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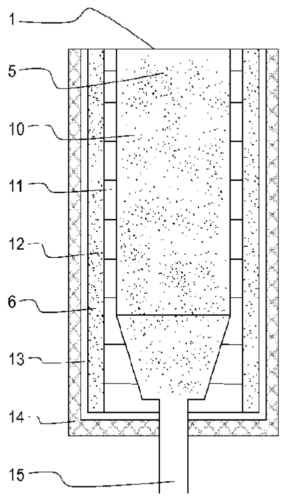

Fig. 1a

(57) Abstract: An energy storage system utilizes solid particles that are heated by the electric power from the renewable energy power plant. A particle container comprises a cylindrical particle chamber (10) for storing particles (5), that are heated for example at a heat exchanger of the energy storage system. The particle chamber walls (11) are made of a refractory material. Between the particle chamber walls (11) and the support wall (13) is a space (12) that is filled with solid particles (6). These solid particles (6) are purposed to stay in said space (12), and act as an insulation for the particle chamber (10) and to provide flexibility to accommodate the thermal expansion of the particle chamber (10).

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A METHOD FOR STORING HEATED PARTICLES AND A PARTICLE CONTAINER FOR AN ENERGY STORAGE SYSTEM

BACKGROUND

The invention relates to heat storage plants that are using solid heat storage material.

Renewable energy resources, such as wind or solar power, provide energy with variable rate according to available sunlight or wind. Energy usage peaks often occur at different times than renewable energy production peaks. Therefore, energy storage systems are important to balance the difference between power supply and demand.

Known energy storage systems include battery technologies, pumped hydroelectricity storages, molten salt storage systems and storage systems using solid particles such as sand. Sand-based heat storage systems comprise fluidized beds that aerate the sand and thereby enable easy transfer of the sand and increase heat transfer power per area. Sand may be heated by excess of the energy production. For example, the electric energy may be stored and released as thermal energy. Known energy storage systems have known disadvantages, that sand-based heat storage systems may at least partially solve. But also, sand-based heat storage systems may face certain problems.

Over time, the sand particles may experience temperature variations, leading to stratification within the solid particles. This can impact the system's overall efficiency and heat transfer capabilities. The choice of materials for the sand particles and the containment structure must consider compatibility with high temperatures and thermal cycling to prevent degradation or breakdown over time.

Designing and maintaining an effective sand-based heat storage system can be complex. The fluidization and circulation of sand require careful engineering to ensure optimal performance. Sand particles may agglomerate or clump together over time, affecting the fluidization process and reducing the efficiency of heat transfer. Sand particles may agglomerate or clump together over time, affecting the fluidization process and disturbing the overall process.

SUMMARY

This summary is provided to introduce a selection of concepts in a simplified form that will be further described below in the detailed description. This summary is intended to neither identify key features or essential features of the claimed subject matter nor to be used to limit the scope of the claimed subject matter. Furthermore, the claimed subject matter is not limited to implementations that solve any or all of the disadvantages noted in any part of this disclosure.

A particle container and a method for heating particles at an energy storage system are disclosed herein. The energy storage system receives energy typically from excess energy from an electric power grid, or more directly, from a renewable energy power plant, a photovoltaic power station or a wind farm. The energy storage system utilizes solid particles, for example sand particles, which are heated by the electric power, for example from the renewable energy power plant.

The particle container comprises a cylindrical particle chamber for storing particles, which are heated for example at a heat exchanger of the energy storage system. One example of the cylindrical particle chamber shape is a silo. In the energy storage system, the solid particles, such as sand particles, are circulated cyclically through a charging phase, a hot storage phase and a discharging phase, and a cool storage phase. In one exemplary embodiment, the solid particles may reach temperatures in the region of 2200 °C. The solid particles may travel between cyclic phases pneumatically by air flow that carries the light particles, or alternatively, by gravity when the different phases are stacked on top of each other. In one example the solid particles travel by a conveyor.

The particle chamber walls are made of a ceramic material. The ceramic material is one example of a refractory material, withstanding the temperatures being used for solid particles. The outer layer of the particle container comprises a support wall. The support wall comprises thermal insulation. Between the particle chamber walls and the support wall is a space that is filled with solid particles. These solid particles are purposed to stay in said space, and act as an insulation for the particle chamber and to provide flexibility to accommodate the thermal expansion of the particle chamber, while supporting the hot refractory layer of the particle chamber. The particle chamber's applied temperature range may be over 2200 °C, from when the particle chamber is being filled for the first time with cold solid particles to full process. The effects of thermal expansion may be significant.

The layer of static solid particles outside the particle chamber may be the same material as the solid particles being used in the energy storage cycle. Static solid particles act as an additional insulation layer. If the ceramic material forming the particle chamber would form a hairline crack, the particle container would still be functional and safe.

As one example of solid particles, sand has a relatively high specific heat capacity, allowing it to store large amounts of thermal energy. Sand enables low heat loss with the system disclosed herein during the storage phase, enhancing overall efficiency. The particle container as disclosed herein can be designed with modular configurations, allowing for scalability based on energy storage requirements. The modular configurations enable receiving solid particles from the charging phase at different temperatures. This enables, for example, capturing short periods of cheap or negatively priced electric energy more efficiently. Different storage temperatures may be used, as an example, for distillation, district heating or other purposes that require lower temperatures than the full target temperature of the heat storage system. As one example, the excess electric energy may be available only for a short period, therefore the heat storage system may select the best usage for smaller peak energy.

The arrangement of moving solid particles, such as sand, functions safely under faults or process stops. The process may be halted at any point, wherein the solid particles merely stop and remain still. The fluidization process may be restarted without causing harm to the heat storage system or to the particle container.

Many of the attendant features will be more readily appreciated as they become better understood by reference to the following detailed description considered in connection with the accompanying drawings. The embodiments described below are not limited to implementations which solve any or all the disadvantages of known energy storage systems or particle containers.

BRIEF DESCRIPTION OF THE DRAWINGS

The present description will be better understood from the following detailed description read in light of the accompanying drawings, wherein

FIG. 1a illustrates schematically a side view of one exemplary embodiment of a particle container;

FIG. 1b illustrates schematically a top view of one exemplary embodiment of the particle container;

FIG. 1c illustrates schematically a top view of one exemplary embodiment of the particle container;

FIG. 2 illustrates schematically a top view of one exemplary embodiment of the particle container;

FIG. 3 illustrates schematically a side view of one exemplary embodiment of the particle container;

FIG. 4a illustrates schematically a side view of one exemplary embodiment of the particle container;

FIG. 4b illustrates schematically a top view of one exemplary embodiment of the particle container;

FIG. 4c illustrates schematically a top view of one exemplary embodiment of the particle container;

FIG. 5 illustrates schematically a flowchart of a method for heating solid particles;

FIG. 6a illustrates schematically a side view of one exemplary embodiment of a particle container; and

FIG. 6b illustrates schematically a top view of one exemplary embodiment of the particle container.

Like reference numerals are used to designate like parts in the accompanying drawings.

DETAILED DESCRIPTION

The detailed description provided below in connection with the appended drawings is intended as a description of the present examples and is not intended to represent the only forms in which the present example may be constructed or utilized. However, the same or any equivalent functions and sequences may be accomplished by different examples.

Although the present examples are described and illustrated herein as being implemented in a particle container utilizing sand as solid particles, they are provided as an example and not a limitation. As those skilled in the art will appreciate, the present examples are suitable for application in a variety of different types of solid particles suitable for operating in temperature ranges for energy storage systems.

In this context directions, such as up, down, horizontal, vertical, etc., are described in reference to the gravity and conventional operational directions.

Energy consumption at the electric grid is not constant. However, the amount of electricity fed into the electricity grid must always be equal to the amount of electricity consumed. At times, the energy production exceeds the demand, and the excess electric energy must be consumed, for example by an energy storage system.

Renewable energy may be very intermittent by nature – solar energy is not available during the nighttime, or the wind may completely calm down. To enable these renewable energy systems being viable energy sources that could replace continuous energy production plants, an energy storage system may be used to balance peaks in energy production or consumption. One exemplary energy storage system uses solid particles, for example sand, to transform the electric energy to thermal energy. Later, the thermal energy may be converted into electric energy, for example by a steam turbine. Simplified process of a sand-based heat storage system comprises three phases: charging, storage and discharging.

The charging phase relates to heat absorption. During periods of excess or low-cost renewable energy, for example from windmills, photovoltaic cells, solar collectors or industrial processes, a heating element provides thermal energy through a bed of sand. The electric heating element may be resistive, inductive, arced or any other means that convert electric energy to thermal energy. The sand absorbs and stores the thermal energy. Exemplary, but not limiting exemplary temperature range for solid particles being considered cold or cool is up to 300 °C. Exemplary, but not limiting, temperature range for solid particles being considered hot or heated is between 500 °C and 2200 °C, depending on the choice of solid particles being used. Examples of solid particles are natural sand, aluminium oxide, quartz sand and graphite powder. Particle size distribution is in one example 50 - 1000 microns, in one example 100 – 250 microns.

In the storage phase the thermally charged sand acts as a heat reservoir, holding the absorbed energy until it is needed. The sand is suitable for retaining heat and to provide an efficient storage. The storage is insulated. The storage may be a silo extending over ground level or the storage may be positioned at least partially under ground level.

In the discharging phase thermal energy is retrieved from the sand. When there is a demand for electric energy, for example during the night or on cloudy days, a working fluid is circulated via tubes through the now-hot sand. As the fluid passes through the hot sand bed, it absorbs the stored thermal energy, becoming hot in the process. This hot fluid can then be utilized for various applications. In one embodiment, the fluid is water flowing via pipes through the hot sand converting into superheated steam. The steam rotates a turbine generator that converts the thermal energy into electric energy.

FIG. 1a illustrates schematically a side view of one exemplary embodiment of the particle container. FIG. 1b illustrates schematically a cross-sectional view of the same embodiment. The particle container is a part of the energy storage system, configured to receive heated particles 5 from the energy transfer system, such as the charging phase. In one embodiment, the charging phase comprises a fluidized bed for solid particles 5. After being heated, the solid particles 5 are moved to the particle container via an inlet 1 to a cylindrical particle chamber 10. An outlet 15 allows the heated particles 5 to travel from the particle chamber 10 forward into the energy transfer system, for example to the discharging phase. In one embodiment, the outlet 15 steers the flow of heated particles 5 again into the charging phase to further heat the solid particles 5.

In one embodiment, the heated particles 5 travel from the particle container gravitationally, by allowing the heated particles 5 to fall to the next phase, for example to the discharging phase. In one example the heated particles 5 travel gravitationally along an inclined surface to the next phase.

In one embodiment, the heated particles 5 travel along a moving air in a pneumatic conveying system, or gravitationally. Rapidly moving air may carry heated particles 5 upwards. In one embodiment, the particle container comprises a fluidization system for the heated particles 5 in the particle chamber 10. When conveying solid particles 5, such as sand to the particle chamber 10, or from the particle chamber 10, compressed air may be used for a fluidization process. The fluidization system is one example of a pneumatic conveying application that uses fluidizing gas pressure to aerate the mass of solid particles 5. Example velocity for the fluidizing gas is in the range between 0,1 and 0,5 m/s. In one example the velocity is about 0,2 m/s. The pressure of the fluidizing gas in one example in the range of 0,1 - 0,7 bar. In one example the pressure is 0,3 bar.

A fluidization system converts granular solid particles 5 to a dynamic fluid-like state. In one embodiment, gas, for example air, is passed up through the solid particles 5. When the air flow is introduced through the bottom of a bed of solid particles 5, it will move upwards through the bed via the empty spaces between the solid particles 5. At an increased air flow velocity, the aerodynamic drag forces on the solid particles 5 will begin to counteract the gravitational forces, wherein the upward drag forces equal the downward gravitational forces, causing the solid particles 5 to become suspended within the air flow. Increasing the air flow would cause the solid particles 5 to travel along the air flow. Selecting a suitable air flow rate causes the solid particles 5 to act in the fluidized state, where the bed of solid particles 5 will behave like a liquid or gas.

In one embodiment, the charging phase is positioned above the particle container and the solid particles 5 fall from the charging phase, through the inlet 1 to the cylindrical particle chamber 10.

One embodiment of the cylindrical particle chamber 10 shape is a silo. The cylindrical particle chamber 10 comprises wall 11 made of refractory material that withstands the temperatures inside the particle chamber 10. One example of the refractory material is ceramic material, such as ceramic bricks as illustrated in FIG. 1b. Ceramic bricks are chemically and physically stable at high temperatures. In one embodiment, as illustrated in FIG. 1c, the wall 11 is constructed of cylindrical well rings made of refractory material, such as ceramic material. In one embodiment, the wall 11 is made by slip forming ceramic material.

The cylindrical shape requires less support and insulation, for example compared to any corner shapes.

The particle chamber walls 11 define the outer perimeter of the particle chamber 10. At a distance from the particle chamber wall 11 is a support wall 13, wherein said distance defines a space 12 around the outer perimeter of the particle chamber 10. The support wall 13 may be constructed from plate material, such as steel. The space 12 surrounds the walls 11 of the cylindrical particle chamber 10. The space 12 is filled with a second set of solid particles 6. In one embodiment, the solid particles 6 residing in said space 12, or solid particles 5 residing in the particle chamber 10 are not fluidized under heat storage process. The solid particles 6 act as one insulation layer around the cylindrical particle chamber 10 and extend the support from the support wall 13 to the wall 11, while accommodating to a thermal expansion of the particle chamber 10. The temperature range of the particle chamber 10 may be over 2200 °C, from the process startup to the fully charged particle container.

The particle chamber 10 may be cooled and emptied for maintenance purposes. Also, in one embodiment, the solid particles 6 may be removed pneumatically, and/or by gravity, during maintenance cycles. The solid particles 6 may be the same material and particle size as the heated particles 5.

An insulation layer 14 is in one embodiment the outermost layer of the particle container, wherein the insulation layer 14 is in contact with outer surface of the support wall 13. The insulation layer 14 may comprise further structural outer surface that is visible outside the particle container. The particle container may be a silo, standing upright on the ground. In one embodiment, the particle container resides at least partially underground.

FIG. 1c illustrates schematically a top view of one exemplary embodiment of the particle container, where the particle chamber 10 and the walls 11 are not concentric with the support wall 13. The second set of solid particles 6 in the space 12 provide support for the walls 11, as the solid particles 6 are free to move inside said space 12. The non-concentric arrangement provides more space 12 on one side of the walls 11. In this example, the additional space 12 on one side is used for vertical devices 18. Examples of vertical devices 18 are elevator devices used for lifting material through the particle container, preheating tubes for transferring thermal energy between two phases of the energy storage system or a shaft for enabling various devices or passage inside the particle container.

FIG. 2 illustrates schematically a cross-sectional view of one exemplary embodiment of the particle container. In one embodiment, the particle container comprises multiple particle chambers 10 surrounded by the space 12 filled with solid particles 6. Various alternatives may be used to optimize the particle chambers' 10 effectiveness inside the particle container. Optimizable parameters include the target temperature, allowable height and radius of the particle container, solid particle material, solid particle size, total number of available particle containers, or other feature that influences the particle storage economy.

In one embodiment, the at least one cylindrical particle chamber 10 stands upright. The illustrated examples have shown the cylindrical particle chambers 10 and the particle containers to be silo-shaped objects standing mainly in vertical position. In one embodiment, the particle container standing in vertical position comprises at least one heated particle chamber 10 in horizontal position.

In one exemplary embodiment, the multiple particle chambers 10 are arranged in parallel, wherein the heated particles 5 may fall into any of the particle chambers 10. In one exemplary embodiment, the heat storage system comprises multiple particle containers, wherein the particle flow may be selectable to at least one of the particle containers or equally into any one of the particle containers. In one embodiment, multiple particle chambers 10 are arranged sequentially. Different phases of the heat storage system may be stacked vertically or placed laterally.

In one exemplary embodiment, at least one inlet 1 of the multiple particle chambers 10 comprises an inlet valve for the flow of heated particles 5. The inlet valve enables selecting the temperature range and usage of the particle container. The inlet valve is not illustrated in the schematic illustrations. One example of the inlet valve is an L-valve, a pinch valve, a gate valve, or a flow valve. The L-valve is a nonmechanical device that can control solid particle flow in high-pressure, high-temperature systems. One example of the L-valve is a right angled, L-shaped pipe applied to transfer solid particles 5 between two vessels, using gas injection and pipe geometry for controlling the flow of particulate solids. Valves provide control over the particle flow, either by on/off configuration or by adjusting the flow rate.

In one embodiment at least one outlet 15 of the multiple particle chambers 10 comprises an outlet valve for a particle flow. The outlet valve is not illustrated in the schematic illustrations. One example of the outlet valve is the L-valve or the pinch valve. Any inlet or outlet in this disclosure may be fitted with a flow control valve, such as the L-valve.

FIG. 3 illustrates schematically a side view of one exemplary embodiment of the particle container, where the space 12 around the particle chamber 10 is configured for circulating cool particles 7. The particle container comprises a cool particle inlet 2 and a cool particle outlet 16, which are controllable by flow control valves. The particle container may be connected to multiple solid particle flows, inlets and outlets, with solid particles having different temperatures applied for the specified cycle. The space 12 is suitable for accommodating solid particles 7 of a cool circuit. In one embodiment, the solid particles 7 of the cool circuit are different material or different size than the solid particles 5 being stored in the particle chamber 10. In one embodiment, the solid particles 7 of the cool circuit are the same particles than the solid particles 5 being stored in the particle chamber 10. The solid particles 7 of the cool circuit may be changed continuously or periodically. In one example, the solid particles 7 of the cool circuit receive thermal energy from the solid particles 5 being stored in the particle chamber 10. When the solid particles 7 of the cool circuit reach a predetermined temperature, they are removed from the space 12 and moved to an application suitable for the predetermined temperature, for example district heating, industrial process, or pre-heating other applications. Simultaneously, a new cooler batch of solid particles 7 of the cool circuit are transferred to the space 12 to reach the predetermined temperature. In this context, the cool circuit refers to temperature ranges up to 20%, and/or up to 400 °C of the full temperature range being applied to solid particle 56 being stored in the particle chamber 10. In one embodiment, the cool circuit temperature is between 30 °C and 400 °C. In one embodiment, the hot solid particle 5 temperature is between 400 °C and 2.200 °C. In one embodiment, cool particles 7 are solid particles 6.

FIG. 4a illustrates schematically a side view of one exemplary embodiment of the particle container, where the space 12 around the particle chamber 10 comprises stationary solid particles 6, and a cool particle chamber 17 is arranged between the space 12 and the outermost layer of the particle container. FIG. 4b illustrates schematically a top view of the same embodiment. Space 12 is purposed mainly for accommodating the thermal expansion, and to provide insulation for the particle chamber 10. The space 12 and the cool particle chamber 17 are separated by one instance of the support wall 13. The cool particle chamber 17 is configured for circulating cool particles 7 and comprises the cool particle inlet 2 and the cool particle outlet 16, that are controllable by flow control valves.

In one embodiment, the outer surface of the wall 11 is lined with a sheet 19 made of metal, or other suitable material that withstands the applied heat. In one embodiment, the sheet 19 material is composite material. The thermal expansion of the wall 11 both horizontally and vertically could cause the wall 11 segments to become tangled with solid particle 6 agglomerates. The sheet 19 prevents the solid particles 6 from entering possible seams in the wall 11 ceramic construction blocks, that might later cause separation of the blocks.

In one embodiment, air is injected at the floor, side walls or bottom portion side walls of the particle chamber 10. In one embodiment, air is injected at the floor, side walls or bottom portion side walls of the space 12. In one embodiment, air is injected at the floor, side walls or bottom portion side walls of the cool particle chamber 17. The injected air detaches heated particles 5, that may be sticking to the walls 11 of the particle chamber 10, breaks agglomerated clumps or removes arching withing the mass of solid particles 5. Air or other suitable gas may be injected by rapid pulses or bursts through an air injection nozzle. The pulses provide sufficient pressure to cause movement on singular solid particles 5.

FIG. 4c illustrates schematically a top view of an embodiment, where the outer walls 13’ of the cool particle chamber 17, and the insulation layer 14 are rectangular. In one embodiment, the particle container is configured to fit inside the outer dimensions of a shipping container, or an ISO container.

FIG. 5 illustrates schematically a flowchart of method steps for storing heated particles 5 in the energy storage system. In step 50 of the method, heated particles 5 are received from an energy transfer system to the particle chamber

10, through the inlet 1. Step 51 of the method comprises allowing the heated particles 5 to travel into the energy transfer system through an outlet 15. Step 52 of the method comprises filling the space 12 filled with solid particles 6 for accommodating thermal expansion of the particle chamber 10.

FIG. 6a illustrates schematically a side view of one exemplary embodiment of the particle container. FIG. 6b illustrates schematically a cross-sectional view of the same embodiment. The particle container is part of the energy storage system, configured to receive heated particles 5 from the energy transfer system, such as the charging phase. In one embodiment, the charging phase comprises the fluidized bed for solid particles 5. After being heated, the solid particles 5 are moved to the particle container via an inlet 1 to a cylindrical particle chamber 10. An outlet 15 allows the heated particles 5 to travel from the particle chamber 10 forward into the energy transfer system, for example to the discharging phase. In one embodiment, the outlet 15 steers the flow of heated particles 5 again into the charging phase to further heat the solid particles 5.

One embodiment of the cylindrical particle chamber 10 shaped like the silo. The cylindrical particle chamber 10 comprises wall 11 made of refractory material that withstands the temperatures inside the particle chamber 10. One example of the refractory material is ceramic material, such as ceramic bricks as illustrated in FIG. 6b. Ceramic bricks are chemically and physically stable at high temperatures. In one embodiment, the wall 11 is constructed of cylindrical well rings made of refractory material, such as ceramic material. In one embodiment, the wall 11 is made by slip forming ceramic material.

In one embodiment, the insulation layer 14 is divided into two insulation layers 14, 65; a second insulation layer 65 is the outermost layer of the particle container. An insulation chamber 61 is formed at least partially between the inner insulation layer 14 and the second insulation layer 65. The insulation chamber 61 may be filled with fluids such as air or water. An insulation fluid inlet 62 is located in this embodiment at the lower portion of the insulation chamber 61, enabling the fluid such as air to flow into the chamber. An insulation fluid outlet 63 comprises in this embodiment at the top portion of the insulation chamber 61, providing a passageway for heated fluid out of the insulation chamber 61. The particle container is prone to allowing a small portion of thermal energy to escape through the insulation layer 14. The insulation chamber 65 facilitates capturing that energy and directing it with the passing fluid for further use.

In one embodiment, the insulation chamber 61 forms a complete separating layer between the inner insulation layer 14 and the second insulation layer 65. In one embodiment, the insulation chamber 61 is only partially present between the inner insulation layer 14 and the second insulation layer 65, allowing portions of these layers to come into direct contact. The inner insulation layer 14 and the second insulation layer 65 may be made of the same material, for example, a high-performance insulating polymer or ceramic, and their contact in regions where the insulation chamber 61 is absent may provide additional structural or thermal properties.

The insulation chamber 61 enables less expensive insulation materials to be used for the inner insulation layer 14 and the second insulation layer 65. Alternatively, or in addition, the insulation layers 14, 65 may be thinner without the risk of losing thermal energy. The arrangement may enable a lighter structure, reducing the need for load-carrying components such as steel to withstand high temperatures. The heat energy carried by the fluid exiting through the insulation fluid outlet 63 is moderate, being suitable for continuous heat consumption such as residential heating. The insulation chamber 61 enables steps for the method for transferring the residual thermal energy for further use.

A particle container for an energy storage system is disclosed herein. The particle container comprises a cylindrical particle chamber for storing heated particles; an inlet for receiving heated particles from an energy transfer system to the particle chamber; an insulation layer outside the particle chamber; and an outlet for allowing the particles to travel into the energy transfer system. The particle chamber comprises walls made of ceramic material. A support wall outside the outer perimeter of the particle chamber defines a space around the particle chamber. The insulation layer is outside the support wall, wherein said space is filled with solid particles accommodating thermal expansion of the particle chamber. In one embodiment, the particle container comprises multiple particle chambers surrounded by the space filled with solid particles. In one embodiment, the outer surface of the support wall is lined with a sheet. In one embodiment, the multiple particle chambers are in parallel. In one embodiment, at least one inlet of the multiple particle chambers comprises an inlet valve for a particle flow. In one embodiment, at least one outlet of the multiple particle chambers comprises an outlet valve for a particle flow. In one embodiment, the particle container comprises an air injection nozzle at the particle chamber, at the space wall or at the cool particle chamber to provide rapid pulses of gas that separate agglomerated solid particles. In one embodiment, the particle chamber wall comprises ceramic bricks, ceramic well rings or slip formed ceramic material. In one embodiment, a cool particle chamber is around the space, comprising a cool particle inlet and a cool particle outlet, wherein the cool particle chamber is configured for housing cool particles of a cool circuit. In one embodiment, the insulation layer is divided at least partially into two insulation layers, wherein a second insulation layer is the outer layer of the particle container; an insulation chamber is at least partially between the inner insulation layer and the second insulation layer, configured to be filled with fluid configured to transfer thermal energy from the inner insulation layer and the second insulation layer.

Alternatively, or in addition, a method for storing heated particles in an energy storage system is disclosed herein. The system comprises a particle container, having a cylindrical particle chamber for storing heated particles; and an insulation layer outside the particle chamber. The method comprises the steps of receiving heated particles from an energy transfer system to the particle chamber through an inlet; and allowing the particles to travel into the energy transfer system through an outlet. The particle chamber comprises walls made of ceramic material; a support wall outside the outer perimeter of the particle chamber, defining a space around the particle chamber; and the insulation layer is outside the support wall. The method further comprises filling said space filled with solid particles for accommodating thermal expansion of the particle chamber. In one embodiment, the particle container comprises multiple particle chambers surrounded by the space filled with solid particles. In one embodiment, the method comprises selecting a particle flow through at least one inlet of the multiple particle chambers by an inlet valve. In one embodiment, the method comprises selecting a particle flow through at least one outlet of the multiple particle chambers through an outlet valve. In one embodiment, the method comprises fluidizing the particles in the particle container by a fluidization system. In one embodiment, the method comprises receiving cool particles of a cool circuit via cool particle inlet to the space around the particle chamber, storing cool circuit particles in the space; and cool particles of the cool circuit exiting via cool particle outlet. In one embodiment, the method comprises separating agglomerated solid particles by rapid pulses or bursts of gas via an air injection nozzle at the particle chamber, at the space wall or at the cool particle chamber. In one embodiment, the insulation layer is divided into two insulation layers, wherein a second insulation layer is the outer layer of the particle container. An insulation chamber is at least partially between the inner insulation layer and the second insulation layer, transferring thermal energy from the inner insulation layer and the second insulation layer along said fluid.

Any range or device value given herein may be extended or altered without losing the effect sought.

Although at least a portion of the subject matter has been described in language specific to structural features and/or acts, it is to be understood that the subject matter defined in the appended claims is not necessarily limited to the specific features or acts described above. Rather, the specific features and acts described above are disclosed as examples of implementing the claims and other equivalent features and acts are intended to be within the scope of the claims.

It will be understood that the benefits and advantages described above may relate to one embodiment or may relate to several embodiments. The embodiments are not limited to those that solve any or all of the stated problems or those that have any or all of the stated benefits and advantages. It will further be understood that any reference to ‘an’ item refers to one or more of those items.

The steps of the methods described herein may be carried out in any suitable order, or simultaneously where appropriate. Additionally, individual blocks may be deleted from any of the methods without departing from the spirit and scope of the subject matter described herein. Aspects of any of the examples described above may be combined with aspects of any of the other examples described to form further examples without losing the effect sought.

The term ‘comprising’ is used herein to mean including the method blocks or elements identified, but that such blocks or elements do not comprise an exclusive list and a method or apparatus may contain additional blocks or elements.

It will be understood that the above description is given by way of example only and that various modifications may be made by those skilled in the art. The above specification, examples and data provide a complete description of the structure and use of exemplary embodiments. Although various embodiments have been described above with a certain degree of particularity, or with reference to one or more individual embodiments, those skilled in the art could make numerous alterations to the disclosed embodiments without departing from the spirit or scope of this specification.

CLAIMS

1. A particle container for an energy storage system, comprising:
a cylindrical particle chamber (10) for storing heated particles (5);
an inlet (1) for receiving heated particles (5) from an energy transfer system to the particle chamber (10);
an insulation layer outside the particle chamber (10); and
an outlet (15) for allowing the heated particles (5) to travel into the energy transfer system;
c h a r a c t e r i z e d in that:
the particle chamber (10) comprises walls made of ceramic material;
a support wall (13) outside the outer perimeter of the particle chamber (10), defining a space (12) around the particle chamber (10); and
the insulation layer (14) is outside the support wall (13);
wherein said space (12) is filled with solid particles (6) accommodating thermal expansion of the particle chamber (10).

2. A container according to claim 1, c h a r a c t e r i z e d by comprising multiple particle chambers (10) surrounded by the space (12) filled with solid particles (6).

3. A container according to claim 1 or claim 2, c h a r a c t e r i z e d in that the outer surface of the support wall (11) is lined with a sheet (19).

4. A container according to claim 2 or claim 3, c h a r a c t e r i z e d in that the multiple particle chambers (10) are in parallel.

5. A container according to any of the claims 2 to 4, c h a r a c t e r i z e d in that at least one inlet (1) of the multiple particle chambers (10) comprises an inlet valve for a particle flow.

6. A container according to any of the claims 2 to 5, c h a r a c t e r i z e d in that at least one outlet (15) of the multiple particle chambers (10) comprises an outlet valve for a particle flow.

7. A container according to any of the claims 1 to 6, c h a r a c t e r i z e d by comprising an air injection nozzle at the particle chamber (10), at the space (12) wall or at the cool particle chamber (17) to provide rapid pulses of gas that separate agglomerated solid particles (5, 6, 7).

8. A container according to any of the claims 1 to 7, c h a r a c t e r i z e d in that the particle chamber (10) wall comprises ceramic bricks, ceramic well rings or slip formed ceramic material.

9. A container according to any of the claims 1 to 8, c h a r a c t e r i z e d in that a cool particle chamber (17) is around the space (12), comprising a cool particle inlet (2) and a cool particle outlet (16), wherein the cool particle chamber (17) is configured for housing cool particles (7) of a cool circuit.

10. A container according to any of the claims 1 to 9, c h a r a c t e r i z e d in that the insulation layer (14) is divided at least partially into two insulation layers (14, 65), wherein a second insulation layer (65) is the outer layer of the particle container; an insulation chamber (61) is at least partially between the inner insulation layer (14) and the second insulation layer (65), configured to be filled with fluid configured to transfer thermal energy from the inner insulation layer (14) and the second insulation layer (65).

11. A method for storing heated particles (5) in an energy storage system, the system having a particle container, comprising:
a cylindrical particle chamber (10) for storing heated particles (5); and
an insulation layer (14) outside the particle chamber (10); wherein the method comprises the steps of:

receiving heated particles (5) from an energy transfer system to the particle chamber (10) through an inlet (1); and
allowing the heated particles (5) to travel into the energy transfer system through an outlet (15);
characterized in that:
the particle chamber (10) comprises walls (11) made of ceramic material;
a support wall (13) outside the outer perimeter of the particle chamber (10), defining a space (12) around the particle chamber (10); and
the insulation layer (14) is outside the support wall (13);
wherein the method comprises filling said space (12) filled with solid particles (6) for accommodating thermal expansion of the particle chamber (10).

12. A method according to claim 11, characterized by the particle container comprising multiple particle chambers (10) surrounded by the space (12) filled with solid particles (6).

13. A method according to claim 12, characterized by selecting a particle flow through at least one inlet (1) of the multiple particle chambers (10) by an inlet valve.

14. A method according to any of the claims 11 to 13, characterized by selecting a particle flow through at least one outlet (15) of the multiple particle chambers (10) through an outlet valve.

15. A method according to any of the claims 11 to 14, characterized by separating agglomerated solid particles (5, 6, 7) by rapid pulses or bursts of gas via an air injection nozzle at the particle chamber (10), at the space wall (11) or at the cool particle chamber (17).

16. A method according to any of the claims 11 to 15, characterized by receiving cool particles (7) of a cool circuit via cool particle inlet (2) to the space (12) around the particle chamber (10), storing cool circuit

particles (7) in the space (12); and cool particles (7) of the cool circuit exiting via cool particle outlet (16).

17. A method according to any of the claims 11 to 16, c h a r a c t e r i z e d in that the insulation layer (14) is divided into two insulation layers (14, 65), wherein a second insulation layer (65) is the outer layer of the particle container; an insulation chamber (61) is at least partially between the inner insulation layer (14) and the second insulation layer (65), transferring thermal energy from the inner insulation layer (14) and the second insulation layer (65) along said fluid.

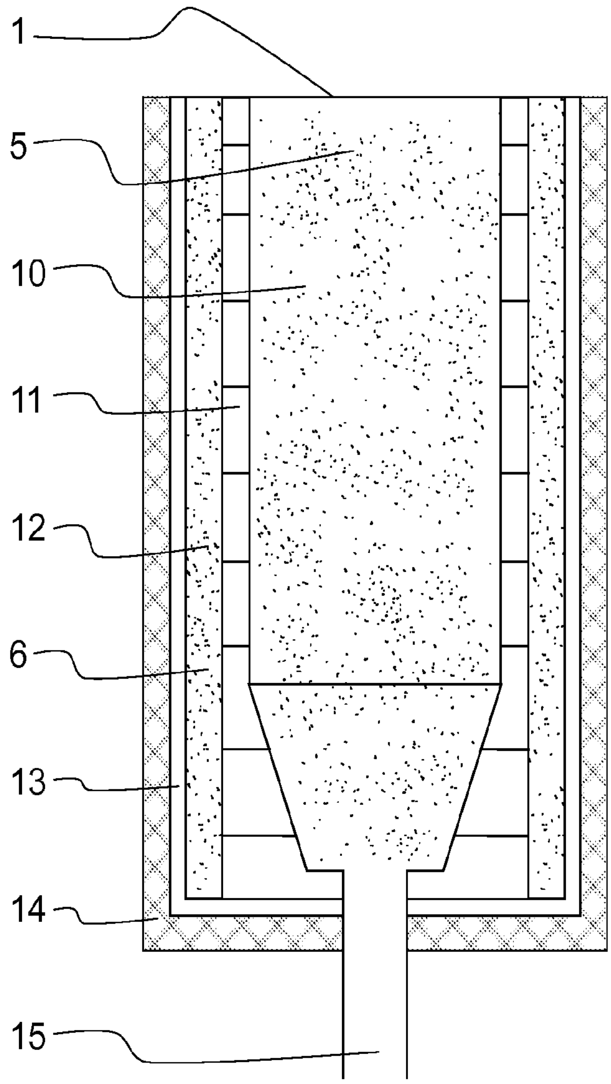


Fig. 1a

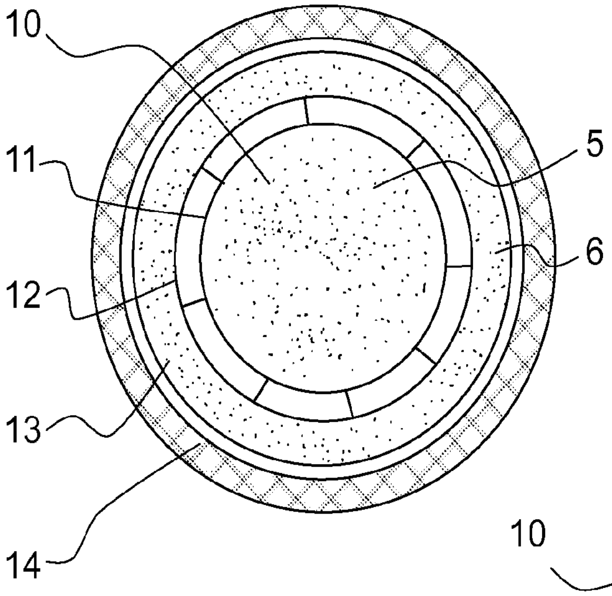
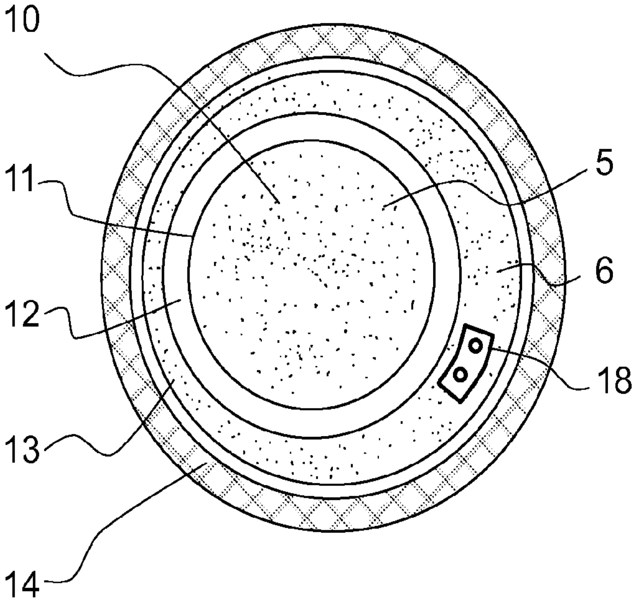


Fig. 1b

Fig. 1c



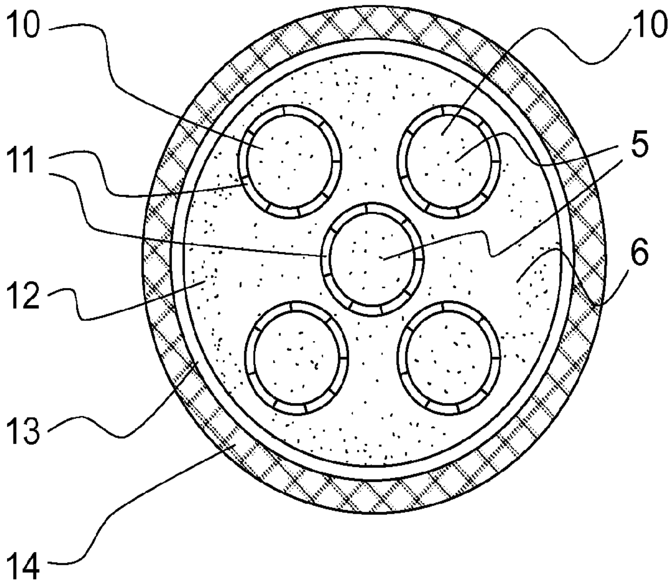


Fig. 2

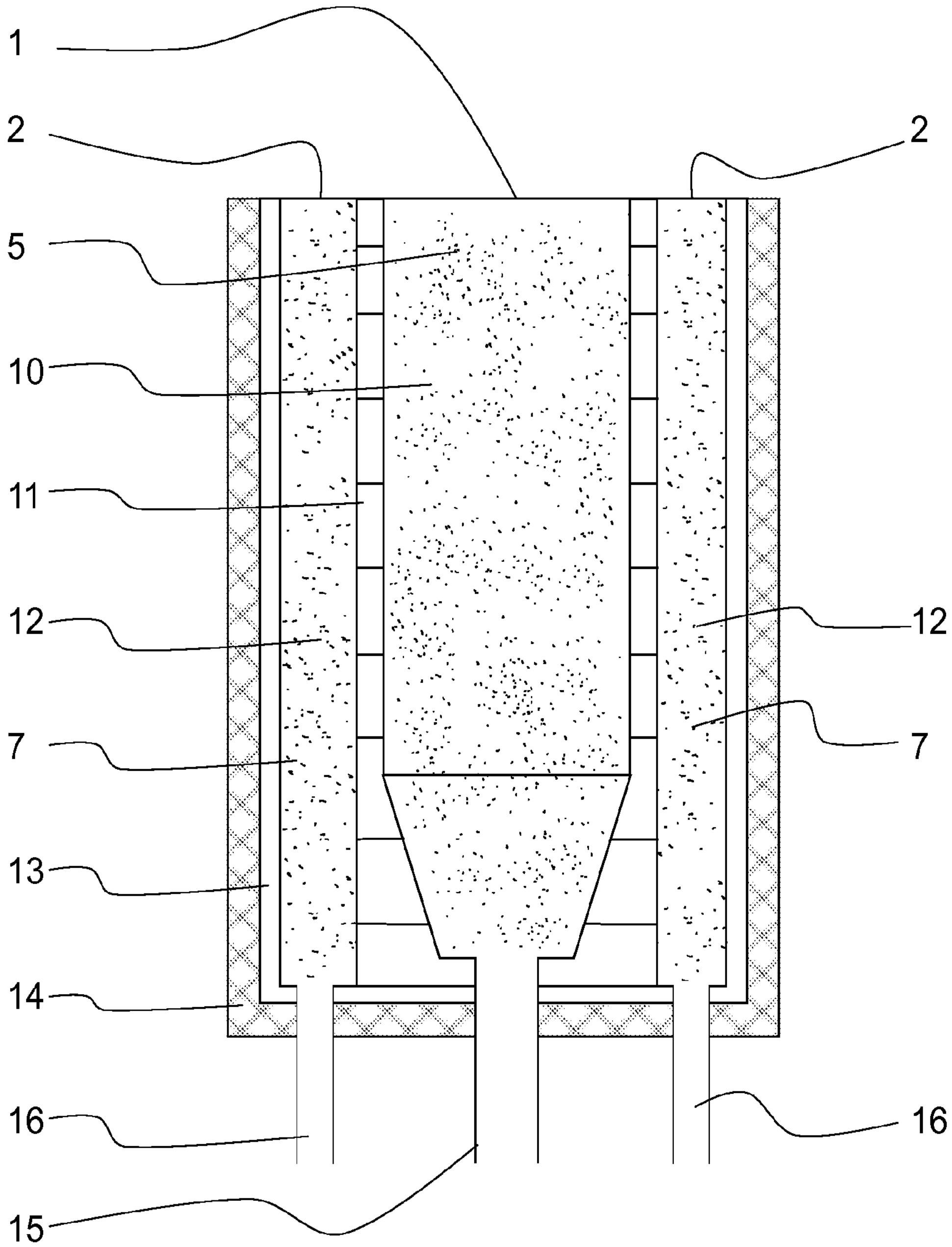


Fig. 3

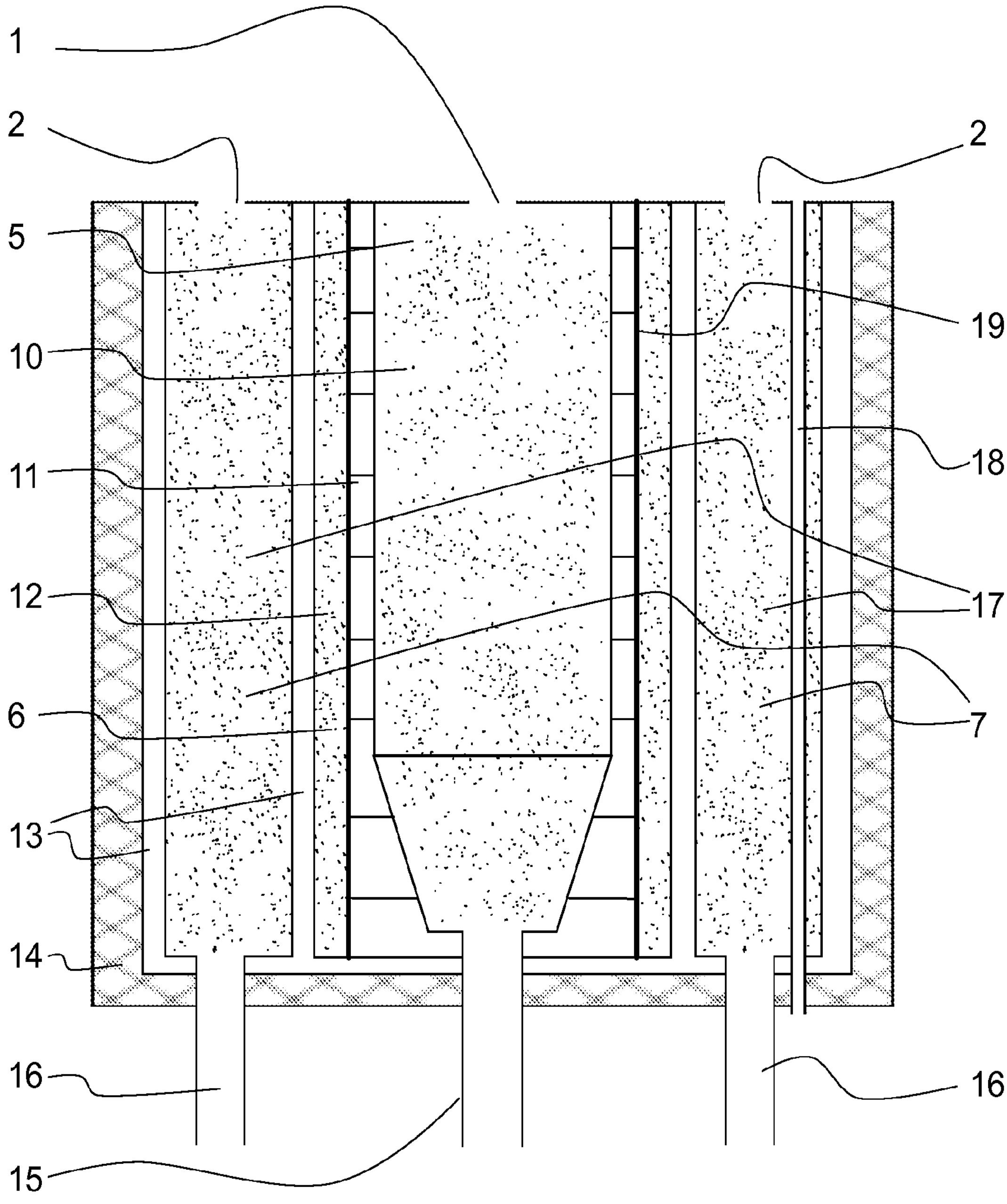


Fig. 4a

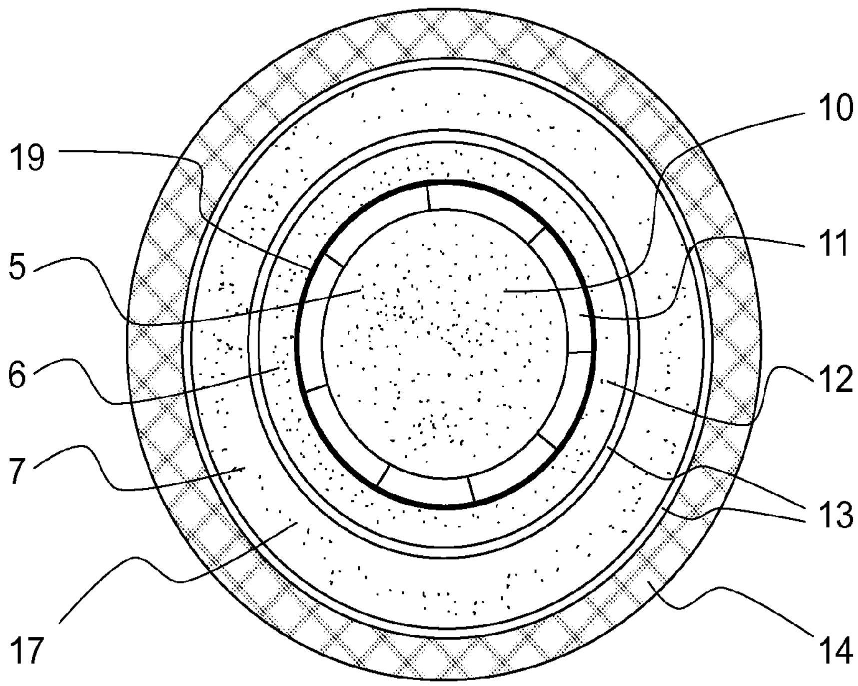


Fig. 4b

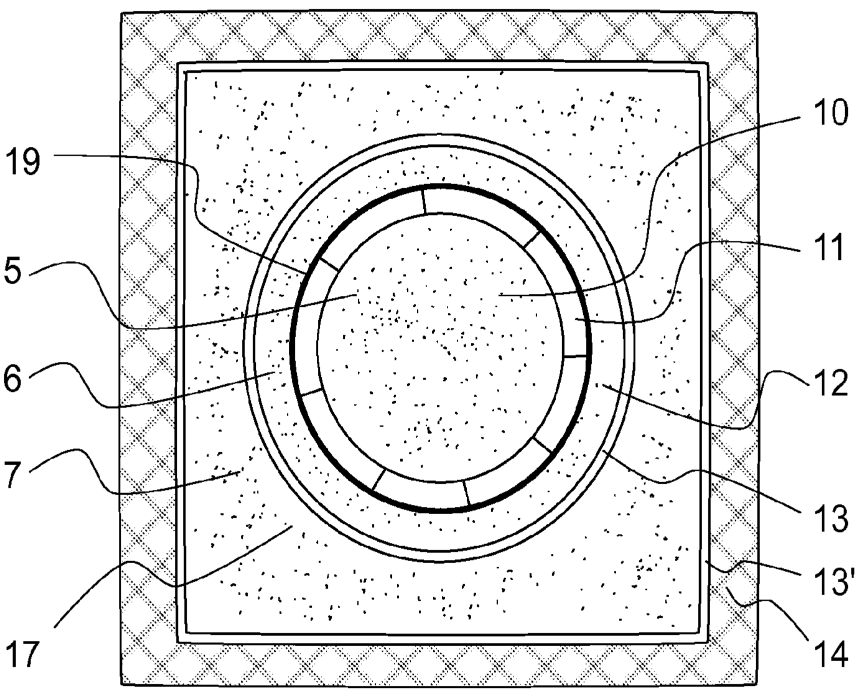


Fig. 4c

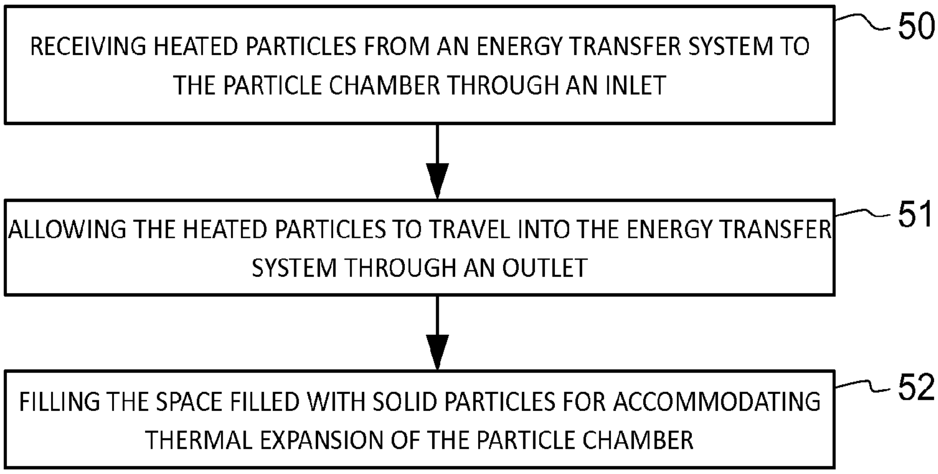

RECEIVING HEATED PARTICLES FROM AN ENERGY TRANSFER SYSTEM TO THE PARTICLE CHAMBER THROUGH AN INLET
50
ALLOWING THE HEATED PARTICLES TO TRAVEL INTO THE ENERGY TRANSFER SYSTEM THROUGH AN OUTLET
51
FILLING THE SPACE FILLED WITH SOLID PARTICLES FOR ACCOMMODATING THERMAL EXPANSION OF THE PARTICLE CHAMBER
52

Fig. 5

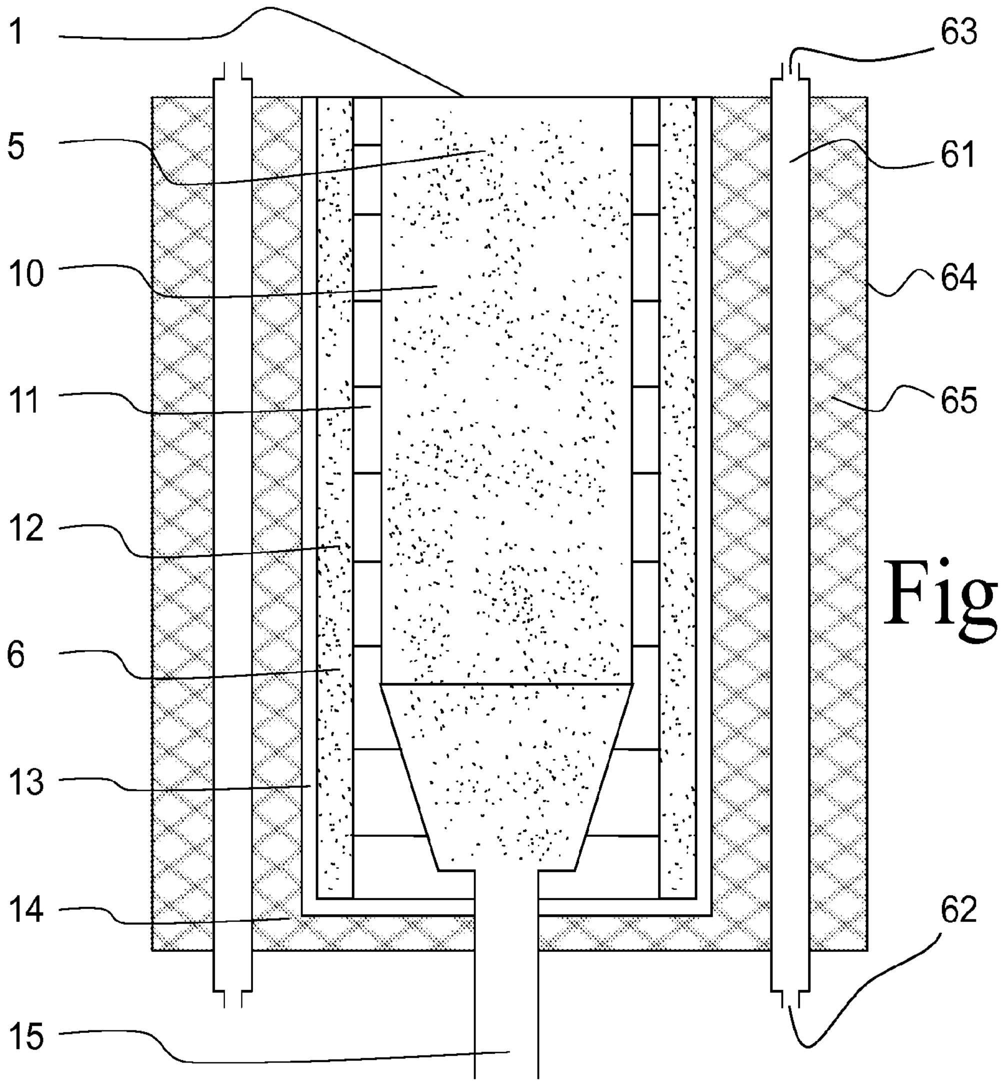


Fig. 6a

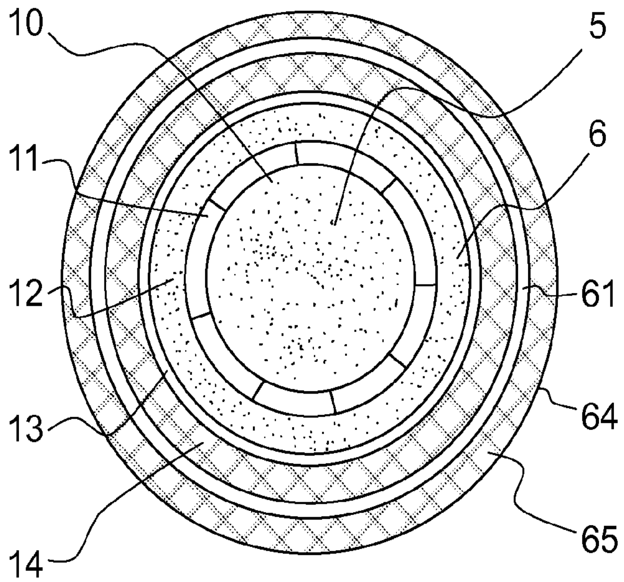


Fig. 6b

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI2025/050022

A. CLASSIFICATION OF SUBJECT MATTER

See extra sheet

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: F28D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

FI, SE, NO, DK

Electronic database consulted during the international search (name of database and, where practicable, search terms used)

EPODOC, EPO-Internal full-text databases, Ansera full-text translation and non-patent literature databases, WPIAP, IPRally

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	CN 116119201 A (BLUESTAR BEIJING CHEMICAL MACH) 16 May 2023 (16.05.2023) figure 1 & machine translation into English by EPO [online] Ansera, especially page 1, line 25 – page 4, line 8	1-3, 5, 6, 8, 10-14, 17 4, 7, 9, 15, 16
Y A	US 2018016984 A1 (DELEAU FABRICE [FR] et al.) 18 January 2018 (18.01.2018) paragraphs [0086]-[0110], [0121] and [0128]; figures 2-11	1-3, 5, 6, 8, 10-14, 17 4, 7, 9, 15, 16
A	US 2022034600 A1 (MA ZHIWEN [US] et al.) 03 February 2022 (03.02.2022) paragraphs [0028], [0029], [0044] and [0058]; figures 1 and 11	1-17

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"D" document cited by the applicant in the international application
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 April 2025 (10.04.2025)	10 April 2025 (10.04.2025)

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		BR 112021005563 A2	29/06/2021

CLASSIFICATION OF SUBJECT MATTER

IPC
F28D 20/00 (2006.01)