conduction from the housing to the graphite core. The housing material has a high emissivity and the heat is re-radiated away from it. Heat loss is proportional to T^4 (where T is temperature) which amplifies the issue when the skin temperature increases. Another cause for the high heat loss is the difficulty of avoiding hot air leakage paths from the heater cavity. As such, the thermal energy storage module as described in WO 2015/085357 requires a large heating surface area of the heater assemblies which can be expensive to operate.

[0011] Given the limitations in the graphite storage technology as discussed above, it may therefore be desirable to develop an alternative energy storage apparatus and a method for storing energy for use in high temperature applications for electricity generation such as sCO_2 Brayton cycle generators and which can be more efficient and easier to maintain for the end user or operator.

[0012] It is an object of the present invention to overcome or ameliorate at least one of the disadvantages of the prior art, or to provide a useful alternative.

[0013] Unless the context clearly requires otherwise, throughout the description and the claims, the words “comprise”, “comprising”, and the like are to be construed in an inclusive sense as opposed to an exclusive or exhaustive sense; that is to say, in the sense of “including, but not limited to”.

[0014] Although the invention will be described with reference to specific examples it will be appreciated by those skilled in the art that the invention may be embodied in many other forms.

Summary of the Invention

[0015] Continuous development of energy storage systems has driven the desire to develop alternative energy storage systems particularly for use in high temperature applications such as Brayton cycle generators. In particular, there is a desire to develop alternative energy storage systems which are efficient at storing and/or extracting thermal energy as well as being easy to maintain for long term use in the event that the energy storage apparatus is faulty or damaged.

Method for reversibly storing/extracting energy

[0016] According to one aspect, the present invention provides a method of reversibly storing and/or extracting energy comprising the steps of:

-heating an inner region of a sensible heat storage body using a removable heating element thereby storing energy, wherein the sensible heat storage body has a heat exchanger channel and a heating element channel adapted to receive the removable heating element, wherein the heating element channel is located internally of the sensible heat storage body; a heat exchanger having an inlet and an outlet, wherein at least a portion of the heat exchanger is disposed along the heat exchanger channel;

wherein the removable heating element is sealingly engaged with the sensible heat storage body; and

wherein a portion of the heating element is in contact with the inner region of the sensible heat storage body;

wherein the sensible heat storage body is graphite and the heating element comprises an elongated heating portion at one end; a thermally insulated portion at an opposite end; wherein the thermally insulated portion further comprises an electrical conductor adapted to be in electrical communication with an electrical terminal; and wherein the elongated heating portion comprises at least one tubular loop; and

-extracting energy by flowing a heat transfer medium having a temperature below that of said sensible heat storage body such that energy is transferred from the sensible heat storage body to the heat transfer medium,

[0037] In certain embodiments, the working fluid has an operating temperature ranging between about 400 ^{o}C to about 1000 ^{o}C, between about 400 ^{o}C to about 850 ^{o}C, between about 500 ^{o}C to about 800 ^{o}C, between about 400 ^{o}C to about 775 ^{o}C and between about 400 ^{o}C to about 675 ^{o}C.

[0038] In certain embodiments, the working fluid has an operating pressure ranging between about 20 bar to about 350 bar (about 2 MPa to about 35 MPa), between about 20 bar to about 300 bar (about 2 MPa to about 30 MPa), between about 20 bar to about 250 bar (about 2 MPa to about 25 MPa), between about 50 bar to about 350 bar (about 5 MPa to about 35 MPa), between about 50 bar to about 300 bar (about 5 MPa to about 30 MPa), between about 50 bar to about 250 bar (about 5 MPa to about 25 MPa), between about 70 bar to about 250 bar (about 7 MPa to about 25 MPa), between about 80 bar to about 250 bar (about 8 MPa to about 25 MPa), more preferably between about 100 bar to about 250 bar (about 10 MPa to about 25 MPa). In certain embodiments, the working fluid has an operating temperature ranging between about 400 ^{o}C to about 775 ^{o}C at 250 bar (about 25 MPa) and more preferably between about 400 ^{o}C to about 675 ^{o}C at 250 bar (about 25 MPa).

Energy Storage Apparatus

[0039] According to another aspect, the present invention provides an energy storage apparatus comprising:

-a sensible heat storage body having a heat exchanger channel and a heating element channel adapted to receive a removable heating element, wherein the heating element channel is located internally of the sensible heat storage body; and

-a heat exchanger having an inlet and an outlet, wherein at least a portion of the heat exchanger is disposed along the heat exchanger channel; and

wherein the sensible heat storage body comprises the removable heat element and the removable heating element is sealingly engaged with the sensible heat storage body, wherein the sensible heat storage body is graphite and the heating element comprises:

-an elongated heating portion at one end;

-a thermally insulated portion at an opposite end;

-wherein the thermally insulated portion further comprises an electrical conductor adapted to be in electrical communication with an electrical terminal; and

wherein the elongated heating portion comprises at least one tubular loop.

[0040] In preferred embodiments, the energy storage apparatus is a thermal energy storage apparatus.

[0041] The energy storage apparatus of the present invention provides at least one of the following advantages over the prior art provides for easier maintenance allowing the removable

heating elements to be replaced and/or repaired as required, improves energy storage efficiency as the removable heating element is located internally of the energy storage apparatus and can reduce operational costs by requiring fewer heating elements.

[0042] The person skilled in the art would appreciate that the sensible heat storage body can be, but is not necessarily required to be, constructed from a single piece of material (a unit body). While in some embodiments, the sensible heat storage body is a unit body, in others it is assembled by component parts.

[0043] Constructing the sensible heat storage body from component parts can provide ease of fabrication and assembly. Each component part of the sensible heat storage body can be

CLAIMS

1. A method of reversibly storing and/or extracting energy comprising the steps of:

-heating an inner region of a sensible heat storage body using a removable heating element thereby storing energy, wherein the sensible heat storage body has a heat exchanger channel and a heating element channel adapted to receive the removable heating element, wherein the heating element channel is located internally of the sensible heat storage body; a heat exchanger having an inlet and an outlet, wherein at least a portion of the heat exchanger is disposed along the heat exchanger channel;

wherein the removable heating element is sealingly engaged with the sensible heat storage body; and

wherein a portion of the heating element is in contact with the inner region of the sensible heat storage body;

wherein the sensible heat storage body is graphite and the heating element comprises an elongated heating portion at one end; a thermally insulated portion at an opposite end; wherein the thermally insulated portion further comprises an electrical conductor adapted to be in electrical communication with an electrical terminal; and wherein the elongated heating portion comprises at least one tubular loop; and

-extracting energy by flowing a heat transfer medium having a temperature below that of said sensible heat storage body such that energy is transferred from the sensible heat storage body to the heat transfer medium,

thereby providing reversible energy storage and extraction.

2. A method according to claim 1, wherein a heating portion of the heating element is in contact with the inner region of the sensible heat storage body.

3. A method according to claim 1 or 2, wherein the sensible heat storage body is enclosed in an enclosure.

4. A method according to claim 3, wherein the heating element is sealingly engaged with the enclosure.

5. A method according to any one of claims 1 to 4, wherein the inner region of the sensible heat storage body is heated by a plurality of heating elements.

6. A method according to any one of claims 3 to 5, wherein the enclosure comprises a gas inlet to substantially fill the enclosure with an inert gas and a gas outlet to vent inert gas.

7. An energy storage apparatus comprising:

-a sensible heat storage body having a heat exchanger channel and a heating element channel adapted to receive a removable heating element, wherein the heating element channel is located internally of the sensible heat storage body; and

-a heat exchanger having an inlet and an outlet, wherein at least a portion of the heat exchanger is disposed along the heat exchanger channel; and

wherein the sensible heat storage body comprises the removable heating element and the removable heating element is sealingly engaged with the sensible heat storage body, wherein the sensible heat storage body is graphite and the heating element comprises:

-an elongated heating portion at one end;

-a thermally insulated portion at an opposite end;

-wherein the thermally insulated portion further comprises an electrical conductor adapted to be in electrical communication with an electrical terminal; and

wherein the elongated heating portion comprises at least one tubular loop.

8. An energy storage apparatus according to claim 7, wherein the sensible heat storage body comprises a heat exchanger channel having at least two open ends within the sensible heat storage body.

9. An energy storage apparatus according to claim 7 or 8, wherein the sensible heat storage body is assembled by component parts.

10. An energy storage apparatus according to any one of claims 7 to 9, wherein the heat exchanger is in the shape of a serpentine coil or a helical coil.

11. An energy storage apparatus according to any one of claims 7 to 10, wherein the energy storage apparatus further comprises insulation.

12. An energy storage apparatus according to any one of claims 7 to 11, wherein the energy storage apparatus further comprises an enclosure.

13. An energy storage apparatus according to claim 12, wherein the enclosure comprises at least one aperture adapted to receive a heating element and/or a heat exchanger.

14. An energy storage apparatus according to claim 13, wherein the at least one aperture further comprises a sealing flange.

15. An energy storage apparatus according to claim 13 or 14, further comprising a sealing gasket.

16. An energy storage apparatus according to claim 14 or 15, wherein the heating element is sealingly engaged with the sealing flange.

17. An energy storage apparatus according to claim 14 or 15, wherein the heat exchanger is sealingly engaged with the sealing flange.

18. An energy storage array comprising: a plurality of energy storage apparatus according to any one of claims 7 to 17.

19. An energy storage array according to claim 18, wherein the energy storage apparatus according to any one of claims 7 to 17 are in thermal and/or electrical communication.