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(54) **REVERSIBLE HYDRIDE THERMAL ENERGY STORAGE CELL OPTIMIZED FOR SOLAR APPLICATIONS**

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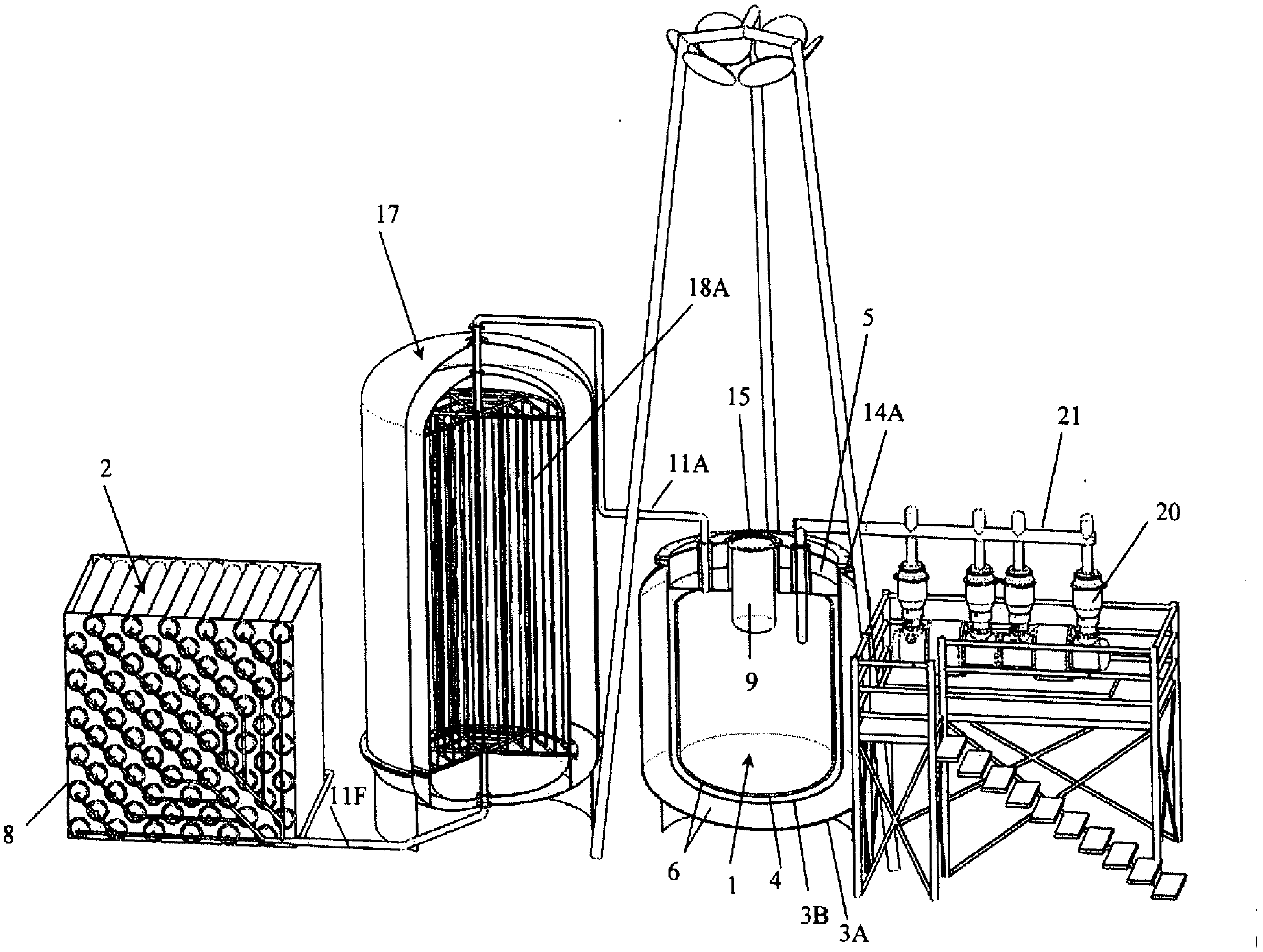
(57) **ABSTRACT**

A solar energy collection and storage system and a method of collecting and storing solar energy. The system includes a device for focusing solar energy onto a reaction chamber for the conversion of metal hydride to liquid metal and hydrogen, a metal/metal hydride chamber containing a metal/metal hydride mixture, a hydrogen storage system using hydrides and a thermo-cline for recovering the thermal energy from the hydrogen when it is cooled from 2000 F to ambient conditions for storage.



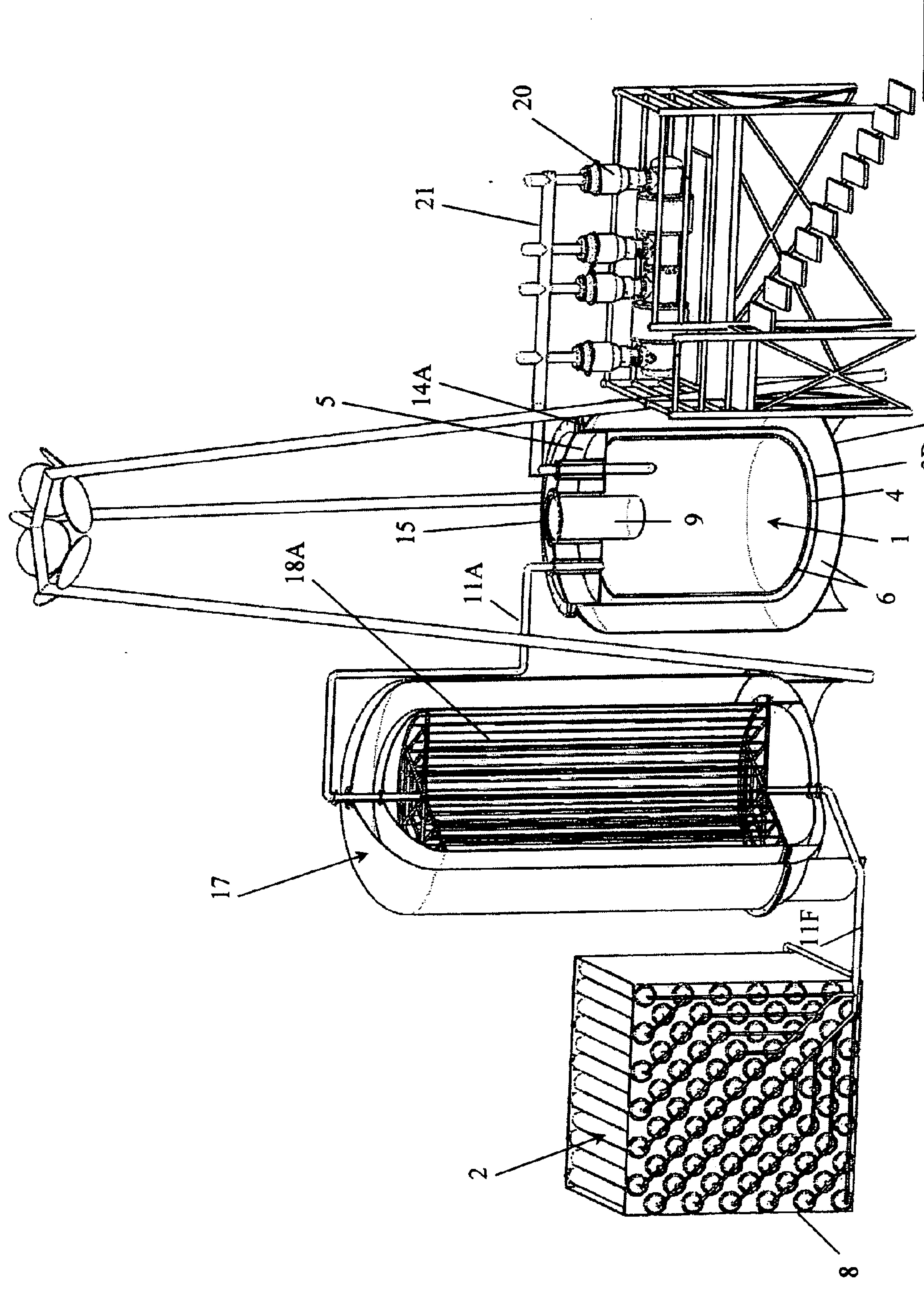


Figure 1

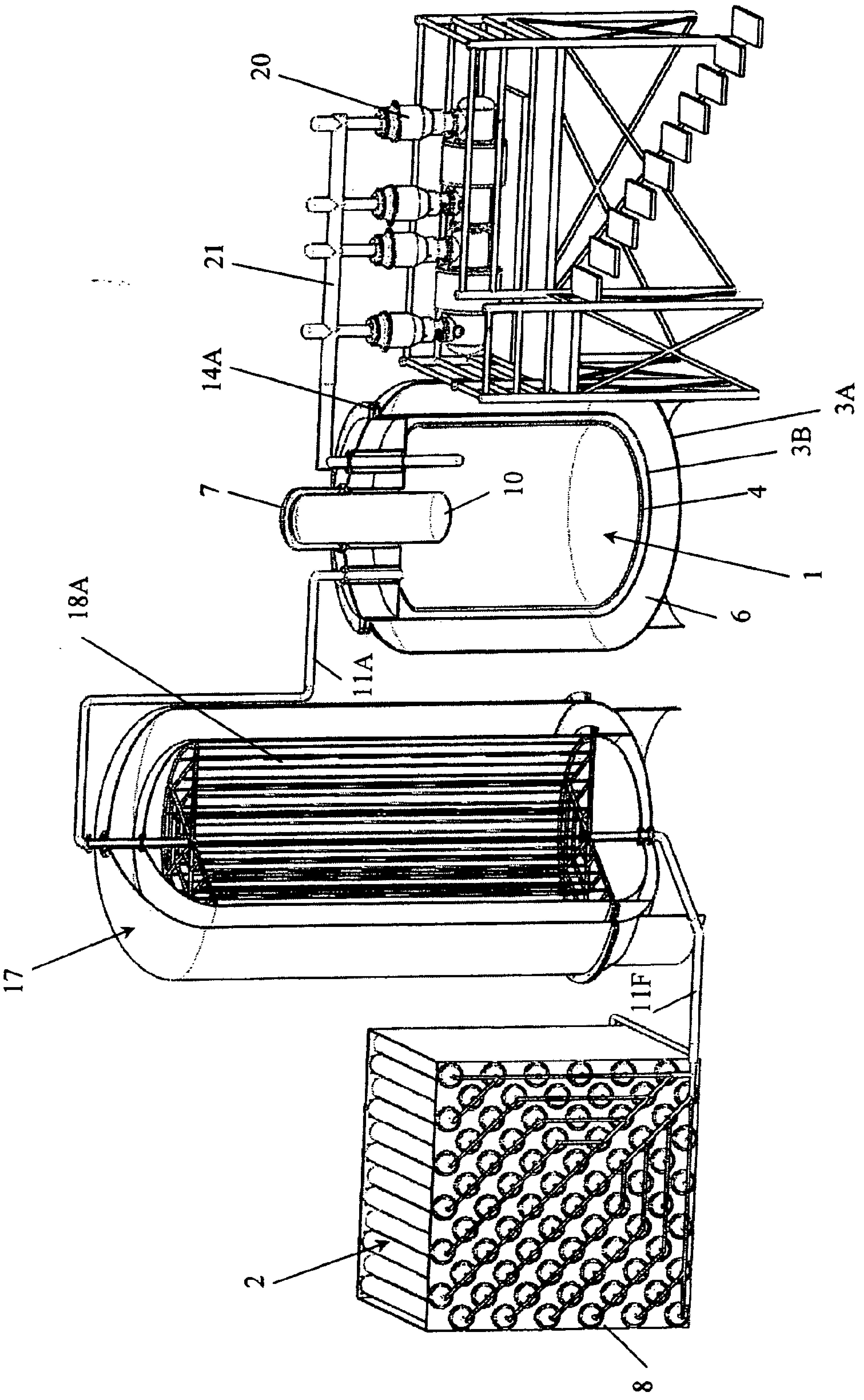


Figure 2

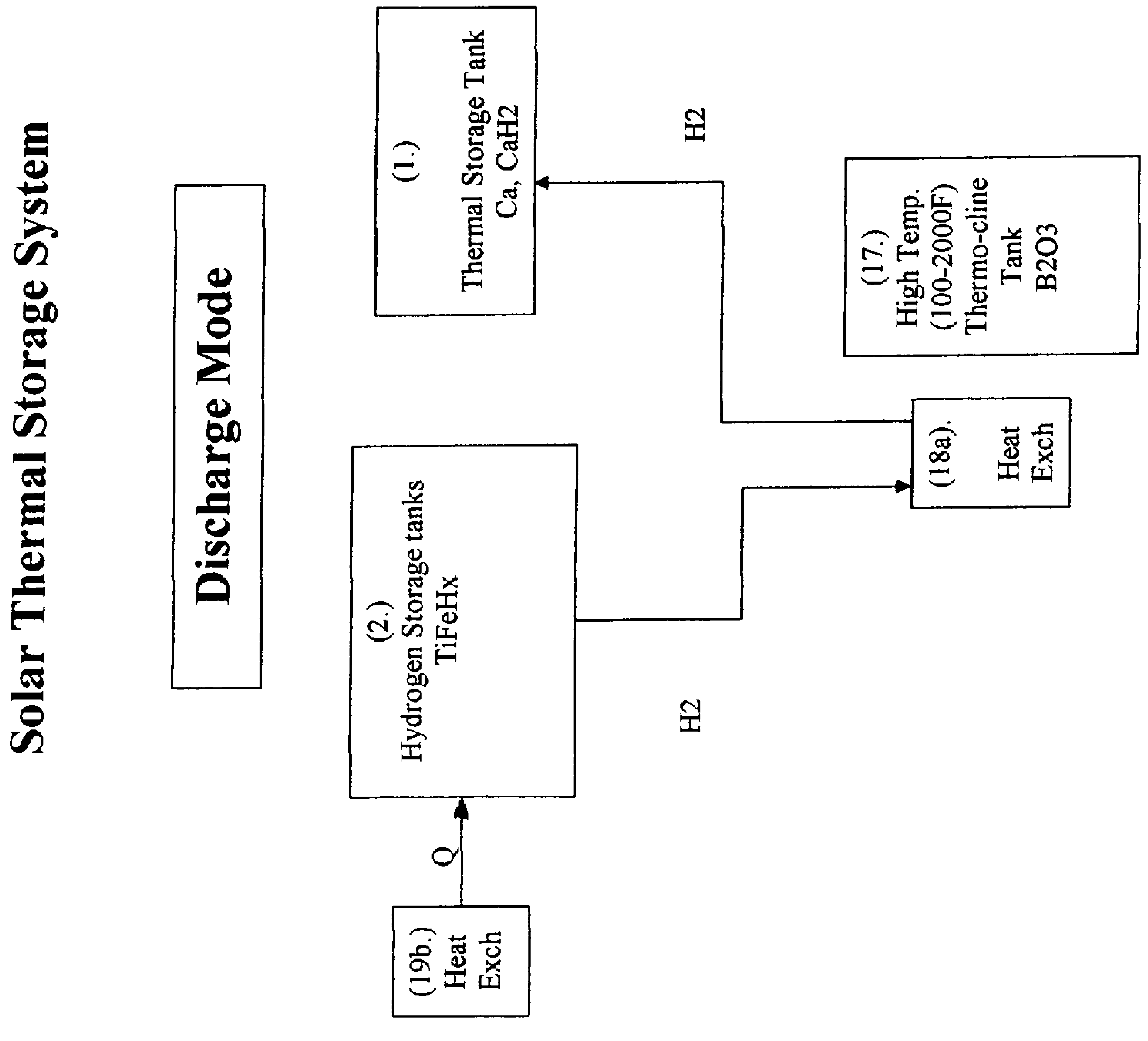

Solar Thermal Storage System
Discharge Mode
(1.)
Thermal Storage Tank
Ca, CaH2
(2.)
Hydrogen Storage tanks
TiFeHx
(17.)
High Temp.
(100-2000F)
Thermo-cline
Tank
B2O3
(18a).
Heat
Exch
(19b.)
Heat
Exch
Q
H2
H2

FIGURE 3

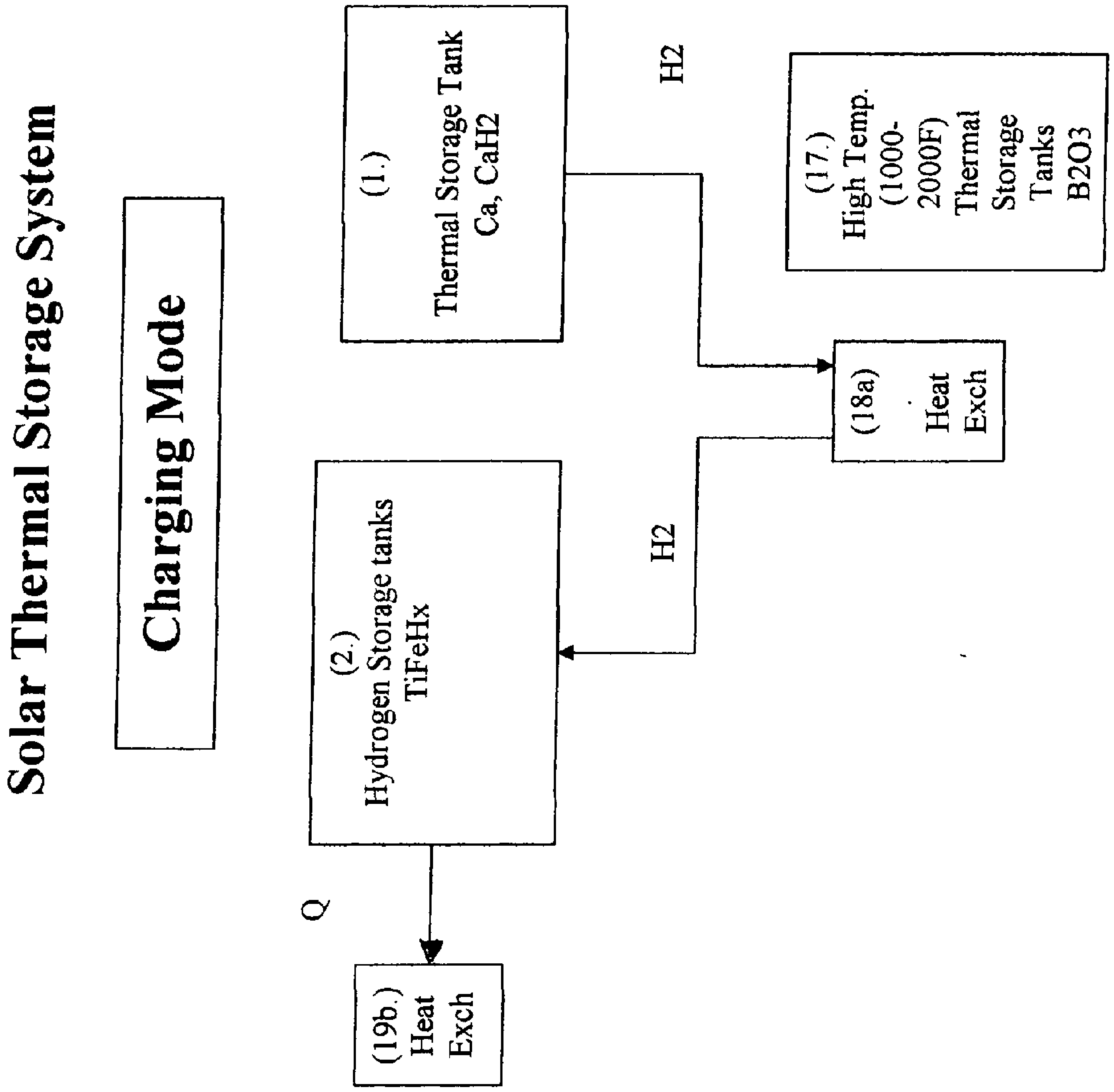

Solar Thermal Storage System
Charging Mode
(1.) Thermal Storage Tank Ca, CaH2
H2
(17.) High Temp. (1000-2000F) Thermal Storage Tanks B2O3
(18a) Heat Exch
H2
(2.) Hydrogen Storage tanks TiFeHx
Q
(19b.) Heat Exch

Figure 4

REVERSIBLE HYDRIDE THERMAL ENERGY STORAGE CELL OPTIMIZED FOR SOLAR APPLICATIONS

FIELD OF INVENTION

[0001] This invention relates to a solar energy collection and storage system and more particularly to a solar energy collection and storage system which converts solar energy into thermal energy storing the energy in the heat of formation of calcium hydride.

BACKGROUND

[0002] Solar energy provides a thermal power source which can supply a significant fraction of the world energy needs. A complete system which can absorb the sunlight during the day and produce continuous electricity provides a benefit to the society. Large scale solar power production, in GWatt quantities, is the focus of this patent. A power tower concept provides a solution where a central receiver absorbs sunlight from a field of mirrors focused on the tower. The Barstow facility, Solar 1 and 2, provides an example of this type of facility. For extended operation a thermal storage medium of potassium nitrate/sodium nitrate salts allow several hours of extended run time beyond the daylight hours. These systems use the heat of fusion within the salt, ie when a material transitions from a liquid to a solid, as the storage medium. The energy density of the salt mixture requires significant quantities of salts to provide a few extra hours of operation due to the low energy density.

SUMMARY

[0003] Providing continuous electricity from solar significantly increases the benefit and usefulness of this energy source. This invention utilizes the heat of formation between calcium and hydrogen to form calcium hydride as the energy storage medium. Calcium hydride provides up to 20 times the energy density of the solar 1 and 2 salt systems.

[0004] Calcium hydride is chosen due to its ability to be broken apart using a thermal heat source; such as the sun. The process is endothermic absorbing the suns energy during the day and storing it chemically. The process is reversed at night with the calcium and hydrogen recombining to form calcium hydride in an exothermic reaction. The direction of the reaction is controlled by the temperature and pressure in the reaction chamber. Calcium hydride is one of the more stable hydrides and will operate reversibly in the 1200 F to 2200 F temperature range. At these temperatures a Stirling engine or supercritical CO2 Brayton cycle can be used, integrated with a heat pipe, to produce electricity from the thermal storage.

[0005] The hydrogen, separated during the daytime, is stored in a separate low temperature hydride tank which allows a low cost bulk storage technique for the hydrogen. Titanium iron hydride provides a low cost storage solution for the hydrogen.

[0006] Heat exchangers with thermal storage can be used to store the heat when the hydrogen is cooled from temperatures of approximately 2000 F to 100 F. A method for storing the thermal energy from the hydrogen is to use a thermo-cline filled with boron oxide and dispersed graphite fibers placed perpendicular to the hydrogen flow heat exchanger. The top of the thermo-cline remains at high temperature while the bottom remains at a lower temperature. Hydrogen flows between two manifolds located within the thermo-cline within a series of tubes dispersed within the boron oxide to transfer thermal energy to and from the hydrogen. When the hydrogen flows from the reactor to the storage it is cooled by the boron oxide. When the hydrogen flows from the storage to the reactor it is heated by the boron oxide. A second method for storing the hydrogen thermal energy uses a high temperature boron oxide liquid counter-flow heat exchanger which provides an efficient solution to recover the majority of the heat from the hydrogen. A second low temperature counter flow heat exchanger, using a nitrate salt mixture, can also be integrated to extract more of the energy from the hydrogen.

[0007] The advantage of this system is that it is a completely reversible closed cycle. The intermittent sunlight can be chemically stored and released at a controlled rate for electric power production. The system uses materials which are low cost and provide a competitive electrical production facility for both small and very large scale application.

BRIEF DESCRIPTION (OF THE FIGURES)

[0008] FIG. **1** depicts a reversible hydride thermal energy storage system coupled with a thermally driven generator in a down mirror configuration. From left to right, the four components displayed are a cooled tank containing hydride hydrogen storage cylinders, a thermocline heat exchanger double tank, a calcium hydride thermal storage cell (directly below the down mirror structure), and a 100 kW Stirling engine driven electrical power generator.

[0009] FIG. **2** depicts a reversible hydride thermal energy storage system coupled with a thermally driven generator in a direct beam heating configuration. The components are identical to FIG. **1** as described above, excepting that the down mirror is omitted and a black body heat pipe is incorporated at the top of the calcium hydride storage cell.

[0010] FIG. **3** is a solar thermal storage system flow chart useful for visualizing how the system operates when in discharge mode, after the sun has set.

[0011] FIG. **4** is a solar thermal storage system flow chart useful for visualizing how the system operates when in charging mode, when the sun is shining.

DETAILED DESCRIPTION

[0012] The storage system consists of three tank systems: The first is the calcium and calcium hydride storage cell (**1**) with reaction chamber. The second is the hydrogen storage tanks (**2**) using a low temperature titanium iron hydride material. The third tank provides thermal storage used for extracting the energy from the hydrogen prior to the hydrogen being stored in the low temperature hydride tanks (**2**). A single thermo-cline tank is used to store the hydrogen energy as it cools from 2000 F to near room temperature. This embodiment uses a high temperature double tank (**17**) to cool the hydrogen from 2000 F to 100 F. This thermal storage tank combination is also used to heat the hydrogen prior to it entering the calcium cell (**1**).

[0013] FIG. **1** shows an embodiment of a three tank system. The calcium/calcium hydride tank (**1**) consists of an outer tank (**3***a*), a mid tank (**3***b*), and inner tank (**4**) with an insulation layer (**6**) between the three tanks. The inner tank (**4**) is maintained at temperatures of 1500 F to 2000 F while the outer tank (**3***a*) is slightly above room temperature. The insulation (**6**) maintains a minimal heat loss between the three tanks. The inner tank (**4**) contains the two materials calcium and calcium hydride. The calcium floats above the calcium hydride. Above 1800 F both materials are liquid. The insulation layer (**6**) extends completely around both inner tank (**4**) and mid tank (**3***b*) including the top and bottom.

[0014] The mid shell serves as a containment shell for the liquids during operation. The temperature drop through the insulation is sufficient so that the mid tank (**3***b*) operates below the melting point of Calcium. If a leak occurs the liquid Calcium freezes prior to reaching the mid tank (**3***b*). The use of silicon dioxide insulation is due to the reaction which occurs with the liquid Calcium. Free silicon will form which solidifies stopping the reaction. Calcium oxide powder provides an inert layer between the mid tank (**3***b*) and inner tank (**4**).

[0015] The reaction between calcium and hydrogen to produce calcium hydride is exothermic. This provides the heat source to drive a thermal engine such as a Stirling engine, Brayton turbine, or steam turbine. Calcium, calcium hydride, and hydrogen gas are in equilibrium with the hydrogen pressure a function of the reaction temperature. At approximately 1800 F this equilibrium is 1 atmosphere pressure. At 2000 F this is approximately 3 atmospheres pressure. The system pressure and temperature combination is used to create either an exothermic or endothermic reaction between the 3 components.

[0016] The level of calcium and calcium hydride, within the inner tank (**4**), varies depending on the state of charge of the thermal cell. A fully charged cell is all calcium with hydrogen stored separately. A fully discharged cell is all calcium hydride. Hydrogen is used to pressurize the three tank regions within cell (**1**); including the lid (**5**).

[0017] A hydrogen inlet and outlet line (**11***a*) is located in the top of the calcium/calcium hydride tank (**1**). A bolt flange (**14***a*), at the top of tanks (**3***a*), and (**3***b*) join together to seal the two tanks. A water cooled lid (**5**) maintains o-ring seal temperatures. A quartz window (**15**) is located on the top of the calcium/calcium hydride tank (**1**), in lid (**5**), so that sunlight can project onto the reaction chamber (**9**). The reaction chamber (**9**) is fabricated of a molybdenum lanthanum oxide material. The inner surface of the reaction chamber (**9**) is chromium plated to protect the molybdenum from oxidation if air enters into the reaction chamber (**9**) while at high temperature and to provide a low emissivity surface for the sunlight absorption after the chromium plating is oxidized. A series of helio-stat mirrors located on the ground around the solar thermal reaction tower are focused on a down facing mirror, which is attached to the top of a down mirror tower, and which is located above the calcium/calcium hydride tank (**1**) and focuses sunlight through the quartz window (**15**). The area between the quartz window (**15**) and the reaction chamber (**9**) does not have insulation. Argon, nitrogen gas or a vacuum fills the reaction chamber (**9**).

[0018] A means of filling the inside of the reaction chamber (**9**) with insulation reduces heat loss at night. A movable set of plates, fitted within the reaction chamber (**9**), could be setup to close the region with insulation at night. During the day the plates would move in an outward direction to allow a clear space between the quartz window (**15**) and the reaction chamber (**9**). An alternative would be to have a hinged insulated or reflective lid which closes over the quartz window (**15**) during the night.

[0019] The inner tank (**4**) is made of molybdenum with Lanthanum oxide dispersed within the metal which raises the recrystallization temperature above the metal operating temperature. Remaining below the recrystallization temperature is very important to the strength and toughness of the molybdenum. The outer tank (**3***a*) is made of a low temperature stainless such as 304 or 316. The mid tank (**3***b*) is made of a high temperature stainless such as RA330 or Haynes 230. A Rhenium layer (**16**) is coated on the inside of the inner tank (**4**). This Rhenium layer (**16**) provides a barrier between the Calcium or calcium hydride and the braze junctions used to fabricate the molybdenum tank (**4**). If the molybdenum parts can be fabricated without seams, or with e-beam welds, then the Rhenium coating layer is not required. The inner tank (**4**) is fabricated from sheet stock and is brazed together at the side, top, and bottom locations. The molybdenum is machined to provide a tapered overlapping joint for brazing. A chromium layer is electroplated at the joint locations. The parts are brazed with a Cobalt-Palladium alloy to provide sealed junctions. Once the brazes are complete the Rhenium is applied locally over the braze junction with a thickness of approximately 0.004 inches on the inner tank surface. In order to enhance the e-beam welding characteristics of the molybdenum an addition of 10% to 40% Rhenium can be added. As an alternative the inner tank (**4**) could be fabricated from a ceramic material such as calcium aluminate or calcium oxide. The material could have a molybdenum lanthanum oxide wire mesh distributed within the ceramic wall to increase the inner tank strength and prevent large cracks from forming. The insulation between tank (**4**) and (**3***b*) can be a powder fill of calcium oxide or it can be a rigid insulation such as silicon dioxide or aluminum oxide.

[0020] The hydride tanks (**2**) are used to hold the hydrogen at ambient temperature. The tanks contain a solid porous material which allows rapid hydrogen transport in and out of the porous material. A chemical bond is created within the material which creates a metal hydride. Titanium iron hydride is chosen for this application as ambient temperature low cost material. Over 1% hydrogen by weight is absorbed when the hydride is created. Hydrogen is absorbed and released when maintained between 0 C and 50 C. The hydrogen pressure varies with temperature. As the temperature is raised the pressure rises to several atmospheres. A flowing water heat exchanger tank (**8**) surrounds the hydride tanks (**2**) and maintains the hydride powder temperature during the hydrogen absorption and desorption processes. The hydrogen movement results in either an exothermic or endothermic reaction. When hydrogen is added to the titanium iron powder thermal energy is released into the water bath (**8**). When hydrogen is removed from the titanium iron hydride thermal energy is added from the water bath into the hydride powder to maintain the hydrogen pressure.

[0021] The thermo-cline double tank (**17**) is used to store the hydrogen thermal energy when it is being cooled from approximately 2000 F to 100 F. The thermo-cline tank uses the specific heat of liquid boron oxide to store the hydrogen energy. The high temperature dual tanks (**17**) operate between approximately 2000 F at the top of the tank and 100 F at the bottom using boron oxide as a heat transfer fluid. The thermo-cline tank (**17**) is used to cool the hydrogen during charging and heat the hydrogen during discharge.

[0022] A Stirling engine (**20**) is located next to the calcium/calcium hydride storage tank (**1**). A metal vapor boiler and heat pipe/metal boiler (**21**) connects from the Stirling engine (**20**) into the inner tank (**4**). Magnesium vapor is used as a heat transfer fluid within the boiler and heat pipe (**21**).

[0023] The hydrogen lines are attached as follows:

[0024] 1) Hydrogen inlet and outlet (**11***a*) connects from the reactor (**1**) to the top of the thermo-cline heat exchanger (**17**). A floating seal at the thermo-cline junction provides for thermal expansion.

[0025] 2) The bottom of the thermo-cline heat exchanger (**17**) connects to the hydride tanks (**2**). The common hydride tank feed line is (**11**F).

[0026] Water flowing through an underground heat exchanger is used to maintain the hydride tank (**2**) temperature by circulating through a reservoir surrounding the hydride tanks (**2**)

[0027] FIG. **2** shows an embodiment of the system where a heat pipe (**10**) is integrated at the top of the hydride storage cell (**1**). In this configuration the system behavior for the hydrogen flow and energy flow is identical to FIG. **1** where the solar heat is applied directly to the bottom of the reaction chamber (**9**). The difference is in the location of the solar heat target. For FIG. **1** the solar energy passes through the quartz window (**15**) and projects directly onto the bottom of the reaction chamber (**9**). This system requires that the solar input beam be substantially vertical passing through the quartz window (**15**). To accomplish the solar heat input in FIG. **1** the side focusing helio-stats first create an approximately constant diameter sunlight beam of 12 inches in diameter for the 100 kW system. Multiple beams, from the side focusing helio-stats, are reflected from individual down beam mirrors located directly above the quartz window (**15**). The design in FIG. **2** eliminates the need for the down beam mirrors and allows the side focusing helio-stat beam to project directly on the side of the heat pipe (**10**) which is projecting from the top of the reactor (**1**). A quartz bell (**7**) is added over the heat pipe (**10**) to minimize thermal losses and protect it from atmospheric corrosion. At night an insulation cover is folded over the quartz bell (**7**) to minimize thermal losses.

[0028] Operation

[0029] The system operates in a charging mode and a discharging mode. System operation can be maintained by controlling temperatures in both the calcium reactor and titanium iron hydride storage tanks. The total system can operate without valves so that the pressure is constant throughout the system. Hydrogen pressure in the hydride storage (**2**), thermo-cline (**17**), and reactor (**1**) are constant as long as the flow rates are slow or stopped. Piping is sized to minimize pressure drop through the system while the hydrogen is flowing during normal operation. The equilibrium hydrogen pressure is approximately **1** atmosphere at 1800 F and 5 atmospheres at 2000 F in the calcium reactor (**1**) between the calcium, hydrogen, and calcium hydride. Below equilibrium temperature the reaction is exothermic creating calcium hydride. Above equilibrium temperature the reaction is endothermic creating calcium and hydrogen. As an example of system operation: if the pressure is approximately constant at 3 atmospheres then the equilibrium temperature is approximately 1900 F. If the reactor (**1**) is heated by the sun then the temperature rises slightly and hydrogen is formed. The rate of hydrogen produced from the reactor (**1**) is a function of the temperature above equilibrium. The hydrogen generation rate will increase until a new equilibrium is reached in solar energy absorbed and the energy required for the endothermic reaction. When the solar energy is reduced, at night or when a cloud passes overhead, then the temperature drops within the calcium reactor (**1**) until a new equilibrium is reached in hydrogen flow. As the solar energy goes to zero then the temperature drops to a point where hydrogen wants to flow back into the calcium reactor (**1**). The hydrogen reacts with the calcium and creates an exothermic reaction which produces a new equilibrium temperature. The system is designed so that all processes operate in the 1 to 5 atmospheres and 1800 F to 2000 F reactor (**1**) temperature ranges. One of the features of this system is the automatic stability based on heat input to the calcium reactor which allows the system to operate without hydrogen flow rate controls.

[0030] The second part of the system is the hydrogen storage using an ambient temperature hydride. Titanium iron hydride provides an ideal solution for the storage of hydrogen due to its ability to combine and release hydrogen near ambient temperature conditions. The process is exothermic when hydrogen is combining to form the titanium iron hydride and endothermic when hydrogen is being released. Operating near ambient conditions allows this heat, to and from the titanium iron hydride reaction, to come from the surroundings so that extra energy is not required by the system. The movement of hydrogen in and out of the titanium iron hydride is a function of the titanium iron hydride temperature which also operates in an equilibrium condition. The equilibrium pressure is approximately 1.5 atmospheres at 32 F and 5.5 atmospheres at 86 F. To keep the hydrogen pressure below 5 atmospheres the titanium iron hydride needs to be cooled during the day while hydrogen is flowing into the titanium iron hydride powder as this process is exothermic and releases heat. To maintain an approximately constant temperature a flowing water bath (**8**) is used which surrounds multiple tanks (**2**). The tanks (**2**) are positioned sideways, with the hydride powder filling approximately 70% of the volume, to allow for expansion of the titanium iron hydride during the absorption process. Using the earth as a heat sink allows an almost constant temperature for both day and night for the water bath (**8**). A temperature of approximately 60 F, based on an average ground temperature, allows the hydrogen equilibrium to stay near 3 atmospheres during the system operation.

[0031] Charging mode: During the daylight hours solar energy is available for thermal storage. The reaction of the calcium hydride breaking apart to form calcium and hydrogen is endothermic and absorbs the focused heat from the sunlight. A group of side focusing helio-stats direct the suns energy through the quartz window (**15**) and onto the reaction chamber (**9**). The equilibrium pressure for calcium hydride varies with temperature. The calcium and calcium hydride located in tank (**4**) is maintained at approximately 1900 F by controlling the hydrogen pressure in storage cell (**1**) using the temperature of the titanium iron hydride tanks as an automatic control system. Maintaining the same pressure in tanks (**3**A), (**3**B) and (**4**) eliminates the stress on the wall of tanks (**4**) and (**3**B) due to the pressure. The tank (**3**A) is at low temperature and provides the structure for the pressure. When solar energy is available to heat the calcium reactor the temperature rises above equilibrium, for a given pressure, which causes hydrogen to be released. The calcium temperature is maintained using the energy balance between the incoming solar energy, the calcium, and the hydrogen reaction rate and direction. The temperature increment above equilibrium increases the hydrogen flow rate until an energy balance occurs between the incoming solar energy and the endothermic reaction rate of the calcium and hydrogen evolution. The process stabilizes automatically so that no valves or control system is required for the hydrogen flow. The hydrogen exits through the hydrogen outlet (**11***a*).

[0032] The hydrogen exiting the hydrogen line (**11***a*) is at approximately 1900 F and contains a substantial amount of thermal energy. The hydrogen flows through the thermo-cline heat exchanger (**18***a*) and is cooled by the boron oxide in the thermal storage (**17**). The hydrogen temperature drops from 2000 F to 100 F while the boron oxide is heated from 100 F to 2000 F. Graphite fiber oriented perpendicular to the hydrogen flow increases the heat transfer within the boron oxide in the radial direction. Graphite has a much lower thermal conductivity perpendicular to the fiber direction. This allows the boron oxide to operate with the 1900 F temperature gradient within the tank with minimal thermal losses.

[0033] The temperature of the calcium/calcium hydride, is maintained at approximately 1900 F in tank (**4**) by maintaining the hydrogen pressure above the calcium to approximately 3 atmospheres. The system flow chart is shown in FIG. **4**.

[0034] Discharge mode: The Stirling engine (**20**) extracts heat directly from tank (**4**) which contains the calcium and calcium hydride. A heat pipe (**21**) connects to the hot side of the Stirling engine and passes through the outer tank lid (**5**) and into tank (**4**). Sufficient heat pipe area is extended within tank (**4**), or on the external surface of tank (**4**), to prevent the calcium hydride from solidifying around the heat pipe while the engine is extracting thermal energy.

[0035] The rate of hydrogen flowing out of the hydride tanks (**2**) is controlled by the temperature of the reaction chamber (**1**). As the calcium and calcium hydride temperature drops the equilibrium pressure drops until the pressure in the reactor (**1**) falls below the hydride tank (**2**) pressure.

[0036] Hydrogen flows from the hydride tank (**2**) into the heat exchanger (**18**A). Passing through the heat exchanger (**18**A) heats the hydrogen to approximately 1900 F where it then flows into the hydrogen inlet line (**11***a*). The temperature in the inner tank (**4**) is maintained at approximately 1900 F by the hydrogen flow rate out of the hydride tank (**2**).

[0037] The system flowchart is shown in FIG. **3**.

[0038] Variations to the Baseline System:

[0039] Different metals could be used in place of the calcium. These could include: magnesium, strontium, barium, lithium, sodium, potassium, titanium, or zirconium. Also boro-hydrides could be used such as lithium, sodium, or potassium.

[0040] The system could operate without either the high temperature storage tank (**17**) or the low temperature storage tank (**22**). In this case a secondary cooling loop using an external heat exchanger with the surroundings could be used such as with air, a solid heat sink, or water cooling.

[0041] Multiple heat engines or a single engine could be used to extract the heat from tank (**4**). The heat engines could include any variation of brayton, Stirling, or rankine cycles. A secondary steam cycle could also be used to supply peaking power utilizing a steam turbine.

[0042] An inert gas within tank (**3**A) could be nitrogen or argon instead of hydrogen to reduce the heat loss. The gas in (**3**A) would not have the filter (**24**) through the (**3***b*) wall.

[0043] The hydride storage material could be a number of hydrides including: Magnesium nickel hydride, lithium aluminum hydride, magnesium iron hydride, lanthanum nickel aluminum hydride, calcium nickel hydride, titanium iron hydride, or magnesium hydride. The hydrogen could also be stored as a compressed gas or liquid.

[0044] The system can be operated over a wider temperature range such as 1200 F to 2500 F.

[0045] The system can operate with the temperature in tank (**4**) below 1800 F so that the Calcium hydride is a solid.

[0046] A Kovar seal could be used to support reaction chamber (**9**) at the top of lid (**5**). Both the bolt flange (**14***a*) and the quartz window (**15**) hold down ring could be water cooled.

[0047] The nitrate salt mixture could use lithium nitrate instead of, or with, the calcium nitrate as a eutectic with the potassium and sodium nitrate salts.

[0048] For operation during long periods of cloudy weather a 2nd heat source is required. One solution is to use a burner and air pre-heater assembly where the heat is directed into an exhaust heat exchanger to absorb the combustion energy. A closed hydrogen loop between the calcium tank (**1**) and the exhaust heat exchanger would provide a technique to maintain the calcium temperature. The hydrogen would be pumped in and out of the region above the liquid calcium in tank (**1**) with the additional heat being extracted from the exhaust heat exchanger. Any type of fuel could be used for this purpose.

[0049] A variation on the quartz window (**15**) cover would be to use a **2** way shape memory alloy attached to an insulated multi-segment door. The segments would be hinged against the top wall of the reaction chamber (**9**). During daylight hours heating from the sun would cause the memory metal to flex downward opening the segments by rotating the insulation up against the reaction chamber (**9**) wall so that sun could enter. At night the cooling from lack of sunlight would cool the memory metal and it would flex to rotate the insulation segments so as to close the lid which reduces thermal loss at night.

CONCLUSIONS

[0050] The thermal storage system provides a unique and significant advantage in that it provides a continuous low cost high energy density control system. Integration of these features allows economically viable storage systems over a much broader size range than existing storage systems. The claims provide details of how the unique features are integrated into a complete system.

1. A solar energy collection and storage system including:
A device for focusing solar energy, or any type of thermal energy, into a reaction chamber for the conversion of metal hydride to liquid metal and hydrogen,
a metal/metal hydride vessel containing a metal/metal hydride mixture,
a hydrogen storage system.

2. The system of claim **1** wherein the metal is selected from the group of calcium, magnesium, strontium, barium, lithium, sodium, potassium, titanium, or zirconium.

3. The system of claim **1** wherein the hydride is selected form the group of metal boro-hydrides of lithium, sodium, or potassium.

4. The system of claim **1** wherein the reaction vessel is at the focus of a helio-stat or field of solar mirrors.

5. The system of claim **1** wherein the reaction vessel has a quartz window and a molybdenum conduit projecting within the metal/metal hydride so that sunlight can project onto the bottom of the conduit for heating the metal/metal hydride.

6. The system of claim **1** wherein the reaction vessel has a heat pipe projecting out of the top of the reaction vessel with the heat pipe also extending into the metal/metal hydride for heating the metal/metal hydride.

7. The system of claim **1** wherein a heat transfer conduit projects through reactor lid and into the metal/metal hydride.

8. The system of claim **1** wherein a hydrogen flow line projects into the reactor vessel.

9. The system of claim **1** wherein the metal/metal hydride pressure vessel is located within an outer pressure vessel and an annular space exists between the metal hydride pressure vessel and the inner wall of the outer pressure vessel.

10. The system of claim **1** wherein the metal/metal hydride is contained within an inner metal or ceramic vessel, a mid metal container supports the inner vessel, and an outer pressure vessel supports both the inner and mid vessels.

11. The system of claim **1** wherein the inner vessel is fabricated from molybdenum with a lanthanum oxide dispersion.

12. The system of claim **1** wherein the inner vessel is fabricated from a calcium aluminate or calcium oxide ceramic.

13. The system of claim **1** wherein the inner vessel is fabricated with an internal metal wire mesh which is covered with ceramic creating an enhanced structural inner vessel.

14. The system of claim **1** wherein the inner vessel is supported by a rigid or powdered ceramic such as silicon dioxide or aluminum oxide or calcium oxide.

15. The system of claim **1** wherein a primary gas stream extends from the reaction chamber to a hydrogen storage vessel.

16. The system of claim **1** wherein a primary gas stream extends from the reaction chamber through a heat transfer thermocline to a hydrogen storage vessel.

17. The system of claim **1** wherein hydrogen storage system comprises one or multiple hydrogen storage vessels, the hydrogen storage material comprising a metal or metal alloy capable of reacting with or absorbing hydrogen.

18. The system of claim **1** wherein the hydride storage material is at least one metal hydride selected from the group of magnesium nickel hydride, lithium aluminum hydride, magnesium iron hydride, lanthanum nickel aluminum hydride, calcium nickel hydride, titanium iron hydride, and magnesium hydride.

19. The system of claim **1** wherein multiple hydride storage vessels are contained within a water cooled tank.

20. The system of claim **1** wherein the hydrogen storage system is hydrogen stored as a compressed gas or liquid.

21. The system of claim **1** wherein a heat exchanger and heat storage system is provided to recover heat from the primary hydrogen gas stream between the reaction chamber and the hydrogen storage vessel.

22. The system of claim **1** wherein the heat changer material is boron oxide.

23. The system of claim **1** wherein the heat exchanger has graphite fiber, dispersed within the boron oxide, oriented predominantly sideways relative to the direction of hydrogen flowing within multiple heat transport tubes with the heat exchanger operating as a thermo-cline.

24. The system of claim **1** wherein the boron oxide, in the heat exchanger, flows within a counter flow heat exchanger transferring heat with the hydrogen gas.

25. The system of claim **1** wherein the heat exchanger consists of a high and low temperature tanks system with separate heat transfer materials handling a high and low temperature hydrogen temperature range.

26. The system of claim **1** wherein the 2^{nd} heat exchanger utilizes a nitrate salt mixture from the group of alkaline metal nitrates.

27. The system of claim **1** wherein the heat exchange occurs with the hydrogen gas without mixing between the hydrogen gas and the heat exchange materials.

28. The system of claim **1** wherein the hydrogen gas flows from the hydrogen storage system into the reactor providing a chemical reaction with the metal to create the hydride and thermal energy.

29. A thermal storage method wherein energy is stored when a compound of two or more materials are separated into components.

Said components operate reversibly so that when they combine they release thermal energy and when they are separated they absorb thermal energy.

Said components store their energy in the heat of formation differences between the individual materials or elements and the compound which is formed when they are brought together.

30. The method of claim **29** wherein one of the components is hydrogen and the second component is a metal with the metal remaining in the reactor and the hydrogen being transported to a separate container.

31. The method of claim **29** wherein the hydrogen is cooled by flowing the hydrogen through a heat exchanger, with the energy stored in a separate thermal storage container, before the hydrogen is stored.

32. The method of claim **29** wherein the hydrogen is stored within a hydride material which can reversibly release the hydrogen when required.

33. The method of claim **29** wherein the hydride material uses a flowing liquid reservoir surrounding the storage vessels, such as water, to maintain a constant hydride temperature.

34. The method of claim **29** wherein the flowing liquid, used to maintain the hydride storage tanks, uses the thermal heat capacity and temperature of the ground, to maintain the hydride storage tank temperature.

35. The method of claim **29** wherein the metal hydride sinks below the metal surface providing a fresh surface for the hydrogen reaction to occur.

36. The method of claim **29** wherein the hydrogen pressure is used to control the rate and direction of the exothermic and endothermic processes.

37. A thermal storage system wherein the process of separating two materials provides a means for the storage of thermal energy in chemical form.

Said materials release energy when they are recombined.

The direction of said materials to combine or separate is determined by the hydrogen gas pressure at a constant operating temperature.

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