A self-powered space heater comprises a fan, a burner, a heat exchanger, and a fuel cell assembly. The fan generates an air flow. The burner is positioned downstream of the fan and communicates therewith. The burner produces a hot gas. The heat exchanger is positioned downstream of the burner and is operatively connected therewith for receiving at least some of the hot gas. The heat exchanger provides heat for an associated enclosure. The fuel cell assembly provides electrical energy to operate the space heater. The fuel cell assembly is operatively connected to the burner for receiving at least some of the hot gas. The fuel cell assembly includes a fuel cell component and a heat compartment for generating heat to heat the fuel cell component. A thermal output of the burner provides sufficient hot gas to operate both the heat exchanger and the fuel cell assembly.
FUEL CELL HEATER

RELATED APPLICATIONS

[0001] This application claims priority from U.S. Provisional Patent Application Ser. No. 61/042,809, filed 7 Apr. 2008, the disclosure of which is incorporated herein by reference.

BACKGROUND

[0002] The present disclosure generally relates to heaters such as self-powered heaters, and particularly, to the replacement of thermolectric generators currently used in a self-powered heater by the integration of an electrochemical generation fuel cell that provides a percentage of total combustion gases for heating. The combustion gases are created from liquid fuels and a common burner that has a fire rate or hot gas output sized to provide soft or hard wall shelter heat with the use of a breathable air heat exchanger.

[0003] Space heaters have wide spread success and have been in production for the military for several years. A space heater is generally one of three types, namely, non-powered, powered and self-powered. The non-powered heater is generally a “light it with a match” type vaporizing convection heater that comes in various BTU outputs. The powered heater requires external power, such as power generated from a generator or from a local power grid. The self-powered heater provides forced air heat and has all of the features of a powered heater except that no external power is required. The self-powered heater generally is thermostat controlled, producing burner turn down rates with built in diagnostic and prognostic controls. The self-powered heater typically operates by the manipulation of a single switch.

[0004] In military application, the self-powered heater is primarily used to heat soft and hard wall shelters in military field conditions, but have use in any application where space heating is desirable. The self-powered heater can be operated in ambient temperatures to -60° F, and from sea level to 10,000 feet. The self-powered heater can operate on liquid fuel, such as diesel, bio fuels and kerosene, such as JP-8 and Jet-A.

[0005] The self-powered heater generally uses an internal thermolectric generator integrated within a main hot gas stream to extract a portion of the combustion heat to provide electricity for heater operation. Due to the required heat output, the amount of hot gas BTUs used for electrical generation is considerably less than the BTUs applied to a breathable hot air heat exchanger. Depending upon the operation cycle, excess electrical power is available for export power after an internal battery is fully charged. Current self-powered heaters use the export power for electrical heating that is added internally to the heated air stream.

[0006] The current art of the fuel cell industry is to increase electrical conversion efficiency and reduce balance of plant system cost per electrical watt produced. To increase the overall or apparent efficiency, fuel cell generators are being integrated into combined chill heat (CHP) cogeneration applications and combined chill heat and power (CHCP) tri-generation applications. Even though fuel cell generators are being integrated into CHP for home or business use, the waste heat output is not sufficient to be used for primary heat but can be used for low level heating. Additional heat and electrical power is required in order to provide the desired comfort level during peak cold weather heat load demands.

[0007] Conventional fuel cell generators cannot produce sufficient electrical wattage during high building demand periods. Fuel cells are typically designed to operate very efficiently using the least amount of fuel energy for the conversion to electrical output. The waste heat of many fuel cell applications is used to heat liquids or an air stream. This efficient operation limits the heat output of the fuel cell. Using the fuel cell electrical output to augment the rejected heat by using resistive heating can be counterproductive due to having less electrical power available for building demands.

[0008] Conventional fuel cell cogeneration designs for buildings utilize a fuel cell with an electrical output capacity (kW) that is near the time-averaged electrical power consumption rate for the building and with a heat generation capacity that is useful for meeting building heating needs. The actual onsite time-variable power demand (kW) is met by a combination of the cogeneration electrical power produced on sight and electrical power from the public electrical power grid or another external power source. When heat from the cogeneration fuel cell is insufficient to heat the building, an auxiliary heater, operated typically by burning fuel, supplements or augments the heat provided by the cogeneration of the fuel cell. The ability of using a fuel cell as a primary or single source space heater is limited due to this efficiency.

[0009] The following list of patents relate to cogeneration heat and power. However, this type of fuel cell integration, when used for primary heating, provides insufficient waste heat. Therefore, the patents further disclose provisions for external electrical and/or additional fuel burner augmentation.

[0010] WO 2005/047776 teaches a liquid cooled fuel cell system and cogeneration (CHP) of building heat. The system comprises of an auxiliary heater which is used when a primary heat exchanger is insufficient to provide desired space heating. The auxiliary heater can be connected to an external electric power source.

[0011] U.S. Pat. No. 6,054,299 teaches a fuel cell for the production of electricity, with a heating, ventilation and cooling system using waste heat generated by the fuel cell. An interface-exchanging element can be adapted to receive thermal energy from an incoming fluid having an elevated temperature. By having the ability to operate an additional burner source, the fuel cell low thermal output can be augmented during high heating demands.

[0012] GB 2404007 discloses an air heater comprising electrical air heating elements powered by a fuel cell unit.

[0013] As is evident from the above prior art, buildings that derive some or all of their electrical needs from a fuel cell require a second burner or an additional resistive heating device for adequate space heating comfort during the winter season. Using the rejected heat and power output of a fuel cell for primary space heating is not practical due to the increased cost, size and weight of a cogeneran fuel cell that is sized to produce electrical resistive and combustion heat outputs sufficient for total space heating requirements.

[0014] The following list of patents relate to start-up burners and combustors.

[0015] US Patent Application Publication No. 2005/0257427 relates to a start-up burner for rapidly heating a catalyst in a reformer as well as related methods and modules. The module can further contain an auxiliary burner adapted for warming fluids in the module.
U.S. Pat. No. 7,086,853 is directed to a start-up combustor for a fuel cell having a filter used to trap soot that is generated during start up.

U.S. Pat. No. 6,007,620 discloses a fuel cell system with a combustor-heated reformer capable of operating a combustor to heat a fuel processor over a wide range of heat outputs.

U.S. Pat. No. 6,451,465 B1 teaches a method for operating a combustor in a fuel cell system to heat a fuel processor by monitoring temperature and regulation of fuel flows.

U.S. Pat. No. 6,777,123 discloses a combustor temperature control of a fuel cell power plant. A combustor generates heat from the combustion of fuel. The combustion system is directly coupled to the fuel cell for fuel cell operation, which is the burner used for start-up, reforming or exhaust gas management.

As evident from the above prior art, space heating by using a single burner for the combustion is insufficient as a provider of primary building heat, even if combined with the teachings of integrating burners and combustors with a fuel cell. Also lacking in the prior art is the ability to switch between available fueled fuels, such as diesel, kerosene, DEF, Jet-A, JP-5, and JP-8. The additional concern of combustion inefficiencies with altitude changes renders these approaches ineffective for space heater applications.

Further, a deficiency of current fuel cell designs that operate on diesel, bio-fuels and kerosene when used in a co-generation primary heater application is the requirement for a cold start to rated power and heat output. The heating of the fuel cell component is a managed thermal process requiring time for component normalization, reformer heating, water boiling, water vaporization and related system and subsystem component warming depending upon the type of fuel cell used. A military self-powered heater is required to provide heat within minutes of the system being turned on. Component warming before fuel cell operation and heat output can be a lengthy process delaying sufficient hot air output. A self-powered heater begins to provide heat airflow within minutes after the heater system is energized. The battery is sized to provide the necessary wattage capacity to operate the heater components until the generator is online producing the required power and subsequent battery re-charging.

Another deficiency of current fuel cell designs when used in a co-generation primary heater application becomes apparent when the application requires a higher heat output than is available from capturing all of the fuel cell’s waste heat and electrical output. Sufficient resistive heating required for space heating will increase the heat output, but will also increase cost, weight and size of the fuel cell. For example, a 35,000 BTU heat output will need electrical power for a breathable inter-circulation air fan, combustion blower, fuel system and related balance of plant. To provide a 35,000 BTU output, the fuel cell generator would be sized in excess of 10 kW to provide the needed balance of plant power and the resistive heating current. Weight and size become excessive when compared to a current 35,000 BTU self-powered thermoelectric heater.

Yet another deficiency of current fuel cell designs when used in a co-generation primary heater application is the burner used for start-up, reforming or exhaust gas management. The burner, which is sized and coupled to the fuel cell component for fuel cell operation, has the inability to increase combustion for additional space heating.

Another deficiency is the inability to operate in cold temperatures of -60°F. This severe cold operation is a standard requirement for shelter heating. Current fuel cell heat recovery methods are overly efficient, not addressing dew point condensation during severe cold start up and subsequent ice buildup in heat recovery and exhaust systems during severe cold starting and operation.

Another deficiency is that current fuel cell component integration requires thermal coupling of components for operation, such as a reformer being integrated within the same hot zone as a fuel cell stack. This makes repair in the field difficult requiring sub-component removal to gain access, remove and replace components such as the reformer.

Taken individually or as a whole, the prior art fails to provide an overall design for a practically implemented forced air, multi-fueled warm air heating system that provides space heating for soft and hard wall shelters while simultaneously operating a fuel cell that provides electrical power for safe and efficient heater operation.

Thus, there is a need to have a single heat source to supply sufficient hot gases for use as a space heater that can simultaneously provide a hot zone used for fuel cell component start up and operation. Accordingly, the present disclosure provides a space heater which overcomes certain difficulties with the prior art designs while providing better and more advantageous overall results.

**BRIEF DESCRIPTION**

According to one aspect of the present disclosure, a self-powered space heater comprises a fan, a burner, a heat exchanger and a fuel cell assembly. The fan generates an air flow. The burner is positioned downstream of the fan and communicates therewith. The burner produces a hot gas. The heat exchanger is positioned downstream of the burner and is operatively connected therewith for receiving at least some of the hot gas. The burner and the heat exchanger provide primary heat for an associated enclosure. The fuel cell assembly provides electrical energy to operate the space heater. The fuel cell assembly is operatively connected to the burner for receiving at least some of the hot gas. The fuel cell assembly includes a fuel cell component and a heat compartment for generating heat to heat the fuel cell component. A thermal output of the burner provides sufficient hot gas to operate both the heat exchanger and the fuel cell assembly.

According to another aspect of the present disclosure, a self-powered space heater comprises a fan for generating an air flow and a burner positioned downstream of the fan and communicating therewith for receiving a hot gas. A first fuel cell assembly is operatively connected to the burner for receiving the hot gas produced by the burner. A second fuel cell assembly is operatively connected to the burner for receiving hot gas produced by the burner. The second fuel cell assembly is positioned in series with the first fuel cell assembly. The first and second fuel cell assemblies provide electrical energy to operate the space heater. A heat exchanger is positioned downstream of the first and second fuel cell assemblies and provides heat for an associated enclosure. A thermal output used of the burner for space heating exceeds a thermal input required for power generation.

According to another aspect of the present disclosure, a self-powered space heater comprises a fan for generating an air flow and a burner positioned downstream of the
fan and communicating therewith for producing a hot gas. A first fuel cell assembly is operatively connected to the burner for receiving the hot gas produced by the burner. A second fuel cell assembly is operatively connected to the burner for receiving the hot gas produced by the burner. The first and second fuel cell assemblies provide electrical energy to operate the space heater. A heat exchanger is positioned downstream of the first and second fuel cell assemblies. A blower is located downstream of the first fuel cell assembly and second fuel cell assembly. Spent by-pass hot gases and effluent from the first and second fuel cell assemblies are directed into one of the burner and heat exchanger via the blower.

BRIEF DESCRIPTION OF THE DRAWINGS

[0031] FIG. 1 is a schematic diagram of a conventional fuel fired, hot air space heater.
[0032] FIG. 2 is a schematic diagram of a conventional self-powered heater.
[0033] FIG. 3 is a schematic diagram of a fuel cell self-powered space heater according to one aspect of the present disclosure.
[0034] FIG. 4 is a schematic diagram of a fuel cell self-powered space heater according to another aspect of the present disclosure.
[0035] FIG. 5 is a schematic diagram of a fuel cell self-powered space heater according to yet another aspect of the present disclosure.
[0036] FIG. 6 is a schematic diagram of a fuel cell self-powered space heater according to still yet another aspect of the present disclosure.
[0037] FIG. 7 is a schematic diagram of a heat compartment of the fuel cell space heaters of the present disclosure according to one aspect of the present disclosure.
[0038] FIG. 8 is a schematic diagram of a reformer for the heat compartment of FIG. 7.
[0039] FIG. 9 is a schematic diagram of a fuel processor for the heat compartment of FIG. 7.
[0040] FIG. 10 is a schematic diagram of a heat compartment of the fuel cell space heaters of the present disclosure according to another aspect of the present disclosure.
[0041] FIG. 11 is a schematic diagram of a fuel cell self-powered space heater according to yet another aspect of the present disclosure.
[0042] FIG. 12 is a schematic diagram of a fuel cell self-powered space heater according to yet another aspect of the present disclosure.
[0043] FIG. 13 is a schematic diagram of a mantel for the heat compartment of FIGS. 7 and 10 according to one aspect of the present disclosure.
[0044] FIG. 14 is a schematic diagram of a mantel for the heat compartment of FIGS. 7 and 10 according to another aspect of the present disclosure.

DETAILED DESCRIPTION

[0045] It should, of course, be understood that the description and drawings herein are merely illustrative and that various modifications and changes can be made in the structures disclosed without departing from this disclosure. Like numerals refer to like parts throughout the several views. It will also be appreciated that the various identified components of the space heater disclosed herein are merely terms of art that may vary from one manufacturer to another and should not be deemed to limit the present disclosure.

[0046] With reference to FIG. 1, a schematic of a conventional fuel fired, hot air space heater 105 is illustrated. The heater is the type which that would operate on externally supplied electrical power from a local power grid or a generator. The heater 105 includes an enclosure 115 for housing a burner 111 operably connected to a heat exchanger 112. A fan 114 is provided at an inlet of the enclosure for generating air flow through the enclosure. The enclosure 115 is configured to manage the cooling air flow created by the fan 114 and to protect the burner 111 and heat exchanger 112 from environmental conditions. The burner 111 provides the combustion process and supplies hot gas through a gas conduit 117 to the heat exchanger. Spent hot gas is expelled to the atmosphere by an exhaust pipe 113. Air flow created by the fan travels around the burner, through and around the heat exchanger contained by the enclosure leaving as a heated breathable air stream 116.

[0047] The burner 111 provides an atomization process and air mixing. The atomization process can be vaporizing, air atomized by using a small compressor or blower, spinner, or high-pressure nozzle (not shown). The atomized fuel is introduced to combustion airflow and ignited to produce a flame pattern that is managed within the burner. The hot gases leaving the burner can still have a visible flame pattern of unburned fuel depending upon the type of atomization process selected and the downstream requirements of the thermal qualities of the exiting hot gas. Thus, the hot gas conduit 117 is shown to visualize the collection of burner hot gases; although, the heat exchanger 112 can be directly connected to the burner 111. The heat exchanger 112 can be a multi-pass type which is designed to be radial with multiple passes connected with crossover tubes. The heat exchanger 112 provides cooling airflow between the multiple passes and crossover tubes with lesser air flow around an outer area.

[0048] With reference to FIG. 2, a schematic of a conventional self-powered heater 110 using a thermoelectric generator 50 is illustrated. A battery 25 is provided for starting and post purging the self-powered heater. The battery is recharged by the thermoelectric generator, thus, no external power is required for operation of the heater. The air inlet fan 114 draws air with or without a return duct (not shown) and creates an air flow through the enclosure 115. The burner 111 provides the combustion process for supplying hot gas through a hot gas conduit 117a to the thermoelectric generator 50. The generator supplies hot gas through a hot gas conduit 117b to the heat exchanger 112, the hot gas exiting the heat exchanger via the exhaust pipe 113. Air flow created by the fan 114 exits the self-powered heater 110 with or without a supply air duct (not shown) as a heated breathable air stream.

[0049] The thermoelectric generator 50 is integrated within the hot gas flow created by the burner 111. The hot gases are directed and circulated within the thermoelectric generator 50 for efficient heating. The hot gases exiting the generator 50 are introduced into the heat exchanger 112 for primary heat transfer into the cooling airflow. The majority of thermal transfer into the breathable air stream is from the heat exchanger 112. The outer area of the thermoelectric generator 50 is usually finned to increase cold junction thermal transfer into the cooling breathable airflow created by the fan 114.

[0050] In the description of the present disclosure below, the fuel cell or fuel cell assembly is at times described as a single unit even though it can contain various designs and types of components that are required by the type of fuel cell.
It would be known to those skilled in the art that the various fuel cell components require heat or specific ratios of oxygen to hydrocarbon for operation. The use of the term fuel cell or fuel cell assembly for clarity is used to include such components. The present disclosure is capable of supplying bypassed hot gas that can be treated in various ways in a hot zone, referred to as a heat compartment, for proper operation of these various types and configurations of fuel cell generator components.

Generators that can use direct injection of carbonaceous fuels, thermally integrated vaporizer-reformers, fuel cell oxidation facilitators, liquid anode preheating and operation of a carbon-oxygen fuel cell, startup heating, heating the reformer and fuel cell in its own optimal temperature range simultaneously, removing moisture and purging components after fuel cell shut down and the re-burning of residual hydrogen or fuel cell exhaust by-products are a few examples of the integration flexibility achieved by using hot by-pass gas from a high BTU out-put burner intended for space heating.

As will be described in greater detail below, the present disclosure generally relates to the management of hot gas produced from a single burner, for space heating, wherein a portion of this hot gas is used for preheating and/or component operation of a fuel cell. While the present disclosure can be implemented in many different forms, it will be described herein as a self-powered breathable air heating system that re-circulates breathable air flow, and contains all necessary major and minor subsystems for startup operation and shut down that derives their respective electrical power requirements from a fuel cell generator. The thermal energy created by the fuel-fired burner is in excess of the requirements of the fuel cell generator, and is largely used for re-circulated airflow space heating. The fuel cell generator is configured to support the safe and efficient operation of the self-powered heater used for soft and hard wall space heating.

Further, by redirecting a portion of the hot gas flow created by a burner, various types of hot gases, such as rich or lean, having varying temperatures and humidity can be created. These hot gases can be used for fuel cell stack preheating, component heating, such as reformers, or to provide the stack or fuel cell element with fuel delivery.

The present disclosure is not limited to a co-generation device, even though the nature of all heated components housed within a common enclosure would qualify the integrated package as being co-generated. The term co-generation includes combined heat and power (CHP), MicroCHP, a distributed energy resource and tri-generation (a system that produces electricity, heat and cold via a fuel cell).

With reference now to FIG. 3,a space heater according to one aspect of the present disclosure is schematically illustrated. The heater comprises an air inlet fan (not shown), a burner 111, a fuel cell assembly 200 and a heat exchanger. The burner is positioned downstream of the air inlet fan and produces a hot gas. The heat exchanger is positioned downstream of the burner and is operatively connected therewith for receiving at least some of the hot gas. The burner and the heat exchanger provide primary space heating, which can be regulated by the adjustment of the burner combustion process by varying the air fuel ratio. This, in turn, changes the temperature of the hot gas produced by the burner. The fuel cell assembly 200 provides electrical energy to operate the space heater. The fuel cell assembly is also operatively connected to the burner 111 for receiving at least some of the hot gas. The fuel cell assembly 200 includes a housing 210 for accommodatibg a fuel cell component 240 and a heat compartment 241 (i.e., a hot zone) for management of combustion hot gasses to heat the fuel cell component. An enclosure 220 accommodates the burner 111, heat exchanger 112 and fuel cell assembly 200. The air inlet fan creates an air flow through the enclosure 220. The schematic block of the fuel cell component 240 is used to depict the various components required for fuel cell operation. The schematic block for the heat compartment 241 depicts an area that can be used to manage, distribute and house different components that need heating. By having a heat source produced by a single burner 111, with a fire rate many times greater than what a fuel cell would require when used for operational electrical power, one can appreciate the freedom of component layout and hot zones that can be thermally detached from one another, thus providing optimum temperature control while still producing heater related BTU output. Another aspect of the disclosure is communicating with a hot gas BTU content many times greater than previously used to preheat the fuel cell component 240. This allows for very fast preheating of the fuel cell component. Testing has shown preheat temperatures of the heat compartment 241 with the fuel cell component 240 to both 700 and 1000 degrees Celsius in under 10 minutes while maintaining proper atmosphere around fuel cell component.

The heat compartment 241 can be controllable both in temperature and atmosphere for fuel cell component operation. The heat compartment can be of a variety of designs and mainly is a high temperature furnace consisting of basic components such as heat shields, external stainless steel foil, or internal ceramic type insulation selected for the specific fuel cell component temperature and atmosphere requirement. The shape of the heat compartment 241 can be form fitting for the fuel cell component that it houses. A basic shape can be a rectangular or cylindrical form designed to be modular for ease of removal and repair.

The fuel cell assembly is connected to the burner 111 via hot gas conduit 117a, and is connected to the heat exchanger 112 via hot gas conduit 117a. The hot gas conduits depict the transfer of hot gas from one component to another. It should be appreciated that a direct coupling of the components is also contemplated. The fuel cell component 240 is separated from the heat compartment by a mantel 242. An predetermined percentage of hot gas energy is harnessed from the main hot gas air stream by radiation using the mantel 242. The remainder of burner hot gas is expelled through exhaust pipe 113 after passing through the air-to-air heat exchanger 112. The temperature of the fuel cell component can be further regulated by the adjustment of the burner combustion process by varying the air fuel ratio, which, in turn, changes the temperature of the hot gas.

The mantel 242 can be a solid plate mantel (see FIG. 13) such that the fuel cell component 240 is heated via radiant heat within the heat compartment 241. Alternatively, the mantel 242 can be a perforated plate mantel to allow radiation and convection flow through heat compartment 241 (see FIG. 14). The fuel cell component is heated by a combination of radiant heat and hot gas flow using a perforated plate mantel.

With reference to FIG. 4, a hot gas conduit 243 is connected to the fuel cell assembly 200 and expels the hot gas flow to atmosphere. A variable flow restrictor 244 is connected to the hot gas conduit 243 and communicates with the fuel cell component 240. The variable flow restrictor can regulate gross BTU by shutting off or throttling the amount of
hot gas flow through the heat compartment 241, mantel 242 and fuel cell component 240. By opening and closing the variable flow restrictor 244, a bypass flow of hot gas and temperature is regulated by increasing or decreasing the hot gas flow through the fuel heat compartment 241, the fuel cell component 240, the hot gas conduit 243, the variable flow restrictor 244 and then to atmosphere via hot gas conduit 245. A benefit of continuous heating of the fuel cell component 240 can be realized by reduction or elimination of conventional fuel cell component insulation. Insulation is used for efficiency and to provide heat shielding from other components. This reduction or elimination of insulation saves cost and reduces weight thereby making the fuel cell component 240 less complicated to manufacture and maintain in the field. All fuel cell component rejected heat is captured within the airflow generated by the fan 114 (see FIG. 2) and added to the cooler airflow prior to the heat exchanger 112. The heat output of the fuel cell component 240 and heat exchanger 112 is the total heated airflow output. Thus, the heat conversion efficiency of the fuel cell component 240 can be low because the heat loss is re-introduced into the breathable air stream. Another advantage of using the heat exchanger 112 hot gas flow is by use of the mantel 242. Temperatures of 700 to 1000 degrees Celsius can be easily obtained and transferred through use of various mantel shapes from this pass through high velocity hot gas flow. By using the correct shape of the mantel, various temperatures can be created from the same temperature and BTU pass through heat exchanger 112 intended hot gas flow. By changing the shape of the heat compartment 241 and the mantel 242, hot gas velocities and impingement can be controlled to various temperatures. After the heat compartment 241 reaches near temperature equilibrium with the mantel 242, less BTUs are transferred and are retained in the hot gas flow to the heat exchanger 112.

With reference to FIG. 5, a space heater according to another aspect of the present disclosure is schematically illustrated. The space heater of FIG. 5 is similar to the space heater of FIG. 4 except that the fuel cell assembly 200 is located downstream of both the burner 111 and the heat exchanger 112. An enclosure (not shown) accommodates the burner, heat exchanger and fuel cell assembly. An air inlet fan (not shown) creates an air flow through the enclosure. The hot gas temperature in the hot gas conduit 117b is reduced by the heat exchanger. Therefore, the temperature required for the operation of the fuel cell component 240 is less than combustion temperature. Particularly, hot gas having temperatures less than 1,000°F flows from the heat exchanger 112, through the hot gas conduit 117b to the heat compartment 241 and exits via the exhaust pipe 113. Again, the variable flow restrictor 244 can regulate hot gas flow through the hot gas conduit 243.

Referring now to FIG. 6, a space heater according to yet another aspect of the present disclosure is schematically illustrated. Similar to the previous embodiments, the heater includes a burner 111, a fuel cell assembly 200 and a heat exchanger 112. In this embodiment, the fuel cell assembly is downstream of the burner and upstream of the heat exchanger. An enclosure (not shown) accommodates the burner, heat exchanger and fuel cell assembly. An air inlet fan (not shown) creates an air flow through the enclosure. Hot gasses from the burner flows through a hot gas conduit 117 to both the heat exchanger and the heat compartment 241 of the fuel cell assembly. A separate hot gas conduit 117c is connected to the hot gas conduit 117 and the heat compartment 241 for directing hot gas into the heat compartment. Again, hot gas flowing through the fuel cell assembly is regulated by the variable flow restrictor 244 and exits through the hot gas conduit 245. The single hot gas conduit 117c can attach to the heat compartment 241 or to a manifold (not shown) to supply more than one hot gas source of heat or combustion gases to multiple components as needed. The regulation of the flow of gas is provided by variable flow restrictor 244. The pressure needed to provide hot gas flow through hot gas conduit 117c and through the various components of heat compartment 241 is regulated by the internal design of the heat exchanger 112 and or at exhaust pipe 113 by the addition of a baffle or restrictor plate (see FIG. 14).

As shown in FIG. 7, a fuel cell assembly includes energy conversion units or fuel cells 350, which can be located within the heat compartment 241. In the depicted embodiment, the energy conversion units are ceramic rods, which are only an example of components that can be heat managed. It should be appreciated that alternative components are also contemplated. As required, the hot gas conduit 117c supplies hot gas flow to the heat compartment 241. The mantel 242 disperses the hot gas flow evenly or to specific areas of the energy conversion units 350. The energy conversion units 350 are preheated and kept at operating temperature by regulation of the flow restrictor 244.

Alternatively, as shown in FIG. 8, a fuel cell assembly includes a reformer 351, which can be located within the heat compartment 241. As is well known, reformers use heat and catalysts to “crack” hydrocarbons and release the hydrogen they contain. A reformer produces a mixture of gases that must then be purified in order to produce hydrogen pure enough for use in a polymer exchange membrane (PEM) fuel cell (see FIG. 9). The PEM fuel cell has a high power density and a relatively low operating temperature (ranging from 60 to 80 degrees Celsius, or 140 to 176 degrees Fahrenheit). The low operating temperature means that it doesn’t take very long for the fuel cell to warm up and begin generating electricity. Similar to the fuel cells 350, the reformer can be pre-heated and, as required, kept at operational temperature during extreme cold ambient temperatures.

With reference to FIG. 9, the PEM fuel cell assembly includes a fuel cell processor 352, which can be located within the heat compartment 241. The fuel cell processor 352 is supplied with fuel 460 through a fuel line 461. The fuel can be alcohol (e.g., methanol or ethanol) or hydrocarbons (e.g., gasoline diesel kerosene), which can serve as the source of hydrogen for the fuel cell. The fuel processor 352 uses steam for the reforming process. Water 464 is supplied by a water line 465 and heat is supplied by the hot gas conduit 117c. The heat is regulated by the variable flow restrictor 244. Reformate can be supplied to the heat compartment 241 by a reformate line. Spent hot gas and fuel processor effluent exit through the hot gas conduit 245.

A solid oxide fuel cell (SOFC) is schematically illustrated in FIG. 10. This type of fuel cell operates at very high temperatures (between 700 and 1,000 degrees Celsius). The SOFC fuel cell generally uses direct diesel or kerosene fuel gas for operation.

In use, the energy conversion units 350, which are housed within the heat compartment 241, are heated to a predetermined operating temperature by opening the flow restrictor 244 and establishing gas flow through the hot gas conduit 117c. When the energy conversion units 350 have reached the operating temperature, the variable flow restrictor 244 is closed. The fuel line 461 supplies a fuel injector 462 to
charge the heat compartment 241 with the proper air fuel ratio for operation. If cooling or steam is needed for the operation, the water line 465 supplies water to an injector 466. During operation, the variable flow restrictor 244 can be partially opened to provide hot gas or purging airflow to expel energy conversion units effluent through the hot gas conduit 245.

[0070] With reference to FIG. 11, a space heater according to yet another aspect of the present disclosure is schematically illustrated. Similar to the previous embodiments, the heater includes a burner 111, at least one fuel cell assembly and a heat exchanger 112. An enclosure (not shown) accommodates the burner, the heat exchanger and the at least one fuel cell assembly. An air inlet fan (not shown) creates an air flow through the enclosure. Hot gasses from the burner flows through the hot gas conduit 117 to both the heat exchanger and the at least one fuel cell assembly via a separate hot gas conduit 117c. Particularly, the hot gas flowing through the hot gas conduit 117c is split between a first fuel cell assembly and a second fuel cell assembly. The first fuel cell assembly is similar in structure to the fuel cell assembly of FIG. 7 and includes the fuel cell component 240. The second fuel cell assembly is similar in structure to the fuel cell assembly of FIG. 8 and includes a reformer 351. Hot gas flowing through the first fuel cell assembly is regulated by variable flow restrictor 244 and exits through the hot gas conduit 245. Hot gas flowing through the second fuel cell assembly is regulated by variable flow restrictor 244b and exits through the hot gas conduit 245b.

[0071] In the embodiment of FIG. 11, the spent by-pass hot gases and effluent from the first and second fuel cell assemblies required for fuel cell operation are re-introduced into the burner 111 by connecting both hot gas conduits 245 and 245b to a blower 119. The blower directs the spent hot gas and fuel cell effluent into the burner 111 via a pressurized combustion waste line 120.

[0072] Alternatively, as shown in FIG. 12, the blower 119 can direct the spent hot gas and fuel cell effluent into the heat exchanger 112 via the pressurized combustion waste line 120. Depending upon the configuration of heater components, the blower 119 provides the overpressure required to inject the effluent into the heat exchanger 112. However, a blower located in a hot combustion gas flow generally has to be protected from condensation and corrosive properties of the fuel cell effluent. A pressure differential can be created by positioning a hot gas restrictor 122 between the blower 111 and the heat exchanger 112 thereby providing a lower pressure within the heat exchanger 112. In some instances, the hot gas restrictor will eliminate the need for the blower 119.

[0073] As is evident from the foregoing, the present disclosure generally relates to a self-powered heater for providing primary heat for use in soft and hard wall shelters. The self-powered heater includes a burner, a heat exchanger and at least one fuel cell assembly. The burner fire rate or fuel consumption far exceeds the fuel rate needed by the fuel cell assembly. The addition of the fuel cell assembly is to provide electrical energy to operate the heater. Though rejected heat and waste effluent of the fuel cell assembly can be captured and added to the thermal output energy of the heater, the percentage of heat reclaimed in comparison to the heat created by the burner and heat exchanger is small. Cogeneration of the fuel cell assembly is a thermodynamically efficient use of fuel. The efficient use of fuel in the self-powered heater is derived by the heat exchanger and combustion efficiency.

[0074] A portion of the burner hot gas flow can be used to heat various types of fuel cell components. The bypassed hot gas is used for heating a hot zone which is controllable both in temperature and atmosphere for fuel cell component operation. The heat output (used for space heating) exceeds the heat (energy input) required for power generation. The burner and heat exchanger provide primary space heating by generating a heated breathable re-circulated airflow. The heater operates from fuel cell generated electricity and is started or sustained by hot gas communication with the fuel fired burner combustion gases. The fuel-fired burner, the fuel cell assembly and the heat exchanger is integrated such that the fuel cell assembly is continuously in communication with the burner hot gas flow before the heat exchanger. Fuel fired burner hot gas flow regulation through the fuel cell assembly can modulates the hot gas flow through the fuel cell assembly. The burner hot gas flow can be lower in temperature by using the hot gas flow after the heat exchanger.

[0075] Components common to the operation of the self-powered heaters described above (balance of plant) can be used to supply the fuel cell assembly with basic operating functions which significantly improve the utility of the fuel cell assembly. Various types of combustion processes and fuel air ratios can be created using existing burner atomization processes such as hot vaporizer, air atomized, spin atomizer, and high-pressure nozzle type. The atomization process is down selected upon the BTU output, hours of operation before repair, fuel types, altitudes, cold temperature starting and burner assembly cost. A fuel pump for the heater can be a pulse pump, diaphragm or gear depending on the pressure required for atomization. A variable speed combustion blower can provide sufficient burner and heat exchanger backpressure during operation. A custom controller designed for low EMI and extreme cold operation can operate the self-powered heater. Altitude air fuel compensation, tent thermostat rate turn down, pre purge with system component checking and wire harness checks are standard designs of today's self-powered heater. These components can also supply the necessary airflows, fuel sources and electronic control of the fuel cell subcomponents. In addition to using common components for fuel cell operation, the burner air fuel ratio can also be changed to provide a rich or lean mixture for fuel cell component operation. These air to fuel ratios can be programmed into the controller logic to provide custom combustion hot gas during operation.

[0076] The ability to shut off the burner or to have the burner at a very low output is also possible. Particularly, the burner is started to create hot gas to provide fuel cell component heating. By-pass heat is provided to the fuel cell component. The burner can then be throttled down via regulation of the variable flow restrictor to provide only the necessary heat for operation of the fuel cell component.

[0077] By providing a single burner heat source much larger in thermal output than is required for fuel cell operation, sufficient temperatures and hot gas flow for space heating and reburning of fuel cell gases is provided. This allows the heater to be smaller in size and less complicated. The heater will have increased reliability and a reduced cost while producing space heating simultaneously.

[0078] It should be appreciated that the schematic diagrams described above generally omit excessive component detail (for example, electronic controls such as micro processors, fuel delivery loops, water storage and separators, pumps, compressors, pressure controls, starting battery, external fuel
supply, temperature and humidity sensors, and the like) in order to focus on the hot gas integration to fuel cell generator components of the self-powered heater. A provision of these necessary items is required for operation of the system, but is common to a thermoelectric self-powered heater and is not required for understanding the disclosure.

The present disclosure is not limited to any one type of fuel cell technology and primary fuel type. Current self-powered heaters use fielded fuels such as diesel, kerosene, JP-8, DF-A, and specific heating applications may require operation on natural gas, propane, bio-fuels and gasoline as an example.

Any type of fuel cell assembly that requires heat can implement the teaching of the present disclosure, such as Polymer Electrolyte Membrane (PEM), Phosphoric Acid, (PAFC), Direct Methanol Fuel Cell (DMFC), Alkaline Fuel Cell (AFC), Molten Carbonate Fuel Cell (MCFC), Solid Oxide Fuel Cell (SOFC), and Regenerative (Reversible) Fuel Cells.

The present disclosure has been described with reference to several embodiments. Obviously, modifications and alterations will occur to others upon reading and understanding the preceding detailed description. It is intended that the present disclosure be construed as including all such modifications and alterations insofar as they come within the scope of the appended claims or the equivalents thereof.

What is claimed is:
1. A self-powered space heater comprising:
a fan for generating an air flow;
a burner positioned downstream of the fan and communicating therewith, the burner producing a hot gas;
a heat exchanger positioned downstream of the burner and operatively connected therewith for receiving at least some of the hot gas, the burner and heat exchanger providing primary heat for an associated enclosure; and
a fuel cell assembly for providing electrical energy to operate the space heater, the fuel cell assembly being operatively connected to the burner for receiving at least some of the hot gas, the fuel cell assembly including a fuel cell component and a heat compartment for generating heat to heat the fuel cell component,

wherein a thermal output of the burner provides sufficient hot gas to operate both the heat exchanger and the fuel cell assembly.

2. The space heater of claim 1, wherein the fuel cell component is separated from the heat compartment by a mantel, the mantel comprising one of a solid plate for allowing the fuel cell component to be heated via radiant heat within the heat compartment and a perforated plate for allowing radiation and convection flow from the heat compartment to the fuel cell component.

3. The space heater of claim 1, further comprising a hot gas conduit connected to the fuel cell assembly, and a variable flow restrictor connected to the hot gas conduit, the variable flow restrictor being configured to regulate gross BTU by throttling a predetermined amount of hot gas flow through the fuel cell assembly.

4. The space heater of claim 3, wherein the fuel cell assembly includes at least one energy conversion unit located within the heat compartment, the at least one energy conversion unit being preheated and generally maintained at a predetermined operating temperature by regulation of the variable flow restrictor.

5. The space heater of claim 1, wherein the fuel cell assembly includes a reformer for obtaining a hydrogen-rich reformate.

6. The space heater of claim 5, wherein the fuel cell assembly further includes a fuel cell processor located within the heat compartment, the fuel cell processor being connected to a source of fuel and a source of water, the fuel cell processor configured to use steam for the reformation process.

7. The space heater of claim 1, further comprising an enclosure for accommodating the burner and the heat exchanger.

8. The space heater of claim 7, wherein the enclosure also accommodates the fuel cell assembly.

9. The space heater of claim 1, further comprising a blower located downstream of the fuel cell assembly, wherein spent by-pass hot gases and effluent from the fuel cell assembly is re-introduced into the burner via the blower.

10. The space heater of claim 1, further comprising a blower located downstream of the fuel cell assembly, wherein spent by-pass hot gases and effluent from the fuel cell assembly is directed into the heat exchanger via the blower.

11. The space heater of claim 10, further comprising a hot gas restrictor positioned between the blower and the heat exchanger for creating a pressure differential for providing a lower pressure within the heat exchanger.

12. The space heater of claim 1, wherein the fuel cell assembly further includes a housing for accommodating the heat compartment and the fuel cell component.

13. The space heater of claim 1, further comprising a second fuel cell assembly positioned in series with the fuel cell assembly, wherein the second fuel cell assembly is operatively connected to the burner for receiving at least some of the hot gas.

14. A self-powered space heater comprising:
a fan for generating an air flow;
a burner positioned downstream of the fan and communicating therewith for producing a hot gas;
a first fuel cell assembly operatively connected to the burner for receiving the hot gas produced by the burner;
a second fuel cell assembly operatively connected to the burner for receiving hot gas produced by the burner, the second fuel cell assembly being positioned in series with the first fuel cell assembly, the first and second fuel cell assemblies providing electrical energy to operate the space heater; and

a heat exchanger positioned downstream of the first and second fuel cell assemblies and providing heat for an associated enclosure,

wherein a thermal output of the burner used for space heating exceeds a thermal input required for power generation.

15. The space heater of claim 15, wherein one of the first and second fuel cell assemblies includes a fuel cell component and a heat compartment for generating heat to heat the fuel cell component and the other of said first and second fuel cell assemblies includes a heat compartment and a reformer located within the heat compartment.

16. The space heater of claim 15, further comprising a hot gas conduit operatively connected to one of the first and second fuel cell assemblies and a variable flow restrictor operatively connected to the hot gas conduit, the variable flow restrictor being configured to regulate gross BTU by throttling a predetermined amount of hot gas flow through the respective fuel cell assembly.
17. The space heater of claim 15, further comprising a blower located downstream of the first fuel cell assembly and second fuel cell assembly, wherein spent by-pass hot gases and effluent from the first and second fuel cell assemblies are directed into one of the burner and heat exchanger via the blower.

18. The space heater of claim 17, further comprising a hot gas restrictor positioned between the blower and the heat exchanger.

19. A self-powered space heater comprising:
   a fan for generating an air flow;
   a burner positioned downstream of the fan and communicating therewith for producing a hot gas;
   a first fuel cell assembly operatively connected to the burner for receiving the hot gas produced by the burner;
   a second fuel cell assembly operatively connected to the burner for receiving the hot gas produced by the burner, the first and second fuel cell assemblies providing electrical energy to operate the space heater;
   a heat exchanger positioned downstream of the first and second fuel cell assemblies; and
   a blower located downstream of the first fuel cell assembly and second fuel cell assembly, wherein spent by-pass hot gases and effluent from the first and second fuel cell assemblies are directed into one of the burner and heat exchanger via the blower.

20. The space heater of claim 19, further comprising an enclosure for housing the burner, the heat exchanger and at least one of the first and second fuel cell assemblies.