INSTALLATION FOR STORING THERMAL ENERGY

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ABSTRACT

An installation for storing thermal energy which can be obtained, for example, at times of overcapacities, from regenerative energy and then be stored is provided. The energy stored in a heat accumulator, a cold accumulator and in an additional heat accumulator can be, when needed, reconverted into electrical energy by circuits via a generator (G) while using a compressor and a turbine. The working gas is humidified by a humidification column, ideally until saturation, whereby, advantageously, a greater mass flow can be obtained at a lower volume flow. For this reason, more economical components can be used while simultaneously a high yield of the installation is achieved.
INSTALLATION FOR STORING THERMAL ENERGY

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application is the US National Stage of International Application No. PCT/EP2012/068858 filed Sep. 25, 2012, and claims the benefit thereof. The International Application claims the benefit of European Application No. EP11183267 filed Sep. 29, 2011. All of the applications are incorporated by reference herein in their entirety.

FIELD OF INVENTION

[0002] The invention relates to an installation for storing thermal energy, the installation having a circuit for a working gas. The circuit may be of open configuration such that it draws in air from the environment as working gas and discharges said air into the environment again; that is to say the environment forms part of the circuit. A closed circuit is also possible in which any desired working gas (including air) may be used. In the circuit, the following units are connected to one another in the stated sequence by a line for the working gas: a cold accumulator, a first thermal fluid energy machine, a heat accumulator and a second thermal fluid energy machine. Here, as viewed in the throughflow direction of the working gas from the cold accumulator to the heat accumulator, the first thermal fluid energy machine is positioned as work machine and the second thermal fluid energy machine is positioned as prime mover.

BACKGROUND OF INVENTION

[0003] The expressions “prime mover” and “work machine” are used within the context of this application with the following meanings: a work machine absorbs mechanical work in order to perform its task. A thermal fluid energy machine that is used as a work machine is thus operated as a compressor. By contrast, a prime mover performs work, wherein a thermal fluid energy machine for performing work converts the thermal energy that is available in the working gas. In this case, the thermal fluid energy is thus operated as a motor.

[0004] The expression “thermal fluid energy machine” is an umbrella term for machines that can extract thermal energy from a working fluid, in the context of this application a working gas, or supply thermal energy to said working fluid. Thermal energy is to be understood to mean both heat energy and also cold energy. Thermal fluid energy machines (also referred to hereinafter for short as fluid energy machines) may for example be designed as piston-type machines. It is preferably also possible for use to be made of hydrodynamic fluid energy machines whose rotors permit a continuous flow of the working gas. Use is preferably made of axially acting turbines and compressors.

[0005] The principle specified in the introduction is described for example in US 2010/0257862 A1. In said document, piston-type machines are used to perform the method described above. Moreover, it is known from U.S. Pat. No. 5,436,508 that, by the installations specified in the introduction for storing thermal energy, overcapacities in the case of the utilization of wind energy for producing electrical current can be temporarily stored in order to be drawn upon again if required.

SUMMARY OF INVENTION

[0006] It is an object of the invention to specify an installation for storing thermal energy of the type specified in the introduction (for example conversion of mechanical energy into thermal energy with subsequent storage or conversion of the stored thermal energy into mechanical energy) in which high efficiency can be achieved with simultaneously reasonable expenditure for the structural units that are used.

[0007] With the installation, specified in the introduction, this object is achieved according to aspects of the invention in that a humidification unit for the working gas is provided in the line between the first thermal fluid energy machine and the heat accumulator. In the context of this invention, a humidification unit is to be understood to mean a device through which the working gas can flow and in which water vapor is supplied to the working gas. Here, the air should be humidified with water vapor up to at most the saturation limit. The use of humidification of the working gas (for example air) has the advantage that the power output at the fluid energy machine that operates as work machine can be increased while maintaining the same structural size. For a demanded power output, it is thus possible to use smaller and thus cheaper components for the installation. Furthermore, it is possible for the hot humidified air exiting the second fluid energy machine to be utilized for supplying heat into the water used in the humidification unit, such that said energy is not lost from the process as a whole. In this way, the efficiency of the installation according to the invention can be advantageously increased.

[0008] The circuit of the installation according to aspects of the invention for storing thermal energy serves, with its humidification unit, to convert the energy stored in the heat accumulator and cold accumulator into mechanical energy by the second thermal fluid energy machine. Said mechanical energy may for example be used for driving an electrical generator. Then, in times of high demand for electrical energy, the stored thermal energy is used for the provision of said electrical energy by the installation.

[0009] Owing to the increased use of regenerative energy, a situation may however also arise in which the total current produced is not demanded at the time of production. In this case, the installation for storing thermal energy may be used for converting the electrical energy for example into mechanical energy by an electric motor and into thermal energy by the fluid energy machines. It should however be noted that the humidification column is not used during the reverse process. Said humidification column must thus be bypassed, for example by suitable bypass lines. Another possibility includes providing a separate circuit in the installation for the charging process of the cold accumulator and of the heat accumulator. Said separate circuit may also be equipped with additional fluid energy machines.

[0010] If the installation is provided with bypass lines, these must be suitable for connecting the first thermal fluid energy machine and the second thermal fluid energy machine such that the heat accumulator is situated upstream of the cold accumulator in the throughflow direction of the working gas. This may be achieved by a reversal of the flow direction in the line system. Another possibility includes the bypass lines issuing into the circuit in each case directly upstream and downstream of the heat accumulator and cold accumulator such that the flow direction of the working gas is reversed only within the thermal accumulators. The reversal of the flow direction in the thermal accumulators (cold accumulator
and heat accumulator) is of importance in order that, during the charging and discharging of the thermal accumulator, the cold-hot front in the storage medium of the thermal accumulator is moved in the opposite direction in each case.  

[0011] If an additional circuit is used for the charging of the thermal accumulators, said additional circuit likewise passes through the same heat accumulator and cold accumulator. By suitable valve mechanisms, it is ensured that in each case only the circuit for charging or the circuit for discharging is connected to the thermal accumulators. Another possibility includes the thermal accumulators comprising in each case two line systems for two circuits. In this case, a switchover is not necessary, and it is even possible in principle to realize simultaneous charging and discharging of the thermal accumulators.

[0012] In one situation, however, the charging of the heat accumulator and of the cold accumulator in the installation is achieved in that the heat accumulator can be connected between a third thermal fluid energy machine and a fourth thermal fluid energy machine by a second line, wherein, as viewed in the throughflow direction of the working gas from the third thermal fluid energy machine to the fourth thermal fluid energy machine, the third thermal fluid energy machine is positioned as work machine and the fourth thermal fluid energy machine is positioned as prime mover. This permits, in the manner already described, the charging of the heat accumulator when the working gas flows through the second line in the stated throughflow direction. Furthermore, the cold accumulator may be provided in the second line downstream of the fourth thermal fluid energy machine, which cold accumulator is then fed with the working gas exiting the fourth fluid energy machine and can absorb the cold energy stored in the working gas.

[0013] In a further refinement of the invention, it is provided that a water separator is arranged in the line downstream of the second thermal fluid energy machine. Owing to expansion and cooling of the working gas, the absorption capacity thereof for water vapor also decreases, such that said water vapor condenses. Said water vapor can then be captured in said water separator, wherein the separated-off water is still at a temperature of approximately 50° C. Said temperature level is thus still higher than ambient temperature, such that the thermal energy stored in the captured water can be supplied back to the process. If the water vapor were discharged into the environment and, instead, feed water from the environment were used for the humidification column, said thermal energy would be lost from the process. The water separator thus serves to increase the efficiency of the process realized by the installation according to the invention. In order for the water from the water separator to be provided back to the process, it is advantageously provided that the water separator is connected to the humidification unit via a feed line.

[0014] In another refinement of the installation according to aspects of the invention, it may be provided that the line leading away from the second fluid energy machine leads through a first heat exchanger situated in the evaporator. The working gas exiting the second fluid energy machine is at temperatures of approximately 200° C. Said heat can be utilized for providing heat energy to the humidification column, which heat energy is required for the evaporation of the water situated in the humidification column. Said heat energy is thus advantageously provided back to the process and thus does not escape unused into the environment. This advantageously increases the efficiency of the process realized by the installation. Furthermore, owing to the cooling of the working gas that has taken place in the humidification column, a water separator connected downstream thereof can operate more effectively, because the water can be separated off more easily from the cooled working gas.

[0015] Yet another refinement of the invention provides that an auxiliary heat accumulator is provided in a branch line, wherein the branch line that leads away from the auxiliary heat accumulator leads through a heat exchanger situated in the evaporator. The energy stored in the auxiliary heat accumulator can thus additionally assist the process of evaporation of the water in the humidification unit. The introduction of thermal energy, which takes place indirectly via the auxiliary heat accumulator, thus advantageously leads to a further increase in air humidity in the humidification unit. This leads to the already-described increase in efficiency of the process realized by the installation according to the invention.

[0016] The auxiliary heat accumulator, like the heat accumulator and the cold accumulator, may be fed from external heat and cold sources. Here, use may expediently be made of district heat from a power plant, for example. It is however particularly advantageous for the auxiliary heat accumulator and the heat accumulator and the cold accumulator to be charged by separate heat pump processes. For this purpose, it is advantageously possible for the auxiliary heat accumulator to be connected between a fifth thermal fluid energy machine and a sixth thermal fluid energy machine by an auxiliary line, wherein, as viewed in the throughflow direction of the working gas from the fifth thermal fluid energy machine to the sixth thermal fluid energy machine, the fifth thermal fluid energy machine is positioned as work machine and the sixth thermal fluid energy machine is positioned as prime mover. A separate heat pump circuit is thus advantageously made available for the charging of the auxiliary heat accumulator, wherein the fifth and sixth fluid energy machines can be optimized for the temperatures to be generated in the auxiliary heat accumulator. It is self-evidently also possible for the auxiliary heat accumulator to be charged by the first or by the third fluid energy machine if suitable interconnection by lines and/or bypass lines is permitted. Here, it is always necessary to weigh up the outlay for components versus the increase in efficiency for the individual processes. Economical considerations are of primary importance in said weighing-up process.

[0017] The working gas may optionally be conducted in a closed or an open circuit. An open circuit always uses the ambient air as working gas. Said ambient air is drawn in from the environment and is also discharged again into the environment at the end of the process, such that the environment closes the open circuit. A closed circuit also permits the use of a working gas other than ambient air. Said working gas is conducted in the closed circuit. Since an expansion into the environment with simultaneous adoption of ambient pressure and ambient temperature is omitted, it is necessary in the case of a closed circuit for the working gas to be conducted through a heat exchanger which permits a dissipation of heat from the working gas to the environment.

[0018] It may for example be provided that the circuit for the storage of the thermal energy in the cold accumulator and the heat accumulator is in the form of an open circuit, and the thermal fluid energy machine that operates therein as prime mover is constructed from two stages, with a water separator
for the working gas being provided between the stages. Here, allowance is made for the fact that air moisture is contained in the ambient air. An expansion of the working gas in a single stage can have the effect that, owing to the intense cooling of the working gas to \(-100^\circ\) C, for example, the air moisture freezes and, in the process, damages the thermal fluid energy machine. In particular, turbine blades can be permanently damaged owing to icing. An expansion of the working gas in two stages however makes it possible for condensed water to be separated off, for example at \(5^\circ\) C, in a water separator downstream of the first stage, such that, upon further cooling of the working gas in the second turbine stage, said water has already been removed and ice formation can be prevented or at least reduced. The risk of damage to the second fluid energy machine is advantageously reduced in this way.

[0019] If a closed circuit is used and, as already described, a heat exchanger is installed into the circuit, the use of a two-stage fluid energy machine as prime mover can then be omitted. In this case, too, it is possible for dehumidified ambient air to be used as working gas, the humidification of which is prevented by the closed nature of the circuit. Other working gases may however also be used.

[0020] For the thermal charging of the heat accumulator and of the cold accumulator, it is advantageous if the working gas flows through the auxiliary heat accumulator before flowing through the first or third (depending on configuration) fluid energy machine. That is to say that the working gas is fed into the first fluid energy machine having been heated by the auxiliary heat accumulator. In this way, the auxiliary heat accumulator can perform a further task in addition to the heating of the humidification unit. The use of the auxiliary heat accumulator has the following advantages. If the installation is used for the storage of thermal energy, the flow passes through the auxiliary heat accumulator before passing through the first/third fluid energy machine that operates in this case as work machine (compressor). In this way, the working gas is already heated to a temperature higher than ambient temperature. This has the advantage that the work machine does not need to absorb as much power to achieve the demanded temperature of the working gas. Specifically, the heat accumulator should be heated to over \(500^\circ\) C, wherein, following the preheating of the working gas, this can advantageously be realized even by commercially available thermodynamic compressors which permit a compression of the working gas to 15 bar. It is therefore advantageously possible, for the structural units of the installation, to resort to components that are commercially available without expensive modifications. It is advantageous possible for the working gas to be heated to a temperature between \(60^\circ\) and \(100^\circ\) C, particularly advantageously to a temperature of \(80^\circ\) C, in the auxiliary heat accumulator. By contrast, for the supply of heat into the humidification column, heating of the working gas to approximately \(190^\circ\) C is particularly advantageous.

[0021] As already mentioned, the working gas can be compressed to 15 bar in the circuit of the heat accumulator and of the cold accumulator, whereby temperatures of the working gas of up to \(550^\circ\) C can be achieved.

[0022] Finally, according to one particular embodiment of the invention, it may be provided that a heat exchanger is provided in the line downstream of the second thermal fluid energy machine, with water for the humidification unit being fed as coolant to said heat exchanger. In this way, an even greater amount of heat energy can be extracted from the working gas flowing through the line, which heat energy is used to preheat the feed water for the humidification unit. In this way, said energy is also provided back to the process, whereby the efficiency of said process is advantageously further increased. In particular in the case of the provision of an open circuit, the humidification unit requires a relatively large amount of feed water, because the water is at least partially discharged back into the environment after passing through the circuit. Even in the case of a closed circuit, however, leaks in the circuit and drying of the ducts in the heat accumulator and the cold accumulator in the event of a switchover from discharging operation to charging operation can have the effect that new feed water must be introduced into the humidification unit.

**BRIEF DESCRIPTION OF THE DRAWINGS**

[0023] Further details of the invention will be described below on the basis of the drawing. Identical or corresponding elements in the drawing are in this case denoted by the same reference signs in each case, and will be explained multiple times only where differences exist between the individual figures. In the drawing:

[0024] FIG. 1 shows, in the form of a circuit diagram, an exemplary embodiment of the installation according to the invention with bypass lines, and

[0025] FIGS. 2 and 3 show, on the basis of further circuit diagrams, another exemplary embodiment of the installation according to the invention with separate circuits for the charging and discharging of the thermal accumulators.

**DETAILED DESCRIPTION OF INVENTION**

[0026] An installation for the storage of thermal energy as per FIG. 1 has a line 11 by which multiple units are connected to one another such that a working gas can flow through them in an open circuit. The working gas is drawn in from the environment via a valve A and flows through a first thermal fluid energy machine 13 which is in the form of a hydrodynamic compressor. Furthermore, the line then leads via a valve B to a heat accumulator 14. The latter is connected by the line 11 and via a valve C to a second thermal fluid energy machine 15, which is in the form of a hydrodynamic turbine. From the turbine, the line 11 leads via a valve D to a cold accumulator 16. From the cold accumulator 16, the line opens into the environment. In the operating state described, the valves A to D are thus open. Valves E to H are closed (more in this regard below).

[0027] The first and second fluid energy machines 13 and 15 are mechanically coupled to one another via a shaft 21 and are driven by an electric motor M which is powered by a wind turbine 22 for as long as the electrical energy generated is not demanded in the electrical grid. During said operating state, the heat accumulator 14 and the cold accumulator 16 are charged, as will be explained in more detail further below, and the installation is traversed by flow through the line 11, wherein flow passes through the units in the above-stated sequence.

[0028] If the demand for electrical energy is greater than the amount of electrical energy presently being generated, then the current generated by the wind turbine 22 is fed directly into the grid. Furthermore, the installation, in another operating state, assists the generation of electricity by virtue of the heat accumulator 14 and the cold accumulator 16 being discharged and a generator G being driven by the fluid energy machines 18 and 19 via the shaft 21. For this purpose, the
valves A to D are closed, and instead, the valves E to H are opened. As a result, flow no longer passes through regions of the line 11, and instead the bypass lines 19 thereof are opened, which change the flow of the working gas.

[0029] The working gas flows through the cold accumulator 16 and passes via a bypass line 19 and via the valve E to the first fluid energy machine (compressor). After exiting the compressor, the working gas is conducted via a valve F through a humidification unit 18, which is provided in a further bypass line 19 and which leads to the heat accumulator 14. The heat accumulator 14 is thus already fed with humidified air, which exits the heat accumulator 14 via the bypass line 19 through a valve G and is supplied to the second fluid energy machine 15 (turbine). The mechanical energy for driving the first fluid energy machine 13 (compressor) and the generator is gained here. The working gas passes back into the environment via the bypass line 19 and through a valve H, wherein prior to that, the working gas is dehumidified by a water separator 17. The water which is separated off and which is at approximately 50° C. is supplied by a feed pump 23a to the humidification unit 18. It is additionally possible, for example, for heat derived from a power plant as district heat to be introduced into the humidification unit. This is indicated in FIG. 1 by a heat exchanger 33a.

[0030] In the installation in FIG. 1, the heat accumulator 14 and the cold accumulator 16 (and also the auxiliary heat accumulator as per FIG. 3) are in each case of identical construction, said construction being illustrated in more detail by way of an enlarged detail based on the cold accumulator 16. A tank is provided, the wall 24 of which is provided with an insulation material 25 which has large pores 26. In the interior of the container there is provided concrete 27 which functions as a heat accumulator or cold accumulator. Pipes 28 are laid, so as to run parallel, within the concrete 27, through which pipes the working gas flows, releasing heat or absorbing heat in the process (depending on the operating mode and accumulator type).

[0031] The thermal charging and discharging process will be explained in more detail on the basis of the installation as shown in FIGS. 2 and 3. FIG. 2 firstly illustrates a two-stage charging process which functions on the basis of the principle of a heat pump. The illustration in FIGS. 2 and 3 shows an open circuit which could however be closed, as indicated by dash-dotted lines, through the use of an optionally provided heat exchanger 17a, 17b. The states of the working gas, which in the exemplary embodiment of FIGS. 2 and 3 is composed of air, are presented in each case in circles at the lines 30, 31, 32. The pressure in bar is indicated at the top left. The enthalpy in kJ/kg is indicated at the top right. The temperature in °C is indicated at the bottom left, and the mass flow rate in kg/s is indicated at the bottom right. The flow direction of the gas is indicated by arrows in the respective line.

[0032] In the model calculation for the charging circuit of the second line 31 as per FIG. 2, the working gas passes at 1 bar and 20°C into a (hitherto charged) auxiliary heat accumulator 12 and exits the latter at a temperature of 80°C. Compression by the third fluid energy machine 34, which operates as a compressor, results in a pressure increase to 15 bar and, as a result, also to a temperature increase to 540°C. Said calculation is based on the following formula:

$$\Delta T = 273 \cdot (T_2 - T_1) / \eta_c \cdot T_2 = T_1 \cdot \pi^{1 \cdot s} \cdot \pi$$

where

$[0033] T_2$ is the temperature at the compressor outlet,
water separator functions in exactly the same way as that which is situated in the second line 31. After expansion of the air by the sixth fluid energy machine 37, said air is at a temperature of –56° C. at ambient pressure (1 bar). If the circuit of the auxiliary line 30 is of closed design, as illustrated by the dashed-dotted line, it is therefore necessary for a heat exchanger 17c to be provided in order that the air can be heated from –56° C. to 20° C. by release of heat to the environment.

[0043] The circuits of the second line 31 and of the auxiliary line 30 are set in operation independently of one another. The third and fourth fluid energy machines are thus mechanically coupled via the shaft 21 to a motor M1, and the fifth and sixth fluid energy machines are mechanically coupled via the other shaft 21 to a motor M2. In the event of overcapacities of the wind turbine 22, the electrical energy can initially drive the motor M2 in order to charge the auxiliary heat accumulator 12. Subsequently, by operation of the motor M1 and simultaneous discharging of the auxiliary heat accumulator 12, the heat accumulator 14 and the cold accumulator 16 can be charged. Subsequently, by operation of the motor M2, the auxiliary heat exchanger 12 can also be recharged. When all the accumulators are fully charged, an effective discharging cycle for the production of electrical energy can be initiated (cf. FIG. 3). However, if the overcapacity of the wind turbine 22 comes to an end without it having been possible for the auxiliary heat accumulator 12 to be charged, the energy provided therein can also be replaced by other heat sources (cf. FIG. 3).

[0044] Also conceivable is an auxiliary heat accumulator 12 which can be fed through separate line systems for the second line 31 and the auxiliary line 30. This would yield two independent circuits without the use of valves I and K. In this way, it would be possible for the auxiliary heat accumulator 12 to be charged and discharged simultaneously. Simultaneous operation of the motors M1, M2 is therefore also conceivable in this case. This operating regime has two advantages. Firstly, even relatively large overcapacities of the wind turbine 22 can be captured through simultaneous operation of the motors M1, M2, resulting in greater flexibility of the system. Furthermore, through simultaneous operation of both motors, it would be possible to ensure that the three thermal accumulators 12, 14, 16 are always charged simultaneously and not in succession. The charging process can thus be stopped at any time, with full operational capability of the discharging process, which now has no longer overcapacities in the electrical grid and, instead, there is a demand for additional electrical energy.

[0045] FIG. 3 serves for illustrating the discharging cycle of the heat accumulator 14 and of the cold accumulator 16, wherein electrical energy is generated at the generator G. The first fluid energy machine 13 and the second fluid energy machine 15, which were not used in the above-described charging processes (see FIG. 2), are available for the discharging cycle. This permits an optimization of the efficiency of the fluid energy machines but also leads to higher investment costs for the acquisition of the installation. It is therefore necessary to weigh up the higher investment outlay for the use of additional fluid energy machines versus the gain in efficiency achieved by virtue of the fact that, if four fluid energy machines are used, each can be optimized for the corresponding operating state. The heat accumulator 14, the cold accumulator 16 and the auxiliary heat accumulator 12 are the same as in FIG. 2, and are merely traversed by flow in the opposite direction. FIGS. 2 and 3 thus illustrate the same installation, wherein, for clarity, the illustrations show in each case only those system components and lines which are involved in the process taking place. Furthermore, the alternative of a closed circuit is illustrated by means of dash-dotted lines.

[0046] The working gas is conducted through the cold accumulator 16. In the process, it is cooled from 20° C. to –100° C. This measure serves to reduce the power consumption for operating the first fluid energy machine that operates as a compressor. The power consumption is reduced by a factor corresponding to the temperature difference in Kelvin, that is to say 293K/173K = 1.69. In the example, the compressor compresses the working gas to 10 bar. Here, the temperature rises to 89° C. A compression of up to 15 bar would also be technically feasible. The compressed working gas flows initially through the humidification unit 18 and then through the heat accumulator 14, and is thereby heated to 145° C. in the humidification unit and to 530° C. in the heat accumulator 14. The working gas is subsequently expanded by the second fluid energy machine 15, which thus operates as a turbine in this operating state. An expansion to 1 bar takes place, wherein a temperature of 201° C. still prevails in the working gas at the outlet of the first fluid energy machine. It is therefore possible for the working gas to be additionally conducted through a heat exchanger 33e in the evaporation unit in order to release heat therein for the evaporation of the water. As a result of the further cooling of the working gas, it is possible for at least a part of the air moisture to be separated off by the water separator 17. The separated-off water is still at a temperature of approximately 50° C. and is pumped back into the humidification unit by a feed pump 23a. The dehumidified air exits the circuit and is discharged into the environment. It may alternatively be provided that, as indicated by dash-dotted lines, a closed circuit is realized by the line 32. In this case, a heat exchanger 17a serves for cooling the working gas, which is still at a temperature of 50° C., to ambient temperature (20° C.). The heat exchanger may also be used for heating fresh water that can be pumped into the humidification unit by a feed pump 23c.

[0047] Heat is required in the humidification unit to effect the evaporation of the feed water. To provide an additional energy source here, it is possible, as already indicated in FIG. 1, for the heat exchanger 33a to be connected to an external heat source. Said external heat source may for example be district heat. It is however also advantageous to utilize the charged auxiliary heat accumulator 12. For this purpose, a branch line 38 is provided which branches off from the line 32 upstream of the cold accumulator 16. Said branch line runs through the auxiliary heat accumulator 12 and downstream through the heat exchanger 33e: in the humidification unit, such that the heat energy stored in the auxiliary heat accumulator 12 can likewise be supplied to the humidification unit. Downstream of the heat exchanger 33c, the branch line 38 issues into line 32 downstream of the heat exchanger 33b. The mass flow of the working gas is thus split up at the branch line 38, wherein 8.5 kg/s is conducted through the branch line 38 and 4.8 kg/s is conducted through the cold accumulator 16, humidification unit 18 and heat accumulator 14.

1. An installation for storing thermal energy, comprising:
   a. a circuit for a working gas, wherein, in the circuit, the following units are connected to one another in the stated sequence by a line for the working gas:
      a. a cold accumulator,
      a first thermal fluid energy machine,
a heat accumulator and
a second thermal fluid energy machine,
wherein, as viewed in a throughflow direction of the working
gas from the cold accumulator to the heat accumulator, the first thermal fluid energy machine is positioned
as work machine and the second thermal fluid energy
machine is positioned as prime mover,
wherein a humidification unit for the working gas is pro-
vided in the line between the first thermal fluid energy
machine and the heat accumulator.

2. The installation as claimed in claim 1, wherein a water
separator is arranged in the line downstream of the second
thermal fluid energy machine.

3. The installation as claimed in claim 2, wherein the water
separator is connected to the humidification unit via a feed
line.

4. The installation as claimed in claim 1, wherein the line
leading away from the second thermal fluid energy machine
leads through a heat exchanger situated in the humidification
unit.

5. The installation as claimed in claim 1, wherein an aux-
iliary heat accumulator is provided in a branch line, wherein
the branch line that leads away from the auxiliary heat ac-
cumulator leads through a heat exchanger situated in the
humidification unit.

6. The installation as claimed in claim 1, wherein a heat
exchanger is provided in the line downstream of the second
thermal fluid energy machine, with water for the humidifica-
tion unit being fed as coolant to said heat exchanger.

7. The installation as claimed in claim 1,
wherein the heat accumulator is connected between a third
thermal fluid energy machine and a fourth thermal fluid
energy machine by a second line,
wherein, as viewed in the throughflow direction of the
working gas from the third thermal fluid energy machine
to the fourth thermal fluid energy machine, the third
thermal fluid energy machine is positioned as a work
machine and the fourth thermal fluid energy machine is
positioned as a prime mover.

8. The installation as claimed in claim 7, wherein the cold
accumulator is connected downstream of the fourth fluid
energy machine as viewed in the throughflow direction as per
claim 7 by the second line.

9. The installation as claimed in claim 1, wherein an aux-
iliary heat accumulator is connected between a fifth thermal
fluid energy machine and a sixth thermal fluid energy
machine by an auxiliary line,
wherein, as viewed in the throughflow direction of the
working gas from the fifth thermal fluid energy machine
to the sixth thermal fluid energy machine, the fifth ther-
mal fluid energy machine is positioned as a work
machine and the sixth thermal fluid energy machine is
positioned as a prime mover.

10. The installation as claimed in claim 1, wherein the first
thermal fluid energy machine and the second thermal fluid
energy machine are, by bypass lines, connected such that the
heat accumulator is situated upstream of the cold accumulator
in the throughflow direction of a working fluid.

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