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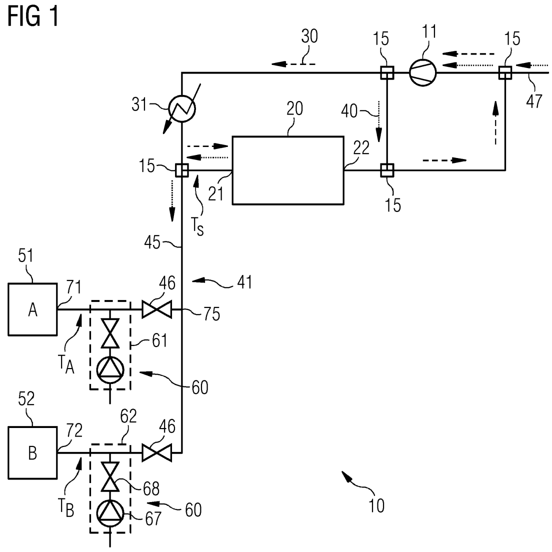
(54) **ENERGY DISTRIBUTION SYSTEM**

(57) An energy distribution system that comprises an energy storage device (20) configured to store thermal energy is provided. The system includes a charging flow path (30) configured to guide a heat transfer medium from a heat source (31) to the energy storage device (20) in order to transfer thermal energy from the heat source (31) to the energy storage device (20) to increase the amount of thermal energy stored in the energy storage device (20), and a discharging flow path (40) configured to guide the heat transfer medium from the energy storage device (20) to heat consumers (51, 52) in order to transfer thermal energy from the energy storage device (20) to the heat consumers (51, 52). The discharging flow path (40) comprises at least one distribution flow path (41) that includes at least a common flow line (45), a first outlet port (71) on the common flow line, the first outlet port (71) being configured to provide the heat transfer medium to a first heat consumer (51), and a second outlet port (72) on the common flow line, the second outlet port (72) being configured to provide the heat transfer medium to a second heat consumer (52).

FIG 1



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Description

FIELD OF THE INVENTION

[0001] The present invention provides an energy distribution system, in particular a system for distributing thermal energy. It further relates to a method of distributing thermal energy to plural heat consumers by means of a respective energy distribution system.

BACKGROUND

[0002] Many industrial processes require heat at a respective temperature level. These include for example physical, chemical and electro-chemical processes. Such industrial processes can include drying, melting and forging of material. The heat required for such industrial processes is typically generated individually by each consumer. For example, a small unit may be provided that burns fossil fuel, thereby generating the heat required by the respective process. Such small units often suffer from relatively low efficiencies. Furthermore, they are not environmentally friendly, as they are powered by fossil fuels.

[0003] To avoid such drawbacks, the electrification of such processes may be attempted. However, such electrification faces several challenges, including the transport of the electricity to the process. Furthermore, when it is desirable to make use of electricity from renewable energy sources to avoid greenhouse gas emissions, it is problematic that such energy may only temporarily be available, for example during sunshine or during respective wind conditions.

SUMMARY

[0004] Accordingly, there is a need to mitigate at least some of the drawbacks mentioned above and to improve the providing of industrial processes with energy, in particular to avoid the need for small individual energy producing units powered by fossil fuels.

[0005] This need is met by the features of the independent claims. The dependent claims describe embodiments of the invention.

[0006] According to an embodiment of the invention, an energy distribution system that comprises an energy storage device configured to store thermal energy is provided. The energy distribution system further includes a charging flow path configured to guide the heat transfer medium from a heat source to the energy storage device in order to transfer thermal energy from the heat source to the energy storage device to increase the amount of thermal energy stored in the energy storage device, and a discharging flow path configured to guide the heat transfer medium from the energy storage device to heat consumers in order to transfer thermal energy from the energy storage device to the heat consumers. The charging and discharging flow paths may be configured so as to guide the heat transfer medium at least partially through the same passage in the energy storage device. In particular, the charging and discharging flow paths may not be separate but may at least partially coincide in the energy storage device. The discharging flow path comprises at least one distribution flow path that includes at least a common flow line, a first outlet port on the common flow line, wherein the first outlet port is configured to provide the heat transfer medium to a first heat consumer, and a second outlet port on the common flow line, wherein the second outlet port is configured to provide the heat transfer medium to a second heat consumer.

[0007] Such system may accordingly provide a central energy storage device from which plural heat consumers can be supplied with thermal energy. The energy distribution system may in particular provide process heat via the outlet ports to the respective heat consumers. Various heat consumers with individual and intermittent heat demand may thus be allowed to use heat from the common central energy storage device. Preferably, the first and second heat consumers are distinct, they may for example correspond to different industrial processes. The same heat transfer medium may thus be used in a charging mode to transport thermal energy from the heat source to the energy storage device, and in a discharging mode to extract thermal energy from the energy storage device (thereby increasing the medium's temperature and energy content) and to provide this thermal energy to the heat consumers. The energy distribution system may thus have a low complexity, thus allowing the storing of large amounts of energy with only minimal costs. The energy distribution system is thus suitable for storing large amounts of energy produced by renewable energy sources, such as wind power plants, solar plants, hydro power plants and the like and for providing this stored energy to plural heat consumers on demand with relatively high conversion efficiency.

[0008] In an embodiment, the first and/or second heat consumers may be industrial processes. In particular, such industrial process may be a chemical process, an electro-chemical process, or a physical process, in particular a drying process, a melting process or a forging process. Each outlet port of the discharging flow path may accordingly be configured to provide the thermal energy via the heat transfer medium to such industrial process, which in particular can be selected from the above examples.

[0009] The heat transfer medium may be a gaseous medium. In particular, it may be air. Accordingly, heat transfer medium may be taken into the system by simply drawing the medium from the ambient air, and after the heat transfer medium has passed on the thermal energy to the respective process, it may be exhausted back into the air. Confinement of the heat transfer medium is thus simple to implement. Also, it is environmental-friendly, as the heat transfer medium cannot contaminate the environment.

[0010] The distribution flow path may implement for at least one of the first and second ports an open cycle in which heat transfer medium given out through the respective port is replaced from a source (in other words, the heat transfer medium is not returned). The heat transfer medium may for example continuously be replaced from the source as it is given out through the respective port. As air from the environment may be used as heat transfer medium, the source may be the environmental air and the industrial process may simply discharge the heat transfer medium into the ambient air after it has transferred its thermal energy to the industrial process. In some embodiments, the distribution flow path may implement an open cycle for each of its outlet ports.

[0011] In some embodiments, the distribution flow path may implement for at least one of the first and second outlet ports an at least partially closed cycle that is configured to return heat transfer medium provided through the respective port at least partially back to the energy storage device. In other words, the respective part of the heat transfer medium may be cycled back from the heat consumer to the energy storage device whereby efficiency may be improved, since the energy transfer medium may still have an elevated temperature after being given out by the heat consumer. For example, a return flow path, which may comprise respective flow lines, may be provided from the respective consumer to the energy storage device, the return flow path forming part of the discharging flow path. Partially closed cycle means that not all of the heat transfer medium provided to the respective heat consumer may be returned, but only part thereof. Some embodiments may also implement a closed cycle that returns substantially all of the heat transfer medium given out through the respective port. It should further be clear that in some embodiments, the distribution flow path may implement for one or more ports an open cycle and may implement for one or more ports an at least partially closed cycle, i.e. both types of cycles may be mixed on the same distribution flow path.

[0012] In an embodiment, the distribution flow path comprises a temperature adjustment assembly that is configured to adjust the temperature of the heat transfer medium. The temperature adjustment assembly may for example be coupled to the common flow line to adjust the temperature of the heat transfer medium in the common flow line (and thus for all downstream ports). Additionally or alternatively, a temperature adjustment assembly may be coupled to the first or the second port to adjust the temperature of the heat transfer medium given out from the respective port (i.e. without affecting the temperature for the other port(s)). For example, one separate temperature adjustment assembly may be provided for each outlet port. The temperature of the heat transfer medium that is given out may then be controlled individually for each port. The assembly coupled to the common flow line may additionally bring down the temperature of the heat transfer medium to a desired distribution temperature. For example, the distribution flow path may comprise for each distribution port a branch line that branches off from the common line, and the temperature adjustment assembly for the respective port may be provided in such branch line, i.e. downstream from the branching point at which the line for the port branches off from the common flow line.

[0013] The temperature adjustment assembly may be configured to adjust the temperature of the heat transfer medium by mixing the heat transfer medium with environmental air. In particular, the temperature adjustment assembly may comprise a port for receiving environmental air, a blower configured to create a flow of the environmental air and a valve arranged in a flow connection from the inlet to the respective flow path, e.g. in a flow connection to the common flow line or to a branch line that branches off towards a respective port. The valve may be arranged upstream or downstream of the blower of the assembly. The blower and/or the valve may be configured to control the flow of environmental air into the respective flow path. The valve may be a simple on/off valve. A junction, such as a T-junction or other junction, may be provided at which the environmental air is, via the valve, provided into the common flow line, or into one of the above-mentioned branch lines in order to mix with the heat transfer medium flowing in the respective line. In some embodiments, the temperature adjustment assembly may not comprise a blower, e.g. in a configuration in which the heat transfer medium is transported in the discharge flow path by a blower (e.g., suction fan) arranged downstream of the respective heat consumer and the air is thus sucked in through the inlet.

[0014] The energy distribution system may for example comprise a respective controller that is configured to control the one or more temperature adjustment assemblies such that the desired temperature is achieved in the line to which the temperature adjustment assembly is coupled, i.e. in the common flow line or in the respective first/second outlet ports.

[0015] The temperature adjustment assembly may furthermore comprise a temperature sensor configured to measure the temperature in the respective flow line, for example prior to the heat transfer medium reaching the temperature adjustment assembly and/or thereafter. Accordingly, feedforward temperature control and/or feedback temperature control may be employed for adjusting the temperature in the respective flow line to the desired value (i.e. by controlling the valve setting of the respective temperature adjustment assembly in dependence on the measured temperature so as to achieve the desired heat transfer medium temperature).

[0016] In some embodiments, the discharging flow path further comprises a second distribution flow path that includes at least a common flow line, a third outlet port on the common flow line, wherein the third outlet port is configured to provide the heat transfer medium to a third heat consumer, and a fourth outlet port on the common flow line, the fourth outlet port being configured to provide the heat transfer medium to a fourth heat consumer. The discharging flow path may for example include a branching point at which the first and second distribution flow paths (in particular the respective common flow lines) branch off, for example from a flow line connected to the energy storage device. In the flow direction of the discharging flow path, such branching point is downstream of the energy storage device.

[0017] The second distribution flow path may likewise implement open and/or closed cycles for its two or more outlet ports. Furthermore, it should be clear that each of the first and second distribution flow paths may include more than two ports, for example three, four, five, six or more outlet ports. Furthermore, it should be clear that the energy distribution system may include more than one or two distribution flow paths, it may for example include three, four, five or more distribution flow paths. A temperature control assembly may likewise be provided for the second or each other distribution flow path. An individual temperature adjustment assembly may furthermore be provided for selected outlet ports or for each outlet port of such second or further distribution flow path. Accordingly, the temperature may be controlled independently in each of the distribution flow paths. Furthermore, for each outlet port, an independent temperature control may be provided. In a preferred configuration, at least two discharging flow paths each including at least two outlet ports are provided, wherein temperature adjustment assemblies are provided both for each of the discharging flow paths and for each of the respective ports.

[0018] By means of a temperature adjustment assembly provided in the first distribution flow path, the energy distribution system may for example control a temperature of the heat transfer medium in the first distribution flow path to be lower than a temperature of the heat transfer medium in the second distribution flow path, for example at least 100°C or at least 200°C lower. Thermal energy may thus be distributed at different temperature levels, allowing the supplying of heat to several consumers having significantly different heat demands by means of the energy distribution system.

[0019] The charging flow path may implement a closed cycle that is configured to cycle the heat transfer medium through the heat source and the energy storage device. The efficiency of the charging cycle may thus be improved.

[0020] The energy distribution system may further comprise a blower configured to create the flow of the heat transfer medium along the discharging flow path through the energy storage device and along the at least one distribution flow path. The same blower may furthermore be used to create the flow through an additional or through all additional distribution flow paths and outlet ports. With respect to the flow direction in the discharging flow path, the blower is preferably arranged upstream of the energy storage device. It should be noted that it is certainly conceivable to arrange further blowers downstream of the energy storage device, for example to compensate or overcome the pressure drop along a distribution flow path. The blower may furthermore be installed downstream from an air inlet through which ambient air can be taken up as a replacement for heat transfer medium given out through the downstream outlet ports, in particular when implementing an open cycle. In other implementations, a blower may be installed downstream of the respective heat consumer with respect to the flow direction in the discharging flow path. This has the advantage of lower temperatures at the blower. Also, the first-mentioned blower may operate only during charging, and one or more of such additional blowers upstream or downstream of the heat storage device may convey the heat transfer medium during discharging.

[0021] 'Downstream' means 'in flow direction behind' with respect to the flow direction of the heat transfer medium in the respective flow path. 'Upstream' means 'in flow direction before' with respect to the flow direction of the heat transfer medium in the respective flow path.

[0022] The blower may furthermore be configured to create the flow of heat transfer medium along the charging flow path. The system configuration may thus be kept simple and cost-efficient, as only a single blower is required. Preferably, the flow direction of the heat transfer medium through the blower is the same for the charging flow path and for the discharging flow path. This has the advantage that the blower can be configured for efficient operation in one flow direction, and there is no need to reverse the blower operation.

[0023] Preferably, the charging flow path is configured to guide the heat transfer medium through the energy storage device in a first flow direction, and the discharging flow path is configured to guide the heat transfer medium through the energy storage device in a second flow direction that is opposite to the first flow direction. An efficient charging and discharging of the energy storage device may thus be achieved. In other embodiments, the flow direction through the energy storage device may be substantially the same for the charging flow path and for the discharging flow path.

[0024] The energy distribution system may for example employ control valves to switch between a (closed) charging cycle in which the heat transfer medium flows along the charging flow path and a (at least partly open) discharging cycle in which the heat transfer medium flows along the discharging flow path. The valves may be arranged and controlled such that the flow direction through the blower stays the same while the flow direction through the energy storage device is reversed when switching from the charging cycle to the discharging cycle. The energy distribution system may comprise a respective control system for controlling such control valves.

[0025] The energy distribution system may in particular be configured to alternatingly operate in a charging mode in which the heat transfer medium is transported along the charging flow path and a discharging mode in which the heat transfer medium is transported/conveyed along the discharging flow path. Alternating flows of heat transfer medium in opposite directions or in the same direction through the energy storage device are thereby generated to deposit thermal energy in or extract thermal energy from the energy storage device. In the charging mode, no heat transfer medium may be passed towards the heat consumers. In the discharging mode, no heat transfer medium may be passed through the heat source, the heat source may be in standby/switched off.

[0026] The energy distribution system may furthermore be configured to operate in a partial charging mode in which the heat transfer medium is transported along the charging flow path and in which a fraction of the heat transfer medium that has taken up thermal energy from the heat source is passed to the heat consumers via the distribution flow path. By such partial charging mode, the heat consumers can be supplied with thermal energy also during the charging of the energy storage device.

[0027] The energy distribution system may furthermore be configured to operate in a supported discharging mode in which the heat transfer medium is transported along the discharging flow path and in which an additional flow of heat transfer medium is provided from the heat source to the heat consumers via the distribution flow path to transport thermal energy from the heat source to the heat consumers. The amount of thermal energy available to the heat consumers during discharging can thereby be increased.

[0028] The energy distribution system may further be configured to operate in a direct heating mode in which the heat transfer medium is guided so as to transport thermal energy directly from the heat source to the heat consumers, i.e. in which there is no intermediate storage of the thermal energy in the energy storage device (the energy storage device is not operating).

[0029] The operating mode in which the system operates may be selected based on one or a combination of the following parameters: heat demand by the heat consumers; amount of energy stored in the energy storage device (charging level); and cost of energy (e.g. for operating the heat source). The system is preferably at least operable in the charging mode and the discharging mode; it may be operable in the charging mode, the partial charging mode, the discharging mode and the supported discharging mode. In some embodiments, it may be operable in all of the above mentioned modes.

[0030] The energy storage system may be configured to store thermal energy in the energy storage device at a temperature between 300 °C and 1000 °C, preferably between 500 °C and 1000 °C, more preferably between 600°C and 900°C in a charged state (in particular in a hot region of the device). For example, the temperature in the energy storage device may be between 650 and 800°C in the charged state. It should be clear that the temperature can be significantly lower if the storage device is discharged.

[0031] In the discharging flow path, the temperature of the heat transfer medium leaving the energy storage device may lie within the range of about 500°C to 900°C, preferably 600°C to 800°C.

[0032] In some implementations, the energy storage system may be configured to provide via the first distribution flow path the heat transfer medium at a temperature between 500°C and 800°C. It may further be configured to provide via the second distribution flow path the heat transfer medium at a temperature between 200°C and 500°C. The temperature may be adjusted by the above-mentioned temperature adjustment assembly. Accordingly, the energy storage system may provide a high temperature distribution and a medium temperature distribution via the respective distribution flow path. It should be clear that other implementations are conceivable, such as providing additionally or alternatively a low temperature distribution path (e.g. between 100°C and 300°C) or providing two high/medium temperature distribution paths, or the like. Thermal energy may thus be provided to plural different consumers at the desired temperature, which may further be individually adjusted for each consumer, as outlined above.

[0033] In an embodiment, the energy storage device comprises an insulated storage chamber and a heat storage material disposed in the insulated storage chamber, wherein flow channels are provided in the heat storage material and/or the heat storage material has open pores through which the heat transfer medium can flow. Flow channels (or heat exchange channels) can be built into the heat storage material, or such channels may form due to the structure of the material, e.g. by interspaces or gaps in the heat storage material, e.g. between rocks/stones. Preferably, the heat storage material comprises a mesh of heat exchange channels through which the heat transfer medium passes, both along the charging and the discharging flow path.

[0034] For example, the heat storage material may comprise or consist of rocks, bricks, stone, lava stone, granite, basalt and/or ceramics provided as bulk material (which may be configured as pebble bed). Preferably, the heat storage material comprises or consists of sand and/or stones, in particular gravel, rubble and/or grit. The stones can be natural stones or artificial stones (e.g. containers filled with material, such as clinkers or ceramics). The heat storage device can thus be provided cost efficiently while being capable of storing large amounts of thermal energy.

[0035] The energy storage device may be a horizontal storage device wherein a main flow direction of the heat transfer medium through the storage device is in horizontal direction (i.e. substantially parallel to the earth's surface). It may include a first port and a second port which operate either as inlet or outlet, depending on the flow direction through the energy storage device. A horizontally oriented direction of the heat exchange flow may be achieved by providing the ports laterally, e.g. in side walls/boundaries of the storage chamber. In other embodiments, the energy storage device may be a vertical storage device wherein a main flow direction of the heat transfer medium through the storage device is in vertical direction (i.e. substantially perpendicular to the earth's surface). The inlet/outlet ports may then be provided in upper/lower walls/boundaries of the storage chamber, or one port may be provided in an upper part and the other in a lower part of a side wall/boundary of the storage chamber.

[0036] In some implementations, the energy storage device may comprise a diffuser section for evenly distributing the heat transfer medium into the storage and for reducing the flow speed of the medium. The diffuser may be provided at either port of the storage device. The diffuser may comprise a convection reducing structure, for example by providing a vertical layer of convection reducing elements within the diffuser of the respective port.

[0037] The storage chamber may be a space, a cavity, an excavation or a housing in which the heat storage material is located. The energy storage device may further comprise a nozzle section provided between the storage chamber and the respective port. The nozzle section may for example include a tapered portion leading from the storage chamber to the respective port. Flow speed and pressure of the heat transfer medium entering/leaving the energy storage device through the respective port may be adjusted by such nozzle section.

[0038] In the charging mode, heat transfer medium that has been heated by the heat source passes through the energy storage device and thereby heats the heat storage material, a cooler medium being exhausted from the energy storage device. After the charging is completed, the storage device may be left in a standstill period of hours or even days until the stored thermal energy is needed. In the discharging mode, the flow direction is reversed, so that colder heat transfer medium (e.g. environmental air) is introduced into the port that acted as outlet in the charging mode. The heat storage material transfers heat to the heat transfer medium, which leaves the energy storage device at the other (hot) end through the port that acted as inlet in the previous charging mode. The storage device may thus have a hot port (inlet for charging and outlet for discharging) and a cold port (inlet for discharging and outlet for charging). For a modified distribution of the medium within the storage, the energy storage device may include a plurality of hot ports and/or a plurality of cold ports. In other embodiments, the flow direction through the energy storage device may substantially be the same in the charging and discharging modes, as outlined above.

[0039] The heat storage material may be separated into a layered thermal energy storage structure by dividing elements, such as steel plates or metal sheets. The sheets or plates may comprise any suitable heat resistant material, such as metal, synthetic fabric or the like, that are substantially impermeable for the working fluid. The dividing elements may prevent a change in the temperature distribution within the thermal energy storage structure due to natural convection during the standstill period, i.e. prevent that hot fluid surrounding heat storage material in the lower part of the chamber flows to the upper part of the chamber.

[0040] In some configurations, the energy storage device may include several storage chambers placed in series and/or parallel with valves and piping in between, including bypass-lines. This may allow an adaptation of the size of the active storage chamber to the present needs. For example, during charging, the flow of the heat transfer medium and thus the heating may be stopped for one chamber if the specific chamber has been fully charged. This allows the maintaining of a desired temperature gradient within each of the storage chambers.

[0041] In particular, the system may be configured such that during the charging cycle of a storage chamber, a temperature front travels through the heat storage material from the hot end to the cold end of the chamber. The temperature front is a zone of strong temperature gradient in the heat storage material, which separates the hot and the cold zones in the chamber. The charging of the respective storage chamber will preferably be stopped when the temperature at the cold end begins to rise above a predetermined temperature threshold. By using a plurality of chambers interconnected in series via valves and bypass-lines, during idling operations, i.e. between charging and discharging phases, the chambers can be disconnected from each other to prevent a mass flow between them initiated by natural convection. A valve may thus be provided for isolating a charged storage chamber from its neighboring storage chamber(s). Thus, mass flow caused by convection inside a heat storage chamber, which contains the temperature gradient, is limited to this single storage chamber.

[0042] The energy storage device may in particular be configured as described in the document EP3102796A1.

[0043] The heat source may include an (electrical) heater or a heat exchanger. The energy distribution system may further comprise the heat source, wherein the heat source is provided with energy from a renewable energy source. Such renewable energy source may for example be a wind turbine, a solar energy converter, or a hydro power plant. A solar energy converter may for example directly provide thermal energy for heating the heat transfer medium during the charging cycle. In other implementations, the renewable energy may first be converted to electricity, and the respective electricity may be used for heating the heat transfer medium during the charging cycle (via such electrical heater). It should be clear that in other implementations, the electricity for heating the heat transfer medium during the charging cycle may come from different sources.

[0044] In some embodiments, the energy distribution system may comprise the first and/or second heat consumer, e.g. a respective heat exchanger or the like, in particular when implementing a closed cycle for the respective heat consumer.

[0045] The charging/discharging flow path and in particular the common flow line may be implemented by respective pipes or other conduits through which the heat transfer medium may flow. Such pipes or conduits may in particular be heat insulated pipes or conduits, for example externally or internally insulated pipes or conduits. Heat losses during transportation of the heat transfer medium may thus be kept low.

[0046] According to a further embodiment of the invention, a method of distributing thermal energy to plural heat consumers by means of an energy distribution system is provided. The method comprises guiding a heat transfer medium from a heat source to an energy storage device along a charging flow path in order to transfer thermal energy from the heat source to the energy storage device to increase the amount of thermal energy stored in the energy storage device; and guiding the heat transfer medium from the energy storage device to heat consumers along a discharging flow path in order to transfer thermal energy from the energy storage device to the heat consumers. The charging and discharging flow paths are configured such that the heat transfer medium is at least partly transported along same passage through the energy storage device. The discharging flow path comprises at least one distribution flow path that includes at least a common flow line, a first outlet port on the common flow line, wherein the first outlet port provides the heat transfer medium to a first heat consumer, and a second outlet port on the common flow line, wherein the second outlet port provides the heat transfer medium to a second heat consumer. By means of such method, advantages similar to the ones outlined further above may be achieved.

[0047] In an embodiment, the method further comprises alternatingly operating the energy distribution system in a charging mode in which the heat transfer medium passes from the heat source to the energy storage device and in a discharging mode in which the heat transfer medium passes from the energy storage device to the first and second heat consumers. A simple but efficient storage and extraction of thermal energy may thus be implemented, which further benefits from low costs due to its reduced complexity. The system may further be operated in the above-mentioned partial charging mode, supported discharging mode, and direct heating mode. It may also be operated in an idle mode.

[0048] It should be clear that the method may be performed by the energy distribution system in any of the configurations described herein. Furthermore, any of the methods steps described herein with respect to the energy distribution system may form part of embodiments of the method.

[0049] It is to be understood that the features mentioned above and those yet to be explained below can be used not only in the respective combinations indicated, but also in other combinations or in isolation, without leaving the scope of the present invention. In particular, the features of the different aspects and embodiments of the invention can be combined with each other unless noted to the contrary.

BRIEF DESCRIPTION OF THE DRAWINGS

[0050] The forgoing and other features and advantages of the invention will become further apparent from the following detailed description read in conjunction with the accompanying drawings. In the drawings, like reference numerals refer to like elements.

Fig. 1 is a schematic diagram showing an energy distribution system according to an embodiment of the invention.

Fig. 2 is a schematic drawing showing an energy distribution system according to an embodiment of the invention.

Fig. 3 is a schematic diagram showing an energy distribution system according to an embodiment of the invention.

Fig. 4 is a schematic diagram showing an energy storage device according to an embodiment of the invention.

Fig. 5 is a schematic flow diagram illustrating a method according to an embodiment of the invention.

DETAILED DESCRIPTION

[0051] In the following, embodiments of the invention will be described in detail with reference to the accompanying drawings. It is to be understood that the following description of the embodiments is given only for the purpose of illustration and is not to be taken in a limiting sense.

[0052] It should be noted that the drawings are to be regarded as being schematic representations only, and elements in the drawings are not necessarily to scale with each other. Rather, the representation of the various elements is chosen such that their function and general purpose become apparent to a person skilled in the art. As used herein, the singular forms "a," "an," and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. The terms "comprising," "having," "including," and "containing" are to be construed as open-ended terms (i.e., meaning "including, but not limited to,") unless otherwise noted.

[0053] Fig. 1 schematically shows an energy distribution system 10 according to an embodiment. The energy distribution system 10 includes an energy storage device 20 that is configured to store thermal energy, i.e. energy in the form of heat. To deposit thermal energy in the storage device 20 when operating the system 10 in a charging mode, a heat source 31 heats a heat transfer medium (i.e. increases its temperature), which is transported along a charging flow path from the heat source 31 to the energy storage device 20. The heat transfer medium flows through the storage device 20 and transfers heat to a heat storage material 24 (see Fig. 4) of the energy storage device 20. In other words, the heat transfer medium heats up the heat storage material and is thus cooled down, so that it leaves the storage device 20 through a port 22 at lower temperature. The charging flow path is preferably implemented as a closed cycle, so that the heat transfer medium (short: medium) is cycled back to the heater 31 for again taking up thermal energy. The system 10 includes a blower 11 that transports or conveys the heat transfer medium.

[0054] The charging flow path accordingly includes a flow connection from an outlet of the heater 31 to a first port 21 (acting as an inlet) of storage device 20, a flow connection from the second port 22 (acting as an outlet) of storage device 20 to an inlet or suction side of the blower 11, and a flow connection from an outlet or blowing side of the blower 11 to an inlet of the heat source 31. The charging flow path is indicated with dashed arrows in Fig. 1. Heat transfer medium is thus conveyed in a closed cycle, wherein any medium that is lost may for example be replaced from a fresh air port 47.

[0055] For extracting stored thermal energy from the energy storage device 20 when operating the system 10 in a discharging mode, a discharging flow path 40 is provided, which is indicated by dotted arrows in Fig. 1. In the example of Fig. 1, heat transfer medium is transported (or pumped) by the blower 11 via the second port 22 (acting as an inlet) into the energy storage device 20, in which stored thermal energy is transferred to the heat transfer medium. The heat transfer medium flows through the energy storage device 20 and leaves device 20 through the first port 21 (acting as an outlet). The heated (or energized) heat transfer medium is then transported towards a heat consumer. The discharging flow path thus at least includes a flow connection from the blower 11 to the port 22 of energy storage device 20, and a flow connection from the first port 21 of the energy storage device 20 to the heat consumer(s).

[0056] System 10 may include a control unit that is configured to operate the energy distribution system 10 alternatingly in the charging mode and the discharging mode. It may further be configured to operate the system 10 in the above-mentioned partial charging mode, supported discharging mode and/or direct heating mode. For this purpose, controllable valves 15 may be provided that direct the flow of heat transfer medium either along the charging flow path (dashed arrows) or along the discharging flow path (dotted arrows) under control of the control unit. The control unit may further be configured to direct all or a fraction of heat transfer medium that has been energized by the heat source directly to the heat consumers by controlling respective valves, e.g. in combination with directing the flow of medium along the charging flow path or along the discharging flow path, in order to implement the further modes of operation. The valves may be controllable three-way valves, while other solutions are certainly conceivable. A three-way valve may for example direct the heat transfer medium from blower 11 either towards heater 31 (charging mode) or towards the storage device 20 (discharging mode). A further three-way valve may be provided downstream of heater 31 and direct the flow of heat transfer medium either towards the energy storage device 20, or may direct a flow of heat transfer medium from the energy storage device 20 towards the heat consumer(s). A further three-way valve 15 may direct heat transfer medium leaving the storage device 20 through port 22 towards the blower 11 (charging mode), or may direct heat transfer medium coming from blower 11 towards the second port 22 into the storage device 20 (discharging mode). A further valve may control the supply of additional heat transfer medium via port 47. It should be clear that implementations other than three-way valves are certainly possible, for example directional valves and simple on/off valves may be used.

[0057] A respective control unit configured to control valves 15 may include a microprocessor and memory, which stores control instructions which are executed by the processor and which alternatingly operate the system 10 in the charging mode and the discharging mode. Such processor may for example be a digital signal processor, an application specific integrated circuit (ASIC), a microprocessor or the like. The memory may include flash-memory, a hard disk drive, RAM, ROM, and other types of volatile and non-volatile memory. Such control unit may furthermore include input and output interfaces for controlling the valves 15 and for receiving sensor signals. As an example, the temperature in the energy storage device 20 may be monitored to determine when operation in a charging cycle is necessary or when the maximum amount of energy is stored. Likewise, it may determine the heat demand of heat consumers and operate the system 10 accordingly in a discharging mode to supply the respective thermal energy.

[0058] When heat demand is present while the storage device requires charging, it may operate the system in the partial charging mode to supply thermal energy from the heat source to both, the energy storage device and the heat consumers. If the heat demand of the consumers is larger than what can be supplied by discharging the storage device, then the system can be operated in the supported discharging mode in which thermal energy is additionally provided from the heat source to the consumers. The control unit may be further configured to select the operating mode based on economic considerations, such as the cost of energy.

[0059] The flow path of the heat transfer medium through the energy storage device 20 may substantially be the same for the charging flow path and the discharging flow path (although the heat transfer medium is transported in opposite directions). In particular, the same heat transfer medium may be employed in a charging flow path and the discharging flow path. Preferably, the heat transfer medium is air. The heat transfer medium is thus cost-efficient and can simply be replaced with air from the ambient environment. Likewise, as the energy storage device 20 does not require separate circuits for effecting a heat exchange between a charging and a discharging flow path, it is simple to implement and further cost-efficient. Further, it allows a simple up-scaling, so that substantial amounts of thermal energy can be stored.

[0060] The heat source 31 may for example include an electrical heater, a heat exchanger, or the like. Heat source 31 may in particular obtain energy from a renewable source, such as wind or solar power, hydro power and the like. As an example, a solar power plant may heat up a respective medium, which transfers its thermal energy to the heat transfer medium circulated along a charging flow path (e.g. via a respective heat exchanger). As another example, a wind power plant which may include one or more wind turbines produces electrical energy, which is transformed into thermal energy by means of a heater. Heat source 31 may accordingly include a respective heat exchanger or heater, which may form part of the system 10. Another possible implementation of the heat source 31 is a heat pump. It should be clear that thermal energy may also be obtained from other sources, such as a conventional power plant, waste heat from an industrial process or the like.

[0061] As indicated in Fig. 1, both for the charging flow path and the discharging flow path, the heat transfer medium passes in the same direction through the blower 11. Blower 11 thus needs to be operated only in one direction and allows an efficient transportation or conveyance of the heat transfer medium. It should be clear that in other configurations, two separate blowers may be provided, one for the charging flow path and one for the discharging flow path. Also, it is possible to provide redundant blowers or parallel blowers to increase the flow capacity.

[0062] In the embodiment of Fig. 1, the discharging flow path 40 includes at least one distribution flow path 41. Distribution flow path 41 includes a common flow line 45 that branches off towards the first outlet port 71 and a second outlet port 72. First outlet port 71 is configured to be coupled to a first heat consumer 51 and to provide heat transfer medium to the first heat consumer 51. Likewise, the second outlet port 72 is configured to be coupled to the second heat consumer 52 and to provide heat transfer medium to the second consumer 52. The first and second consumers 51, 52 are preferably industrial processes, and the heat transfer medium preferably provides process heat to these industrial processes. The distribution flow path 41 may comprise further outlet ports configured to provide process heat to further heat consumers in form of industrial processes. The discharging flow path can thus supply multiple consumers with process heat. These plural heat consumers can accordingly use thermal energy from the common energy storage device 20, which may thus also be termed central energy storage device, as it supplies from a central location.

[0063] The industrial processes are thus efficiently powered with thermal energy that has been produced by renewable sources. As the energy storage device 20 may store the thermal energy over a prolonged period of time, it can be charged with energy from a renewable source whenever such energy is available. The stored energy can then be provided in the form of heat to the respective heat consumers 51, 52 whenever a respective demand exists. Consequently, it is not necessary to power the respective industrial processes by small individual power units that have relatively low efficiency and that often consume fossil fuels. Renewable energy sources may thus be used more efficiently, and greenhouse gas emissions may be reduced.

[0064] The distribution flow path includes a branching point 75, at which a branching line branches off towards the first port 71. A further branching line leads from the branching point 75 to the second port 72. It should be clear that further outlet ports may be provided, and accordingly, further branching points and respective branching lines may be comprised in the distribution flow path. Furthermore, the branching point 75 may be located closer to the energy storage device 20, i.e. the common flow line 45 may be relatively short. The distribution flow path in the example of Fig. 1 in particular includes the common flow line 45 leading from the first port 21 (acting as an outlet) to the branching point 75, and the respective branching lines leading from the branching point 75 to the first and second ports 71, 72.

[0065] The flow conduits for flow lines may for example be provided by respective pipes or conduits, which are preferably insulated. They may be internally or externally insulated and may for example include a steel pipe with a thermal insulation layer.

[0066] It should be clear that the distribution flow path may comprise further elements. For example, shut-off valves 46 may be provided in each branch line in order to start and stop the supply of thermal energy to the heat consumer coupled to the respective outlet port. Such shut-off valves may be manually operated, or may be controlled, for example by the above-mentioned control unit of system 10.

[0067] Preferably, the energy distribution system 10 includes one or more temperature adjustment assemblies 60 in the distribution flow path. Each temperature adjustment assembly 60 may include a blower 67, a valve 68 and a junction at which it is connected to the distribution flow path. It may further include an inlet for ambient air. If the blower conveying the medium in the discharging flow path is arranged downstream of the heat consumer and implemented as a suction fan, the temperature adjustment assembly may not include a blower. Air may then be sucked in through the inlet by opening the valve of the temperature adjustment assembly.

[0068] Accordingly, by operating the blower 67 and controlling the valve 68, a controlled amount of environmental air can be sucked in through the air inlet and may be injected into the distribution flow path, where it mixes with the heat transfer medium. As the injected air is at ambient temperature, it is significantly cooler than the heat transfer medium, so that the temperature of the heat transfer medium can be lowered. The temperature of the heat transfer medium can thus be controlled and can be adjusted to the desired temperature. If the heat transfer medium is air, the composition of the heat transfer medium does furthermore not change. It should be clear that in other implementations, no air may be injected, but another type of fluid corresponding to the fluid implementing the heat transfer medium.

[0069] A temperature adjustment assembly may be provided at different positions along the distribution flow path, and plural such assemblies 60 can be provided. In the example of Fig. 1, a first temperature adjustment assembly 61 is provided in the branch line towards the first port 71, and a second assembly 62 is provided in the branch line towards the second port 72. The temperature of the heat transfer medium leaving the storage device 20 in the discharge mode is T_S. The temperatures at ports 71, 72 are then controlled such that they correspond to the desired temperatures T_A, T_B for the respective heat consumer 51, 52, wherein $T_A, T_B < T_S$. Energy distribution system 10 thus allows the providing of process heat to each of various consumers at an individual required temperature.

[0070] It should be clear that a temperature adjustment assembly 60 may be provided for each port of the distribution flow path, or only for selected ports. Furthermore, a temperature adjustment assembly 60 may be provided in the common flow line 45, thus adjusting the temperature for all downstream outlet ports. Also, it should be clear that in some implementations a feedback or feedforward control of the temperature may be employed. For this purpose, a temperature sensor may be placed upstream and/or downstream of the respective temperature adjustment assembly, and the amount of environmental air that is injected into the heat transfer medium may be controlled so as to achieve the desired temperature. Such control may for example be performed by the above-mentioned control unit of the energy distribution system 10.

[0071] In the example of Fig. 1, the discharging flow path 40 implements open cycles both for the first outlet port 71 and the second outlet port 72, i.e. the heat transfer medium given out through these ports is not returned. The given out heat transfer medium is replaced by fresh medium, in particular by ambient air, which is taken in through the fresh air port 47. Consequently, the system is relatively simple to implement, and leakages of the transfer medium into the environment are also not problematic, relaxing the technical requirements for the distribution system 10.

[0072] The heat transfer medium may be transported along the respective flow path at a pressure that is lower than 2 bar, preferably at a pressure that is close to the atmospheric pressure. The pressure may for example lie below 1.3 bar, for example between 0.8 and 1.2 bar.

[0073] The embodiment of Fig. 2 is a modification of the embodiment of Fig. 1, so that the above explanations are equally applicable. In addition to the first distribution flow path 41, the embodiment of Fig. 2 comprises a further distribution flow path 42. The second distribution flow path 42 includes the outlet ports 73, 74 which again branch off from a common line 45. Again, it should be clear that more or fewer outlet ports may be provided on the second distribution flow path 42. For each outlet port 73, 74, a respective temperature adjustment assembly 63, 64 is provided that operates as outlined above. Shut-off valves for stopping the flow of heat transfer medium through the respective port are furthermore provided.

[0074] Additional shut-off valves 46 are provided in the common flow lines of each of the first and second distribution flow paths 41, 42. Accordingly, each flow path may selectively be shut off and thus disconnected. This may for example be beneficial for maintenance operation or for stopping the supply of heat transfer medium to each of the consumers connected to the respective distribution flow path. Furthermore, each distribution flow path 41, 42 comprises a respective temperature adjustment assembly 65, 66. It thus becomes possible to independently adjust the temperature for each whole distribution flow path. This allows the implementation of a high temperature distribution and a medium or low temperature distribution of the thermal energy. As an example, the storage device 20 may discharge the heat transfer medium at a temperature T_S of about 600 to 800°C, e.g. 700°C. Temperature adjustment unit 65 may then adjust the temperature in the first distribution flow path 41 to a desired distribution temperature T_1, which may e.g. be about 200 to about 400°C. The assembly 66 in the second distribution flow path 42 may adjust the temperature of the heat transfer medium to a different distribution temperature T_2, which may be higher or lower, for example be a high temperature in the range of 400 to 600°C. The temperature in the respective distribution path is preferably chosen such that it is relatively close to the temperature required by the individual consumers connected to the respective distribution flow path. Consumers with similar temperature and/or timing requirements are therefore coupled to the same distribution flow path.

[0075] The embodiment of Fig. 2 furthermore allows the controlling of the individual temperatures T_A, T_B, T_C and T_D for each individual heat consumer 51 to 54 by the respective temperature adjustment assemblies 61 to 64.

[0076] Again, it should be clear that only selected outlet ports may be provided with a respective temperature adjustment assembly, and that for all or only for selected discharging flow paths, respective temperature adjustment assemblies may be provided.

[0077] Fig. 3 shows a further embodiment of the energy distribution system 10 that is a modification of the embodiment of Fig. 2, so that the above explanations are equally applicable. In the embodiment of Fig. 3, an at least partially closed cycle is implemented for the outlet port 74 and thus for the fourth consumer 54. The discharging flow path 40 includes a return path 48 that returns at least part of the heat transfer medium given out through port 74 towards the blower 11. While in some embodiments, the cycle may be fully closed, returning all of the heat transfer medium, it should be clear that some heat transfer medium may be lost in the heat consumer 54 so that only part of the heat transfer medium may be returned. Accordingly, thermal energy that remains in the heat transfer medium after passing the heat consumer 54 may be returned into the cycle, thus improving the energy efficiency of the energy distribution system. The heat consumer may for example implement a heat exchanger the outlet of which provides the medium to the return path 48. Such heat exchanger may form part of system 10.

[0078] In some embodiments, such closed cycle may be provided for at least one of the outlet ports. In other embodiments, no such closed cycle may be provided, or a closed cycle may be provided for each of the outlet ports. It should be clear that a respective closed cycle with a respective return path may be provided for each of the ports 71 to 74 shown in Figs. 1 or 2.

[0079] Fig. 4 illustrates an exemplary implementation of the energy storage device 20. It comprises a storage chamber 23 in which a heat storage material 24 is disposed. The storage chamber 23 may be formed by a housing with walls, yet it may also be formed by simply and excavation that is covered. The heat storage material may be a material that is capable of storing heat at higher temperature and that may be simple and cost-efficiently to obtain. Examples or rocks or stones, sand, bricks, granite, basalt, ceramics or the like. It should be clear that it may also include a mixture of such materials. Preferably, the material 24 comprises or consists of natural stones, artificial stones, sand, or a combination thereof. Chamber 23 is preferably thermally insulated. This may be achieved by a housing comprising insulated walls, or for example by a layer of earth or other insulating material when chamber 23 is implemented as an excavation.

[0080] To allow the flow of heat transfer medium through the energy storage device 20, flow channels or heat exchange channels may be provided in the material 24. Such channels may form naturally, for example by inter-spaces between stones making up the material 24. Alternatively, they may also be built into the material 24. Also, the material 24 may be porous, thus forming respective flow channels.

[0081] The energy storage device 20 includes a first port 21, which acts as an inlet during the charging mode (receiving hot air from the heater) and acts as an outlet during the discharging mode (exhausting hot transfer medium heated up by material 24). It further comprises a second port 22, which acts as an outlet during the charging mode (exhausting cooled-down heat transfer medium) or as an inlet during the discharging mode (receiving cold heat transfer medium). In operation during the charging mode, hot heat transfer medium enters port 21 at start to heat up the material 24 close to the port, the cooled-down transfer medium being exhausted. This causes a heat front to travel through the material 24 from the hot port 21 towards the cold port 22. When the temperature front reaches a position close to the second port 22, in particular when the temperature at the cold port begins to rise above a predetermined temperature threshold, the charging cycle is complete and the energy storage device 20 is fully charged. Such temperature front is a zone that includes a high temperature gradient in the heat storage material. Such front may separate the heat storage material into a hot zone and a cold zone.

[0082] The energy storage device 20 further includes nozzle sections 25 adjacent to the respective ports 21, 22. These nozzle sections have a tapered shape that extends between the respective port and the chamber.

[0083] In Fig. 4, the arrows indicate a flow direction of the heat transfer medium corresponding to the charging flow path. When operating in the discharging mode, the flow direction of the heat transfer medium is preferably reversed, so that these arrows would be reversed (in other embodiments, the flow direction may be kept the same). The heat transfer medium flows along essentially the same passages through the heat storage material 24 in both charging and discharging modes. Other configurations are conceivable. For example, to achieve a particular temperature distribution, plural first ports 21 and plural second ports 22 may be provided. Also it is conceivable that the ports used by the charging flow path are different from the ports used by the discharging flow path.

[0084] The energy storage device 20 may be configured as described further above, and may in particular be configured as disclosed in the document EP3102796A1.

[0085] Fig. 5 illustrates a flow diagram of a method of distributing thermal energy to plural heat consumers according to an embodiment. In step S1, the energy storage system 10 is operated in a charging mode by circulating heat transfer medium, in particular air, through the heat source 31 and the energy storage device 20. Operation in the charging mode may be stopped after a certain charging state has been achieved, after a predetermined amount of time, after receiving a demand for thermal energy, or in situations in which charging is no longer economically feasible (e.g. due to the cost of energy required for the charging). For example upon receiving a heat demand, the energy storage system 10 is operated in a discharging mode (step S2) in which the heat transfer medium is conveyed by blower 11 through the energy storage device 20 along a discharging flow path, wherein the medium passes through storage device 20 in reverse direction. The discharging flow path includes one, two or more distribution flow paths. To adjust the temperature of the heat transfer medium in the first and/or second distribution flow path 41, 42, a desired amount of ambient air is introduced into the respective distribution flow path, in particular by means of the temperature adjustment assemblies 65, 66 (step S3). It should be clear that this is optional, since the transfer medium may be distributed at temperature T_s. In step S4, a desired amount of ambient air is introduced into each branch line of the active outlet ports in order to adjust the temperature of the heat transfer medium for the heat consumer coupled to the respective outlet port. The temperature adjustment assemblies 61 to 64 may be employed for this purpose. As indicated above, some outlet ports may be shut-off, for example by using the shut-off valves 46. The heat transfer medium is then given out at the desired temperature through the respective outlet ports (step S5). In step S6, it is checked if the heat consumers still have a heat demand, and if the temperature of the energy storage device has dropped below a predetermined threshold (i.e. the temperature front in the storage device has moved close to the hot port 21). If there is no further heat demand, or the temperature has dropped below a threshold, the operation continues with step S1 in the charging mode in which thermal energy is again deposited in the heat storage device 20. It should be clear that operation in the charging mode does not need to start immediately, but may be started later, e.g. as desired by the operator. Charging may for example be started if excess energy is available that needs to be stored or if costs of energy are low enough. Otherwise in step S6, if a heat demand is still present and the storage device is not discharged yet, the operation continues in the discharging mode in which the heat consumers are supplied with thermal energy. It should be clear that the charging mode may be terminated prior to the energy storage device reaching a fully charged state (e.g. 100% charged), it may for example stop at a predetermined charging level. Likewise, discharging may not stop at a charging state of 0%, but may stop at a predetermined discharging level.

[0086] It should further be clear that steps S2 to S6 may be performed continuously and simultaneously in the discharging mode. It should further be clear that the system may operate alternatingly in the charging mode and the discharging mode and that it may furthermore operate in an idle mode in which no heat transfer medium flows through the energy storage device. The system may for example operate in the idle mode if the storage device 20 is fully charged and no heat demand exists, or if the idle mode is entered for economic reasons, e.g. due to the cost of energy. As indicated above, some of the steps are further optional, such as steps S3 and S4. Also, the heat consumers may not solely depend on energy supply from the energy distribution system, but may also be supplied with energy from a different source, e.g. from a backup supply.

[0087] It is further noted that in all of the above embodiments, the energy storage device 20 may comprise plural chambers, which may be connected in series or in parallel, for example to increase the energy storage capacity of device 20.

[0088] By the above embodiments, multiple consumers can be supplied from a common central heat source in form of the energy storage device 20. Due to the larger scale, this makes such type of energy supply technically feasible and economical. For example, multiple individual heat consumers, or even a full industry park may be supplied with thermal energy by the energy distribution system 10, wherein the thermal energy can be generated by renewable energy sources at any desired time, as it is stored and thus buffered. Although the energy storage device may operate at a fixed predetermined temperature, for example within a range of 600 to 800°C, the energy distribution system can supply the thermal energy at the temperature required by the respective consumer, and is thus capable of meeting individual heat requirements with respect to temperature, time and duration. The temperature adjustment assemblies provide a simple but efficient way of controlling the temperature for each consumer or along a whole distribution path. Although only employing one common source of thermal energy, a high degree of flexibility with regard to the providing of thermal energy can thus be achieved.

[0089] While specific embodiments are disclosed herein, various changes and modifications can be made without departing from the scope of the invention. The present embodiments are to be considered in all respects as illustrative and non-restrictive, and all changes coming within the meaning and equivalency range of the appended claims are intended to be embraced therein.

Claims

1. An energy distribution system, comprising:

   - an energy storage device (20) configured to store thermal energy;
   - a charging flow path (30) configured to guide a heat transfer medium from a heat source (31) to the energy storage device (20) in order to transfer thermal energy from the heat source (31) to the energy storage device (20) to increase the amount of thermal energy stored in the energy storage device (20),
   - a discharging flow path (40) configured to guide the heat transfer medium from the energy storage device (20) to heat consumers (51, 52) in order to transfer thermal energy from the energy storage device (20) to the heat consumers (51, 52), wherein the charging and discharging flow paths (30, 40) are configured such that the heat transfer medium is at least partly transported along same passage through the energy storage device (20),

   wherein the discharging flow path (40) comprises at least one distribution flow path (41) that includes at least a common flow line (45), a first outlet port (71) on the common flow line, the first outlet port (71) being configured to provide the heat transfer medium to a first heat consumer (51), and a second outlet port (72) on the common flow line, the second outlet port (72) being configured to provide the heat transfer medium to a second heat consumer (52).

2. The energy distribution system according to claim 1, wherein the first and/or second heat consumer (51, 52) is an industrial process, in particular a chemical process, an electro-chemical process, a physical process, a drying process, a melting process or a forging process.

3. The energy distribution system according to claim 1 or 2, wherein the heat transfer medium is a gaseous medium, in particular air.

4. The energy distribution system according to any of the preceding claims, wherein the distribution flow path (41) implements for at least one of the first and second outlet ports (71, 72) an open cycle in which heat transfer medium given out through the respective outlet port (71, 72) is replaced from a source.

5. The energy distribution system according to any of the preceding claims, wherein the distribution flow path (41) implements for at least one of the first and second outlet ports (71, 72) an at least partially closed cycle that is configured to return heat transfer medium provided through the respective outlet port (71, 72) at least partially back to the energy storage device (20).

6. The energy distribution system according to any of the preceding claims, wherein the distribution flow path (41) comprises a temperature adjustment assembly (60; 61-66) that is configured to adjust the temperature of the heat transfer medium, wherein preferably, the temperature adjustment assembly (60; 61-66) is coupled to the common flowline (45) to adjust the temperature of the heat transfer medium in the common flowline, or is coupled to the first or second outlet port (71, 72) to adjust the temperature of the heat transfer medium given out by the respective outlet port (71, 72).

7. The energy distribution system according to claim 6, wherein the temperature adjustment assembly (60; 61-66) comprises an inlet for receiving environmental air, a blower (67) configured to create a flow of the environmental air and a valve (68) arranged in a flow connection from the inlet to the respective flow path.

8. The energy distribution system according to any of the preceding claims, wherein the distribution flow path (41) is a first distribution flow path, wherein the discharging flow path (40) further comprises a second distribution flow path (42) that includes at least a common flow line (45), a third outlet port (73) on the common flow line, the third outlet port being configured to provide the heat transfer medium to a third heat consumer (53), and a fourth outlet port (74) on the common flow line, the fourth outlet port (74) being configured to provide the heat transfer medium to a fourth heat consumer (54).

9. The energy distribution system according to claims 6 and 8, wherein the temperature adjustment assembly (60) is provided at least for the first distribution flow path (41), and wherein the energy distribution system is configured to control the temperature adjustment assembly such that a temperature of the heat transfer medium in the first distribution flow path (41) is lower than a temperature of the heat transfer medium in the second distribution flow path (42), preferably at least 100K lower.

10. The energy distribution system according to any of the preceding claims, further comprising a blower (11) configured to create the flow of the heat transfer medium along the discharging flow path (40) through the energy storage device (20) and along the at least one distribution flow path (41).

11. The energy distribution system according to claim 10, wherein the blower (11) is further configured to create the flow of heat transfer medium along the charging flow path (30), wherein the system is preferably configured such that the flow direction of heat transfer medium through the blower (11) is the same for the charging flow path (30) and for the discharging flow path (40).

12. The energy distribution system according to any of the preceding claims, wherein the energy storage device (20) comprises an insulated storage chamber (23) and a heat storage material (24) disposed in the insulated storage chamber (23), wherein the heat storage material (24) forms flow channels and/or has open pores through which the heat transfer medium can flow.

13. The energy distribution system according to any of the preceding claims, further comprising the heat source (31), wherein the heat source (31) is provided with energy from a renewable energy source, in particular from a wind turbine, from a solar energy converter, and/or from a hydropower plant.

14. The energy distribution system according to any of the preceding claims, wherein the charging flow path (30) is configured to guide the heat transfer medium through the energy storage device (20) in a first flow direction and wherein the discharging flow path (40) is configured to guide the heat transfer medium through the energy storage device (20) in a second flow direction that is opposite to the first flow direction.

15. A method of distributing thermal energy to plural heat consumers (51, 52) by means of an energy distribution system (10), wherein the method comprises:

- guiding a heat transfer medium from a heat source (31) to an energy storage device (20) along a charging flow path (30) in order to transfer thermal energy from the heat source (31) to the energy storage device (20) to increase the amount of thermal energy stored in the energy storage device (20);
- guiding the heat transfer medium from the energy storage device (20) to heat consumers (51-54) along a discharging flow path (40) in order to transfer thermal energy from the energy storage device (20) to the heat consumers (51, 52), wherein the charging and discharging flow paths (30, 40) are configured such that the heat transfer medium is at least partly transported along same passage through the energy storage device (20),

wherein the discharging flow path (40) comprises at least one distribution flow path (41) that includes at least a common flow line (45), a first outlet port (71) on the common flow line, the first outlet port providing the heat transfer medium to a first heat consumer (51), and a second outlet port (72) on the common flow line, the second outlet port (72) providing the heat transfer medium to a second heat consumer (52).

16. The method according to claim 15, further comprising alternatingly operating the energy distribution system (10) in a charging mode in which the heat transfer medium passes from the heat source (31) to the energy storage device (20) and in a discharging mode in which the heat transfer medium passes from the energy storage device (20) to the first and second heat consumers (51, 52).

FIG 1

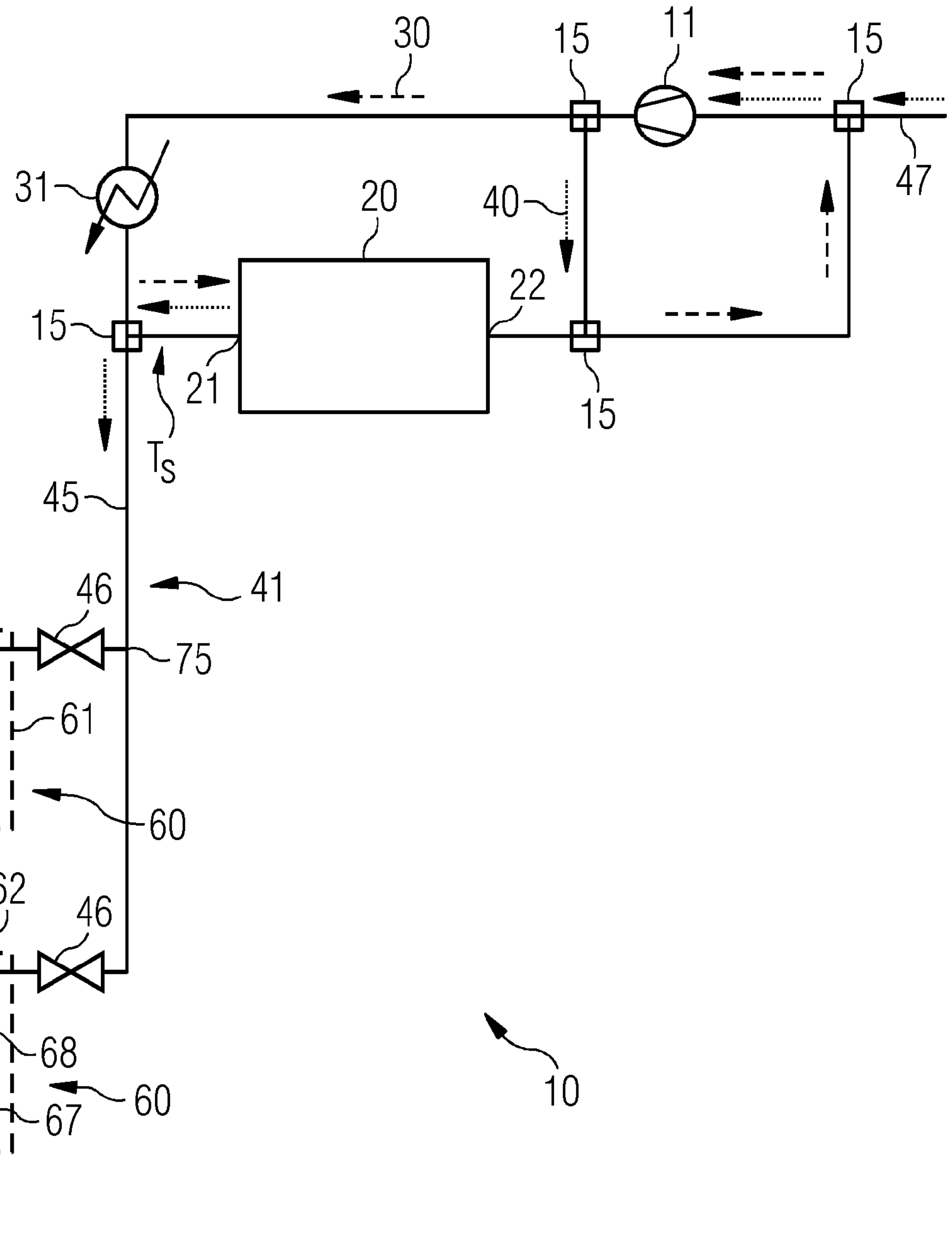
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FIG 2

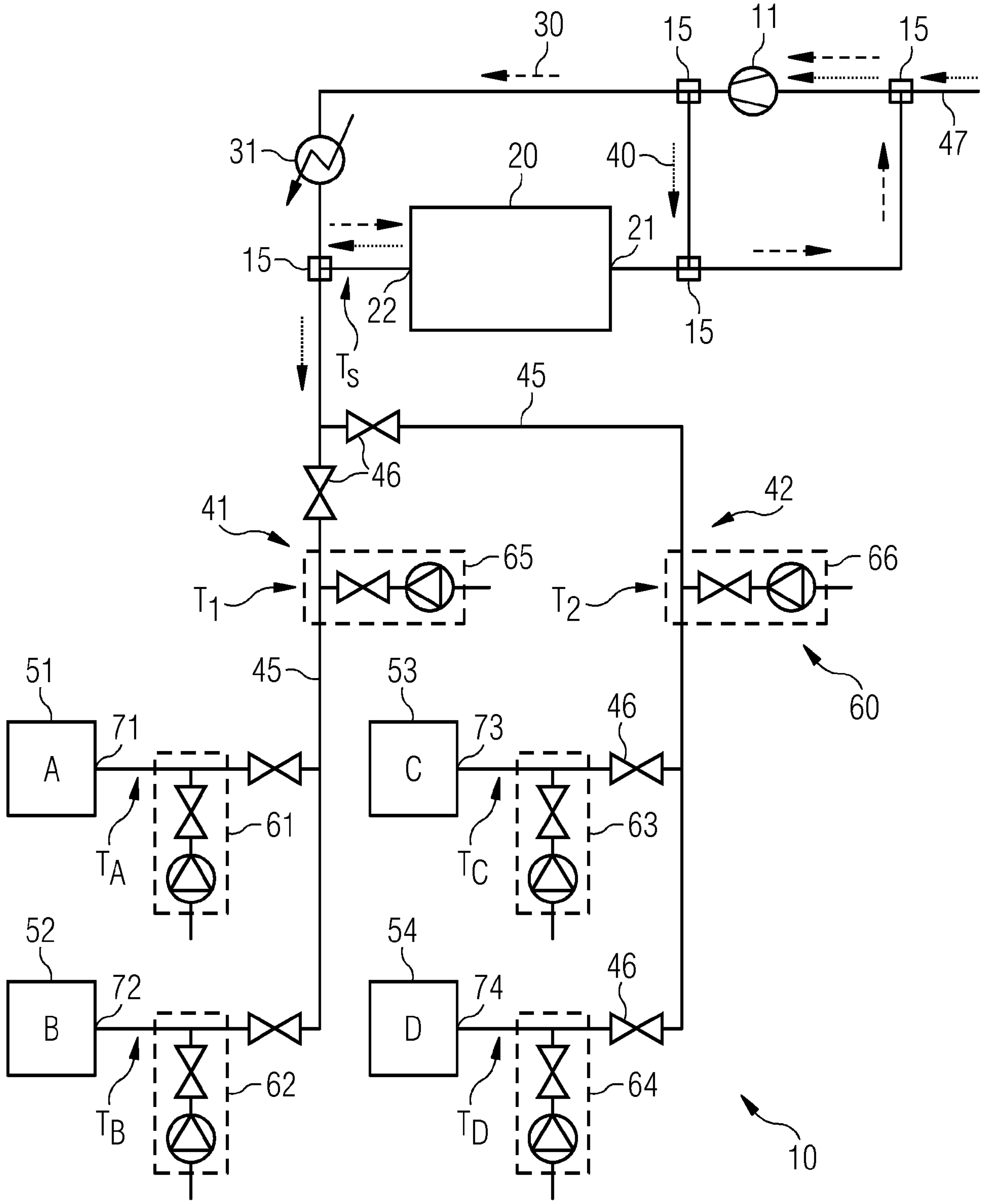
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FIG 3

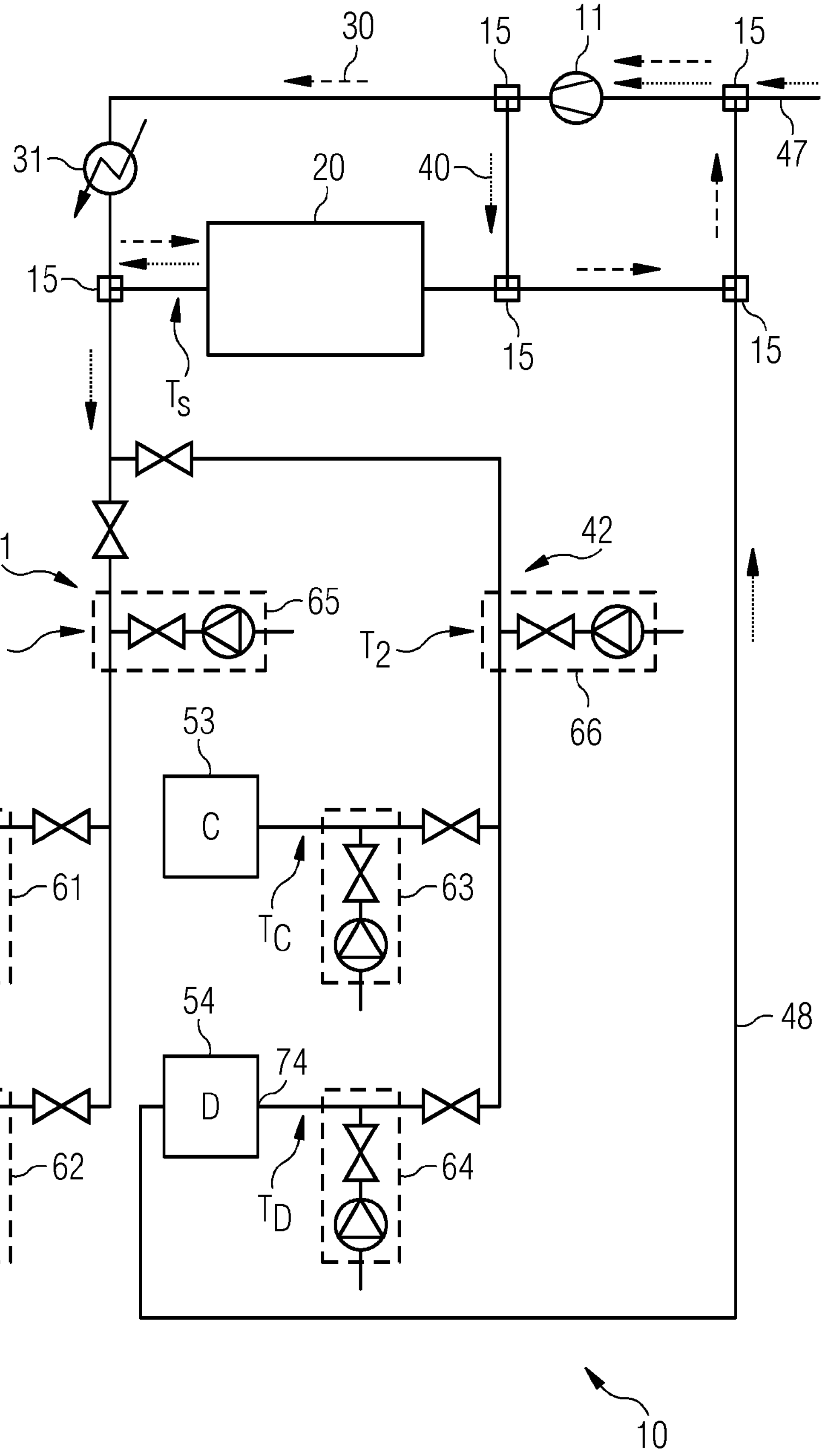
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FIG 4

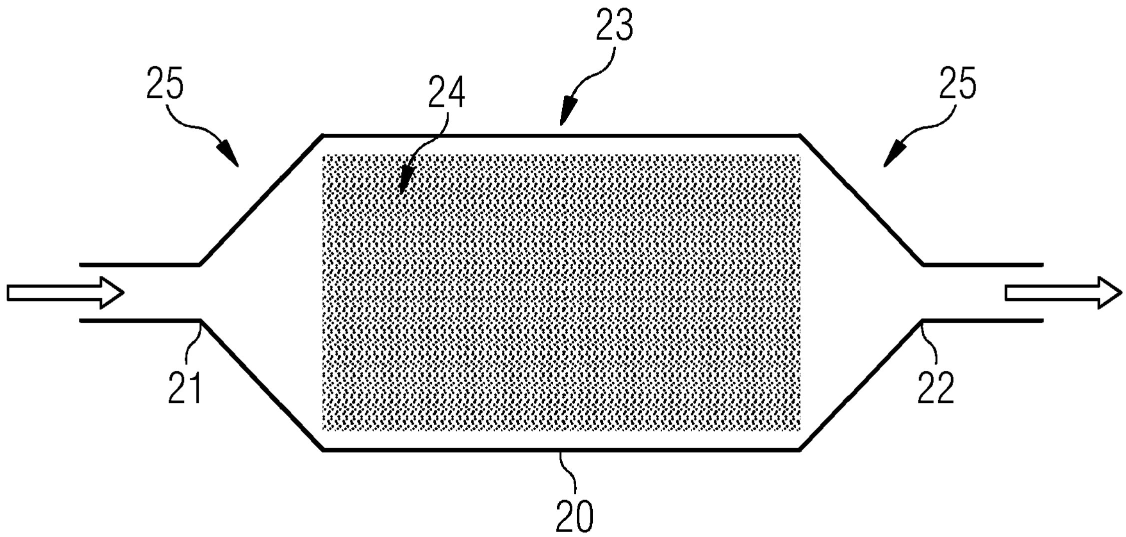
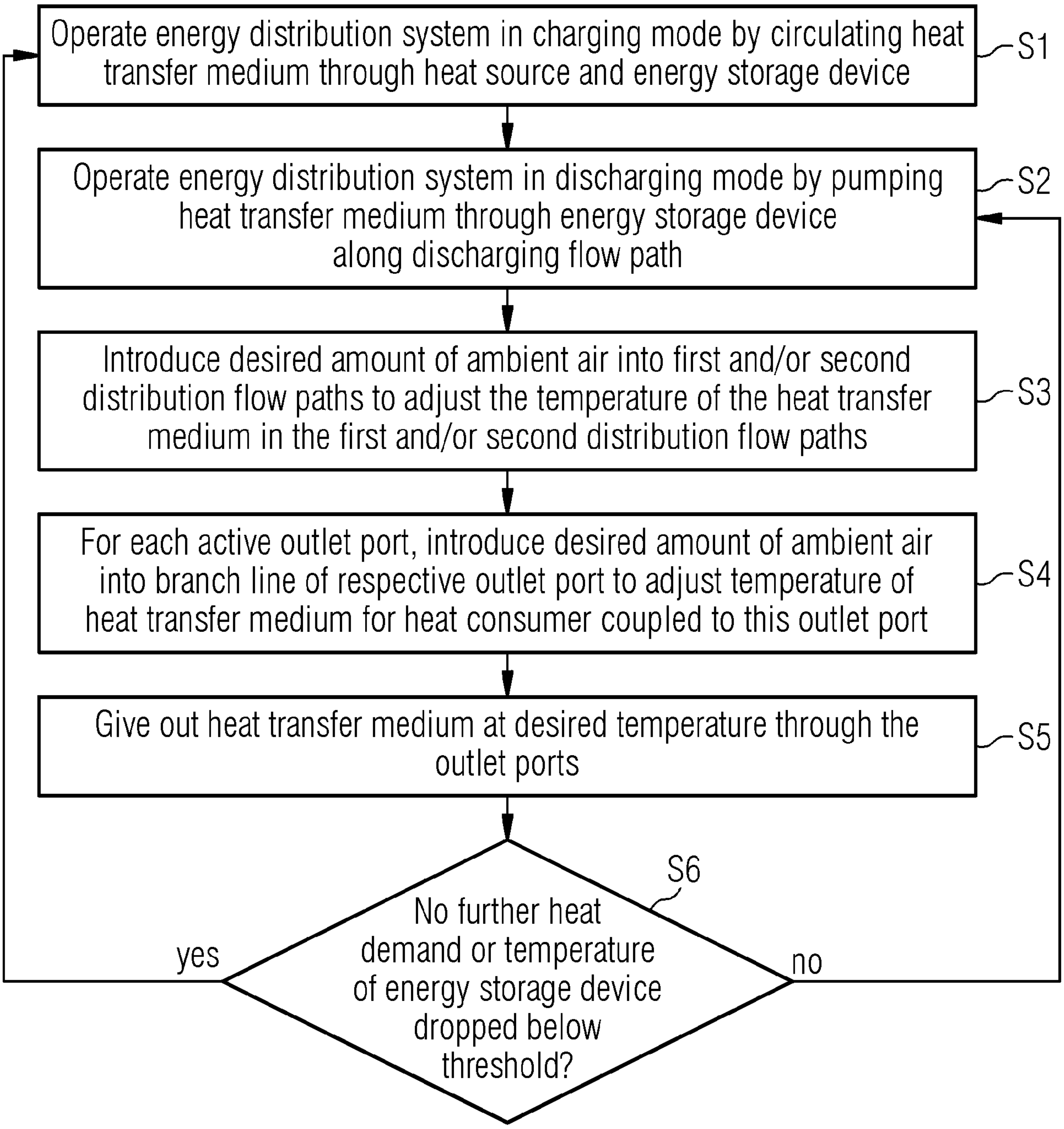


FIG 5


Operate energy distribution system in charging mode by circulating heat transfer medium through heat source and energy storage device
S1
Operate energy distribution system in discharging mode by pumping heat transfer medium through energy storage device along discharging flow path
S2
Introduce desired amount of ambient air into first and/or second distribution flow paths to adjust the temperature of the heat transfer medium in the first and/or second distribution flow paths
S3
For each active outlet port, introduce desired amount of ambient air into branch line of respective outlet port to adjust temperature of heat transfer medium for heat consumer coupled to this outlet port
S4
Give out heat transfer medium at desired temperature through the outlet ports
S5
S6
No further heat demand or temperature of energy storage device dropped below threshold?
yes
no

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EUROPEAN SEARCH REPORT

Application Number
EP 20 18 3438

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X Y A	US 4 094 148 A (NELSON HAZEN E) 13 June 1978 (1978-06-13) * column 2, line 54 - column 5, line 49; figure 1 * * column 6 * * column 6, line 27 - column 9, line 28 *	1-3,5,8, 10-16 4 6,7,9	INV. F01K3/18
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X	WO 2015/149124 A1 (GRAPHITE ENERGY N V [NL]) 8 October 2015 (2015-10-08) * page 18, line 19 - page 20, line 36; figure 14 *	1,5,6,8, 13,15	
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The present search report has been drawn up for all claims

2

Place of search	Date of completion of the search	Examiner
Munich	4 December 2020	Röberg, Andreas

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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