Compressed-Gas based generator
702

Fig. 5B

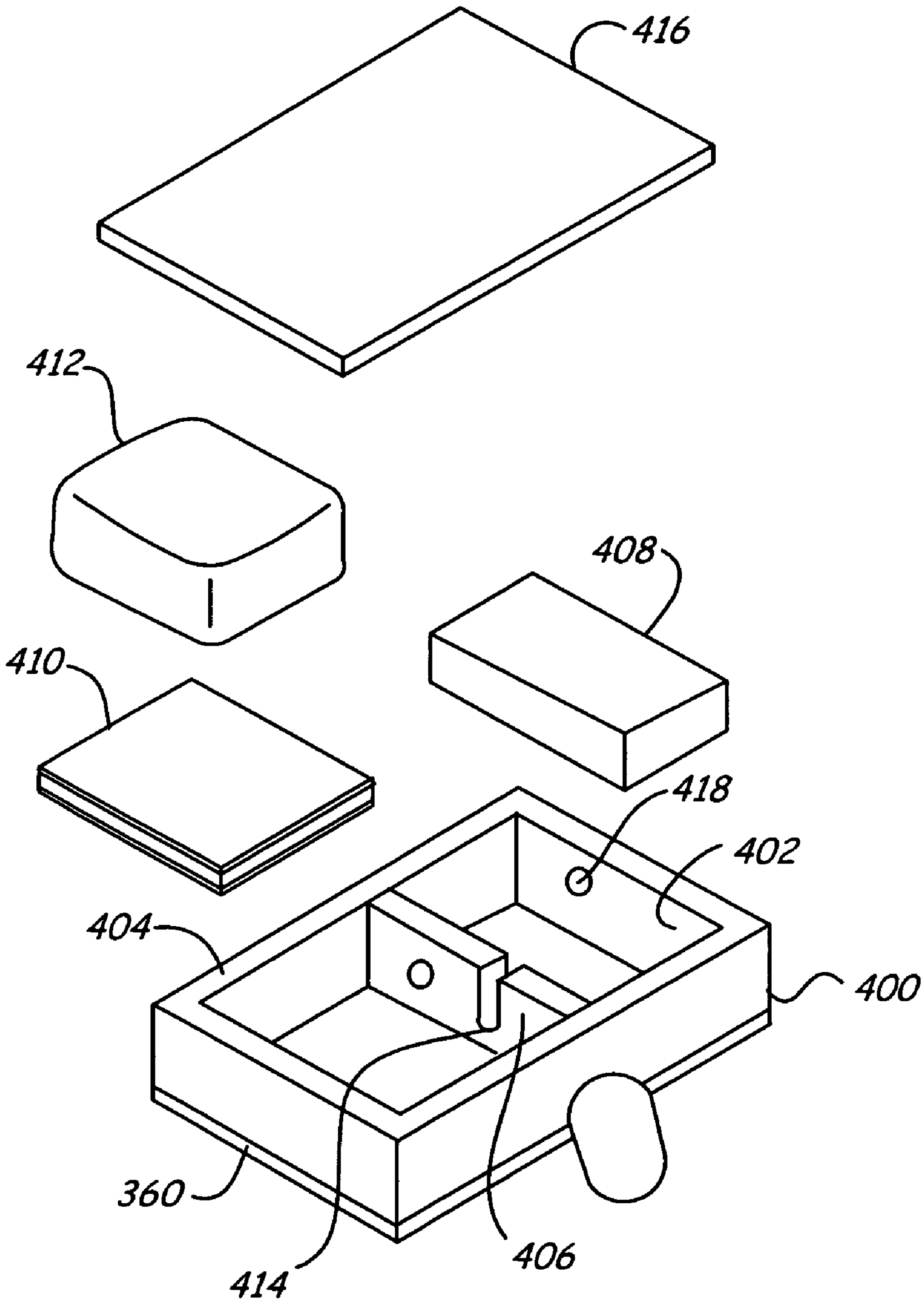
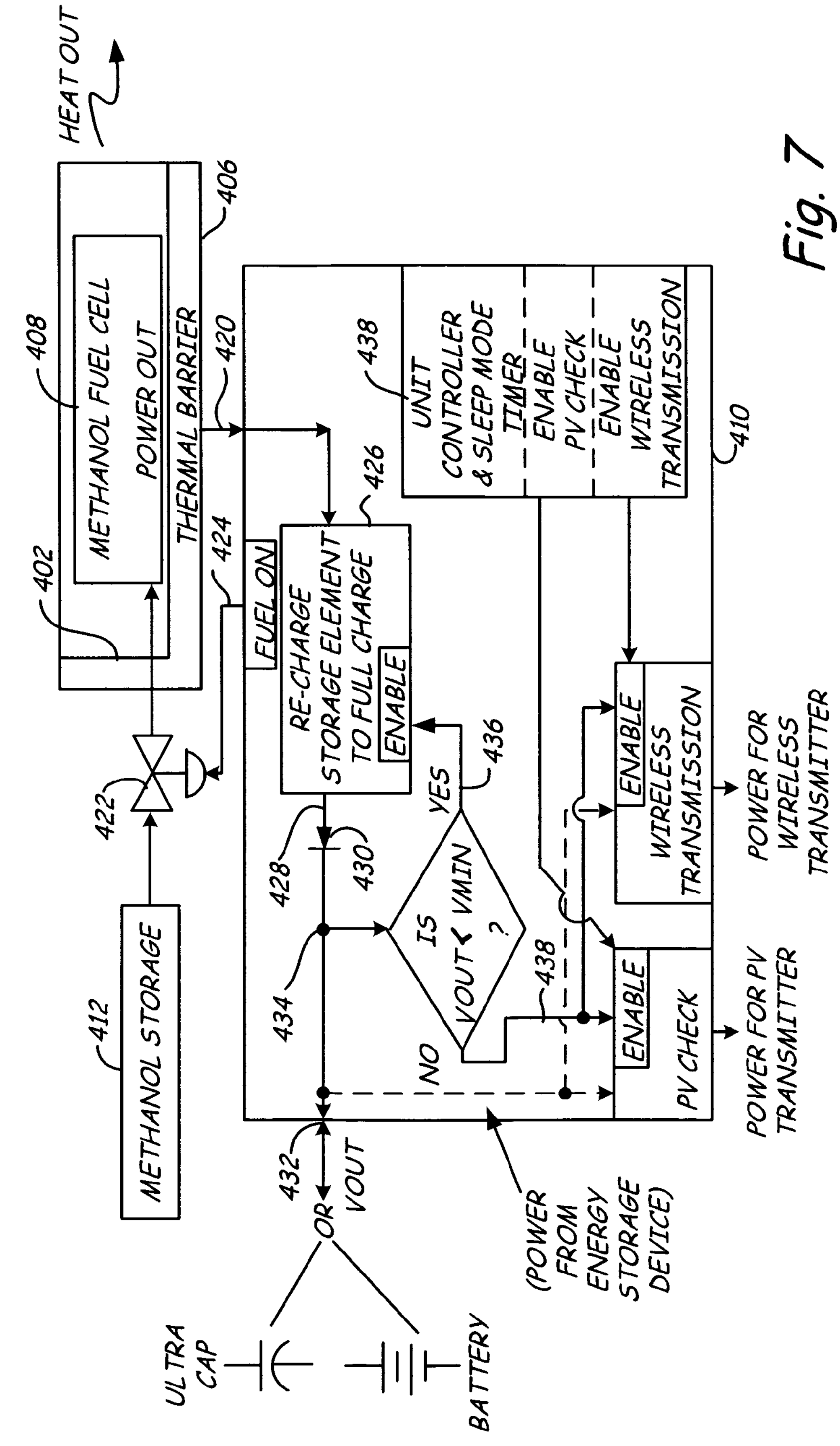


Fig. 6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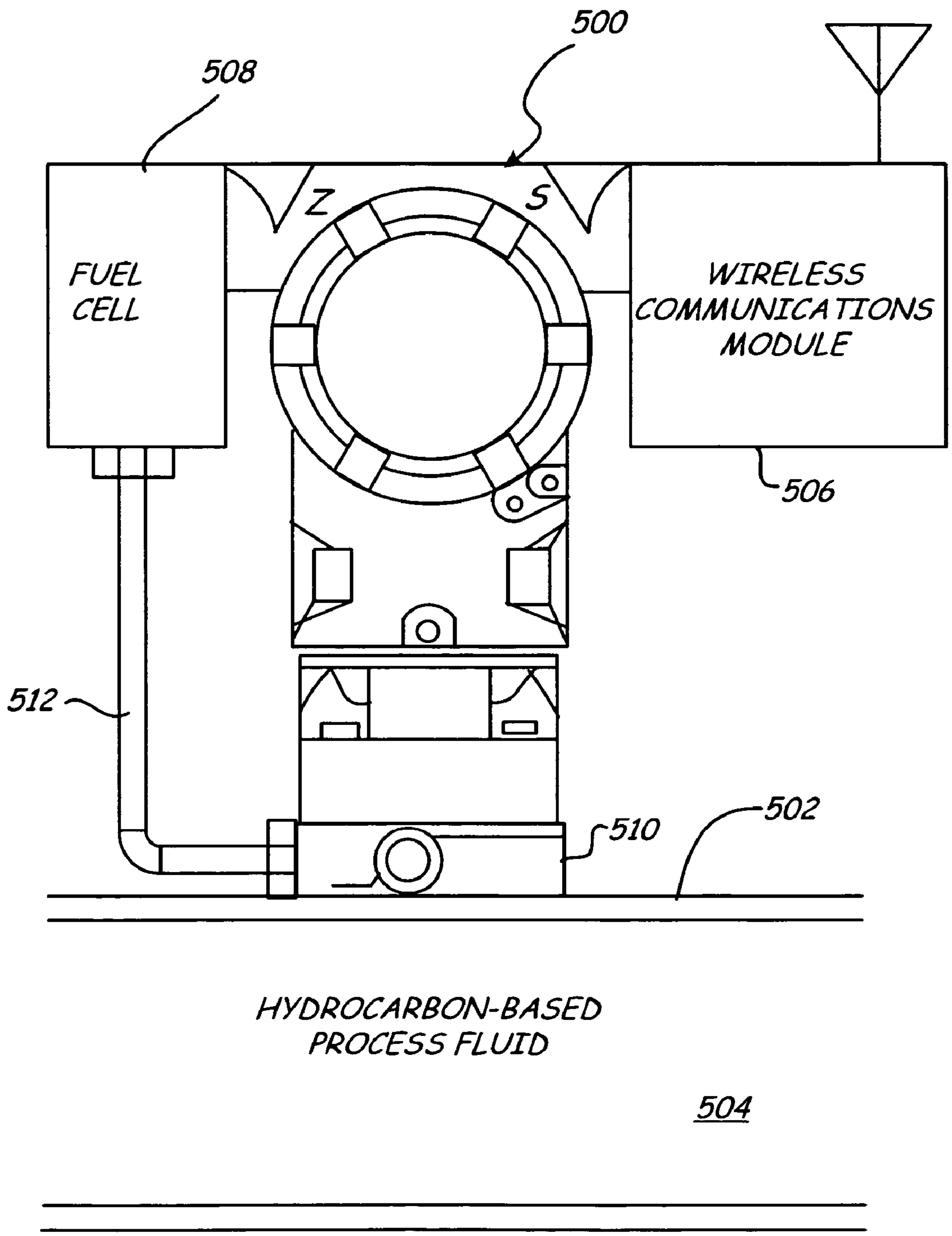
408
METHANOL FUEL CELL
POWER OUT
THERMAL BARRIER
420
402
424
FUEL ON
426
RE-CHARGE
STORAGE ELEMENT
TO FULL CHARGE
ENABLE
438
UNIT
CONTROLLER
& SLEEP MODE
TIMER
ENABLE
PV CHECK
ENABLE
WIRELESS
TRANSMISSION
410
412
METHANOL STORAGE
422
436
YES
428
430
IS
VOUT < VMIN
?
434
NO
438
ENABLE
WIRELESS
TRANSMISSION
ENABLE
PV CHECK
POWER FOR
WIRELESS
TRANSMITTER
POWER FOR PV
TRANSMITTER
432
VOUT
OR
(POWER
FROM
ENERGY
STORAGE
DEVICE)
ULTRA
CAP
BATTERY

Fig. 7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WIRELESS COMMUNICATIONS MODULE
506
512
510
502
HYDROCARBON-BASED PROCESS FLUID
504

Fig. 8

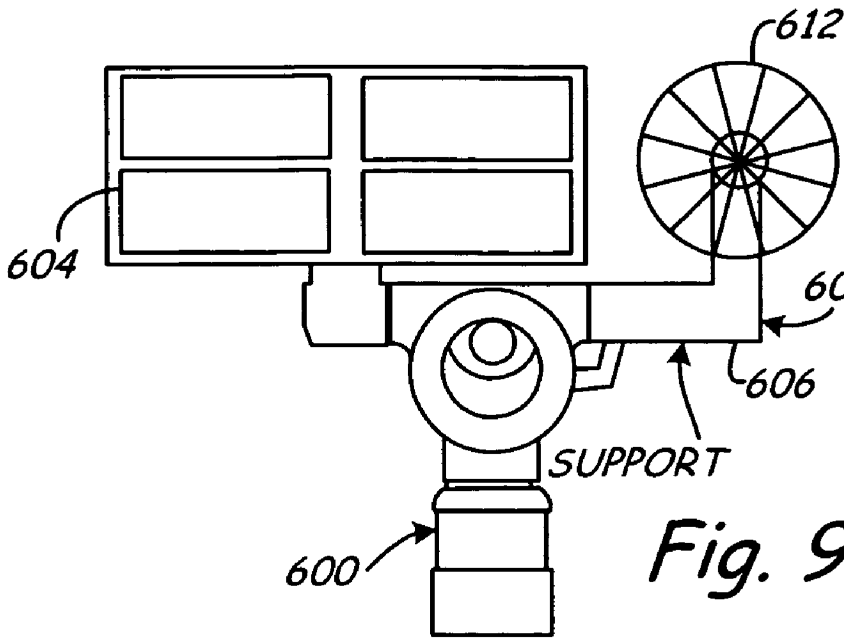

Fig. 9A

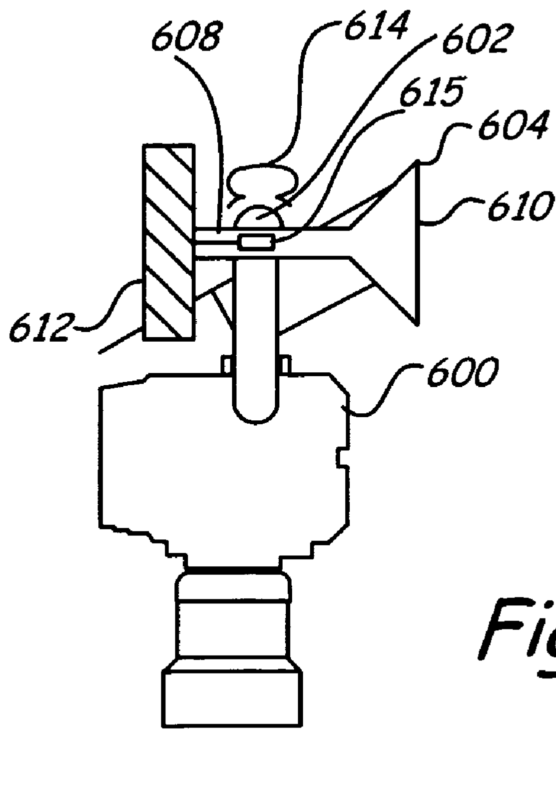

Fig. 9B

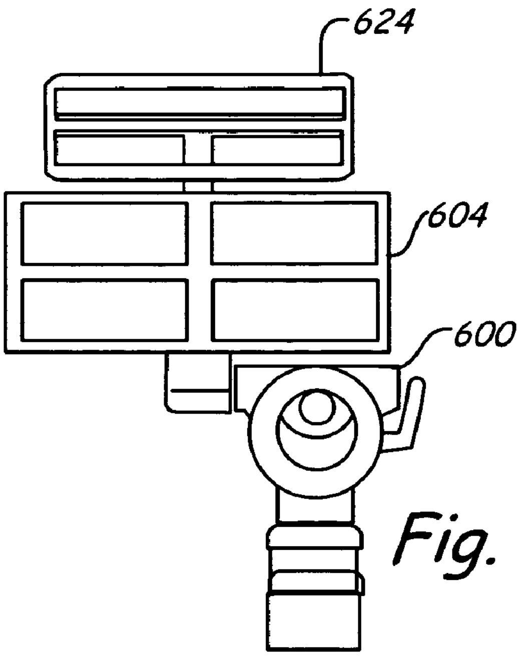

Fig. 10A

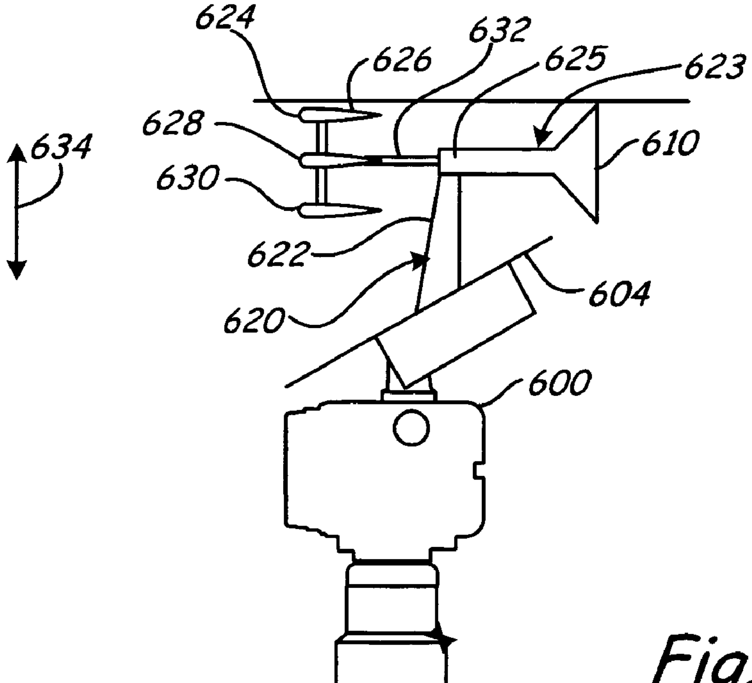

Fig. 10B

POWER GENERATION FOR PROCESS DEVICES

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part application of U.S. patent application Ser. No. 10/850,828, filed May 21, 2004, entitled WIRELESS POWER AND COMMUNICATION UNIT FOR PROCESS FIELD DEVICES.

BACKGROUND OF THE INVENTION

The present invention relates to industrial process control and monitoring systems. More specifically, the present invention relates to the generation of electrical power for such field devices.

In industrial settings, control systems are used to monitor and control inventories of industrial and chemical processes, and the like. Typically, the control system performs these functions using field devices distributed at key locations in the industrial process and coupled to the control circuitry in the control room by a process control loop. The term "field device" refers to any device that performs a function in a distributed control or process monitoring system, including all devices used in the measurement, control and monitoring of industrial processes.

Field devices, also referred to herein as process devices, are used by the process control and measurement industry for a variety of purposes. Usually such devices have a field-hardened enclosure so that they can be installed outdoors in relatively rugged environments and are able to withstand climatalogical extremes of temperature, humidity, vibration, mechanical shock, etc. These devices also can typically operate on relatively low power. For example, field devices are currently available that receive all of their operating power from a known 4-20 mA loop. These devices are able to not only operate upon the loop but communicate over the loop both with analog signals (actually modulating the 4-20 mA signal) and digitally.

Some field devices include a transducer. A transducer is understood to mean either a device that generates an output signal based on a physical input or that generates a physical output based on an input signal. Typically, a transducer transforms an input into an output having a different form. Types of transducers include various analytical equipment, pressure sensors, thermistors, thermocouples, strain gauges, flow transmitters, positioners, actuators, solenoids, indicator lights, and others.

Typically, each field device also includes communication circuitry that is used for communicating with a process control room, or other circuitry, over a process control loop. In some installations, the process control loop is also used to deliver a regulated current and/or voltage to the field device for powering the field device.

Traditionally, analog field devices have been connected to the control room by two-wire process control current loops, with each device connected to the control room by a single two-wire control loop. Typically, a voltage differential is maintained between the two wires within a range of voltages from 12-45 volts for analog mode and 9-50 volts for digital mode. Some analog field devices transmit a signal to the control room by modulating the current running through the current loop to a current proportional to the sensed process variable. Other analog field devices can perform an action under the control of the control room by controlling the magnitude of the current through the loop. In addition to, or in the alternative, the process control loop can carry digital signals used for communication with field devices. Digital communication allows a much larger degree of communication than analog communication. Field devices that communicate digitally can respond to and communicate selectively with the control room and/or other field devices. Further, such devices can provide additional signaling such as diagnostics and/or alarms.

In some installations, wireless technologies have begun to be used to communicate with field devices. Wireless operation simplifies field device wiring and setup. Wireless installations are currently used in which the field device is manufactured to include an internal battery, potentially charged by a solar cell without any sort of wired connection. Problems exist in using an internal battery as the energy demands of wireless devices may vary greatly depending on numerous factors such as the device reporting rate, device elements, et cetera.

Difficulties also arise in installations where solar power is not reliable. For example, it becomes problematic to use solar power in areas that experience full shade twenty-four hours a day, seven days a week, or in parts of the world where solar isolation numbers are very small, such as in the Arctic circle. Accordingly, in these installations, powering a wireless process device using solar power is not reliable. Accordingly, there is an ongoing significant need for wireless process devices that can operate using an abundant renewable source of power that is not dependent upon the sun.

SUMMARY OF THE INVENTION

A process device includes a controller, a wireless communications module. The wireless communications module is coupled to the controller. A power generation module is provided to generate electricity for the process device. The power generator module can be disposed within the process device or it can be a separate unit coupled to the process device.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a diagrammatic view of an exemplary field device with which the wireless power and communication unit in accordance with the present invention is particularly useful.

FIG. **2** is a block diagram of the field device shown in FIG. **1**.

FIG. **3** is a block diagram of a field device including wireless communication circuitry for communicating with a remote device such as a display or hand held unit.

FIG. **4** is a front elevation view of a wireless power and communication unit in accordance with embodiments of the present invention mounted to a field device.

FIG. **5**A is a block diagram of a wireless power and communication unit in accordance with embodiments of the present invention.

FIG. **5**B is a block diagram of an energy conversion module in accordance with an embodiment of the present invention.

FIG. **6** is a diagrammatic view of an electrical power generation system for a process device in accordance with an embodiment of the present invention.

FIG. **7** is a diagrammatic view of a power generation system for process devices in accordance with an embodiment of the present invention.

FIG. **8** is a diagrammatic view of a wireless process device in accordance with an embodiment of the present invention.

FIGS. **9**A and **9**B are front and side elevation views, respectively, of a process device in accordance with an embodiment of the present invention.

FIGS. **10**A and **10**B are front and side elevation views, respectively, of a process device in accordance with another embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention provides electrical power generation for field devices using sources of energy that are located proximate the field device. Additionally, these sources of energy do not rely upon solar energy. Embodiments of the present invention include providing a wireless power and communication unit for allowing field devices that are designed for wired communication to operate wirelessly. Additionally, embodiments of the present invention include generating power for a field device using a non-solar source of energy disposed proximate the field device.

Embodiments of the present invention utilize a non-solar energy source proximate the field device in order to generate power for use by the field device. As used herein, the term "non-solar" includes any source of power generated by molecules physically proximate the process device. Thus, non-solar energy can include wind power, fuel cell technology that makes use of oxygen proximate the field device, and/or fuel cell technology that makes use of molecules in the process fluid itself for energy. Detailed descriptions of each of these embodiments is set forth in greater detail below.

FIGS. **1** and **2** are diagrammatic and block diagram views of an exemplary field device with which a wireless power and communication unit in accordance with the present invention is useful. Process control or monitoring system **10** includes a control room or control system **12** that couples to one or more field devices **14** over a two-wire process control loop **16**. Examples of process control loop **16** include analog 4-20 mA communication, hybrid protocols which include both analog and digital communication such as the Highway Addressable Remote Transducer (HART®) standard, as well as all-digital protocols such as the FOUNDATION™ Fieldbus standard. Generally process control loop protocols can both power the field device and allow communication between the field device and other devices.

In this example, field device **14** includes circuitry **18** coupled to actuator/transducer **20** and to process control loop **16** via terminal board **21** in housing **23**. Field device **14** is illustrated as a process variable (PV) generator in that it couples to a process and senses an aspect, such as temperature, pressure, pH, flow, or other physical properties of the process and provides and indication thereof. Other examples of field devices include valves, actuators, controllers, and displays.

Generally field devices are characterized by their ability to operate in the "field" which may expose them to environmental stresses, such as temperature, humidity and pressure. In addition to environmental stresses, field devices must often withstand exposure to corrosive, hazardous and/or even explosive atmospheres. Further, such devices must also operate in the presence of vibration and/or electromagnetic interference. Field devices of the sort illustrated in FIG. **1** represent a relatively large installed base of legacy devices, which are designed to operate in an entirely wired manner.

FIG. **3** is a block diagram of a wireless field device. Field device **34** includes power generation module **38**, controller **35**, wireless communication module **32**, and actuator/transducer **20**. Module **38** may include an internal power storage unit, and is adapted to power field device **34**. Power generation module **38** generates electricity for device **34**. The manner in which this generation occurs can take many forms and specific examples such as fuel cell and wind-based generators are provided later in the specification. The power from module **38** energizes controller **35** to interact with actuator/transducer **20** and wireless communications module **32**. Wireless communications module **32**, in turn, interacts with other devices as indicated by reference numeral **24** via antenna **26**.

FIG. **4** is a front elevation view of a wireless power and communication unit **100** attached to a field device **14**, shown in phantom. Unit **100** preferably attaches to device **14** via a standard field device conduit **102**. Examples of suitable conduit connections include ½-14 NPT, M20×1.5, G½, and ⅜-18 NPT. Unit **100** may include a joint allowing rotation **104** about axis **106** and rotation **108** about axis **110**. Further, attachment region **112** of unit **100** is preferably hollow in order to allow conductors therein to couple unit **100** to device **14**. In embodiments where positional adjustment of the housing is not desired, attachment region **112** could simply be a piece of conduit.

Unit **100** includes housing **114** that is mounted upon attachment region **112**. Housing **114** contains circuitry (described with respect to FIG. **8**) to allow unit **100** to power and communicate with device **14** in accordance with a standard industry protocol such as 4-20 mA, HART®, FOUNDATION™ Fieldbus, Profibus-PA, Modbus, or CAN. Preferably, the protocol accommodates digital communication in order to enhance the level of interaction between unit **100** and device **14**.

Since unit **100** is external to device **14**, multiple variations of unit **100** can be provided with varying internal power generation modules depending upon the specific power requirements of the field device to which the unit will be attached. Unit **100** also preferably includes wireless communication circuitry (not shown in FIG. **4**) which is coupled to antenna **120**. Providing external antenna **120** facilitates wireless communication in comparison to internal antennas since many field-hardened enclosures are metal and would likely attenuate the wireless signal. However, embodiments with an internal antenna proximate a radio-transparent portion of housing **114**, or cell(s) **116** can be practiced as well. External antenna embodiments, however, are particularly advantageous where unit **100** is field hardened in order to withstand environments similar to those for which field devices are designed.

Unit **100** can also include a local user interface. Accordingly unit **100** may include a display, such as an LCD display **122** that may be mounted proximate one of cells **116**. In order to receive local user input, unit **100** can include one or more local inputs such as button **124**. A local user interface is important because when the combined unit/field device system is operating totally wirelessly, it is more convenient for a technician to interact with the local user interface rather than wirelessly trying to access the device via a handheld computing device or the like. The local interface can be used to access the unit, the field device, or both. As defined herein "local user interface" means having either local user input(s) (such as a button), local user output(s) (such as an LCD), or a combination of the two. As illustrated in FIG. **4**, the LCD can be co-located with cell(s) **116**.

FIG. **5** is a block diagram of a wireless power and communication unit in accordance with embodiments of the present invention. Unit **360** includes controller **362**, power storage device **364** (illustrated as a battery), energy converter **365**, loop communicator **368**, and wireless communication interface module **366**.

Controller **362** preferably includes a low-power microprocessor and appropriate charging circuitry to convey suitable amounts of energy from cell(s) **116** and/or storage device **364** to power unit **360** and any field devices coupled to attachment region **112**. Additionally, controller **362** also directs excess energy from cell(s) **116** and/or converter **365** to storage device **364**. Controller **362** can also be coupled to optional temperature measurement circuitry such that controller **362** can reduce charging current to storage device **364** if device **364** begins to overheat. For example, the temperature measuring circuit may contain a suitable temperature-sensing element, such as a thermocouple coupled to storage device **364**. An analog-to-digital converter then converts the signal from the thermocouple to a digital representation thereof, and provides the digital signal to controller **362**.

Controller **362** can be configured, through hardware, software, or both to actively manage power for itself and attached field devices. In this regard, controller **362** can cause itself or any desired field devices to enter a low-power sleep mode. Sleep mode is any operating mode where power consumption is reduced. With respect to field devices, sleep mode could result from commanding the field device to set its operating current at its lowest allowable current rail. Events which may precipitate entering low-power mode could include: the expiration of an activity period, an input from one or more of the local user inputs, communication from one or more attached field devices, or wireless communication. Such events could also be used to cause unit **360** and/or any attached field devices to awaken from sleep mode. Additionally, controller **362** can selectively cause any attached field device to enter sleep mode based upon any logic or rules contained in programming instructions within controller **362** and/or wireless communication received via wireless communication module **366**. Preferably, local inputs, such as button **124** are user configurable. Thus a single button could be used to awaken a field device for a user-selectable period of time, and if so configured, depressed again to cause the field device to return to sleep mode. In one embodiment, the configurable local input button uses a jumper or switch to preset the following functions:

Button Depress Time to Activate—select either 1, 1.5, 2 or 3 seconds. Field device ignores button presses having durations shorter than the preset.

Unit On Time—select either 10, 15, 30 seconds, or 5, 15, 30, 60 minutes.

If the button is pressed twice in close succession, the field device stays on for a preset period (for example 60 minutes) after which it returns to sleep mode.

If the button is pressed a second time after a preset interval (for example 5 seconds) the field device will return to sleep mode.

Controller **362** can also preferably cause portions of circuitry within unit **360** or attached field devices to enter sleep mode. For example, wireless communication module **366** may be a commercially available General Packet Radio Service (GPRS) cell phone module, that has both a normal operating mode and a sleep mode. A signal from controller **362** could cause module **366** to enter sleep mode when significant wireless communication is not warranted.

Energy converter **365** can be any device that is able to generate electrical energy for use by the process device. Converter **365** can preferably include a generator (**612**) coupled to a movable member such that environmental motion, such as waves or wind generate electricity. Further, converter **365** can include fuel cell **408**. Further, converter **365** can employ thermopile devices **702** (shown in FIG. **5**B) to generate electricity from disparate temperatures using the Peltier Effect. Further still, the process may provide a source of energy in the form of compressed gas or the like, that could be transformed into electricity using compressed gas based generator **704** (shown in FIG. **5**B). Finally, in embodiments where the power storage device has a relatively large capacity in comparison to the energy needs of the application, converter **365** may be omitted. It is also expressly contemplated that combinations of the various conversion modules illustrated in FIG. **5**B can be employed.

Wireless communication module **366** is coupled to controller **362** and interacts with external wireless devices via antenna **120** based upon commands and/or data from controller **362**. Depending upon the application, wireless communication module **366** may be adapted to communicate in accordance with any suitable wireless communication protocol including, but not limited to: wireless networking technologies (such as IEEE 802.11b wireless access points and wireless networking devices built by Linksys of Irvine, Calif.), cellular or digital networking technologies (such as Microburst® by Aeris Communications Inc. of San Jose, Calif.), ultra wide band, free space optics, Global System for Mobile Communications (GSM), General Packet Radio Service (GPRS), Code Division Multiple Access (CDMA), spread spectrum technology, infrared communications techniques, SMS (Short Messaging Service/text messaging), or any other suitable wireless technology. Further, known data collision technology can be employed such that multiple units can coexist within wireless operating rage of one another. Such collision prevention can include using a number of different radio-frequency channels and/or spread spectrum techniques.

Wireless communication module **366** can also include transducers for a plurality of wireless communication methods. For example, primary wireless communication could be performed using relatively long distance communication methods, such as GSM or GPRS, while a secondary, or additional communication method could be provided for technicians, or operators near the unit, using for example, IEEE 802.11b or Bluetooth.

Some wireless communications modules may include circuitry that can interact with the Global Positioning System (GPS). GPS can be advantageously employed in unit **360** for mobile devices to allow finding the individual unit **360** in a remote location. However, location sensing based upon other techniques can be used as well.

Memory **370** is illustrated in FIG. **5** as being separate from controller **362**, but may, in fact, be part of controller **362**. Memory **370** can be any suitable type of memory including volatile memory (such as Random Access Memory), non-volatile memory (such as flash memory, EEPROM memory, etc.) and any combination thereof. Memory **370** may contain program instructions for controller **362** as well as any suitable administrative overhead data for unit **360**. Memory **370** may contain a unique identifier for unit **360**, such that unit **360** can distinguish wireless communications meant for it among other wireless communications. Examples of such an identifier could include, a Media Access Controller (MAC) address, Electronic Serial Number, global phone number, Internet Protocol (IP) address, or any other suitable identifier. Moreover, memory **370** may include information about attached field devices, such as their unique identifiers, configurations, and abilities. Finally, controller **362**, using memory **370** can cause the output of unit **360** to be provided in any suitable form. For example, configuration and interaction with unit **360** and/or one or more associated field devices could be provided as HyperText Markup Language (HTML) web pages.

Clock **372** is illustrated as being coupled to controller **362**, but may also be part of controller **362**. Clock **372** allows controller **362** to provide enhanced operation. For example, clock **372** can be used to time the periods set forth above with respect to configurable button **125**. Additionally, controller **362** can store information from one or more attached field devices, and correlate the information with time in order to recognize trends. Further still, controller **362** can supplement information received from one or more field devices with time information before transmitting it via wireless communication module **366**. Further still, clock **372** can be used to automatically generate periodic sleep/awaken commands for unit **360** and/or field devices. Another form of periodic use for clock **372** is to cause controller **362** to issue, via module **366**, a heartbeat type signal to periodically indicate an acceptable status to an external wireless device.

Loop communicator **368** is coupled to controller **362** and interfaces controller **362** to one or more field devices coupled to one or more attachment regions **112**. Loop communicator **368** is known circuitry that generates appropriate signals in order to communicate in accordance with an industry protocol, such as those set forth above. In embodiments where unit **360** is coupled to a plurality of field devices that communicate in accordance with different protocols, it is conceivable that multiple loop communicators could be used to allow controller **362** to interact with the various field devices. The physical connection(s) made through attachment region **112** allows unit **360** to power and communicate with the field devices. In some embodiments, this can be done by providing power over the same conductors used for communication, such as a two-wire loop. However, it is also contemplated that embodiments of the invention can be practiced where power is provided to the field device on separate conductors than those used for communication. For ease of technician access, unit **360** may include two or more terminals proximate loop communicator **368** or attachment region **112** in order to facilitate the coupling of a handheld configuration device, such as the Model 375 Handheld device available from Rosemount, Inc. of Eden Prairie, Minn.

FIG. **5** also illustrates optional operator button block **374** and LCD display block **376** in phantom being coupled to controller **362**. This illustration is intended to show that all local inputs, be they on individual field devices, wireless power and communication unit **360**, or both are coupled to controller **362**. Additionally, local user displays, on each field device, wireless power and communication unit **360**, or both are also coupled to controller **362**. This allows controller **362** to interact with each local display individually based upon inputs from the field device, the configurable button associated with the field device, one or more buttons or inputs disposed proximate unit **360**, or from wireless communication.

FIG. **6** is a diagrammatic view of an electrical power generation system for a process device in accordance with an embodiment of the present invention. System **360** is illustrated as being an external module to a process device, but can also be manufactured to be integral with the process device. Module **360** includes housing **400** that is couplable to the process device. Housing **400** includes a pair of compartments **402**, **404** that are separated by thermal barrier **406**. A small form factor methanol fuel cell **408** is placed in compartment **402**. Electronics control and power management system **410** includes a number of power management components and circuits and is disposed in compartment **404**. Electronics module **410** may include an ultra high capacity capacitor, and/or battery to handle peak transmission power demands. Additional details regarding the actual circuit employed in module **410** that are provided with respect to FIG. **7**. Electronics module **410** is also preferably encapsulated in order to further thermally isolate the electronics in module **410** from the heat generated by the exothermic reaction of fuel cell **408**. A source of liquid methane **412** is adapted to be stored in compartment **404** on top of module **410**. Liquid methane storage system **412** is couplable to methanol fuel cell **408** via groove **414**.

The first fuel cells were based on $H_2+O_2 \rightarrow H_2O+2e^-$. Since H_2 is difficult to store and is dangerous to handle, alternate fuel cell strategies were investigated. One attractive fuel cell technology is that based on the methanol fuel cell. Methanol fuel cells are currently known and can be built practically. Methanol is catalytically decomposed into H_2+|biproducts|+|heat. Atmospheric air is used as an oxygen (O_2) source. A very significant advantage of this type of fuel cell is its compact size. Small, methanol fuel cells based on micro-electro-mechanical systems (MEMS) technology can be built that are capable of supplying adequate power for a wireless process variable transmitter. Current state of the art for methanol fuel cells indicates that a device roughly the size of a deck of cards would provide adequate fuel storage and electricity generation for the wireless process variable field device.

Since the catalytic decomposition of methanol generates heat, cell **408** is separated thermally from electronics **410** and liquid storage tank **412**. Additionally, a heat dissipating cover **416** is disposed on top of housing **400** to release heat generated by cell **408**. It is important to ensure that the heat generated by the catalytic decomposition of methanol is dissipated and prevented from heating electronics **410** beyond their safe operating temperature. In embodiments where the power system housing **400** is made of metal, this generated heat is dissipated by both convection and radiation. Additionally, thermal barrier **406** helps protect electronics **410**. Housing **400** also includes a vent **418** to allow atmospheric oxygen to interact with cell **408**. In embodiments where venting may be objectionable, a miniature fan in a small, sealed duct can be provided as an alternative embodiment.

FIG. **7** is a diagrammatic view of the power generation system for process devices in accordance with an embodiment of the present invention. Electronics module **410** is electrically coupled to methanol fuel cell **408** and receives power therefrom via line **420**. Methanol based fuel cell is disposed within compartment **402** that is thermally isolated from electronics module **410** via thermal barrier **406**. Methanol storage **412** is coupled to methanol fuel cell **408** via electrically controlled valve **422**. Valve **422** receives its control signal from a fuel-on output line **424** from module **410**. Electricity generated in fuel cell **408** is provided through line **420** to charge and control circuit **426**. Charge and control circuit **426** provides an output **428** through diode **430** that is arranged to ensure that energy does not flow back thorough fuel cell **408**. If an additional energy storage unit is provided, it is coupled to V_{out} line **432**. The voltage at node **434** is compared, using preferably a comparator, with a minimum threshold voltage. If the voltage at node **434** is less than the minimum threshold voltage, then charging is enabled via line **436**. If, however, the voltage at node **434** is greater than the minimum threshold, then a signal is provided along line **438** to enable power for the process variable transmitter as well as power for the wireless communicator. Accordingly, if insufficient power is available from the methanol based fuel cell to run the process variable transmitter and/or the wireless transmitter, then the power circuit focuses upon storing enough energy to run either the process variable transmitter or the wireless communicator at some later time. FIG. **7** also illustrates a unit controller and sleep mode timer **438** that generates an enable signal sent to the process variable transmitter and the wireless communicator. Thus, unit controller and sleep mode timer **438** can cause the process variable transmitter, the wireless communicator, or both, to enter a sleep mode where one or both devices draw extremely low power, while fuel cell **408** may be charging the energy storage device. Accordingly, the power storage elements are recharged by the methanol fuel cell when their output voltage decreases below a predetermined value (V_{min}) to ensure successful operation, power for either the process variable check, or the wireless transmission is provided only if the power storage element is not in a discharged state. The predetermined voltage level (V_{min}) is selected so that at any voltage above this level, the energy stored will be sufficient for a complete process variable check, or wireless transmission. Before additional process variable checks or wireless transmissions are initiated, the voltage is preferably rechecked to verify that it is still above the threshold. Electronics **410** may perform other control and communication activities as may be desired.

One clear advantage of the methanol fuel cell as a process device power source is the service intervals that it provides. It is estimated that methanol fuel cells produce approximately 1,000 watt-hours per liter of methanol. Accordingly, a wireless process variable transmitter would operate about 10 years on one-half liter of methanol. A 10 year service interval compares very favorably with the 5 years expected shelf/best-service life of gel cell batteries which are now the untethered power source standard for wireless process devices.

One synergy created by providing the energy storage device, such as a battery or super capacitor in the same physical housing as the fuel cell, is that heat generated by the fuel cell can be used to help keep the energy storage device in a more efficient temperature operating range. In embodiments where rechargeable batteries are used to cover peak energy demands, nickel metal hydride (NiMH) batteries can be used in outdoor applications in conjunction with methanol fuel cells. This is because methanol fuel cells generate heat which can be used to keep the batteries' temperature high enough for charging.

While the embodiments illustrated with respect to FIGS. **4**-**8** show an antenna and associated wireless circuitry co-located with the power management circuitry, it is expressly contemplated that the antenna and wireless circuitry could be located remotely if objects causing wireless signal interference are near the power system housing. Thus, embodiments of the present invention include the provision of all power generation and wireless circuits within the same housing, which may be a housing that is part of, or external to the process device. Additionally, either the power generation circuitry or the wireless circuitry could be located in separate compartments, either one of which could be within the actual process device itself.

FIG. **8** is a diagrammatic view of a wireless process device in accordance with an embodiment of the present invention. Process device **500** is coupled to conduit **502** having a hydrocarbon-based process fluid **504** therein. Device **500** is coupled to wireless communication module **506** and fuel cell module **508**. Unlike the embodiment described with respect to FIGS. **6** and **7**, fuel cell **508** does not include a fuel cell storage tank. Instead, fuel cell **508** draws its fuel from the process itself by virtue of coupling to the process via manifold **510**. Thus, some of process fluid **504** is conveyed to fuel cell **508** via conduit **512**. In order to increase efficiency, fuel cell **508** is preferably designed to function with the anticipated type of hydrocarbon based process fluid. For example, if process fluid **504** is liquid methanol, then **508** can be identical to fuel cell **408** described with respect to FIG. **6**. Though this embodiment differs from the previous embodiment, they are similar in the sense that both embodiments make use of non-solar molecules external to the process device proximate the process device in order to power the device. The embodiment of FIGS. **6** and **7** uses at least molecules of oxygen while the embodiment with respect to FIG. **8** uses at least molecules of process fluid, and likely molecules of oxygen as well, in accordance with known fuel cell technologies.

By relying upon the process fluid itself in order to power fuel cell **508**, a virtually infinite source of energy is available from the process. Accordingly, electricity can also be provided to other local devices that may be coupled to device **500** via wired connections. Such wired connections may take the form of process control loops, or any other suitable wiring arrangements as may be desired. In some situations, the process device is designed such that the process fluid is converted to electrical power at a rate that is proportional to the amount of process fluid flowing in conduit **502**. Thus, the electrical output of fuel cell **508** could be measured and corrected to reflect the actual flow of process fluid in pipe **502**. Yet another important application of the significant power generation abilities of fuel cell **508** is to electrically power heaters to maintain a sensor at a fixed temperature to minimize temperature errors for custody transfer applications and alike.

FIGS. **9**A, **9**B, **10**A, and **10**B illustrate embodiments of the present invention that make use of molecules proximate the process device in order to generate electricity for the process device. More particularly, these embodiments convert kinetic energy of molecules (in the form of wind) into electrical energy.

FIGS. **9**A and **9**B are front and side elevation views, respectively, of a process device **600** in view with an apparatus **602** that converts wind energy to electrical energy. It is preferred, that these wind energy embodiments also include solar energy conversion system **604** for supplemental energy. Wind converter **602** includes a support **606** mounted to process device **600** preferably via a traditional conduit coupling. Mounted to top support **606**, wind moveable element **608** preferably includes at least two parts. First, wind vane **610** is adapted to present a surface area such that wind will cause vane **610** to be positioned down stream thus positioning propeller/impeller portion **612** directly into the wind. Accordingly, movable portion **608** can swivel about support **606** as indicated by arrows **614**. Rotatable impeller/propeller **612** is mechanically coupled to an electrical generator **615** that provides electrical energy to process device **600**. The electrical generator can be any suitable device known in the art, or later developed.

FIGS. **10**A and **10**B are front and side elevation views, respectively, of process device **600** coupled to a wind-to-electricity converter **620** in accordance with another embodiment of the present invention. Converter **620** includes support **622** mounted proximate supplemental solar energy converter **604**. Wind movable member **623** includes a wind vane **610** and wind displaceable members **624**, **628**, and **630** coupled to support **622** via beam **632**. As before, wind pressure acting upon vane **610** will cause member **624** to rotate about support **622** thereby placing airfoils **624**, **628**, and **630** directly into the wind. As wind passes airfoils **624**, **628**, and **630**, such airfoils will cause displacement in the direction indicated by arrows **634** along beam **632**. A piezoelectric transducer **655** positioned on beam **632**, or at the junction of beam **632** with support **622** transforms the displacement of beam **632** into electrical energy which is then conveyed to process device **600**.

Both embodiment shown with respect to FIGS. **9**A, **9**B, and **10**A, **10**B could also be provided with a shroud or cover that will help provide protection against fouling in severe applications.

Other types of rotating wind energy converters may be employed, such as an anemometer like embodiment. This is a rotating cup device that is often used to measure wind speed. While such devices are significantly less efficient than a propeller in extracting energy from wind, they do offer the advantage of being on the directional. Thus, the use of a rotatable wind vane is not required. Since the energy demands of process devices are relatively low, the lower efficiency of such omni directional rotating wind energy converters is not problematic.

Embodiments of the present invention make use of additional sources of potential or kinetic energy available in molecules proximate the process device. Accordingly, such embodiments do not require solar energy, nor do they have the drawbacks of process devices powered solely with internal batteries. Moreover, as described with respect to some embodiments, the degree of energy generation can be so great that other process devices may be wired to and powered by the process device operating in accordance with the embodiments of the present invention.

Although the present invention has been described with reference to preferred embodiments, workers skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope of the invention.

What is claimed is:

1. A system comprising:

a field device coupled to a conduit having a hydrocarbon-based process fluid therein wherein the field device senses an aspect of the hydrocarbon-based process fluid, the unit comprising; and

a wireless power communication for providing wireless operation to the field device, the unit comprising:

a housing;

an attachment region coupled to the housing and being coupled to the field device;

a power generation module including a hydrocarbon-based fuel cell operably coupled to the conduit to receive the hydrocarbon-based process fluid to provide electricity to the field device;

a loop communicator connected to the field device via the attachment region and configured to communicate digitally with the field device;

a controller coupled to the power source and loop communicator, the controller being configured to interact with the field device using the loop communicator; and

a wireless communication module coupled to the controller and being configured for wireless communication.

2. The system of claim **1**, wherein the fuel cell is a methanol fuel cell.

3. The system of claim **1**, and further comprising a storage tank coupled to the fuel cell to provide a stored source of fuel to the fuel cell.

4. The system of claim **3**, wherein the fuel cell, the storage tank, and the controller are disposed within the housing, and wherein the housing includes a thermal barrier that thermally isolates the fuel cell from the storage tank and the controller.

5. The system of claim **1**, wherein the wireless power and communication unit includes a controller disposed within the housing, the controller being configured to actively manage power for itself and the field device.

6. The system of claim **5**, wherein actively managing power includes causing at least one of the controller and the field device to enter a sleep mode.

7. The system of claim **6**, wherein the sleep mode results from commanding the field device to set its operating current at its lowest allowable current rail.

8. The system of claim **6**, wherein the controller generates a sleep mode command based upon the occurrence of an event.

9. The system of claim **8**, wherein the event includes an event selected from the group consisting of the expiration of an activity period, and input from a local user input, communication from an attached field device, and wireless communication.

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