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(71) Applicant: **ABB Research Ltd.**
8050 Zürich (CH)

(72) Inventors:
- **Mercangoez, Mehmet**
  5405 Baden-Dättwil (CH)
- **Hemrle, Jaroslav**
  5405 Baden-Dättwil (CH)
- **Kaufmann, Lilian**
  8902 Urdorf (CH)

(74) Representative: **ABB Patent Attorneys**
C/o ABB Schweiz AG
Intellectual Property (CH-LC/IP)
Brown Boveri Strasse 6
5400 Baden (CH)

(54) Thermoelectric energy storage system having an internal heat exchanger and method for storing thermoelectric energy

(57) A thermoelectric energy storage system (TEES) and method for converting electrical energy into thermal energy to be stored and converted back to electrical energy with an improved round-trip efficiency are disclosed. The TEES comprises a working fluid circuit for circulating a working fluid through a first heat exchanger (18) and a second heat exchanger (20), a thermal storage medium circuit for circulating a thermal storage medium, the thermal storage medium circuit having at least one hot storage tank (24) coupled to a cold storage tank (22) via the first heat exchanger (18). The arrangement maximises the work performed by the cycle during charging and discharging for a given maximum pressure and maximum temperature of the working fluid. Advantageously, this maximises the round-trip efficiency of the system.

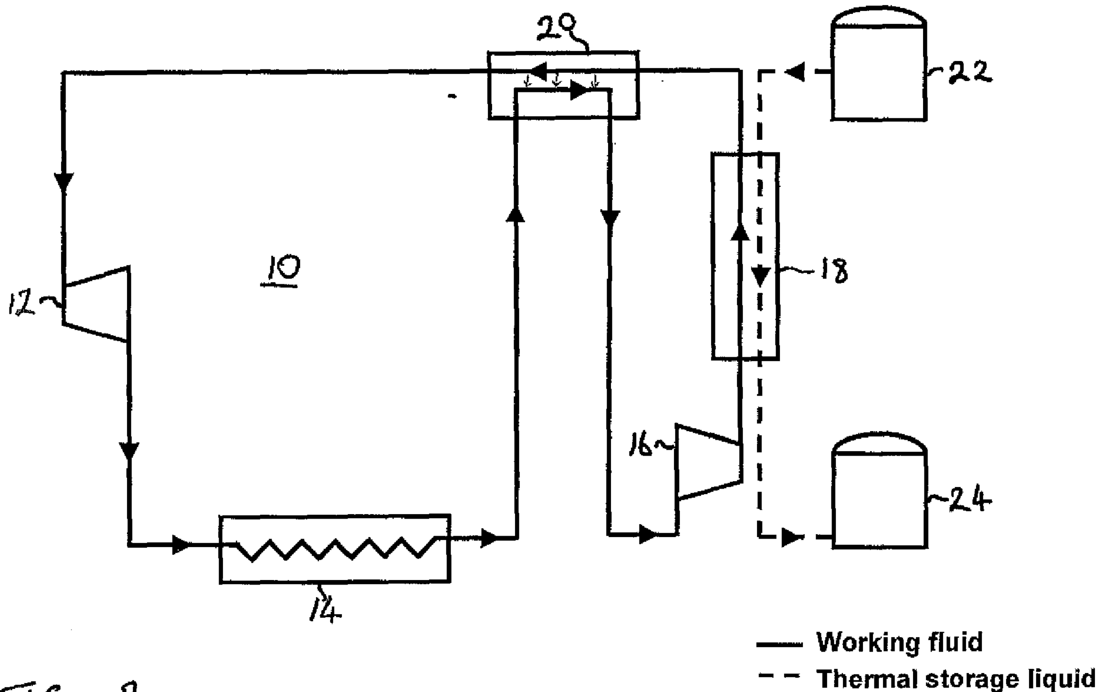

FIG. 2

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Description

FIELD OF THE INVENTION

[0001] The present invention relates generally to the storage of electric energy. It relates in particular to a system and method for storing electric energy in the form of thermal energy in thermal energy storage.

BACKGROUND OF THE INVENTION

[0002] Base load generators such as nuclear power plants and generators with stochastic, intermittent energy sources such as wind turbines and solar panels, generate excess electrical power during times of low power demand. Large-scale electrical energy storage systems are a means of diverting this excess energy to times of peak demand and balance the overall electricity generation and consumption.

[0003] In an earlier patent application EP1577548 the applicant has described the concept of a thermoelectric energy storage (TEES) system. A TEES converts excess electricity to heat in a charging cycle, stores the heat, and converts the heat back to electricity in a discharging cycle, when necessary. Such an energy storage system is robust, compact, site independent and is suited to the storage of electrical energy in large amounts. Thermal energy can be stored in the form of sensible heat via a change in temperature or in the form of latent heat via a change of phase or a combination of both. The storage medium for the sensible heat can be a solid, liquid, or a gas. The storage medium for the latent heat occurs via a change of phase and can involve any of these phases or a combination of them in series or in parallel.

[0004] The round-trip efficiency of an electrical energy storage system can be defined as the percentage of electrical energy that can be discharged from the storage in comparison to the electrical energy used to charge the storage, provided that the state of the energy storage system after discharging returns to its initial condition before charging of the storage. Thus, in order to achieve a high roundtrip efficiency, the efficiencies of both modes need to be maximized inasmuch as their mutual dependence allows.

[0005] It is important to point out that all electric energy storage technologies inherently have a limited round-trip efficiency. Thus, for every unit of electrical energy used to charge the storage, only a certain percentage is recovered as electrical energy upon discharge. The rest of the electrical energy is lost. If, for example, the heat being stored in a TEES system is provided through resistor heaters, it has approximately 40% round-trip efficiency. The roundtrip efficiency of the TEES system is composed of the charging efficiency and the discharging efficiency.

[0006] The roundtrip efficiency of the TEES system is limited for various reasons rooted in the second law of thermodynamics. The first reason relates to the coefficient of performance of the system. When the system is in the charging mode, its ideal efficiency is governed by the coefficient of performance (COP). The COP depends on the temperatures of the cold side (T_c) and the hot side (T_h) as given by

$$COP = \frac{T_h}{T_h - T_c}.$$

[0007] Thus, it can be seen that the COP of a heat pump declines with increased difference between input and output temperature levels. Secondly, the conversion of heat to mechanical work in a heat engine is limited by the Carnot efficiency. When the system is in the discharging mode, the efficiency (η) is given by

$$\eta = \frac{T_h - T_c}{T_h}.$$

[0008] Thus, it can be seen that efficiency increases when the cold side temperature decreases. Thirdly, any heat flow from a working fluid to a thermal storage and vice versa requires a temperature difference in order to happen. This fact inevitably degrades the temperature level and thus the capability of the heat to do work.

[0009] It is noted that many industrial processes involve provision of thermal energy and storage of the thermal energy. Examples are refrigeration devices, heat pumps, air conditioning and the process industry. In solar thermal power plants, heat is provided, possibly stored, and converted to electrical energy. However, all these applications are distinct from TEES systems because they are not concerned with heat for the exclusive purpose of storing electricity.

[0010] It is noted that the charging cycle of a TEES system is also referred to as a heat pump cycle and the discharging cycle of a TEES system is also referred to as a heat engine cycle. In the TEES concept, heat needs to be transferred from a hot working fluid to a thermal storage medium during the charging cycle and back from the thermal storage medium to the working fluid during the discharging cycle. A heat pump requires work to move thermal energy from a cold source to a warmer heat sink. Since the amount of energy deposited at the hot side, i.e. the thermal storage medium part of a TEES, is greater than the compression work by an amount equal to the energy taken from the cold side, i.e. the heat absorbed by the working fluid at the low pressure, a heat pump deposits more heat per work input to the hot storage than resistive heating. The ratio of heat output to work input is called coefficient of performance, and it is a value larger than one. In this way, the use of a heat pump will increase the round-trip efficiency of a TEES system.

[0011] The charging cycle of a known TEES system comprises a work recovering expander, an evaporator, a compressor and a heat exchanger, all connected in series by a working fluid circuit. Further, a cold storage tank and a hot storage tank containing a fluid thermal storage medium are coupled together via the heat exchanger. Whilst the working fluid passes through the evaporator, it absorbs heat from the ambient or from a thermal bath and evaporates. The discharging cycle of a known TEES system comprises a pump, a condenser, a turbine and a heat exchanger, all connected in series by a working fluid circuit. Again, a cold storage tank and a hot storage tank containing a fluid thermal storage medium are coupled together via the heat exchanger. Whilst the working fluid passes through the condenser, it exchanges heat energy with the ambient or the thermal bath and condenses. The same thermal bath, such as a river, a lake or a water-ice mixture pool, is used in both the charging and discharging cycles.

[0012] Figure 1 shows an enthalpy-pressure diagram of the heat transfer from the cycles in a known TEES system. The solid line quadrangle shows both the charging and discharging cycles. The charging cycle can be considered to start at the lower left corner (indicated as I) and follows an anti-clockwise direction. Point I corresponds to the working fluid state before receiving heat from the evaporator 14. Generally, the temperature of the working fluid in this state is approximately -5°C to 10°C. The working fluid is evaporated at constant pressure and temperature to reach point II of Figure 1. The working fluid is then compressed isentropically to the state shown as point III. The temperature of the working fluid in this state is approximately 90°C to 120°C. In this state, the pressure of the working fluid may be up to the order of 20MPa due to the proximity to the critical point. Heat from the working fluid is transferred in an isobaric process between points III and IV to the thermal storage medium in a counter-current flow heat exchanger. The working fluid is then expanded between points IV and I, in an isentropic expansion device, which enables recovery of the energy contained in the pressurized working fluid.

[0013] During discharging the heat transfer cycle of Figure 1 follows a clockwise direction and the transition between points I to VI is carried out with the pump 28. Further, during discharging the transition between points II to III is carried out in the turbine 32.

[0014] The skilled person will be aware that the relative positions of the state points indicated with circles in Figure 1 are illustrative and can be modified to overcome practical issues implied by the specific thermodynamic machines.

[0015] There is a need to provide an efficient thermoelectric energy storage having a high roundtrip efficiency, whilst minimising the system costs involved.

DESCRIPTION OF THE INVENTION

[0016] It is an objective of the invention to provide a thermoelectric energy storage system for converting electrical energy into thermal energy to be stored and converted back to electrical energy with an improved round-trip efficiency. This objective is achieved by a thermoelectric energy storage system according to claim 1 and a method according to claim 6. Preferred embodiments are evident from the dependent claims.

[0017] According to a first aspect of the invention, a thermoelectric energy storage system is provided which has a charging cycle for providing thermal energy to a thermal storage, and a discharging cycle for generating electricity by retrieving the thermal energy from the thermal storage. The thermoelectric energy storage system comprises a working fluid circuit for circulating a working fluid through a first heat exchanger and a second heat exchanger, a thermal storage medium circuit for circulating a thermal storage medium. The thermal storage medium circuit has at least one hot storage tank coupled to a cold storage tank via the first heat exchanger. During a charging cycle, the second heat exchanger further cools the working fluid at the output of the first heat exchanger, and the amount of heat energy stored in the thermal storage medium is adjusted to ensure similar thermal storage medium temperatures during the charging cycle and discharging cycle. During a discharging cycle, the second heat exchanger pre-heats the working fluid at the input into the first heat exchanger, and the amount of heat energy extracted from the thermal storage medium is adjusted to ensure similar thermal storage medium temperatures during the charging cycle and discharging cycle.

[0018] In other words, the amount of heat energy stored is tuned such that the thermal storage medium temperature in the hot storage tank is approximately the same during charging and discharging, and that the thermal storage medium temperature in the cold storage tank is approximately the same during charging and discharging. In an exemplary embodiment, the temperature in the hot storage tank is 120° C and the temperature in the cold storage tank is 10° C.

[0019] Advantageously, the present invention utilises low cost storage materials and the first and second heat exchangers operate at a high efficiency.

[0020] The thermal storage medium is a liquid, and is preferably water. The working fluid of the present invention is preferably carbon dioxide.

[0021] In a preferred embodiment, during the charging cycle, the second heat exchanger comprises; a first input from the first heat exchanger connected to a first output leading to an expander, and a second input from a condenser connected to a second output leading to a compressor.

[0022] In a further preferred embodiment, during the discharging cycle, the second heat exchanger comprises; a first input from a pump connected to a first output leading to the first heat exchanger, and a second input from a thermodynamic machine connected to a second output leading to a condenser.

[0023] In a preferred embodiment of the present invention, at least one section of a charging cycle or a discharging cycle runs transcritically.

[0024] In an alternative embodiment of the present invention, either the charging cycle or the discharging cycle may run without the second heat exchanger.

[0025] In a second aspect of the present invention a method is provided for storing and retrieving energy in a thermoelectric energy storage system. The method comprises charging the system by heating a thermal storage medium, wherein the thermal storage medium circulates between at least one hot storage tank coupled to a cold storage tank, and discharging the system by heating a working fluid in a working fluid circuit with heat from the thermal storage medium and expanding the working fluid through a thermodynamic machine. The method further comprises cooling further the working fluid output from a first heat exchanger during charging to enable the amount of heat energy stored in the thermal storage medium to be adjusted to ensure similar thermal storage medium temperatures during the charging cycle and discharging cycle, and pre-heating the working fluid input into the first heat exchanger during discharging to enable the amount of heat energy extracted from the thermal storage medium to be adjusted to ensure similar thermal storage medium temperatures during the charging cycle and discharging cycle.

[0026] Advantageously, the minimization of the temperature difference between the charging and discharging of the thermal storage medium in the hot tank and the cold tank results in a higher round-trip efficiency of the system.

[0027] In a preferred embodiment, the step of cooling further the working fluid output from the first heat exchanger during charging further comprises transferring heat from the working fluid exiting the first heat exchanger to the working fluid output from an evaporator.

[0028] In a preferred embodiment, the step of pre-heating the working fluid input into the first heat exchanger during discharging further comprises transferring heat from the working fluid exiting the thermodynamic machine to the working fluid input into the first heat exchanger. The skilled person will be aware that the thermodynamic machine may also be referred to as a turbine.

[0029] In a further preferred embodiment, at least one section of a charging cycle or a discharging cycle is performed transcritically.

[0030] In a alternative embodiment of the present invention either the charging cycle or the discharging cycle runs without the second heat exchanger.

[0031] Advantageously, the present invention minimises the amount of heat energy required for the adjustment of storage medium temperatures for charging and discharging, thereby minimising the size of the thermal storage required.

[0032] The present invention maximises the work performed by the cycle during charging and discharging for a given maximum pressure and maximum temperature of the working fluid at point IV, Figure 4 in the cycle. Advantageously, this maximises the round-trip efficiency of the system.

[0033] Further advantage is obtained in the high power density of the system.

BRIEF DESCRIPTION OF THE DRAWINGS

[0034] The subject matter of the invention will be explained in more detail in the following text with reference to preferred exemplary embodiments, which are illustrated in the attached drawings, in which:

Figure 1 shows an enthalpy-pressure diagram of the heat transfer from the cycles in a known TEES system;

Figure 2 shows a simplified schematic diagram of a charging cycle of a thermoelectric energy storage system in accordance with the present invention;

Figure 3 shows a simplified schematic diagram of a discharging cycle of a thermoelectric energy storage system in accordance with the present invention;

Figure 4 shows an enthalpy-pressure diagram of the heat transfer from the cycles in a TEES system of the present invention having an internal heat exchanger.

[0035] For consistency, the same reference numerals are used to denote similar elements illustrated throughout the figures.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0036] Figures 2 and 3 schematically depict a charging cycle system and a discharging cycle system, respectively, of a TEES system in accordance with an embodiment of the present invention.

[0037] The charging cycle system 10 shown in Figure 2 comprises a work recovering expander 12, an evaporator 14, a compressor 16, a high temperature heat exchanger 18, and an internal heat exchanger 20. A working fluid circulates through the components as indicated by the solid line with arrows in Figure 2. Notably, both the output from the evaporator 14 and the output from the high temperature heat exchanger 18 are passed through the internal heat exchanger 20. Further, a cold storage tank 22 and a hot storage tank 24 containing a liquid thermal storage medium are coupled together via the heat exchanger 18. The thermal storage liquid flows between the cold storage tank 22 and the hot storage tank 24 as indicated by the dashed line with arrows.

[0038] In operation, the charging cycle system 10 performs a thermodynamic cycle and the working fluid flows around the TEES system in the following manner. The vaporized working fluid exiting the evaporator 14 is circulated to the compressor 16 via the internal heat exchanger 20. The surplus electrical energy which is to be stored is utilized to compress and heat the working fluid in the compressor 16. When exiting the compressor 16, the working fluid is at the highest temperature and pressure of the cycle. The working fluid is fed through the high temperature heat exchanger 18 where the working fluid discards heat into the thermal storage medium.

[0039] The compressed working fluid exits the heat exchanger 18 and enters the internal heat exchanger 20, where the remaining heat is transferred out of the compressed working fluid and into the working fluid at the outlet of the evaporator 14. The cooled working fluid then enters the expander 12. Here the working fluid is expanded to a lower pressure which corresponds to the evaporator inlet pressure. The working fluid flows from the expander 12 back into the evaporator 14.

[0040] The fluid thermal storage medium is pumped from the cold storage tank 22 through the heat exchanger 18 to the hot storage tank 24. The heat energy discarded from the working fluid into the thermal storage medium is stored in the form of sensible heat.

[0041] The discharging cycle system 26 shown in Figure 3 comprises a pump 28, a condenser 30, a turbine 32, a high temperature heat exchanger 18, and an internal heat exchanger 20. A working fluid circulates through these components as indicated by the dotted line with arrows in Figure 3. Further, a cold storage tank 22 and a hot storage tank 24 containing a fluid thermal storage medium are coupled together via the high temperature heat exchanger 18. The thermal storage medium, represented by the dashed line in Figure 3, is pumped from the hot storage tank 24 through the heat exchanger to the cold storage tank 22.

[0042] In operation, the discharging cycle system 26 performs a thermodynamic cycle reversing the charging cycle and the working fluid flows around the TEES system in the following manner. The working fluid in liquid form is pumped to a high pressure by pump 28. The working fluid then enters the internal heat exchanger 20, where it is preheated by the working fluid leaving the turbine 32. The working fluid then continues to the high temperature heat exchanger 18 in which heat energy is transferred from the thermal storage medium to the working fluid and the working fluid reaches its highest temperature level in the cycle. The working fluid then exits the high temperature heat exchanger 18 and enters the turbine 32 where the working fluid is expanded thereby causing the turbine 32 coupled to a generator (not illustrated) to generate electrical energy.

[0043] Next, the working fluid enters the condenser 30, where the working fluid is condensed by exchanging heat energy with a further thermal storage medium (not illustrated). The condensed working fluid exits the condenser 30 via an outlet and is pumped again into the internal heat exchanger 20 via the pump 28.

[0044] Whilst the charging cycle system of Figure 2 and the discharging cycle system of Figure 3 have been illustrated separately, the internal heat exchanger 20, the condenser 14, 30, the high temperature heat exchanger 18, cold storage tank 22, hot storage tank 24 and thermal storage medium are common to both. The condenser 14, 30 may be common to both the charging and discharging cycle systems. The charging and discharging cycles may be performed consecutively, not simultaneously.

[0045] In the present embodiment, the high temperature heat exchanger is a counterflow heat exchanger, and the working fluid of the cycle is preferably carbon dioxide. The internal heat exchanger is a counter-flow heat exchanger. Further, the thermal storage medium is a liquid, and is preferably water. The compressor of the present embodiment is an electrically powered compressor.

[0046] The thermodynamic cycle of the present invention includes heat exchange in a subcritical range as well as in a supercritical range; therefore the process follows a transcritical cycle.

[0047] Figure 4 shows an enthalpy-pressure diagram of the heat transfer from the cycles in a TEES system of the present invention having an internal heat exchanger. The solid line quadrangle shows both the charging and discharging cycles. The charging cycle can be considered to start at the lower left corner (indicated as I) and follows an anti-clockwise direction. Point I corresponds to the working fluid state before receiving heat from the evaporator 14. Generally, the temperature of the working fluid in this state is approximately -5°C to 10°C. The working fluid is evaporated at constant pressure and temperature to reach point II of Figure 4. The working fluid is then heated in the internal heat exchanger 20 to reach point III. The working fluid is then compressed isentropically to the state shown as point IV. The temperature of the working fluid in this state is approximately 100°C to 180°C. In this state, the pressure of the working fluid may be up to the order of 20MPa due to the proximity to the critical point. Heat from the working fluid is transferred in an isobaric process between points IV and V to the thermal storage medium in a counter-current flow heat exchanger. The residual heat in the working fluid is discarded in the internal heat exchanger, shown from points V to VI. This residual heat provides the heat energy used to heat the working fluid between points II and III. The working fluid is then expanded between points VI and I, in an isentropic expansion device, which enables recovery of the stored energy.

[0048] During discharging the heat transfer cycle of Figure 4 follows a clockwise direction, and the transition between points I to IV is carried out with the pump 28. Further, during discharging the transition between points III to IV is carried out in the turbine 32.

[0049] The skilled person will be aware that the relative positions of the state points indicated with circles in Figure 4 are illustrative and can be modified to overcome practical issues implied by the specific thermodynamic machines.

[0050] The TEES system with an internal heat exchanger within the working fluid circuit advantageously facilitates matching of the charging and discharging modes of operation. Such matching is required in order to achieve a high degree of reversibility. In the present TEES system, the degree of reversibility (heat loss minimization) depends on the inlet and outlet temperatures of the working fluid stream entering and exiting the high temperature heat exchanger (with the thermal storage medium).

[0051] Thus, the operating temperatures of the TEES system in the charging mode of operation are chosen to ensure that the minimum required amount of heat at the minimum required temperature range is stored in the thermal storage medium to enable operation of the discharging mode. Therefore, in the charging cycle, the temperature of the working fluid stream leaving the high temperature heat exchanger and entering the internal heat exchanger should be chosen according to this minimizing condition. Similarly, in the discharging cycle, *the superheat* remaining in the working fluid stream leaving the turbine should be used to the maximum extent for preheating the working fluid stream entering the high temperature heat exchanger. In this way, the amount of heat energy needed from the thermal storage medium is minimized, which in turn will minimize the volume of thermal storage medium required. The operating temperatures of the internal heat exchanger are then determined based on the combined conditions from charging and discharging modes of operation. The size of the internal heat exchanger may be chosen to accommodate the larger of the heat energy loads from the charging mode and the discharging mode.

[0052] The use of such an internal heat exchanger may be referred to as a "regenerative TEES scheme". The regenerative charging and discharging cycles may be considered to result in two competing effects, in both the charging and discharging modes of operation. In the charging mode of operation, the positive effect is the increased heat input via the evaporator 14 and the negative effect is the increased compression work due to higher compressor inlet temperature. It should be noted that the evaporator 14 takes heat from a low temperature heat source, such as ice or cold water, and therewith evaporates working fluid passing through the evaporator. In the discharging mode of operation, the positive effect is the increased heat input to the high pressure side of the system and the negative effect is the loss of recovered work due to extraction of a portion of the working fluid vapor from a lower pressure stage of the system. For transcritical carbon dioxide cycles the positive effects outweigh the negative ones and such regenerative operation results in a net gain of efficiency.

[0053] In an alternative embodiment of the present invention, the internal heat exchanger 20 may be used either during the charging mode or the discharging mode, and bypassed during the other mode. Such an embodiment is dependent upon the operating conditions and relative temperatures of the evaporator 14 and condenser 30.

[0054] In a further alternative embodiment, the size and type of internal heat exchanger 20 may be varied dependent upon the specific TEES design. For instance, if an additional low grade waste heat source is available, the charging cycle may be modified, and the properties of the internal heat exchanger would have to be readapted in order to ensure a high degree of reversibility with minimal heat loss.

[0055] Whilst the thermal storage medium is generally water (if necessary, in a pressurized container), other materials, such as oil or molten salt, may also be used.

[0056] The skilled person will be aware that the condenser and the evaporator in the TEES system may be replaced with a multi-purpose heat exchange device that can assume both roles, since the use of the evaporator in the charging cycle and the use of the condenser in the discharging cycle will be carried out in different periods. Similarly the turbine and the compressor roles can be carried out by the same machinery, referred to herein as a thermodynamic machine, capable of achieving both tasks.

Claims

1. A thermoelectric energy storage system having a charging cycle (10) for providing thermal energy to a thermal storage, and a discharging cycle (26) for generating electricity by retrieving the thermal energy from the thermal storage, the thermoelectric energy storage system comprising;
a working fluid circuit for circulating a working fluid through a first heat exchanger (18) and a second heat exchanger (20),
a thermal storage medium circuit for circulating a thermal storage medium, the thermal storage medium circuit having at least one hot storage tank (24) coupled to a cold storage tank (22) via the first heat exchanger (18),
wherein, during a charging cycle (10), the second heat exchanger (20) further cools the working fluid at the output of the first heat exchanger (18).
wherein, during a discharging cycle (26), the second heat exchanger (20) pre-heats the working fluid at the input into the first heat exchanger (18).

2. The system according to claim 1, wherein, during the charging cycle (10), the second heat exchanger (20) comprises;
a first input from the first heat exchanger (18) connected to a first output leading to an expander (12), and
a second input from a condenser (14) connected to

a second output leading to a compressor (16).

3. The system according to claim 1, wherein, during the discharging cycle (26), the second heat exchanger (20) comprises;
a first input from a pump (28) connected to a first output leading to the first heat exchanger (18), and a second input from a thermodynamic machine (32) connected to a second output leading to a condenser (30).

4. The system according to any preceding claim, wherein at least one section of a charging cycle or a discharging cycle runs transcritically.

5. The system according to any preceding claim, wherein either the charging cycle (10) or the discharging cycle (26) runs without the second heat exchanger (20).

6. A method for storing and retrieving energy in a thermoelectric energy storage system, comprising;
charging the system by heating a thermal storage medium, wherein the thermal storage medium circulates between at least one hot storage tank (24) coupled to a cold storage tank (22),
discharging the system by heating a working fluid in a working fluid circuit with heat from the thermal storage medium and expanding the working fluid through a thermodynamic machine (32),
cooling further the working fluid output from a first heat exchanger (18) during charging, and
pre-heating the working fluid input into the first heat exchanger (18) during discharging.

7. The method according to claim 6, wherein the step of cooling further the working fluid output from the first heat exchanger (18) during charging, further comprises; transferring heat from the working fluid exiting the first heat exchanger (18) to the working fluid output from an evaporator (14).

8. The method according to claim 6, wherein the step of pre-heating the working fluid input into the first heat exchanger (18) during discharging, further comprises;
transferring heat from the working fluid exiting the thermodynamic machine (32) to the working fluid input into the first heat exchanger (18).

9. The method according to any of claim 6 to claim 8, wherein at least one section of a charging cycle or a discharging cycle is performed transcritically.

10. The method according to any of claim 6 to claim 9, wherein either the charging cycle (10) or the discharging cycle (26) runs without the second heat exchanger (20).

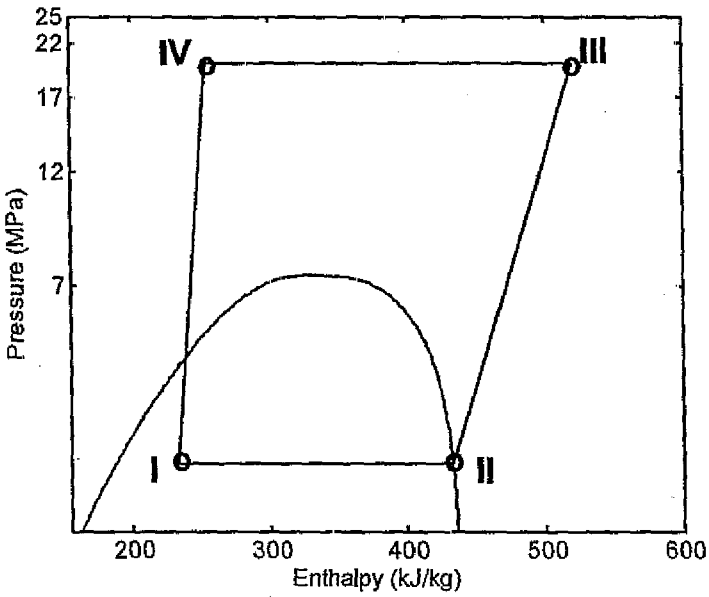
25
22
17
12
7
Pressure (MPa)
IV
III
I
II
200
300
400
500
600
Enthalpy (kJ/kg)

FIG. 1

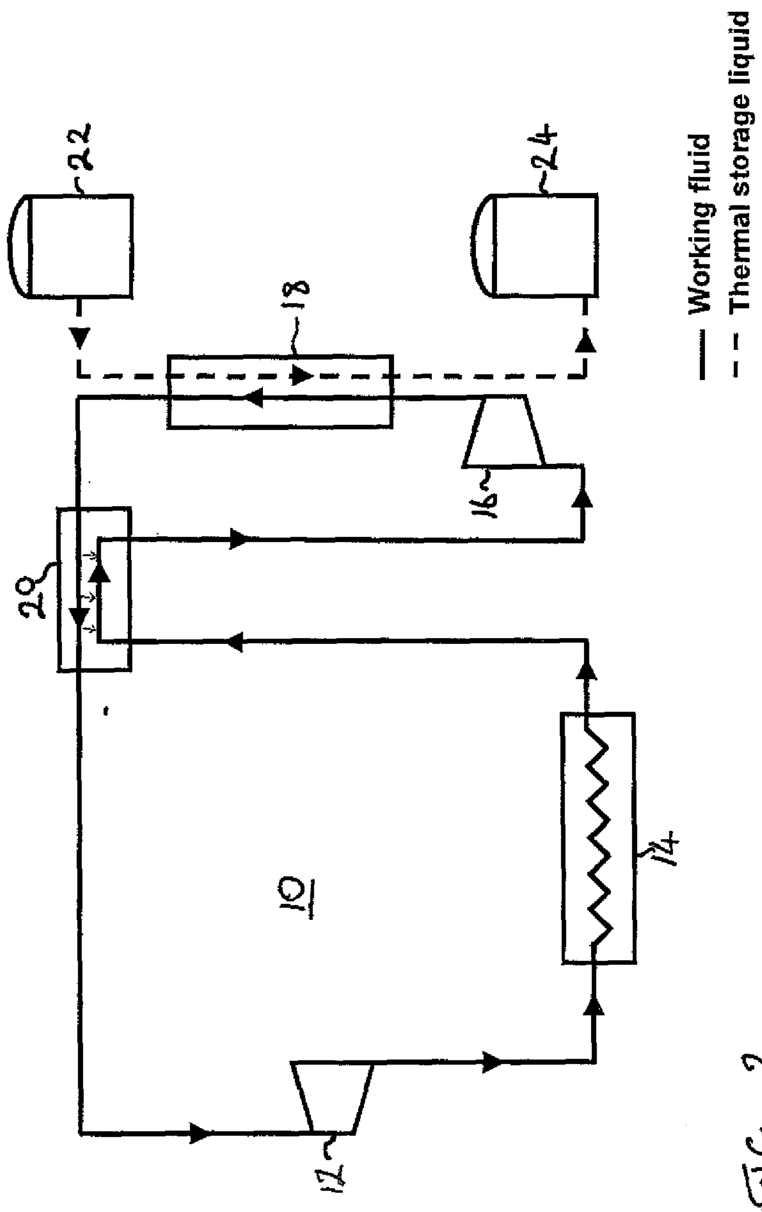

FIG. 2

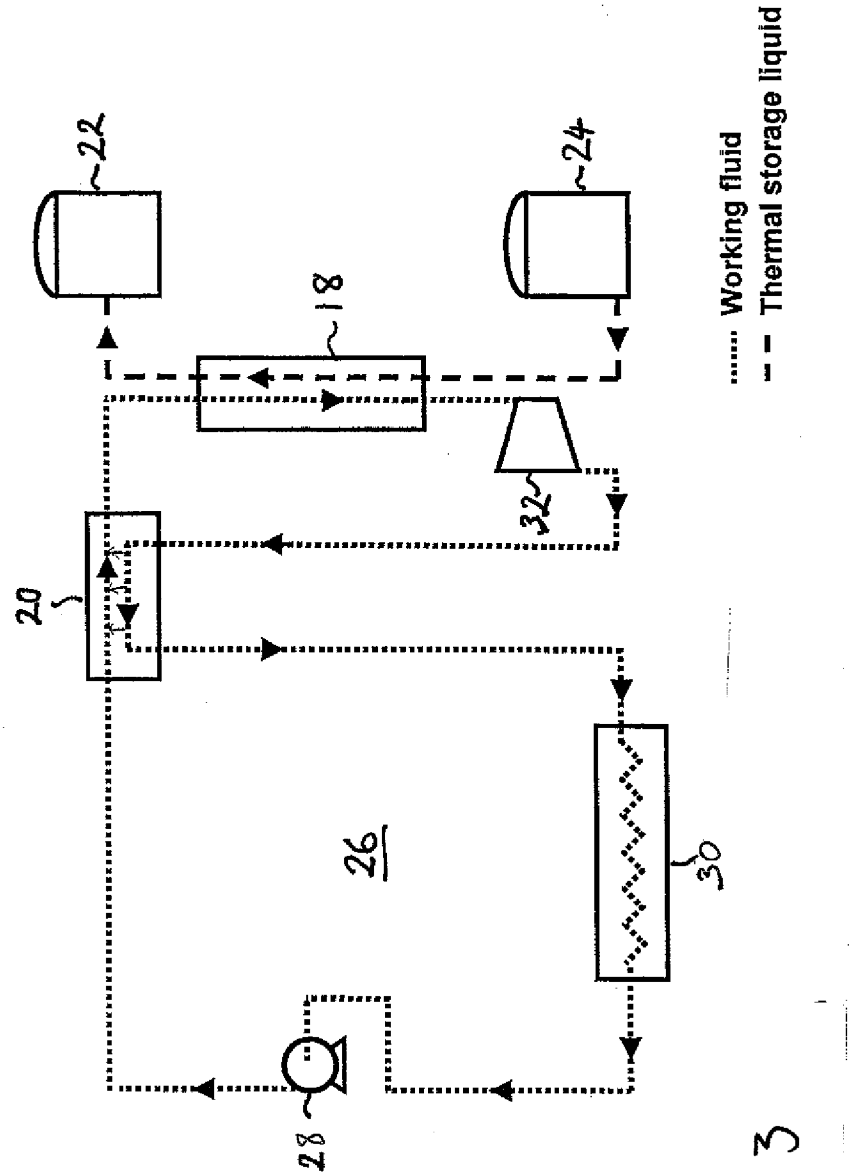

FIG. 3

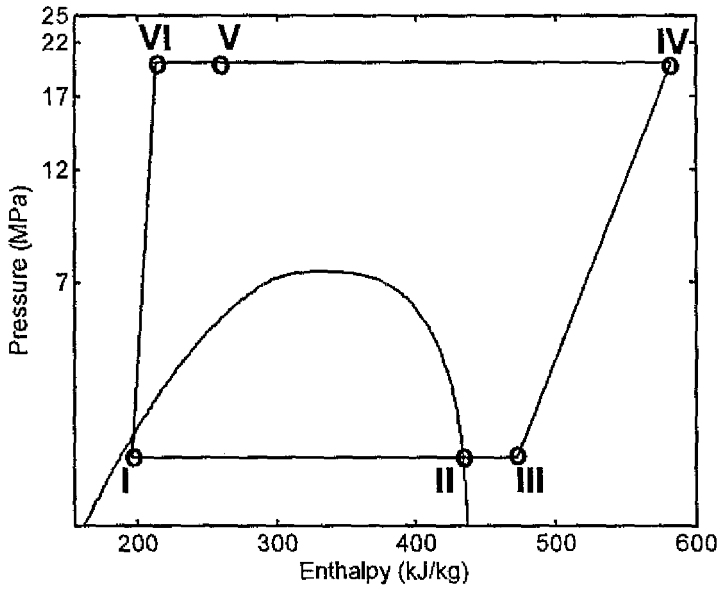
25
22
17
12
7
Pressure (MPa)
VI
V
IV
I
II
III
200
300
400
500
600
Enthalpy (kJ/kg)

FIG. 4

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EUROPEAN SEARCH REPORT

Application Number
EP 09 17 2831

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	US 4 089 744 A (CAHN ROBERT P) 16 May 1978 (1978-05-16) * figures 1,2 * * column 5, line 26 - column 8, line 22 *	1,4-10 2,3	INV. F01K3/12 F01K11/04 F24H7/02 F01K3/00
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TECHNICAL FIELDS SEARCHED (IPC)
F01K
F24H

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	21 May 2010	Lepers, Joachim

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3

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