US 20080066736A1

(19) **United States**

(12) **Patent Application Publication**

Zhu

(10) **Pub. No.: US 2008/0066736 A1**

(43) **Pub. Date: Mar. 20, 2008**

(54) **METHOD AND APPARATUS FOR SOLAR ENERGY STORAGE SYSTEM USING GAS AND ROCK**

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(21) Appl. No.: **11/492,626**

(22) Filed: **Jul. 25, 2006**

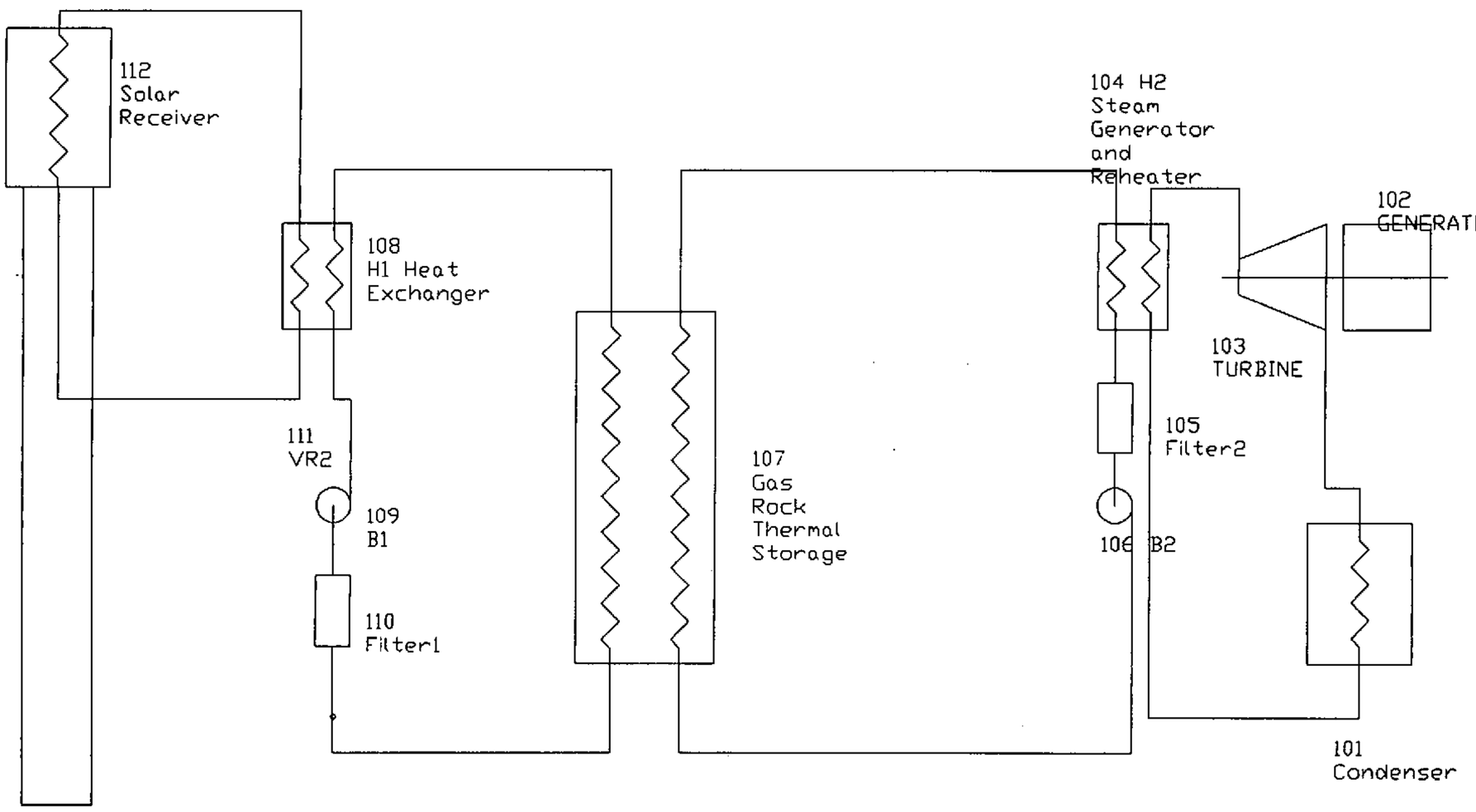
Publication Classification

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

(52) **U.S. Cl.** **126/620**

(57) **ABSTRACT**

A method and Apparatus for solar energy storage system uses gas for thermal transport for central tower solar thermal electric power plant to provide high quality, low cost, and continuously electric power generation. The storage contains a number of storage modules that each module can store energy for a given period of time. The thermal energy from central tower charges the modules one by one during the sunny time, while the thermal electric power plant discharge the modules one by one as long as it works. A control and a connection valve system control and connect the charge and discharge modules with the central tower and the power plant according to pre-arranged sequences. Fans at the cool side of the storage system push the circulation gas into the central tower or the thermal storage modules. In the discharge system, the hot gas from storage system is send to the heat exchange system, and to generate steam and to super heat steam for the power plant. In the charge system, the cold gas is pushed into the central receiver thermal exchange unit and to be heated, and the hot gas is then circulated back to storage system to charge up the storage system.



schematics of central tower power plant with gas and rock thermal storage system.

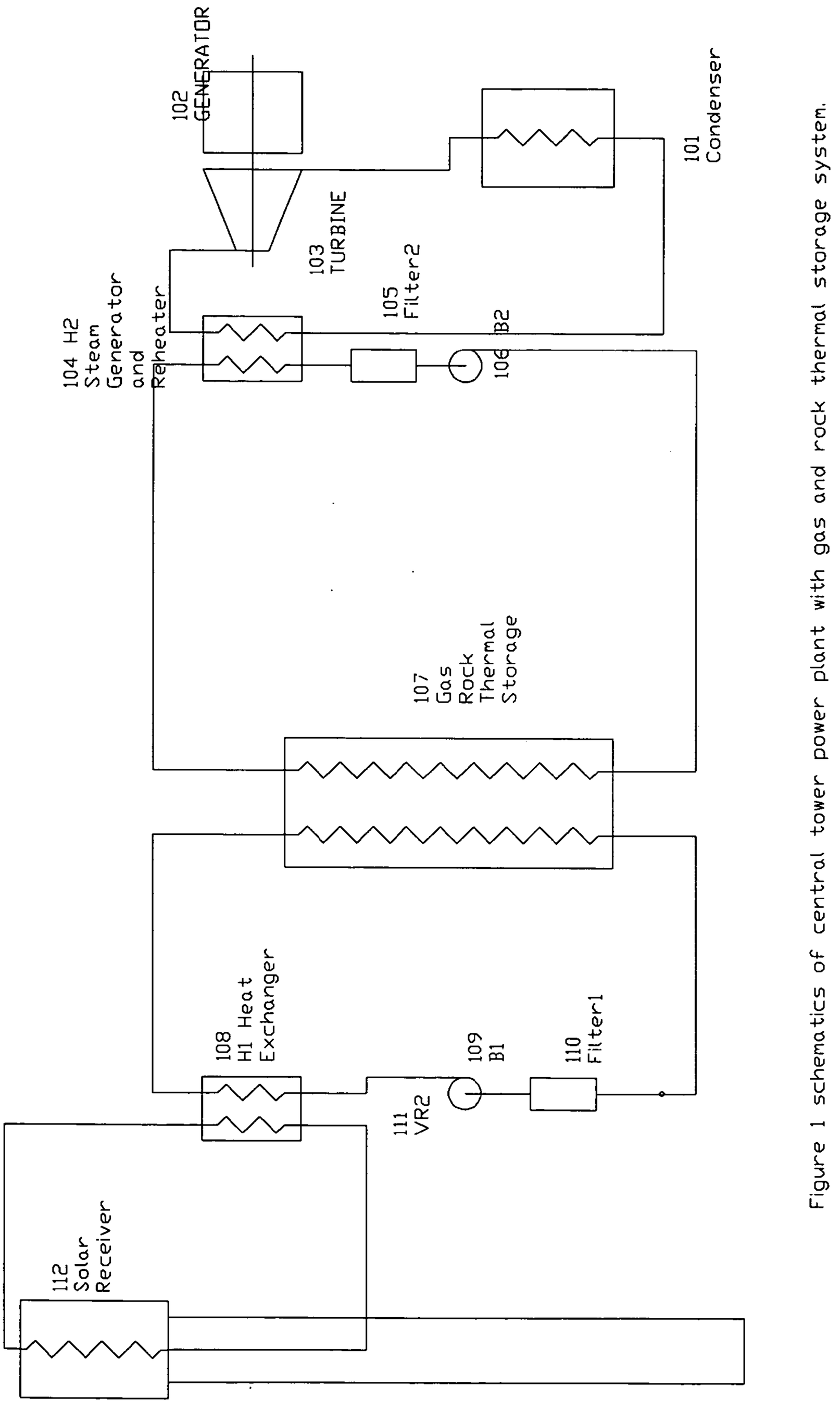


Figure 1 schematics of central tower power plant with gas and rock thermal storage system.

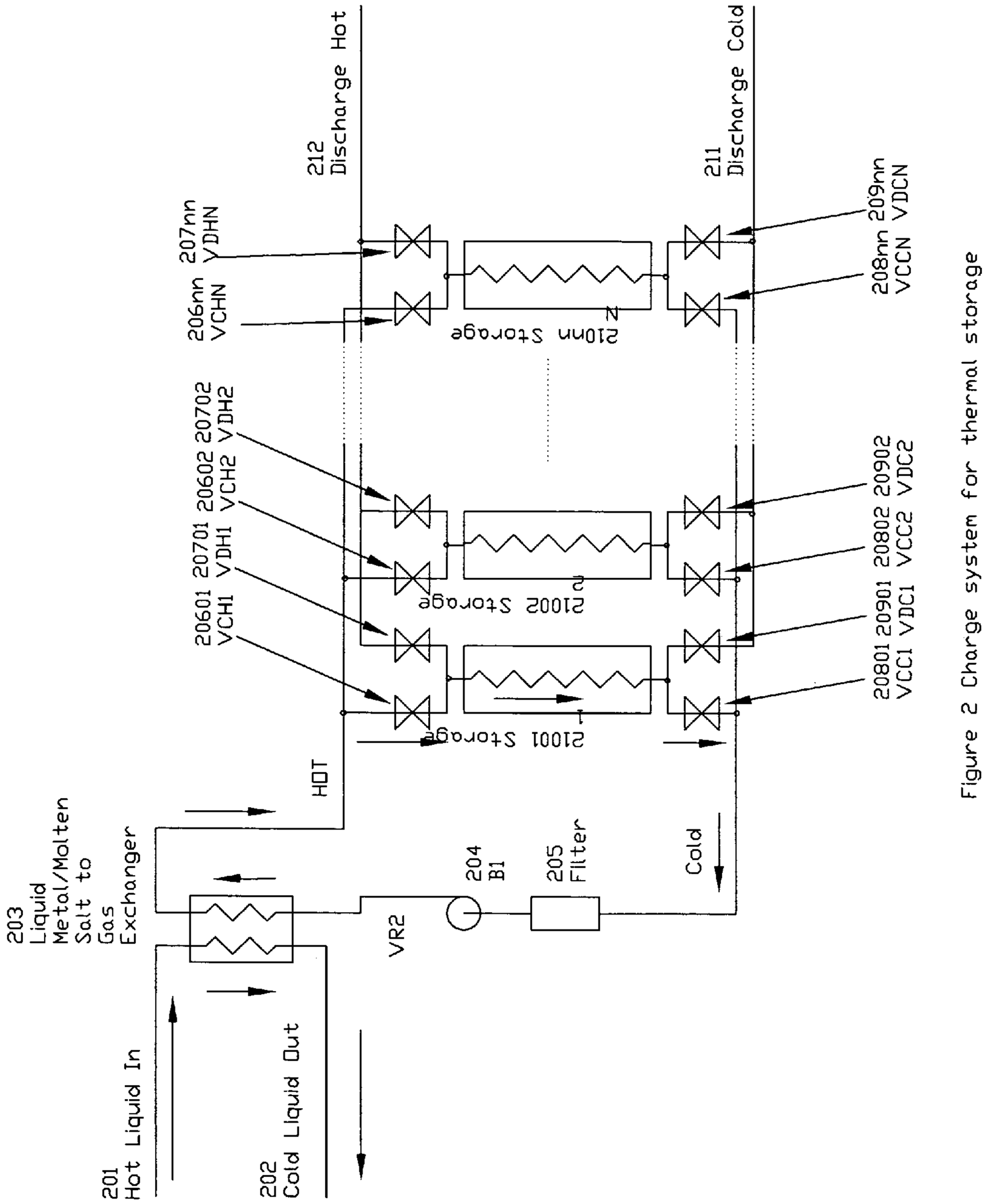


Figure 2 Charge system for thermal storage

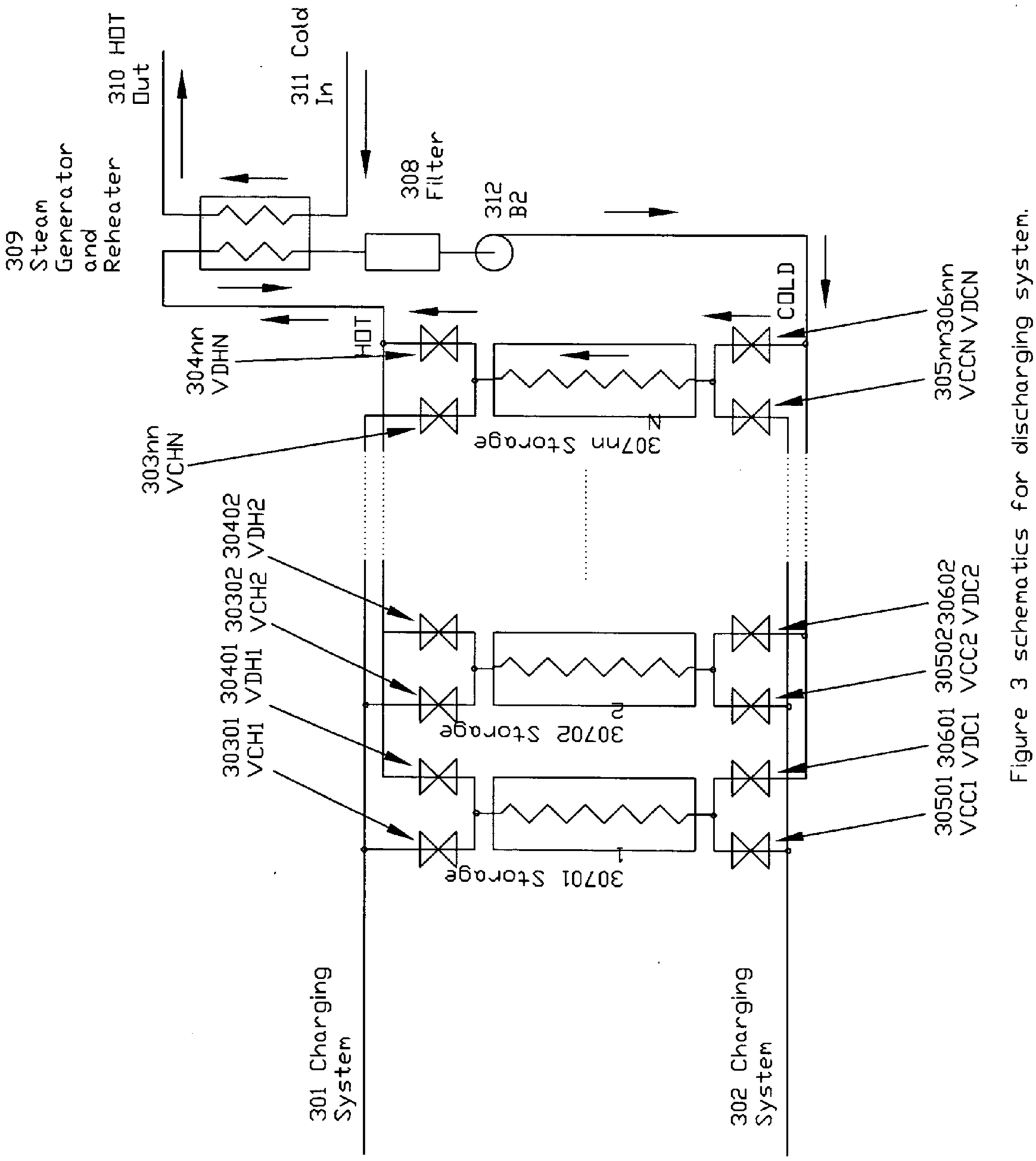


Figure 3 schematics for discharging system.

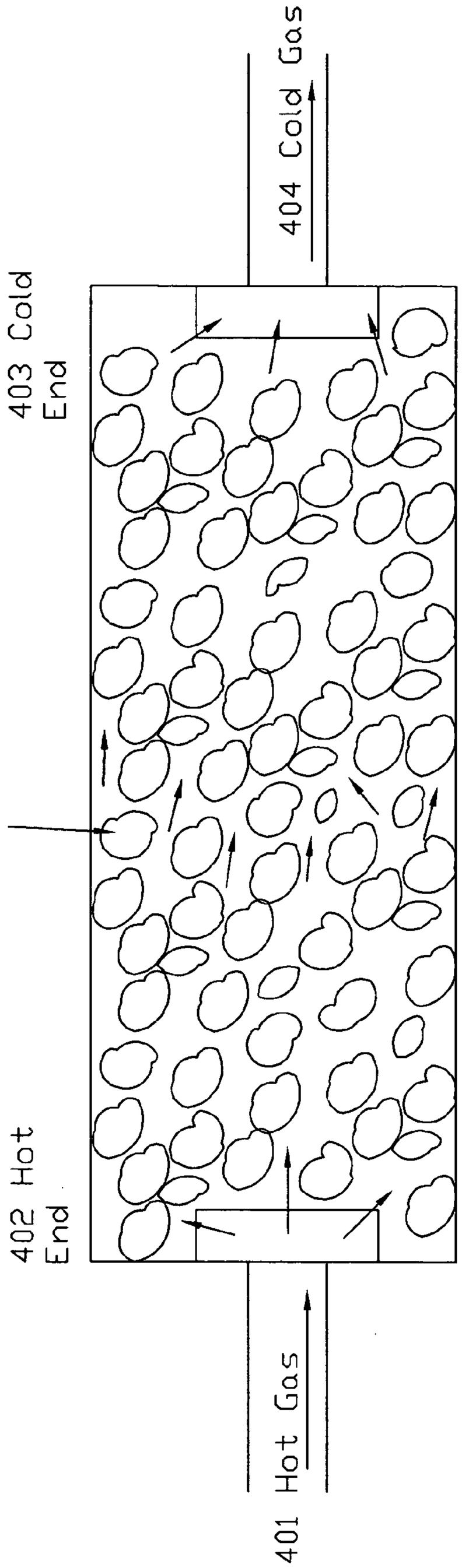


Figure 4 charge a thermal storage module.

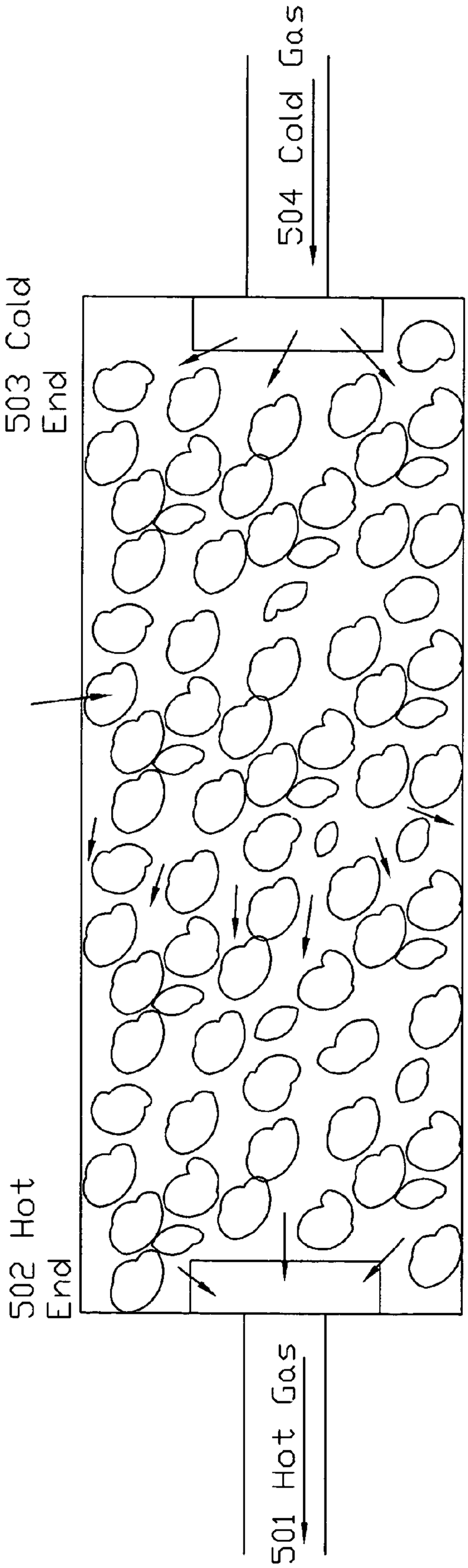


Figure 5 discharge a thermal storage module.

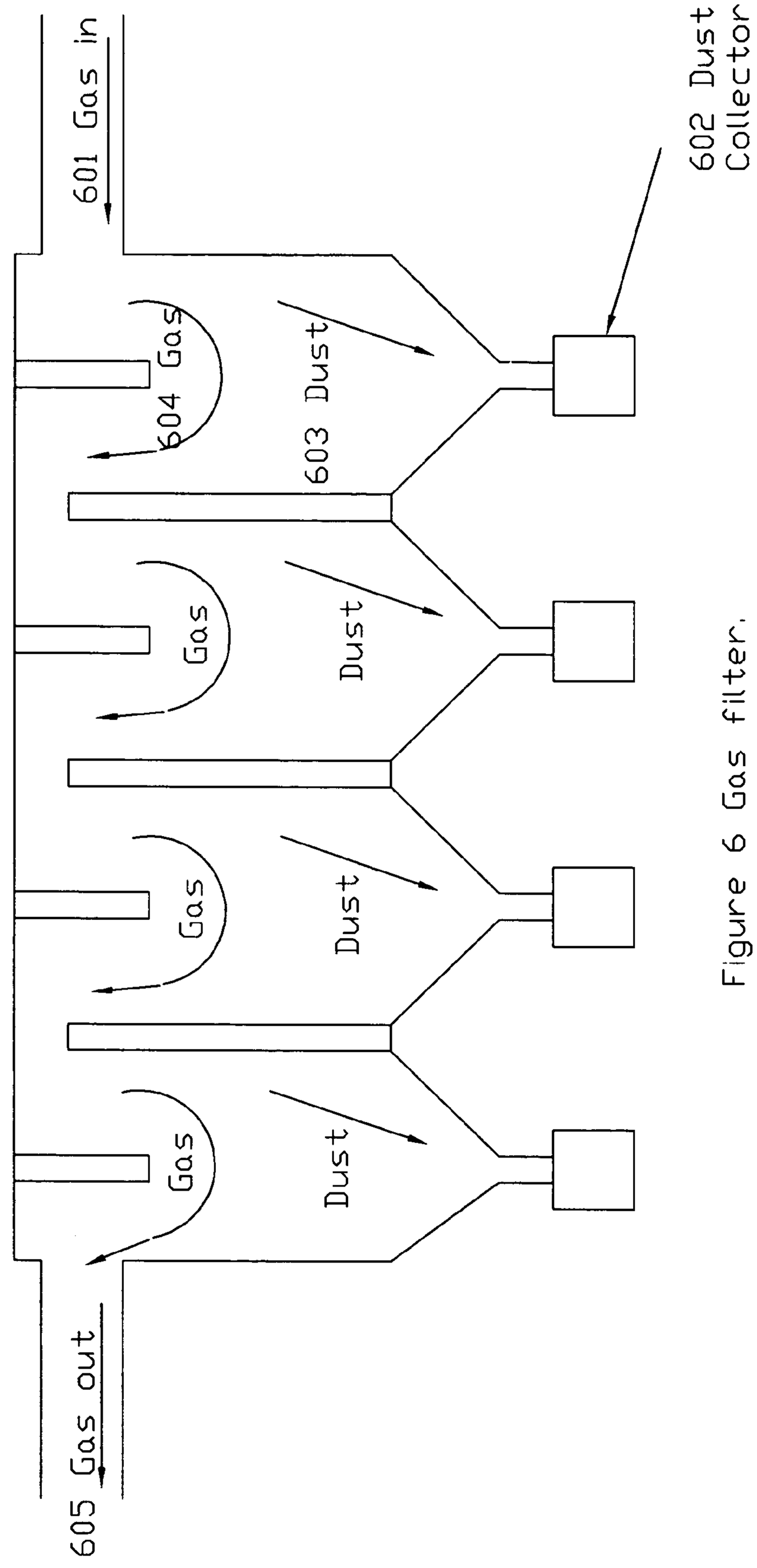


Figure 6 Gas filter.

METHOD AND APPARATUS FOR SOLAR ENERGY STORAGE SYSTEM USING GAS AND ROCK

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] This invention generally relates to solar thermal energy storage by using rock or other type of solid storage media and use gas, liquid metal, and steam as the thermal transfer media.

[0003] 2. Description of Prior Art

[0004] The differences between the nature characters of the solar energy and power grid requirement require thermal storage to buffer and temperature store energy. The nature characters of the solar energy are not service on demand while the power grid requires backbone power plant supply electricity to the grid must be service on demand. The solution for meeting the service on demand requirements is the thermal energy storage system.

[0005] The thermal energy storage system stores the excessive thermal energy to thermal storage during sunshine time and less electric demanding time, and release the stored thermal energy when the power plant is demanding.

[0006] In additional to meet the requirement of service on demand to the power grid, the power plant utilization is also the key to power plant economy. The thermal storage system can significantly increase the utilization factor of the power plant; therefore increase the financial performance of the power plant.

[0007] A number of the energy storage methods are commonly using today, such as battery, flywheel, pumped water hydro power plant, direct steam storage, molten salt, molten salt and rocks, oil and rocks, and etc. None of them can meet the large-scale power grid storage requirements for low cost, less location dependency, high reliability, high efficiency, and environment friendly.

[0008] The lead acid battery is not economical for power gird energy storage plus the short lifetime and un-friendly to natural environment.

[0009] Flywheel has limited capacity, cost, and reliability issue when apply to large-scale grid power storage.

[0010] Pumped water hydro power plant is the most practical way for large grid scale energy storage, but the availability of suitable land for power plant is very limited.

[0011] Direct steam storage is simple, but it is limited by the capacity when come to grid scale power plant.

[0012] Molten salt thermal storage system presented a method for thermal storage. But it faces several major disadvantages, such as low maximum temperature or high freezes temperature, corrosive nature, high power requirement for circulations, and expensive storage medium.

[0013] Oil, or oil and rock, or molten salt and rock methods are suffered from limitation on higher temperature, pollutions, and high cost on heat transport medium.

BRIEF SUMMARY OF THE INVENTION

[0014] A method and Apparatus for solar energy storage system uses gas for thermal transport and uses rock for thermal storage medium for central tower solar thermal electric power plant to provide high quality, low cost, and continuously electric power generation.

[0015] The storage contains a number of storage modules that each module can store energy for a given period of time. The thermal energy from central tower charges the modules one by one during the sunny time, while the thermal electric power plant discharge the modules one by one during the power generation hours.

[0016] The thermal energy stored in the thermal storage can also be used heat the liquid metal or molten salt of the solar receiver during the time the sun is not available.

[0017] A control system and connection valves switch the connections for each storage module between the charge system and the discharge system according to the sensor readings, computer operation models and running experiences.

[0018] For charging a storage module, the storage module has to be connected to the charge system through the controlling valves, a fan at the cold side of the charge system push the circulation gas from the cool end of the storage module into the central tower's thermal exchanger, and the heated gas from the exchanger then returning to hot side of the charge system and pushed to the hot end of the thermal storage module and entering the thermal storage module and dissipate the thermal energy to rocks until the gas cooled down reach the cold side of the charge system to complete the circulation cycle.

[0019] For discharging a storage module, the storage module has to be connected to the discharge system through the controlling valves; a fan at the cold side of the discharge system blows the cold gas into the cold end of the thermal storage module. The gas will be heated through the heat exchange with the rocks and then pushed out through the hot end of the thermal storage module. The hot gas is then pass through the thermal exchange system that generates steam, super heat and reheat the steam, until the gas is cool down and return to cold side of the discharge system to complete the circulation cycle.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] This invention consists in the construction, arrangements and combination of the various parts of the device, whereby the objects contemplated are attained as hereinafter more fully set forth, specifically pointed out in the claims, and illustrated in the accompanying drawings in which:

[0021] FIG. **1** is a illustration of the central tower solar power plant of this invention. The central solar tower receives the concentrated solar energy, the transported by liquid metal or molten salt to heat exchanger to heat the gas. The gas from the exchanger transports the thermal energy to the thermal storage system. The output of the hot gas from the thermal storage system is sent to steam generation, super heating, and reheating for driving the turbine to generate electricity.

[0022] FIG. **2** is a schematic of the thermal charge system. Only one thermal storage module (for example number **1**) is connected to the charging system for charging. The rest of storage modules are disconnected from the charging system by switch off the valves, and ready for discharging if they are charged.

[0023] FIG. **3** is a schematic of the thermal discharge system. Only one thermal storage module (for example number N) is connected to the discharging system for discharging. The rest of the storage modules are disconnected from the discharging system by switch off the related valves and ready for charging if they have been discharged.

[0024] FIG. **4** is an illustration of a thermal storage module in charge mode. The hot gas flow in the storage module from the hot end, and then exchange the thermal energy with the rocks and been cooled down and exit from cold end of the thermal storage module. When all rocks are heated, the storage module is full. The charging system will switch off the valves that connected to this module and starting charge other discharged modules.

[0025] FIG. **5** is an illustration of a thermal storage module in discharge mode. The cold gas enters the thermal storage module from the cold end, and absorbs thermal energy from rock and exit from the hot end.

[0026] FIG. **6** is an illustration of a gas filter. The gas enters the filter and slows down by the dividers to allow gravity and centrifuge force to draw the dusts down to the dusts collectors. The dusts collectors can be emptied once they are full.

DETAILED DESCRIPTION OF THE INVENTION

[0027] This invention is generally related to a method and Apparatus for solar energy storage system uses gas for thermal transport and uses rock for thermal storage medium for central tower solar thermal electric power plant to provide high quality, low cost, and continuously electric power generation.

[0028] The thermal storage system as illustrated by FIG. **1** contains the thermal charge system **112**,**108**,**109**, and **110**, and the thermal discharge system **104**,**105**, and **106**, and the thermal storage modules **107**.

[0029] The thermal charge system charges the thermal storage modules while the discharge system discharge the thermal storage modules. A thermal storage module is connected to charge system for charge and connected to discharge system for discharge. The valves connected at the hot end and the cold end of a thermal storage module can switch the connections of the storage module between the charge and discharge system following the controls of the thermal storage system controller.

[0030] The blower fans **106** and **109** force the working gas to circulate in both charge and discharge systems.

[0031] The heat exchangers at charge system **108** and discharge systems **104** provide bridges between different working fluids with different physical parameters for central receiver and power plant.

[0032] The filters **110** and **105** keep the dusts away from entering the heat exchangers cause excessive ware or clotting.

[0033] FIG. **1** is an illustration of the central tower solar power plant of this invention. The central solar tower **112** receives the concentrated solar energy, and the thermal energy from receiver is transported by liquid metal or molten salt to heat exchanger **108** of charge system. The blower **109** pushes the cold gas from the charge system into exchanger **108**. In the exchanger, the liquid metal or molten salt exchange the heat to the gas. The hot liquid metal or molten salt come in the exchanger and cold liquid metal or molten salt come out the exchanger. The coal gas pushed by blower enters the exchanger and absorb the heat and become hot gas and then exit the exchanger. The cold liquid metal or molten salt is then circulating back to the receiver and the heated gas is circulating back to charge system.

[0034] At the least one of the thermal storage module is connected to the charge system if the charge system is working.

[0035] The hot gas from the charge system exchanger is send to the connected thermal storage module **107**. The hot gas **401** enters the thermal storage module and exchanges the heat with the rocks **405** inside of the thermal storage module as illustrated by FIG. **4**. After the gas cooled down by leave the heat with the rocks, it then exit the thermal storage module at the cold end **403**.

[0036] Before the hot gas entering the exchanger, it is filtered by the gravity and centrifuge and gravity filter to remove the dusts as illustrated by FIG. **6**.

[0037] A thermal storage module is a long container filled with rocks with average dimension optimized according to the design parameters. The mass of the thermal storage module is large enough that during charge period of started with an empty module, the cold end output gas maintained at cold, while the hot end maintained at hot during the discharge period.

[0038] At the least one of the thermal module **21001** as illustrated by FIG. **2** is connected to the discharge system for power plant to generate power.

[0039] During the discharge cycle, the blower **312** pushes the cold gas **504** as illustrated by FIG. **5** entering the thermal storage module **307***nn*, where the cold gas receives the heat from rocks **505** until reaching the hot working temperature, and stabilized with the rock temperature. The hot gas from the output of the thermal storage module will be pushed into the power plant heat exchanger **309**. The power plant heat exchanger consists of boiler, super heater and re-heater for steam turbine, and heaters and re-heaters for gas turbine. The gas from thermal storage will exchange its thermal energy with working medium of steam turbine or gas turbine until cooled down. The cold gas is then send back to blower for next circulation cycle.

[0040] The thermal storage system contains more than two thermal storage modules that each module can store energy for a given period of time. At the least one of the module is in charge mode during the sunny time, and at the lease one of the module is in discharge mode during the power generation time. The storage capacity of each thermal storage module is determined by the optimization between the pressure required to push gas through with give speed, the heat exchange area of the rocks required to heat up and stabilize the temperature of the circulation gas, and thermal storage capacity.

[0041] The thermal energy residuals of the thermal storage modules will be used heat the liquid metal or molten salt of the solar receiver during the time the sun is not available.

[0042] The thermal storage control system switches the valves that connect the storage module between the charge and the discharge sub-system according to the sensor readings, computer operation models and running experiences.

[0043] The gas filters use the gravity, dividers and centrifuge force to separate the dusts from the gas. At the bottom of the filters, the dusts can be removed regularly from the filters.

What is claimed is:

1. A solar energy thermal storage system contains at the least two thermal storage modules and a thermal storage charge system and discharge system;

(a) A thermal storage module is made of small rocks in a large sealed, thermal isolated container for thermal storage and gas freely flow between rocks for the thermal transport;

(b) A thermal charge system and discharge system can select to charge and discharge thermal storage modules at the same time, and are controlled by the thermal storage charge and discharge controller;

(c) A charge and discharge controller is programmed in such a way that allows the maximizing the thermal energy storage from central solar tower while discharge the thermal energy to the power plant as smooth as possible;

(d) A monitoring system for charge and discharge system with sensors is monitoring the temperature of the rocks, the gas, and as well the pressure, and the contaminations of the gas;

(e) A filter system in the gas loop is used to filtering out the dusts or other un-wanted compounds of the gas;

(f) An heat exchanger with the hot liquid metal transport solar thermal energy from the solar central receiver on one side is heating the charging gas on the other side;

(g) A gas loop circulation fan is installed at the cool side of the charging gas loop and another is installed at the cool side of the discharging loop;

2. The solar energy thermal storage system of claim **1** wherein said thermal storage modules means a large size container filled with rocks of suitable sizes with cool gas in and out pipe from one side and hot gas in and out pipe from another side, and covered with thermal isolation material. The cold gas pipe and hot gas pipe of the container are connected with valves that the storage unit can switch the connections between the charge and discharge system,

3. The solar energy thermal storage system of claim **1** wherein said a charge system has hot side and cold side pipes and valves which allow each storage unit connect to or cut off from the charge system, and at the cold side, a fan blows the cooler gas to the central solar tower receiver's heat exchange and push the hot gas out from the hot side of the exchange, and circulating back to thermal storage unit's hot side;

4. The solar energy thermal storage system of claim **1** wherein said a discharge systems have hot side and cold side pipes and valves which allow each storage unit connect to or cut off from the discharge system, and at the cold side, a fan flows cooler gas to thermal storage and push the hot gas out from the hot side of the thermal storage unit and send to the heat exchange of the power plant for power generation;

5. The solar energy thermal storage system of claim **1** wherein said a thermal storage charge and discharge controller contains electric valves, computers, and sensors, and sensors monitoring the status of the thermal storage units, computers analyzing the data from the sensors, and valves connect the thermal storage units on or off or partial open and partial close from the charge system and on or off from the discharge system;

6. The solar energy thermal storage system of claim **1** wherein said a discharge systems have filters installed at the output of the system to protect the heat exchangers. The filters filter dusts being based on gravity and centrifuge force.

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