



(19) **United States**

(12) **Patent Application Publication**
Wait

(10) **Pub. No.: US 2013/0228163 A1**

(43) **Pub. Date: Sep. 5, 2013**

(54) **THERMAL TRANSFER APPARATUS AND METHOD THEREFOR**

(52) **U.S. Cl.**
USPC 126/619; 126/634; 126/640; 126/714

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(21) Appl. No.: **13/409,274**

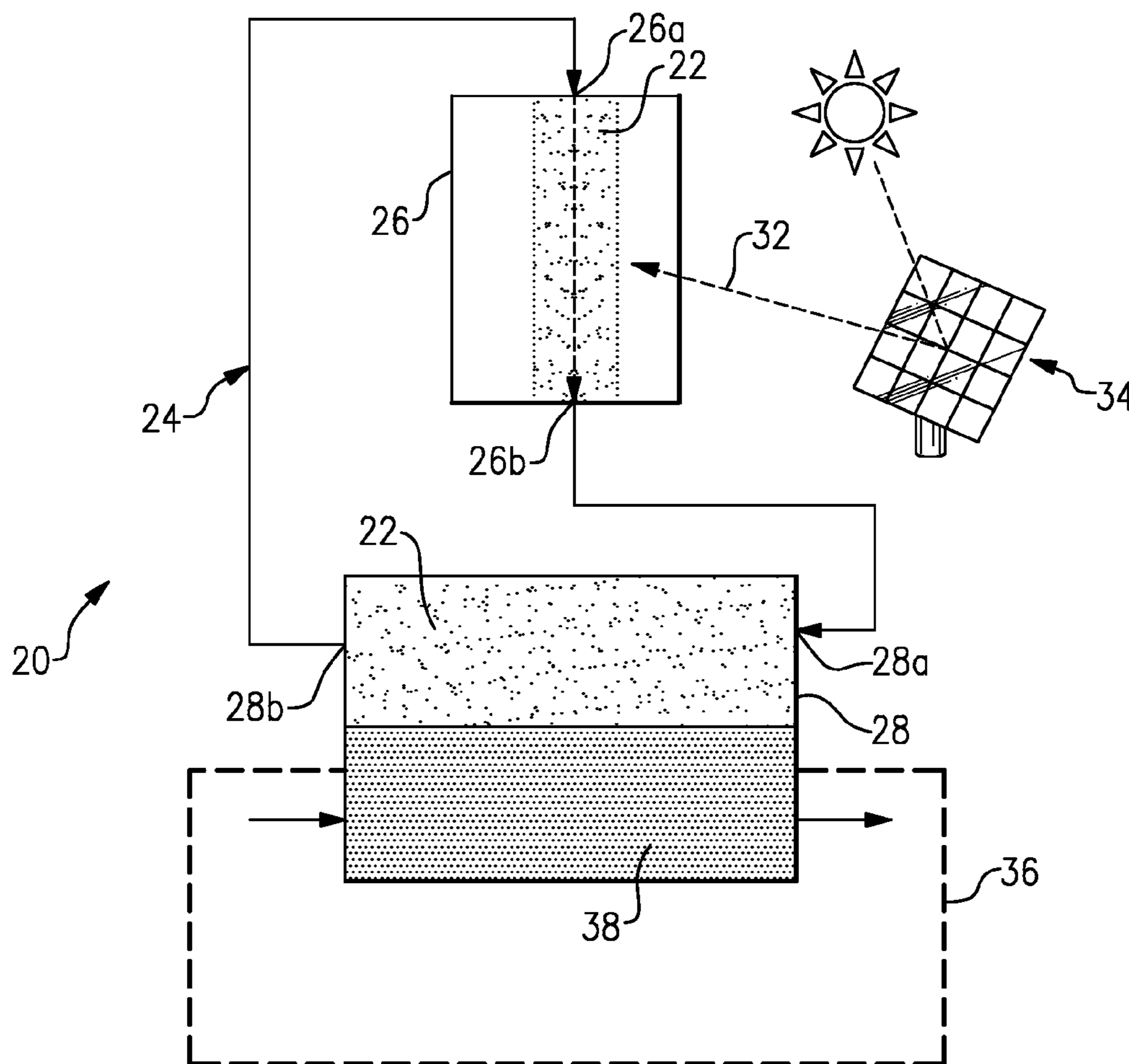
(57) **ABSTRACT**

(22) Filed: **Mar. 1, 2012**

Publication Classification

(51) **Int. Cl.**
F24J 2/04 (2006.01)
F24J 2/00 (2006.01)
F24J 2/34 (2006.01)

An apparatus includes a closed loop circuit that has a concentrated solar receiver and a particulate thermal transfer media moveable through the closed loop circuit. The particulate thermal transfer media has a melting temperature of greater than 600° C./1112° F. A heat exchanger is in communication with the particulate thermal transfer media.



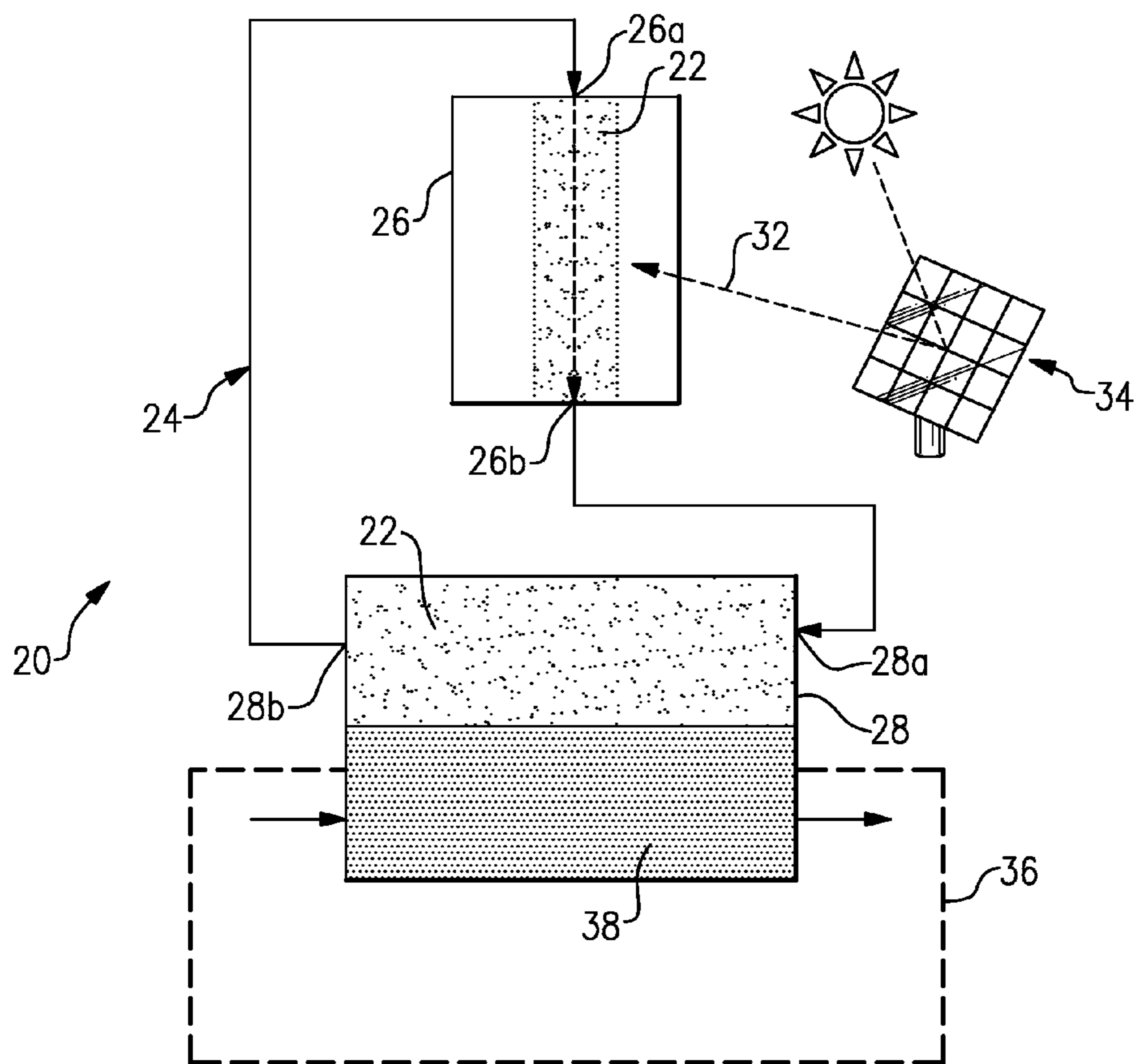


FIG. 1

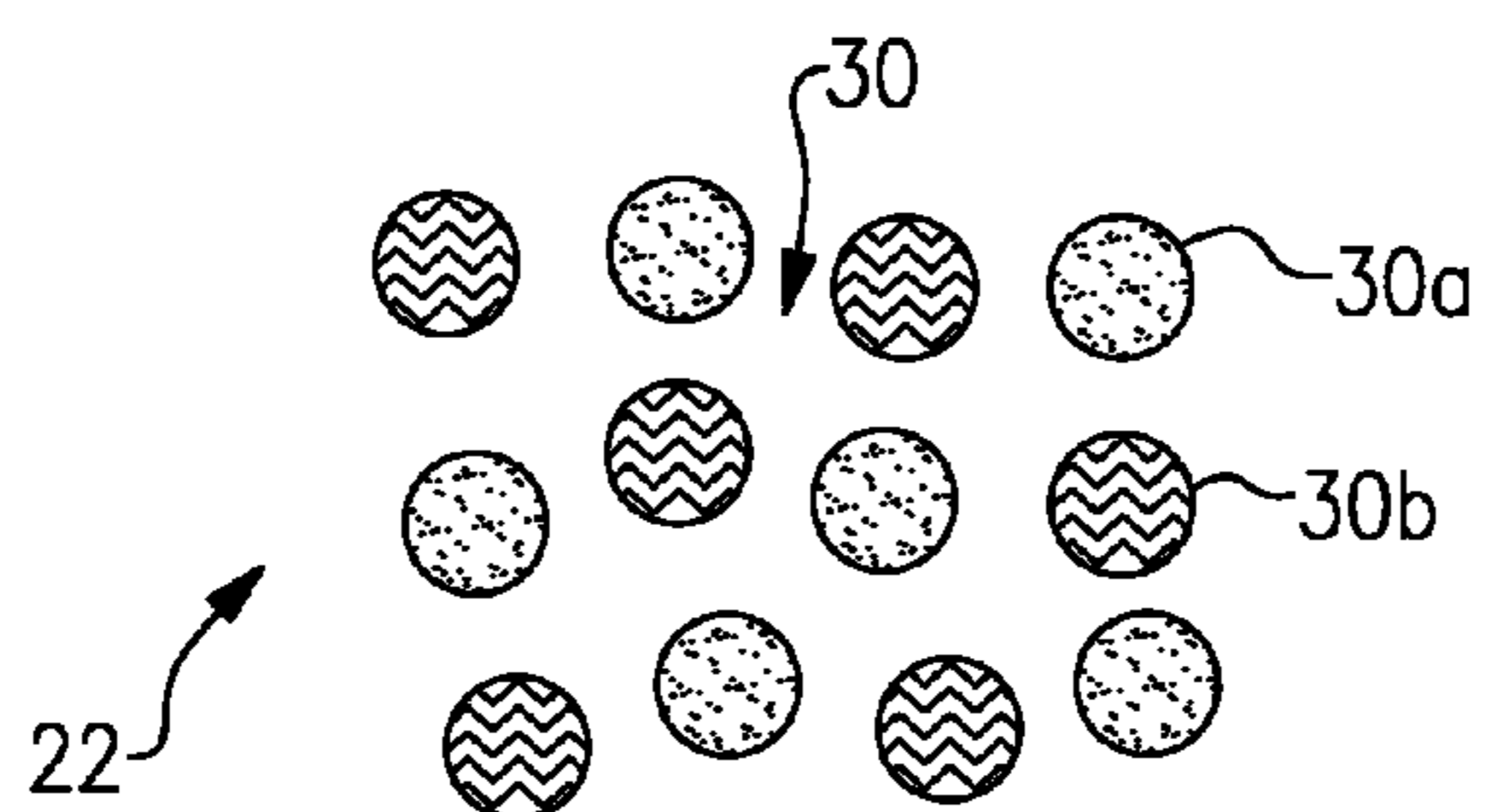


FIG. 2

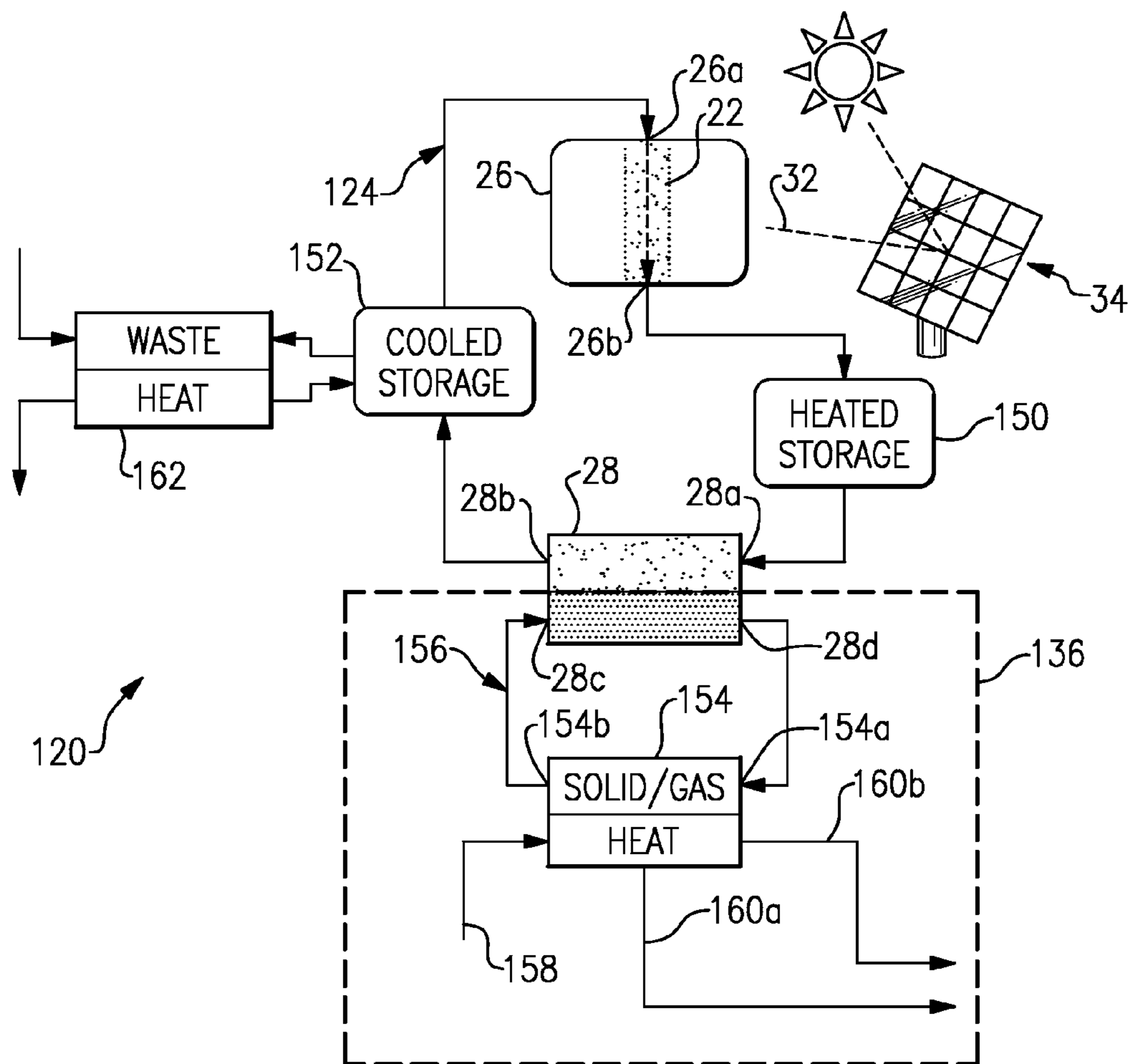


FIG.3

THERMAL TRANSFER APPARATUS AND METHOD THEREFOR

BACKGROUND

[0001] This disclosure relates to a thermal transfer system and, more particularly, to thermal transfer between a concentrated solar receiver and a heat exchanger.

[0002] A variety of different industrial products and processes utilize thermal energy to process raw materials and produce an end product. For example, in the cement industry, quick-lime is produced in a process known as chemical disassociation. When heated to a sufficient temperature, the chemical disassociation of quick-lime generates a solid oxide and a gaseous carbon dioxide. More recently, solar heating has been utilized to heat the quick-lime. However, one challenge in utilizing solar energy, or other sources of thermal energy, is that the availability of the solar energy varies over time.

SUMMARY

[0003] An apparatus according to an exemplary aspect of the disclosure includes a closed loop circuit that has a concentrated solar receiver and a particulate thermal transfer media moveable through the closed loop circuit. The particulate thermal transfer media has a melting temperature of greater than 600° C./1112° F. A heat exchanger is in communication with the particulate thermal transfer media.

[0004] In a further embodiment, the apparatus includes a storage vessel within the closed loop circuit between an outlet from the concentrated solar receiver and an inlet into the heat exchanger.

[0005] In a further embodiment of any of the foregoing examples, the apparatus includes a storage vessel within the closed loop circuit between an outlet of the heat exchanger and an inlet of the concentrated solar receiver.

[0006] In a further embodiment of any of the foregoing examples, the apparatus includes reactor vessel in thermal communication with the heat exchanger.

[0007] In a further embodiment of any of the foregoing examples, the particulate thermal transfer media includes bauxite.

[0008] In a further embodiment of any of the foregoing examples, the particulate thermal transfer media includes silicon carbide.

[0009] In a further embodiment of any of the foregoing examples, the particulate thermal transfer media includes silica.

[0010] In a further embodiment of any of the foregoing examples, the particulate thermal transfer media includes first particles having a first composition and second, different particles, having a second, different composition.

[0011] In a further embodiment of any of the foregoing examples, the particulate thermal transfer media includes particles, the particles, on average, having a size of greater than 1 micrometer.

[0012] A method for operating an apparatus according to an exemplary aspect of the disclosure includes moving a particulate thermal transfer media through a closed loop circuit into a concentrated solar receiver to absorb thermal energy into the particulate thermal transfer media, moving the particulate thermal transfer media from the concentrated solar receiver

into a heat exchanger and heating a working fluid using the thermal energy extracted from the particulate thermal transfer media in the heat exchanger.

[0013] In a further embodiment, the method includes storing the particulate thermal transfer media in a storage vessel after absorbing the thermal energy in the concentrated solar receiver and, at a later time, moving the particulate thermal transfer media into the heat exchanger in response to a demand to heat the working fluid.

[0014] In a further embodiment of any of the foregoing examples, the method includes storing the particulate thermal transfer media in a storage vessel after extraction of the thermal energy from the particulate thermal transfer media in the heat exchanger and, at a later time, moving the particulate thermal transfer media into the concentrated solar receiver in response to an availability of thermal energy in the concentrated solar receiver.

[0015] In a further embodiment of any of the foregoing examples, the particulate thermal transfer media is selected from the group consisting of bauxite, silicon carbide, silica and combinations thereof.

[0016] In a further embodiment of any of the foregoing examples, the particulate thermal transfer media includes first particles having a first composition and second, different particles having a second, different composition.

[0017] In a further embodiment of any of the foregoing examples, the method includes circulating the working fluid through the heat exchanger to extract the thermal energy from the particulate thermal transfer media and heating a reactant material using the thermal energy in the working fluid to chemically disassociate the reactant material into a solid material and a gas material.

[0018] A method for operating an apparatus according to an exemplary aspect of the disclosure includes moving a particulate thermal transfer media through a closed loop circuit into a concentrated solar receiver to receive solar energy and absorb thermal energy from the solar energy into the particulate thermal transfer media, moving the particulate thermal transfer media from the concentrated solar receiver into a heat exchanger, circulating a working fluid through the heat exchanger to extract the thermal energy from the particulate thermal transfer media and heating a reactant material using the thermal energy in the working fluid to chemically disassociate the reactant material into a solid material and a gas material.

[0019] In a further embodiment of any of the foregoing examples, the method includes circulating the gas material from the chemical disassociation of the reactant material as the working fluid.

[0020] In a further embodiment of any of the foregoing examples, the reactant material includes a metal carbonate and the gas material is carbon dioxide.

[0021] In a further embodiment of any of the foregoing examples, the method includes removing the gas material to establish a steady state gas pressure.

[0022] In a further embodiment of any of the foregoing examples, the method includes heating the reactant material within a sealed volume.

[0023] In a further embodiment of any of the foregoing examples, the method includes storing the particulate thermal transfer media in a storage vessel after absorbing the thermal energy in the concentrated solar receiver and, at a later time, moving the particulate thermal transfer media into the heat exchanger in response to a demand to heat the working fluid.

[0024] In a further embodiment of any of the foregoing examples, the method includes storing the particulate thermal transfer media in a storage vessel after extraction of the thermal energy from the particulate thermal transfer media in the heat exchanger and, at a later time, moving the particulate thermal transfer media into the concentrated solar receiver in response to an availability of the solar energy in the concentrated solar receiver.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025] The various features and advantages of the present disclosure will become apparent to those skilled in the art from the following detailed description. The drawings that accompany the detailed description can be briefly described as follows.

[0026] FIG. 1 is a schematic illustration of a thermal transfer apparatus.

[0027] FIG. 2 illustrates particles of a particulate thermal transfer media.

[0028] FIG. 3 is a schematic illustration of another example thermal transfer apparatus.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0029] FIG. 1 schematically illustrates an apparatus 20. As will be described herein, the apparatus 20 utilizes a particulate thermal transfer media 22 for thermal exchange and, optionally, thermal storage. The ability to store thermal energy allows time-shifting of the utilization of the thermal energy to overcome periods when a source of thermal energy, such as solar energy, is weak or unavailable. The particulate thermal transfer media 22 also permits tailoring thermal properties to enhance efficiency.

[0030] In this example, the apparatus 20 includes a closed loop circuit 24 through which the particulate thermal transfer media 22 circulates. A pump, conveyor, gravity or combinations thereof may be used to move the particulate thermal transfer media 22 in the closed loop circuit 24. The term “closed loop” as used herein refers to the particulate thermal transfer media 22 being contained, with the exception of unintentional escape, within the closed loop circuit 24 for recirculation rather than consumption.

[0031] The closed loop circuit 24 includes a concentrated solar receiver 26 and is arranged such that the particulate thermal transfer media 22 is in communication with a heat exchanger 28. The particulate thermal transfer media 22 is thus movable through the closed loop circuit 24 between the concentrated solar receiver 26 and the heat exchanger 28. In this regard, the concentrated solar receiver 26 includes an inlet 26a through which the particulate thermal transfer media 22 is received and an outlet 26b through which the particulate thermal transfer media 22 is discharged from the concentrated solar receiver 26. Similarly, the heat exchanger 28 includes an inlet 28a through which the thermal transfer media 22 is received and an outlet 28b through which the particulate thermal transfer media 22 is discharged. As an example, the heat exchanger 28 has a tube/plate configuration.

[0032] Referring also to FIG. 2, the particulate thermal transfer media 22 has a melting temperature of greater than 600° C./1112° F. and includes particles 30 that are selected for good thermal absorbance and transfer. In one example, the particles 30 are made of inorganic material, such as ceramic

material, that is chemically stable at elevated temperatures of approximately 900° C./1652° F. or higher in the environmental gas that the particulate thermal transfer media 22 is exposed to. For instance, the particulate thermal transfer media 22 may be exposed to air within the closed loop circuit 24 and/or in the concentrated solar receiver 26, if the concentrated solar receiver 26 is open to the surrounding atmosphere. Additionally, the particles 30 have a relatively high thermal capacity and thermal absorbance for effective thermal storage and transfer within the apparatus 20.

[0033] In a further example, the particles 30 are substantially spherical to facilitate flow through the closed loop circulation passage 24 and are made of at least one material having good high temperature chemical stability, good thermal capacity and good thermal absorbance. For example, the particles 30 are made of at least one of bauxite, silicon carbide and silica, which may be provided as sand.

[0034] In a further example, the particles 30, on average, have a size of greater than 1 micrometer to facilitate flow through the closed loop circulation passage 24. Additionally, the disclosed size of the particles 30 also facilitates flow through the concentrated solar receiver 26. For example, if the concentrated solar receiver 26 is open to the surrounding environment, such as to enable solar energy to be received, gusts of wind may alter flow of the particles 30 in the thermal receiver 26. To prevent or limit undesired escape of the particles 30, the particles 30 are provided with the disclosed size to reduce the effects of the wind gusts.

[0035] In a further example, the particles 30 include first particles 30a and second, different particles 30b. The first particles 30a have a first composition and the second particles 30b have a second, different composition. As an example, the first particles 30a include one of bauxite, silicon carbide and silica, and the second particles 30b include a different one of bauxite, silicon carbide and silica. It is to be understood, however, that additional particles of other, different compositions may also be used.

[0036] The use of a hetero-compositional mix in the particulate thermal transfer media 22 allows the properties of the particulate thermal transfer media 22 to be tailored to meet design goals for thermal capacity, thermal absorbance, thermal transfer and flow of the particulate thermal transfer media 22 in the closed loop circuit 24. For example, the first particles 30a are silicon carbide and the second particles 30b are bauxite. In a mixture in the particulate thermal transfer media 22, the combination of silicon carbide and bauxite enhances bulk thermal capacity and bulk thermal transfer of the particulate thermal transfer media 22. The bauxite has a relatively higher heat capacity than silicon carbide and the silicon carbide has a relatively higher thermal conductivity than the bauxite. Thus, in the mixture, the bauxite enhances thermal capacitance and the silicon carbide enhances heat transfer. In further examples, the compositions of the first particles 30a and the second particles 30b can also be selected to reduce expense of the particulate thermal transfer media 22 or tailor other properties, such as color, to enhance solar or thermal absorbance.

[0037] In this example, the apparatus 20 is a solar-based system with regard to the source of thermal energy. The apparatus 20 therefore enables the elimination of the use of fossil fuel as a thermal energy source. The concentrated solar receiver 26 is thus a receiver that is arranged to receive solar energy 32 directed from a solar concentrator 34, such as one or more heliostats. The solar energy 32 is received into the concentrated solar receiver 26 through an opening or a win-

dow, and heats the particulate thermal transfer media 22. In one example, the solar energy 32 directly impinges upon the particulate thermal transfer media 22 to heat the particulate thermal transfer media 22.

[0038] Turning to the operation of the apparatus 20, the particulate thermal transfer media 22 circulates through the closed loop circuit 24 between the concentrated solar receiver 26 and the heat exchanger 28. The particulate thermal transfer media 22 is heated in the concentrated solar receiver 26 and then circulated into the heat exchanger 28 through the inlet 28a. The particulate thermal transfer media 22 may be continuously moved through the heat exchanger 28 or delivered as a “charge” that is held statically in the heat exchanger 28 for a period of time.

[0039] In this example, the heat exchanger 28 is in communication with a sub-system 36. Within the sub-system 36, a working fluid 38 circulates through the heat exchanger 28 to thereby absorb thermal energy from the heated particulate thermal transfer media 22. By way of example, the sub-system 36 may be a reactor system that utilizes the thermal energy to drive a chemical reaction, a system based upon a super-critical carbon dioxide cycle, a Rankine steam cycle or a Brayton cycle. It is to be understood, however, that the sub-system 36 is not limited to any particular type of system.

[0040] As indicated above, the particulate thermal transfer media 22 can be tailored to enhance thermal transfer. As an example, the particulate thermal transfer media 22 includes the first particles 30a and the second particles 30b of different compositions, such as silicon carbide and bauxite, respectively. The first particles 30a, which have better thermal transfer properties, not only facilitate thermal exchange with the working fluid 38 but also facilitate thermal transfer from the second particles 30b by being in close proximity to the second particles 30b to remove thermal energy from the second particles 30b and provide a path of thermal transfer.

[0041] FIG. 3 schematically illustrates another example apparatus 120. In this disclosure, like reference numerals designate like elements where appropriate and reference numerals with the addition of one-hundred designate modified elements that are understood to incorporate the same features and benefits of the corresponding elements. In this example, the apparatus 120 includes a first storage vessel 150 and a second storage vessel 152.

[0042] The first storage vessel 150 is located within a closed loop circuit 124 between the outlet 26b of the concentrated solar receiver 26 and the inlet 28a of the heat exchanger 28. Thus, the storage vessel 150 receives heated particulate thermal transfer media 22 from the concentrated solar receiver 26.

[0043] The second storage vessel 152 is located within the closed loop circuit 124 between the outlet 28b of the heat exchanger 28 and the inlet 26a of the concentrated solar receiver 26. Thus, the second storage vessel 152 receives relatively cool particulate thermal transfer media 22 from the heat exchanger 28.

[0044] The apparatus 120 further includes a sub-system 136. In this example, the sub-system 36 is a reactor system for utilizing the thermal energy from the particulate thermal transfer media 22 to drive a chemical reaction. The sub-system 136 includes a reactor vessel 154 that is in communication with the heat exchanger 28. The reactor vessel 154 includes an inlet 154a in fluid-receiving communication with regard to the heat exchanger 28 and an outlet 154b in fluid-discharge communication with regard to the heat exchanger

28. The heat exchanger 28 includes a second inlet 28c connected to the outlet 154b of the reactor vessel 154 and a second outlet 28d in communication with the inlet 154a of the reactor vessel 154.

[0045] The reactor vessel 154 further includes a feed 158 for delivery of a reactant material into the reactor vessel 154. Product lines 160a and 160b serve to transport reaction product materials, such as solid material and gaseous materials, respectively.

[0046] Turning to the operation of the apparatus 120, the particulate thermal transfer media 22 circulates through the closed loop circuit 124 in a manner described above with reference to FIG. 1. The heated particulate thermal transfer media 22 discharged from the concentrated solar receiver 26 is received into the first storage vessel 150. If there is an immediate demand for thermal energy within the sub-system 136, the particulate thermal transfer media 22 is responsively moved into the heat exchanger 28 for thermal transfer to a working fluid 138 circulating through a circulation loop 156. Alternatively, if there is no immediate demand for thermal energy within the sub-system 136, the heated particulate thermal transfer media 22 is stored in the storage vessel 150 until a later time at which there is a demand.

[0047] Because of the relatively high heat capacity of the particulate thermal transfer media 22, the particulate thermal transfer media 22 retains the thermal energy absorbed from the thermal receiver 26. Thus, the apparatus 120 permits a time-shifting of utilization of thermal solar energy with regard to the collection of the solar energy. That is, solar energy can be collected, as thermal energy, when available, such as when adequate sunshine is available, and immediately used or alternatively stored for a later time when there is a demand for such thermal energy.

[0048] After thermal exchange within the heat exchanger 28, the particulate thermal transfer media 22 circulates to the second storage vessel 152. If there is continued demand for thermal energy within the sub-system 136 and solar energy is available, the particulate thermal transfer media 22 is circulated from the second storage vessel 152 to the concentrated solar receiver 26 for another cycle of thermal absorbance and transfer. Alternatively, if there is no demand or if the solar energy is weak or unavailable, the particulate thermal transfer media 22 is stored within the second storage vessel 152 until a later time when there is demand and/or adequate solar energy availability.

[0049] The particulate thermal transfer media 22 that is discharged from the heat exchanger into the second storage vessel 152 may still include thermal energy that was not fully transferred to the working fluid 138 of the sub-system 136. Optionally, the apparatus 120 includes an additional heat exchanger 162 through which the particulate thermal transfer media 22 can be circulated. The thermal energy absorbed from the particulate thermal transfer media 22 in the heat exchanger 162 may be utilized in another sub-system or within the apparatus 120. As an example, the thermal energy absorbed from the particulate thermal transfer media 22 in the heat exchanger 162 may be used to preheat a reactant material before feeding the reactant material into the reactor vessel 154. Alternatively, the thermal energy may be used in another process, such as a cement-producing process. Thus, the use and ability to store the particulate thermal transfer media 22 enables recovery of the thermal energy for other uses, which increases overall efficiency and reduces costs.

[0050] In a further example, the reactant material fed into the reactor vessel **154** is metal carbonate. The metal carbonate is either preheated using the thermal energy from the heat exchanger **162** or fed without preheating into the reactor vessel **154**. The reactor vessel **154** is used to chemically disassociate the metal carbonate into a constituent solid material and gas material. For metal carbonates, the gas material is carbon dioxide and the solid material is metal oxide.

[0051] As an example, an initial charge of the working fluid **138**, such as carbon dioxide, may be provided within the reactor vessel **154**. The working fluid **138** circulates in the circulation loop **156** through the heat exchanger **28** to receive thermal energy from the particulate thermal transfer media **22**. The heated working fluid **138** circulates back into the reactor vessel **154** and heats the metal carbonate material therein. The heat transfer that occurs in the apparatus **120** is thus double-indirect in that the thermal energy is transferred in two working materials, the particulate thermal transfer media **22** and the working fluid **138**, before being delivered to a target, reactant material.

[0052] The heating of the metal carbonate drives the disassociation reaction to thereby generate additional carbon dioxide. The generated carbon dioxide is then used as additional working fluid **138** and circulates in the circulation loop **156** to the heat exchanger **28** for further heating to further drive the chemical disassociation reaction. As more carbon dioxide is produced in the chemical disassociation, carbon dioxide may be removed through product line **160b** to establish a steady state carbon dioxide partial pressure within the reactor vessel **154**. The solid metal oxide produced may be removed from the reactor vessel **154** during or after the process through product line **160a**.

[0053] The use of the particulate thermal transfer media **22** allows time-shifting between thermal solar energy collection and use in the reaction process within the sub-system **136**. That is, the apparatus **120** can be utilized to collect thermal energy in response to availability of solar energy and store the thermal energy within the first storage vessel **150** until a time at which there is a demand for the thermal energy within the sub-system **136**. Thus, even at times when solar energy is weak or unavailable, the heated particulate thermal transfer media **22** may be circulated from the first storage vessel **150** through the heat exchanger **28** to thereby heat the working fluid **138** and drive the reaction within the reactor vessel **154**.

[0054] Further, the use of the particulate thermal transfer media **22** enables indirect heating of the metal carbonate in the sub-system **136**, which limits exposure of tars or other impurity substances present in the metal carbonate to the sub-system **136** without fouling other components in the apparatus **120**. Additionally, the indirect heating enables the particulate thermal transfer media **22** to be tailored for efficient thermal capacitance and absorbance of solar energy. In comparison, the efficiency for direct heating of metal carbonate or other reactant material is limited by the thermal capacitance and absorbance properties inherent in the reactant material.

[0055] In a further example, the reactor vessel **154** and circulation loop **156** are sealed such that the generated gas remains within the volume of these components. The generated gas is thus sequestered and may be selectively removed through product line **160b** for further use in a downstream process or for economic purposes. The sequestering of the generated gas, such as carbon dioxide, also prevents discharge into the atmosphere which, in the cement industry,

represents a substantial reduction in carbon dioxide emissions and potentially avoids penalties for such emissions. Further, the sealing of the reactor vessel **154** and circulation loop **156** also limits or prevents contamination of the product solid materials and gas materials, which adds economic value. In another example, the gas that is removed from the reactor vessel **154** has a relatively high temperature and is used to preheat the reactant material that is fed into the reactor vessel **154**.

[0056] Although a combination of features is shown in the illustrated examples, not all of them need to be combined to realize the benefits of various embodiments of this disclosure. In other words, a system designed according to an embodiment of this disclosure will not necessarily include all of the features shown in any one of the Figures or all of the portions schematically shown in the Figures. Moreover, selected features of one example embodiment may be combined with selected features of other example embodiments.

[0057] The preceding description is exemplary rather than limiting in nature. Variations and modifications to the disclosed examples may become apparent to those skilled in the art that do not necessarily depart from the essence of this disclosure. The scope of legal protection given to this disclosure can only be determined by studying the following claims.

What is claimed is:

1. An apparatus comprising:
 - a closed loop circuit including a concentrated solar receiver and a particulate thermal transfer media moveable through the closed loop circuit, the particulate thermal transfer media having a melting temperature of greater than 600°C./1112° F.; and
 - a heat exchanger in communication with the particulate thermal transfer media.
2. The apparatus as recited in claim 1, further including a storage vessel within the closed loop circuit between an outlet from the concentrated solar receiver and an inlet into the heat exchanger.
3. The apparatus as recited in claim 1, further including a storage vessel within the closed loop circuit between an outlet of the heat exchanger and an inlet of the concentrated solar receiver.
4. The apparatus as recited in claim 1, further including a reactor vessel in thermal communication with the heat exchanger.
5. The apparatus as recited in claim 1, wherein the particulate thermal transfer media includes bauxite.
6. The apparatus as recited in claim 1, wherein the particulate thermal transfer media includes silicon carbide.
7. The apparatus as recited in claim 1, wherein the particulate thermal transfer media includes silica.
8. The apparatus as recited in claim 1, wherein the particulate thermal transfer media includes first particles having a first composition and second, different particles, having a second, different composition.
9. The apparatus as recited in claim 1, wherein the particulate thermal transfer media includes particles, the particles, on average, having a size of greater than 1 micrometer.
10. A method for operating an apparatus, the method comprising:
 - moving a particulate thermal transfer media through a closed loop circuit into a concentrated solar receiver to absorb thermal energy into the particulate thermal transfer media;

moving the particulate thermal transfer media from the concentrated solar receiver into a heat exchanger; and heating a working fluid using the thermal energy extracted from the particulate thermal transfer media in the heat exchanger.

11. The method as recited in claim **10**, further including storing the particulate thermal transfer media in a storage vessel after absorbing the thermal energy in the concentrated solar receiver and, at a later time, moving the particulate thermal transfer media into the heat exchanger in response to a demand to heat the working fluid.

12. The method as recited in claim **10**, further including storing the particulate thermal transfer media in a storage vessel after extraction of the thermal energy from the particulate thermal transfer media in the heat exchanger and, at a later time, moving the particulate thermal transfer media into the concentrated solar receiver in response to an availability of thermal energy in the concentrated solar receiver.

13. The method as recited in claim **10**, wherein the particulate thermal transfer media is selected from the group consisting of bauxite, silicon carbide, silica and combinations thereof.

14. The method as recited in claim **10**, wherein the particulate thermal transfer media includes first particles having a first composition and second, different particles having a second, different composition.

15. The method as recited in claim **10**, further including circulating the working fluid through the heat exchanger to extract the thermal energy from the particulate thermal transfer media and heating a reactant material using the thermal energy in the working fluid to chemically disassociate the reactant material into a solid material and a gas material.

16. A method for operating an apparatus, the method comprising:

moving a particulate thermal transfer media through a closed loop circuit into a concentrated solar receiver to

receive solar energy and absorb thermal energy from the solar energy into the particulate thermal transfer media; moving the particulate thermal transfer media from the concentrated solar receiver into a heat exchanger;

circulating a working fluid through the heat exchanger to extract the thermal energy from the particulate thermal transfer media; and

heating a reactant material using the thermal energy in the working fluid to chemically disassociate the reactant material into a solid material and a gas material.

17. The method as recited in claim **16**, further including circulating the gas material from the chemical disassociation of the reactant material as the working fluid.

18. The method as recited in claim **16**, wherein the reactant material includes a metal carbonate and the gas material is carbon dioxide.

19. The method as recited in claim **16**, further including removing the gas material to establish a steady state gas pressure.

20. The method as recited in claim **16**, further including heating the reactant material within a sealed volume.

21. The method as recited in claim **16**, further including storing the particulate thermal transfer media in a storage vessel after absorbing the thermal energy in the concentrated solar receiver and, at a later time, moving the particulate thermal transfer media into the heat exchanger in response to a demand to heat the working fluid.

22. The method as recited in claim **16**, further including storing the particulate thermal transfer media in a storage vessel after extraction of the thermal energy from the particulate thermal transfer media in the heat exchanger and, at a later time, moving the particulate thermal transfer media into the concentrated solar receiver in response to an availability of the solar energy in the concentrated solar receiver.

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