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(54) PROCESS OF CONTROL OF THE STORAGE OF THERMAL ENERGY IN THE GROUND AND ASSOCIATED SYSTEM

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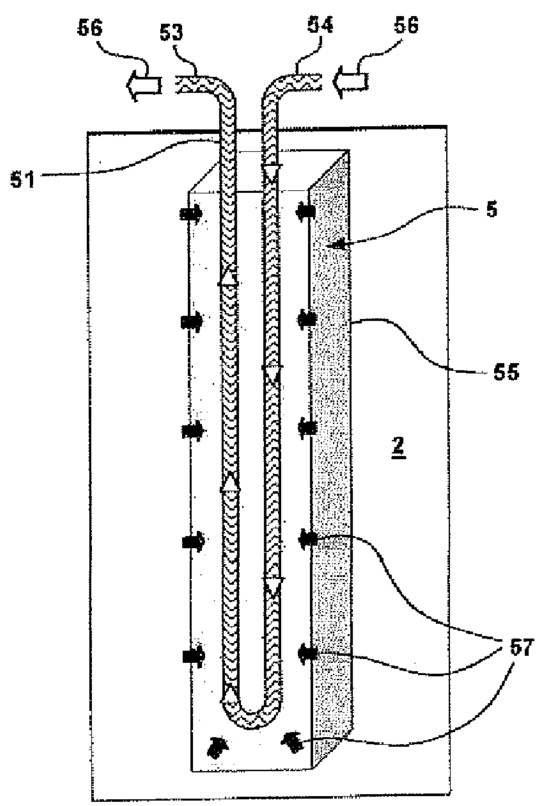
(57) **ABSTRACT**

A process of control of a thermal energy storage unit in the ground includes heat exchangers buried in the ground, each of the exchangers allowing a calorific energy exchange between a heat-conveying fluid traversing it and the ground, the energy storage unit being at the interface between a source and consumer of calorific energy to store thermal energy. One measures the temperature in various points of the ground using buried temperature gauges, the temperatures and flow of a heat-conveying fluid in input and output of the source to determine the thermal power provided by the source, and temperatures and flow of a heat-conveying fluid in input and output of the consumer to determine the thermal power to provide the consumer. One optimizes the storage of thermal energy in the storage unit by selecting active exchangers among the plurality of exchangers according to temperature measurements, flow measurements and thermal power measurements.



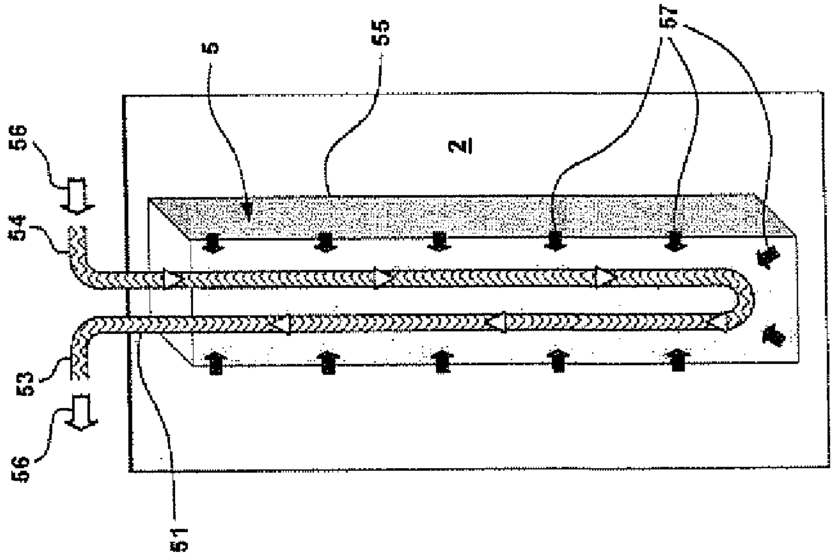


Fig. 1

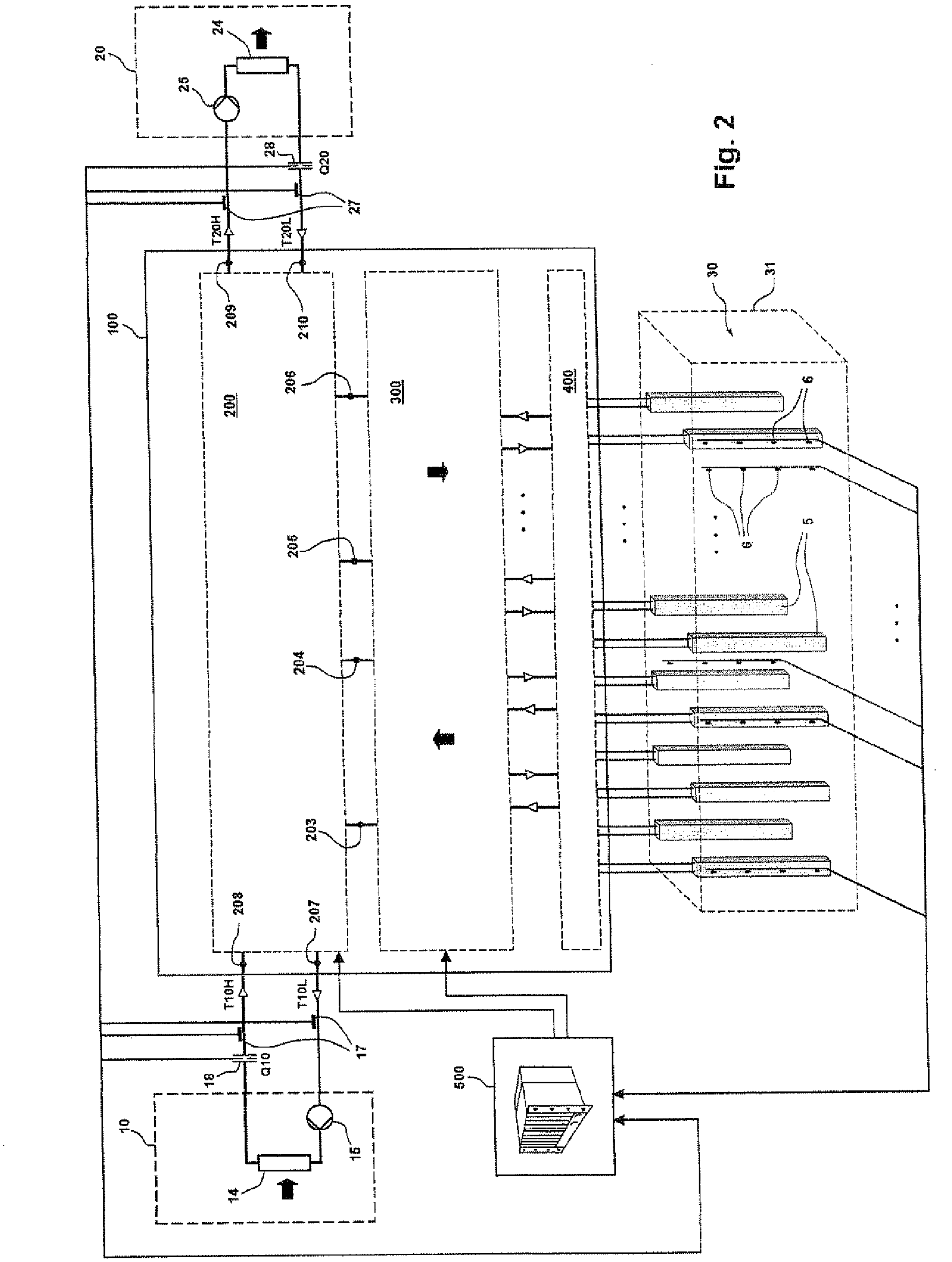

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Fig. 2

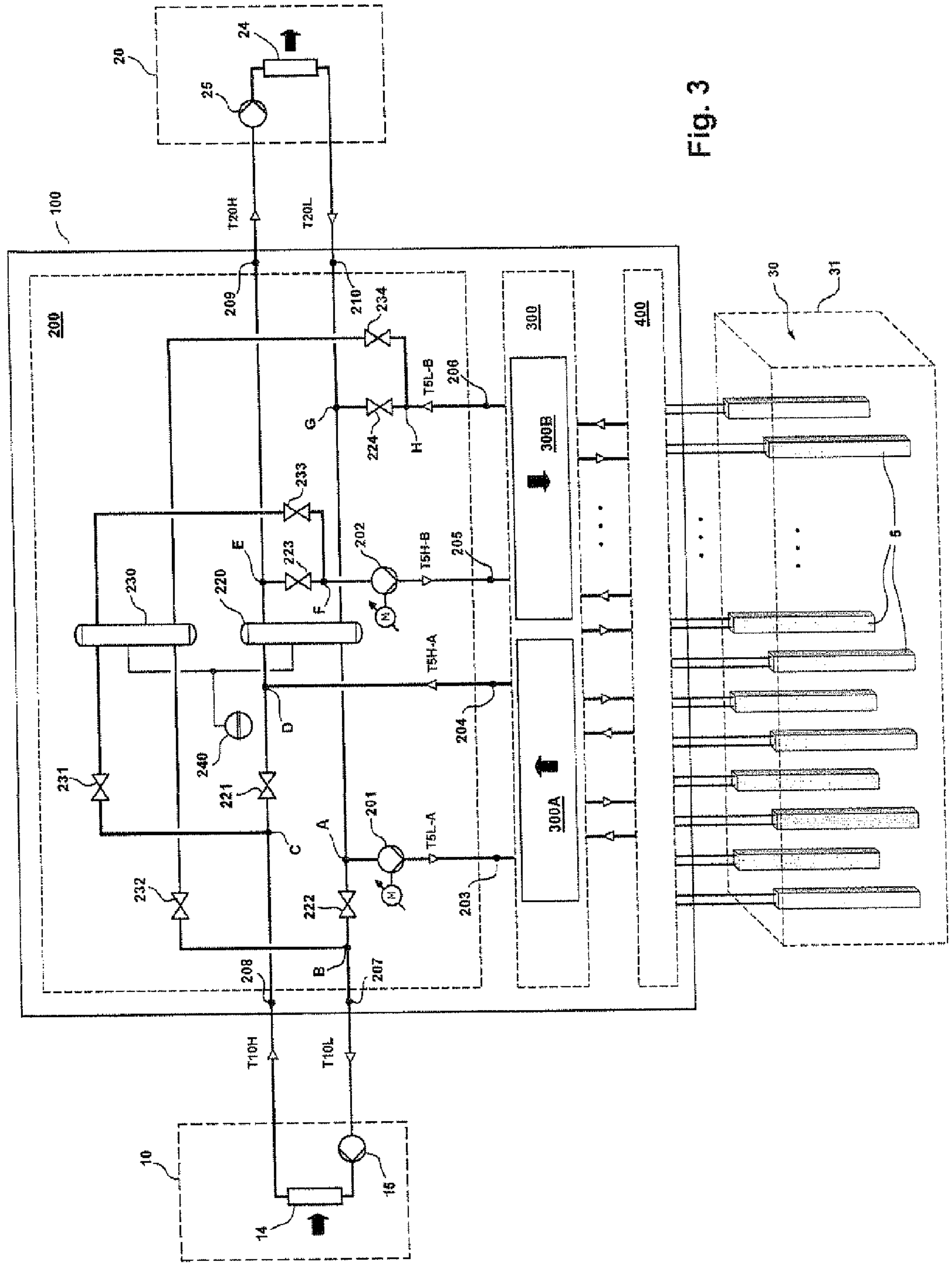

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Fig. 3

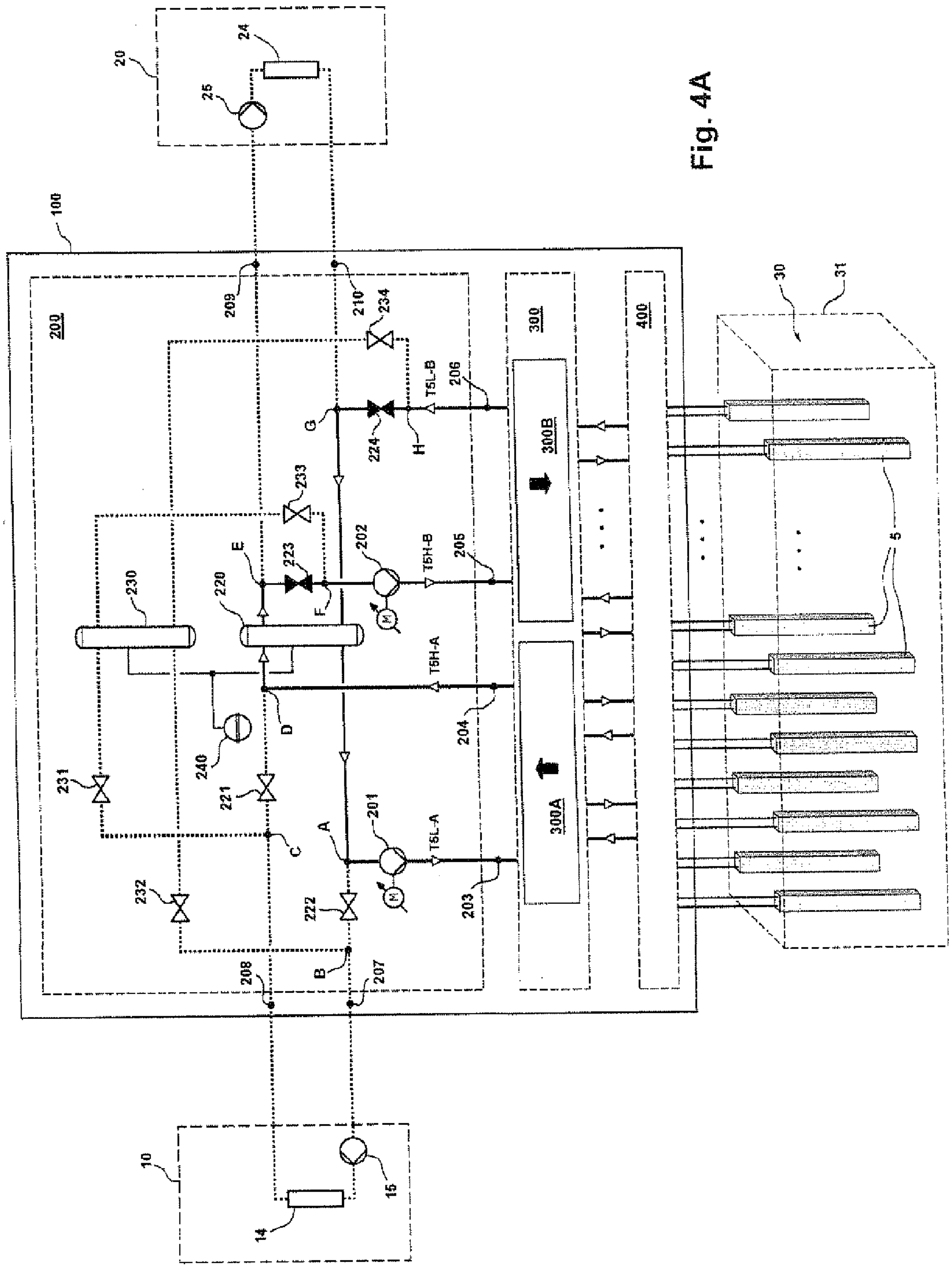
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Fig. 4A

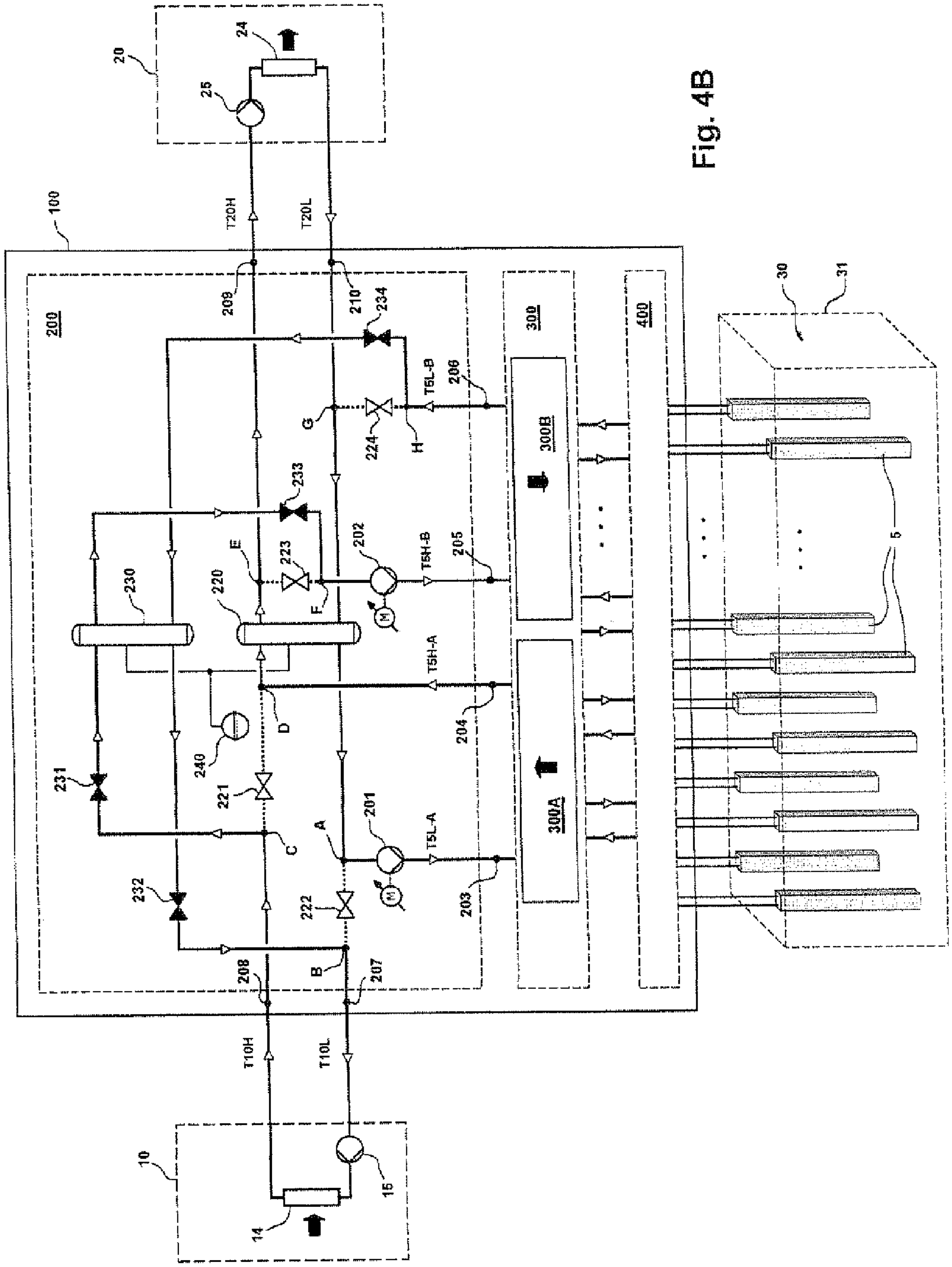
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Fig. 4B

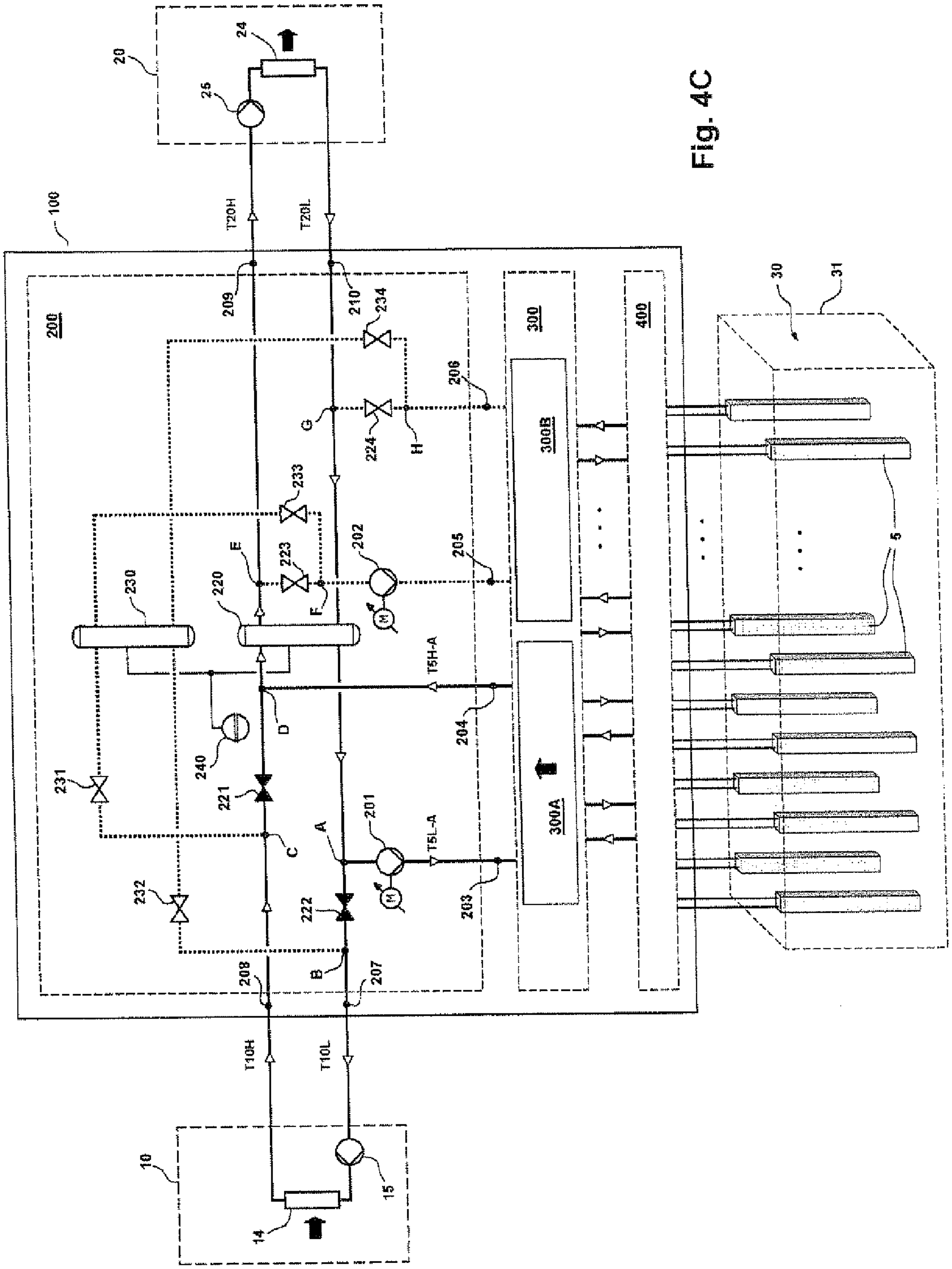
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Fig. 4C

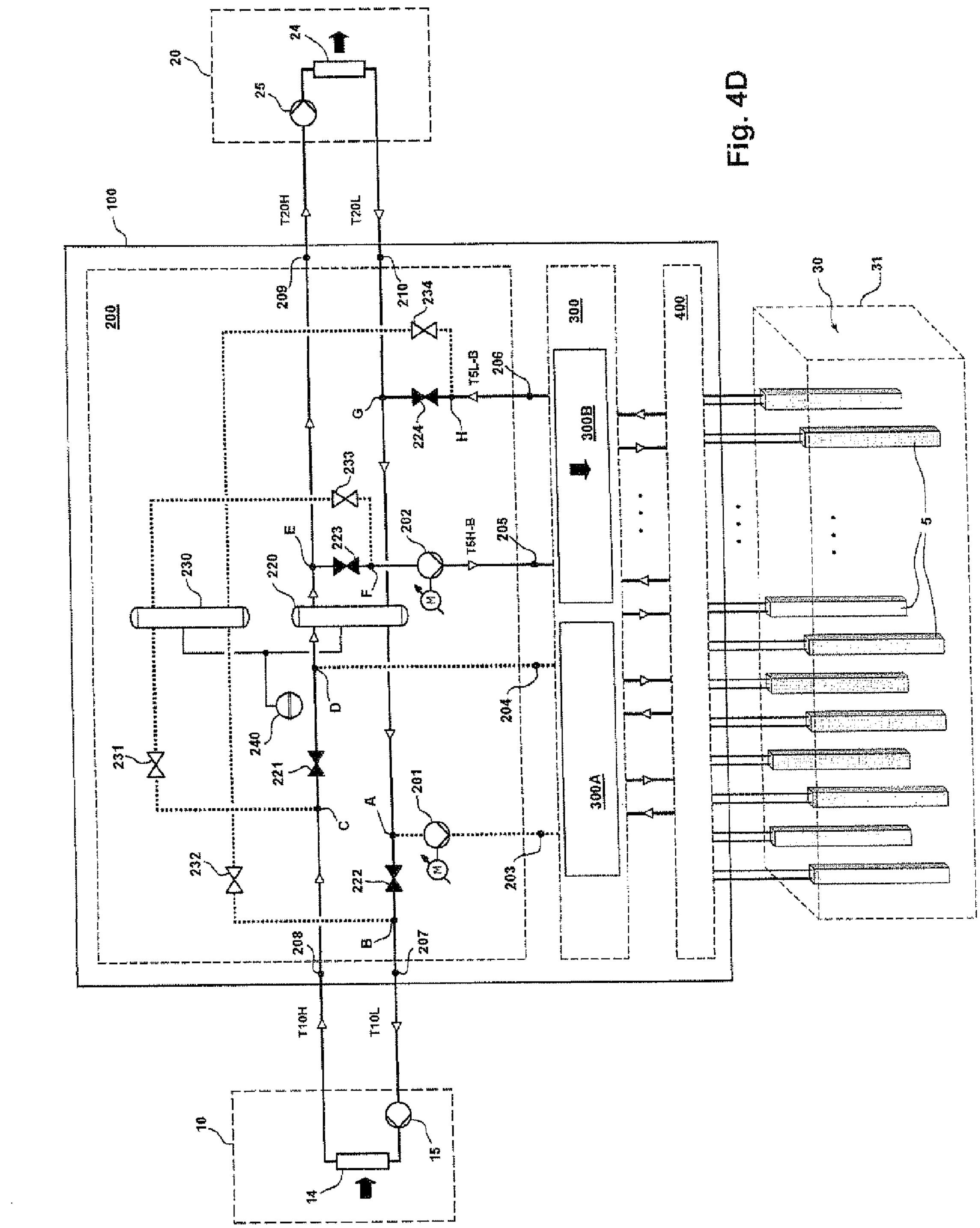
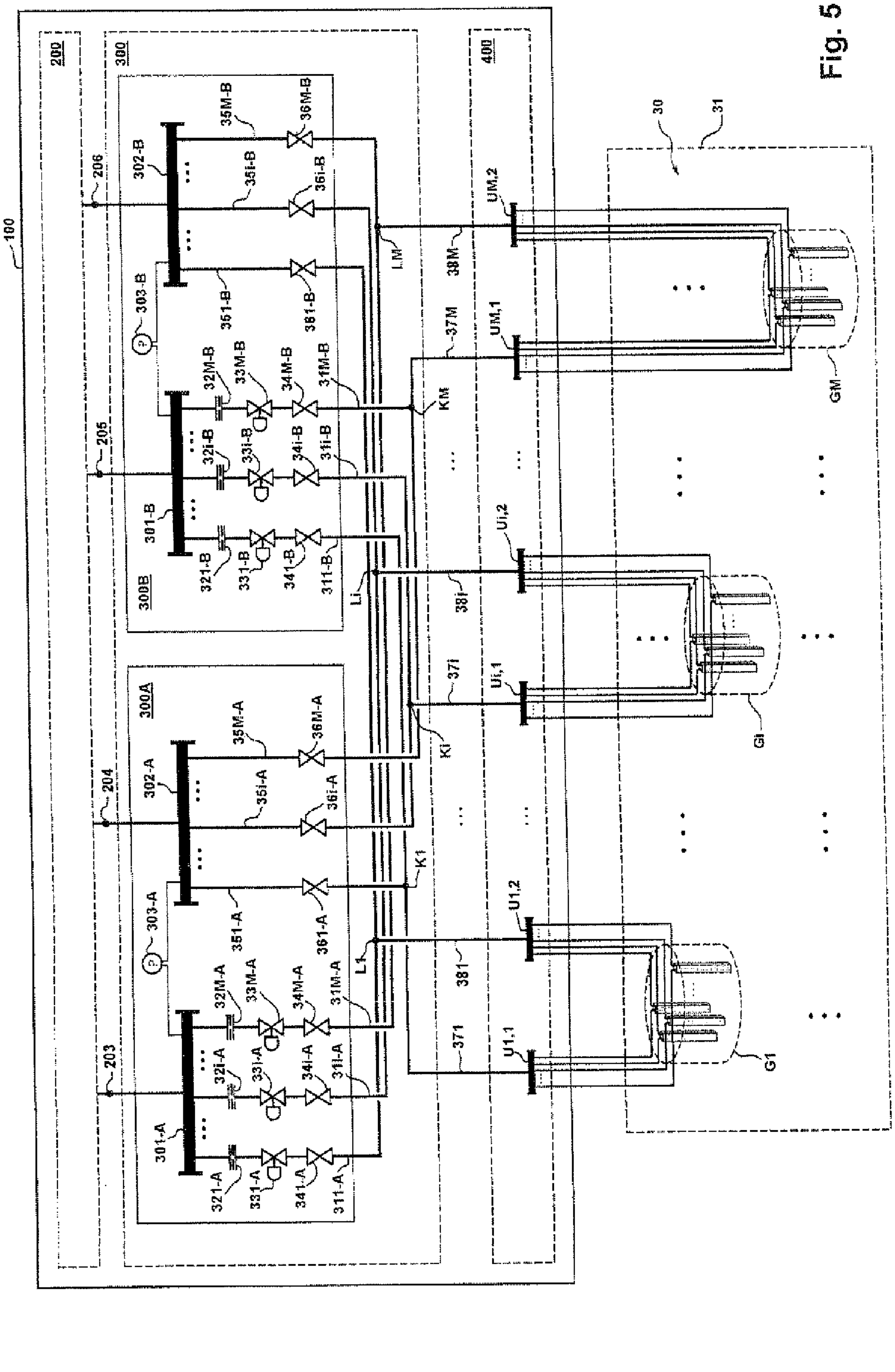


Fig. 4D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38i
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Fig. 5

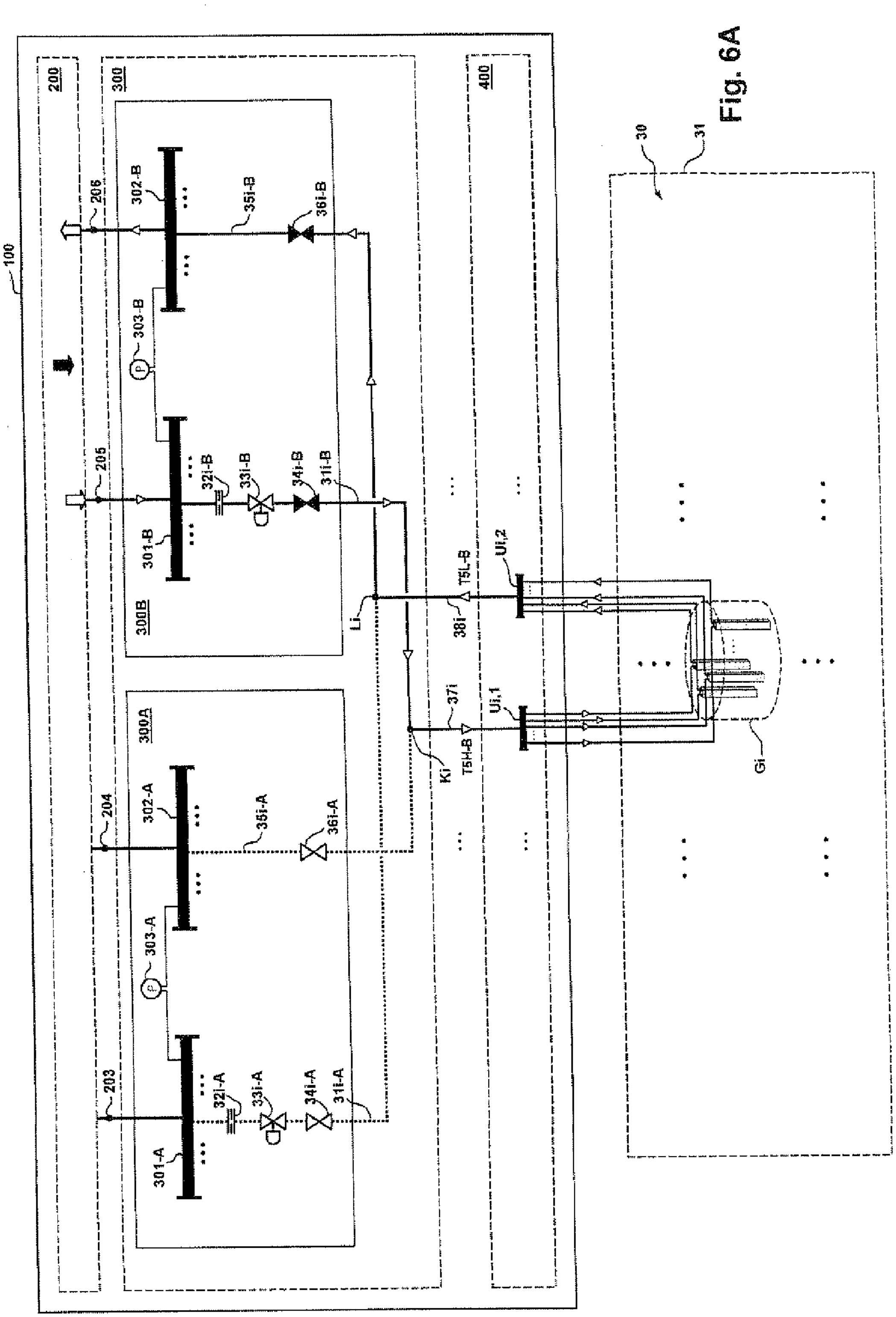
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Fig. 6A

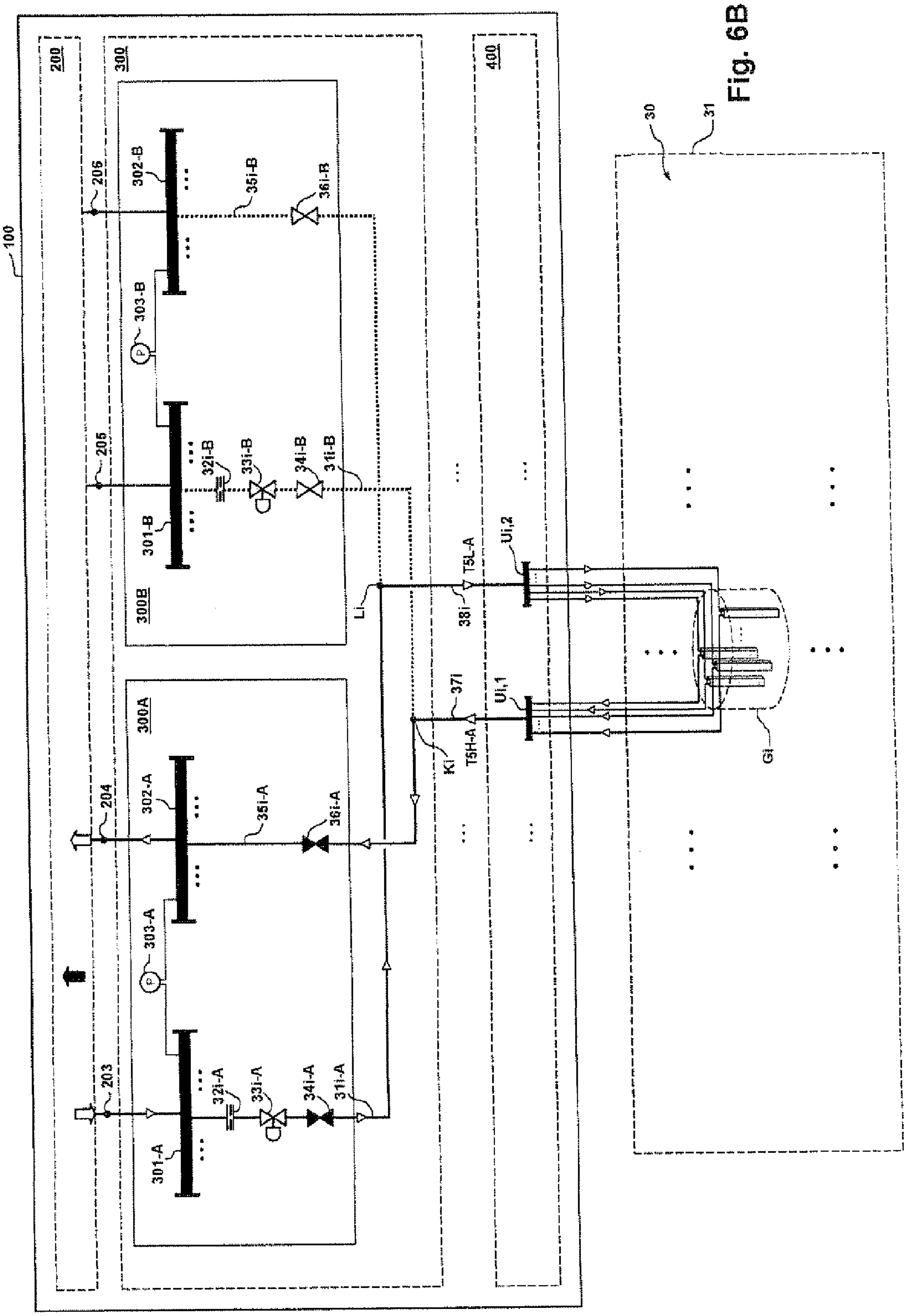
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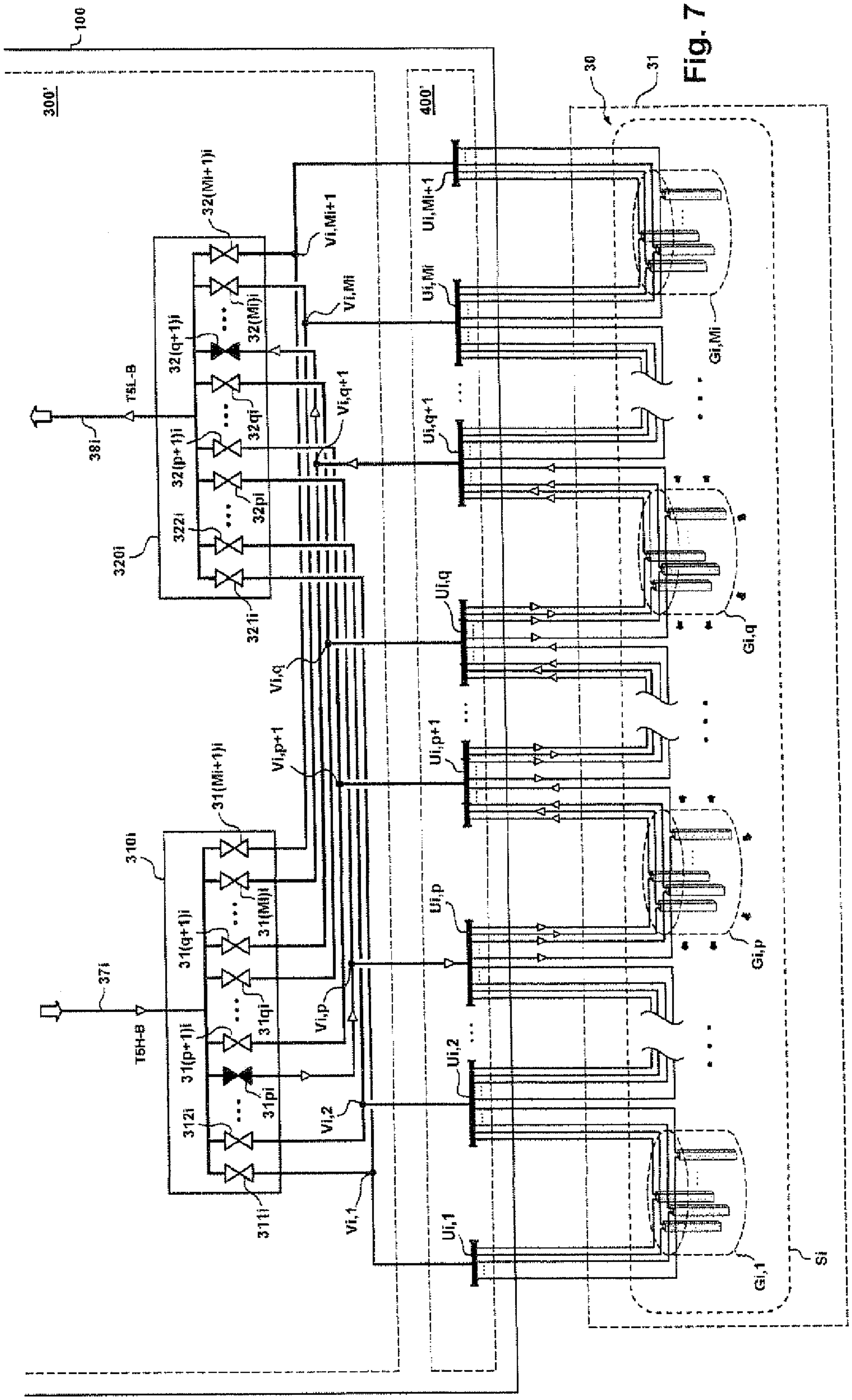
Fig. 6B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31qi
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31(Mi)i
31(Mi+1)i
38i
T5L-B
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321i
322i
32pi
32(p+1)i
32qi
32(q+1)i
32(Mi)i
32(Mi+1)i
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Ui,p
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Fig. 7

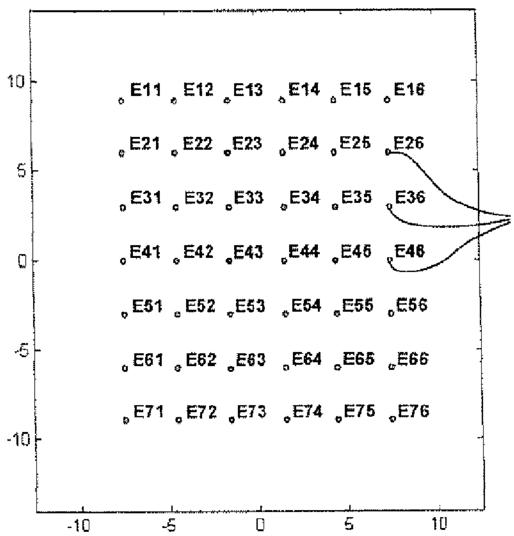

Fig. 8A

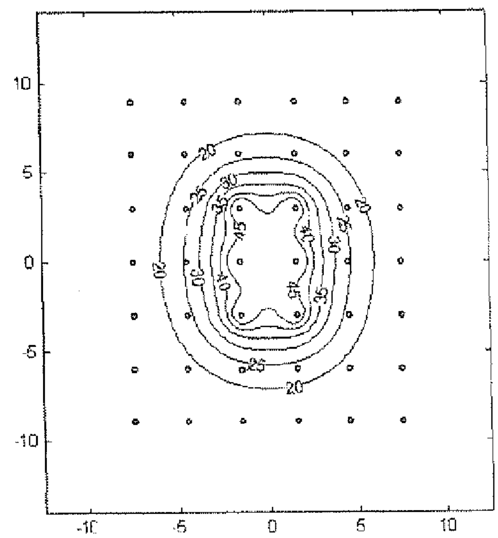

Fig. 8B

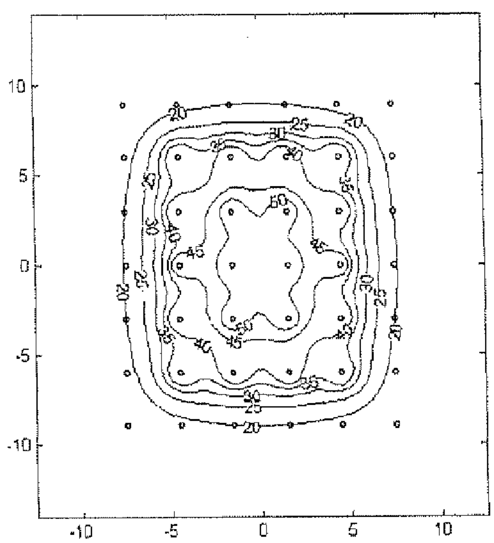

Fig. 8C

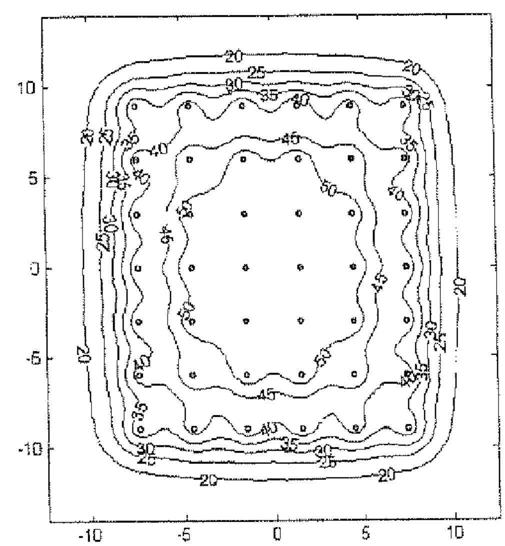

Fig. 8D

PROCESS OF CONTROL OF THE STORAGE OF THERMAL ENERGY IN THE GROUND AND ASSOCIATED SYSTEM

[0001] The invention has as a scope the storage of calorific energy in the ground. More particularly, the invention has as a scope the storage of thermal energy to uncouple a source of heat and/or a consumer of cold, on the one hand, of a consumer of heat and/or a cold source, on the other hand.

[0002] In energy systems using thermal energy in the form of heat, such as heating systems in buildings or industrial heating processes, or in the form of cold, such as the air-conditioning in buildings or the industrial refrigeration, the thermal energy production is generally synchronized with its consumption.

[0003] Mainly because of the rising cost of energy, the efficiency of this kind of synchronized system is an essential aspect, which can only be improved through the optimization of the system of production (improvement of the efficiency) or of the system of consumption (minimization of the power consumption).

[0004] Another way to improve energy systems from the economical point of view consists in uncoupling production and consumption using thermal energy storage systems. This decoupling then allows to produce necessary energy not only during periods of consumption, but also during periods when energy is available at low costs.

[0005] Advantageously, the generalization of such calorific storage systems would also allow the recovery and the exploitation of an important part of industrial thermal energy, today massively unused mainly because of the shift between its production and the periods of consumption.

[0006] Lastly, thermal energy storage systems are very well adapted to the exploitation of renewable energies, which are very often characterized by their intermittency, and whose availability does not always coincide with consumption, in particular in the case of thermal solar energy.

[0007] One knows calorific energy storage devices that use the significant heat of a material of storage, i.e. the energy stored by this material when it undergoes a temperature variation, without phase change and without change of chemical composition, and in which the storage material is nothing but the ground. In what follows, the term of "ground" must be understood in the broad sense and covers indifferently the natural ground such as a volume of mud, a layer of rock, an engineered ground such as the subsoil of a building or the subsoil of a parking surface, the foundations of a building and their geological environment, elements and assemblies of elements of structure of a building (walls, flagstones . . .), or the equivalent. Possibly, the ground is not homogeneous and comprises various structures and materials having different thermodynamic properties. Energy exchanges between material of storage on the one hand, and energy sources and consumers on the other hand, are ensured by the diffusion/convection resulting from circulation of at least a heat-conveying fluid inside buried canalizations.

[0008] An important parameter to take into account to describe these devices is the time scale over which is carried out accumulation, then consumption of the stored calorific energy. For example, a district heating system for the heating of a group of dwelling houses must follow a cycle of seasonal operations: in summer, one accumulates the energy produced by a source of heat like a solar collector, or by a consumer of cold like a device of air conditioning, whereas in winter, one releases this calorific energy to heat the dwellings as consumer of heat.

[0009] This kind of storage devices, functioning over an important scale of time—from a few months to one year, presents specific issues.

[0010] Important heat losses are one of the main issues that limits the efficiency of the calorific storage of energy. These losses, mainly diffusive, are due to the thermal conduction between the energy storage zone, having an average temperature T, and what one could call the external ground zone, which remained to temperature T**0**. This is all the more important that, for example in the case of the storage of energy in the ground, the material of storage can not be physically delimited: the material of storage can thus be a continuous material. There is thus no physical delimitation between the storage zone and the external zone. This mode of realization is particularly advantageous since it allows to avoid the excavation of an important volume of ground, a necessary stage when one wishes to delimit a storage zone, for example using a block of concrete buried in the ground, or more simply of a formwork.

[0011] An important aspect to take into account during the planning of such a thermal storage system is the presence in the site of possible underground hydrogeologic flows. These displacements of water or moisture in subsoil bring about the move of stored heat towards the outside of the storage zone, thus causing consequent losses of thermal energy. These transverse flows thus reduce the effectiveness of the storage unit, when they do not simply prevent its realization.

[0012] Moreover, the necessary volume of storage material for a given application is an important parameter affecting the cost of the installation. This volume depends directly on the difference between the average temperature of the storage zone at the end of the cycle of load, when the storage section is in its "charged" state, and this same temperature at the end of the cycle of discharge, when the storage section is in its "discharged" state. The lower this difference, the larger the necessary volume to store a given quantity of energy.

[0013] The dilemma is then as follows: an increase of the temperature variation in the storage zone during a cycle allows a reduction of the necessary volume, implying the reduction of the cost of construction. But it also increases the difference between the temperature of this storage zone and the natural temperature of the ground, leading to an increase of thermal losses. Conversely, managing the average temperature of the storage zone to evolve during a cycle between two levels of temperatures close to each other (and close to the natural temperature of the ground) will decrease the losses, but will require a larger volume, and thus a higher investment in the construction.

[0014] The purpose of the invention is thus to solve the problems mentioned above.

[0015] To that end, the invention has as an aim a process of control of a thermal energy storage unit in the ground comprising a plurality of heat exchangers buried in the ground, each of the aforesaid exchangers allowing a calorific energy exchange between a circulating heat-conveying fluid traversing it and the ground, the aforementioned energy storage unit being laid out at the interface between a source and a consumer of calorific energy to store thermal energy, characterized in that one measures the temperature in various points of the ground by means of buried temperature gauges, the temperatures and flow of a heat-conveying fluid at the input and the output of the source to determine the thermal power provided by source, and temperatures and flow of a heat-conveying fluid at the input and the output of the consumer to determine the thermal power to provide the consumer, and in that one optimizes the storage of thermal energy in the aforementioned storage unit by selecting active exchangers among the aforementioned plurality of exchangers in function of temperature measurements, flow measurements and thermal power measurements.

[0016] The calorific energy source is defined as one or more elements providing heat to the system by means of a heat-conveying fluid. The calorific consumer of energy is defined as one or more elements absorbing of heat from the system by means of a heat-conveying fluid.

[0017] Preferably, the process comprises stages consisting in determining beforehand an optimal map of temperatures in the ground; determining an instantaneous map of temperatures in the ground by means of the aforesaid temperature measurements taken in various points of the ground; selecting active exchangers among the aforementioned plurality of exchangers according to the local variations of temperature between the aforementioned instantaneous map and the aforementioned optimal map, the temperatures and flow of the heat-conveying fluid at the input and the output of the source, and the temperatures and flow of the heat-conveying fluid at the input and the output of the consumer.

[0018] Thus, one can drive the convergence of the state of the storage zone from its current state towards the optimal state while taking into account constraints related to the production of the source and the needs for the consumer. The various stages can be reiterated as many times as necessary in order to carry out a chronological succession of optimal states of the storage zone that tends to maximize the energetic efficiency of the process according to the invention, while satisfying the constraints induced by the versatility and the asynchronism of both the source and the consumer.

[0019] Preferably, an exchanger is activated in extraction to extract locally calorific energy from the ground or in injection to locally inject calorific energy in the ground.

[0020] Still preferably, one activates an exchanger by selecting the direction and the flow value of heat-conveying fluid which traverses it. According to a functional mode, when the thermal power provided by the source is adapted to the thermal power used by the consumer, none the exchangers is activated and one makes circulate the heat-conveying fluid between a loop containing the source and a loop containing the consumer.

[0021] In another functional mode, when the thermal power provided by the source does not fit consumer needs, one makes circulate the heat-conveying fluid between a loop containing the source and a loop containing some exchangers activated in injection, and one simultaneously makes circulate the heat-conveying fluid between a loop containing the consumer and a loop containing some exchangers activated in extraction.

[0022] According to a functional mode, one moves heat inside the storage unit by circulation of the heat-conveying fluid between a loop containing at least one exchanger activated in extraction and a loop containing at least one exchanger activated in injection.

[0023] According to a functional mode, when the thermal power provided by the source is greater than the thermal power used by the consumer, one makes circulate the heat-conveying fluid on the one hand in a loop comprising the source and on the other hand in a loop comprising the consumer and a loop comprising of the exchangers activated in injection.

[0024] According to a functional mode, when the thermal power used by the consumer is null, the thermal power provided by the source is fully injected into the storage unit.

[0025] According to a functional mode, when the thermal power provided by the source is lower than the thermal power used by the consumer, one makes circulate the heat-conveying fluid on the one hand in a loop comprising the consumer and on the other hand in a loop comprising the source and a loop comprising of the exchangers activated in extraction.

[0026] Still according to another functional mode, when the thermal power provided by the source is null, the thermal power used by the consumer is fully extracted from the storage unit.

[0027] The invention also has as an aim an hydronic system of control of a thermal energy storage unit in the ground comprising a plurality of exchangers of heat buried in the ground, each of the aforesaid exchangers allowing a calorific energy exchange between heat-conveying fluid traversing it and the ground, the aforementioned hydronic system being intended to be laid out between a calorific energy source, a consumer of thermal energy and the aforementioned storage unit, characterized in that it comprises: a plurality of temperature gauges buried in the ground; flow and temperature gauges measuring the thermal power provided by the source and the thermal power used by the consumer; means of regrouping to group the aforementioned exchangers in a plurality of elementary exchange units, an exchange unit comprising at least one exchanger of heat; and, means of activation to selectively activate the aforementioned elementary exchange units.

[0028] Preferably, an exchanger comprising a hot end and a cold end, the means of regrouping make it possible to form groups of exchangers as one exchange unit, the various hot ends of the aforesaid exchangers of the same group being connected to a hot manifold and the cold ends of these same exchangers being connected to a cold manifold, the various exchangers of the said group being in parallel from each other.

[0029] Preferably still, the aforementioned means of regrouping allow to form series of exchangers as one exchange unit, a series of exchangers comprising a plurality of groups of exchangers, the cold manifold of one of the aforesaid groups of a series being connected to the hot manifold of the following group in the aforesaid the series, so that the aforementioned groups of the same series of exchangers are laid out in series between an initial group and a final group.

[0030] In a mode of realization, the aforementioned means of regrouping comprise first and second switches, each switch having one principal canalization and some secondary canalizations, the hot manifold of a group of exchangers being connected to the first switch via one of its secondary canalization, the canalization being equipped with a gate valve, and the cold collector of the group of exchanger being connected to the second switch via one of its secondary canalization, the canalization being equipped with a gate valve, so that the means of regrouping allow to select arbitrarily, at a given moment and in function of the position of the valves of the first and second switches, a first group of exchangers and a last group of exchanger, to form between the latter a branch of exchangers used as an exchange unit.

[0031] Preferably, means of activation comprise means of activation in injection allowing to form a hydraulic loop of injection comprising at least one exchange unit for the injection of energy, and means of activation in extraction allowing to form a hydraulic loop of extraction comprising at least one exchange unit for the extraction of energy.

[0032] Preferably still, the aforementioned means of activation in injection comprise an input branch of injection and an output branch of injection, each exchange unit being connected by its hot end to the said input branch of injection and by its cold end to the said output branch of injection to form a link between the input and output branches of injection, the various exchange units being thus in parallel from each other between the aforementioned input and output branches of injection, each link thus defined being equipped with means of regulation of flow in injection, so that the flow circulating in the aforementioned link can be arbitrarily fixed at the time of one injection.

[0033] In the mode of realization currently preferred, the means of activation in extraction comprise an input branch of extraction and an output branch of extraction, the exchange units being respectively connected by their cold end to the said input branch of extraction and by their hot end to the said output branch of extraction, to form a link between the input and output branches of extraction, the various exchange units being then in parallel from each other between the aforementioned input and output branches of extraction, each link thus defined being equipped with means of regulation of flow in extraction, so that the flow circulating in the aforementioned link can be arbitrarily fixed during an extraction.

[0034] It should be noticed that the means of regulation can apply a null flow to the exchange unit, thus allowing the arbitrary exclusion of the exchange unit during the injection or of the extraction.

[0035] Preferably still, a differential-pressure measuring sensor is connected between the aforementioned input and output branches, the canalization supplying the input branch comprises a pump controlled in differential pressure according to the measure taken by the aforementioned sensor, so that the flow in any of the links in parallel between the input and output branches can be controlled individually.

[0036] Preferably, the system is provided with pumping means including pumps being able to make circulate the heat-conveying fluid in a loop containing the energy source and/or a loop comprising the consumer of energy.

[0037] Preferably still, the system is provided with pumping means including pumps being able to make circulate the heat-conveying fluid in a loop of injection comprising at least an exchange unit functioning in injection of energy and in a loop of extraction comprising at least an exchange unit functioning in extraction of energy, and with the connection means allowing at least one connection among the connection of the loop of circulation in the source with the loop of injection; the connection of the loop of circulation in the consumer with the loop of extraction; the connection of the loop of circulation in the source with the loop of injection, and simultaneously, the connection of the loop of circulation in the consumer with the loop of extraction; the connection of the loop of extraction with the loop of injection; the connection of the loop of circulation in the source with the loop of circulation in the consumer; the connection of the loop of extraction with the loop of injection, and simultaneously, the connection of the loop of circulation in the source with the loop of circulation in the consumer.

[0038] Preferably, the connection means also allow the connection of the loop of circulation in the consumer with the loop of extraction and the loop of circulation in the source; and, the connection of the loop of circulation in the source with the loop of injection and the loop of circulation in the consumer.

[0039] In the considered mode of realization, the means of connection comprise a first hydraulic separator, connected to an expansion tank forming the neutral point of the said hydraulic system, the aforementioned first hydraulic separator being connected to the aforementioned loop of extraction on the one hand and to the aforementioned loop of circulation in the consumer on the other hand; a first pair of gate valves whose state allows to connect the aforementioned loop of circulation in the hot source to the aforementioned first hydraulic separator; a second pair of gate valves whose state allows to connect the loop of injection to the aforementioned first hydraulic separator.

[0040] Preferably still, the means of connection comprise a second hydraulic separator connected to the said expansion tank forming the neutral point of the said hydraulic system; a third pair of gate valves whose state allows, in relation to the state of the aforesaid first pair of valves, to connect the aforementioned loop of circulation in the source to the aforementioned second hydraulic separator, the loop in extraction being connected to the aforementioned first hydraulic separator; a fourth pair of gate valves whose state allows, in relation to the state of the second pair of valves, to connect the aforementioned loop of injection to the aforementioned second hydraulic separator, the loop of circulation in the consumer being connected to the aforementioned first hydraulic separator.

[0041] The means of activation, connection, and pumping being automatically actionable, the system comprises a calculating unit able to receive signals of measure emitted by the various sensors and to emit a control signal towards the aforementioned means of activation, connection, and pumping.

[0042] In the considered mode of realization, the calculating unit carries out the instructions of a program stored by means of memorizing of the aforesaid the calculating unit to implement the process according to the invention.

[0043] The invention also has as an aim a calorific storage system of energy in the ground comprising a hydronic system according to the invention and a storage unit of energy.

[0044] Preferably, the plurality of exchangers of the storage unit of energy comprises at least ten exchangers of heat.

[0045] Advantageously, the possibility to control in an active way, throughout the cycle of load/discharge, the distribution of temperature inside the storage section makes it possible to optimize the necessary volume of storage material. Indeed, the required volume for the storage zone depends only on the level of temperature at two given moments of the cycle, whereas the thermal losses depend on the integral of the heat flow calculated on all the cycle at the frontier of the storage zone. By continuously controlling the distribution of temperature in the storage zone, it is possible to maximize the difference in average temperature on volume between the final state “charged” and the initial state “discharged”, while preserving an optimal distribution of the temperatures near the limits of this zone, thus limiting the heat flow to the limits, and this during all the intermediate states of the cycle.

[0046] The natural phenomenon of thermal diffusion is amplified by the lack of control of the circulation of the heat-conveying fluid in the whole of the storage zone. For example during the load cycle of a heat storage unit by a variable heat source, as for example a solar collector, the circulation of a “tepid” fluid at temperature Tf through successively a “hot” zone, having a temperature higher than Tf, then a “cold” zone, having a temperature lower than Tf, will tend to homogenize the temperature of the two zones, thus accelerating the natural phenomenon of thermal diffusion process inside the storage section. The system according to the invention is able to restrict the circulation of fluid to the only physical zones in adequacy with the targeted behaviour, in particular with requested values of temperature of fluid at the input and at the output of the storage zone.

[0047] Advantageously, sources and consumers being heterogeneous, if at a given time the source produces a thermal energy which is not exploitable by the consumer, in particular because of the inadequate temperature of the heat-conveying fluid, knowing that up until now it was in this case not directly stored in the diffusive system but in an additional device of storage of the calorific fluid itself, this energy can now be directly stored for a later use. Indeed, the system according to the invention is able to inject this energy produced by the source in the storage unit, while simultaneously extracting energy of this same storage unit to feed the consumer. The levels of temperature of the fluid influencing injected energy and extracted energy being different, the system selects, according to the distribution of temperature in the storage zone, adequate regions for the injection and adequate regions for the extraction.

[0048] The invention will be better understood and other goals, details, characteristics and advantages of the invention will appear more clearly during the following description provided only on a purely illustrative and non restrictive basis in reference to the annexed drawings.

[0049] FIG. **1** represents, in a diagrammatic way, an exchanger of heat of an energy storage unit;

[0050] FIG. **2** is a diagrammatic overview of the hydronic system according to the invention, which interfaces between a source, a consumer and an energy storage unit;

[0051] FIG. **3** represents in a diagrammatic way a particular mode of realization of the subsystem of pumping of the hydronic system of FIG. **2**;

[0052] The FIG. **4**A schematically represents the subsystem of pumping functioning in mode of recycling of energy;

[0053] The FIG. **4**B schematically represents the subsystem of pumping functioning in mode of simultaneous injection and extraction;

[0054] The FIG. **4**C schematically represents the subsystem of pumping functioning in mode of partial extraction of energy;

[0055] The FIG. **4**D schematically represents the subsystem of pumping functioning in mode of partial injection of energy;

[0056] FIG. **5** represents, in a diagrammatic way, the flow control subsystem and the connection subsystem of the hydronic system according to the invention;

[0057] The FIG. **6**A represents the flow control subsystem in mode of injection of energy;

[0058] The FIG. **6**B represents the flow control subsystem in mode of extraction of energy;

[0059] FIG. **7** is a diagrammatic representation of an alternative realization of the subsystem of connection of the hydronic system according to the invention; and,

[0060] The FIGS. **8**A, B, C and D present successive optimal maps for a heat storage zone.

[0061] In a general way, a physical system being delimited by a closed surface, calorific energy will be counted positively when it corresponds to a heat flow entering the system and is counted negatively when it corresponds to a heat flow leaving the system.

[0062] On FIG. **1**, one schematically represented a simple example of an exchanger of heat **5** buried vertically in ground **2**. According to this example, it is a U-shaped pipe **51** having a “hot” end **53** and one “cold” end **54**. Pipe **51** is inserted in a sheath **55** facilitating the heat transfers between ground **2** and the heat-conveying fluid circulating in pipe **51**. Exchanger **5** is placed in a borehole drilled in the ground which can be several tens of meters depth (typically 50 m) and the material constituting sheath **55** is injected in the borehole as a filling material. The heat-conveying fluid can circulate in pipe **51** with an adjustable flow, in a direction or in another, that is from the cold end **54** towards the hot end **53** (as indicated by arrows **56** on FIG. **1**), or, reciprocally, from the hot end towards the cold end. In alternative a sheath **55** could accommodate several pipes **51**.

[0063] In functional mode allowing the extraction of the heat from the material of storage, heat exchanger **5** is activated so that the heat-conveying fluid at temperature T**5**L is injected by the cold end **54**. T**5**L is selected so as to be lower than the temperature of the ground T**2** in the surroundings of the exchanger. There is thus a transfer of heat from the ground to the fluid along the whole pipe **51**. The transfer is represented by the black arrows **57** on FIG. **1**. The heat-conveying fluid leaves the pipe by the hot end **53** with a temperature T**5**H higher than temperature T**5**L, but lower or equal to the T**2** temperature.

[0064] In an inverse functional mode, consisting in locally injecting heat in ground **2**, exchanger **5** is activated so that the heat-conveying fluid, having a temperature T**5**H higher than the local temperature of the ground T**2**, is injected by the hot end **53**. A heat transfer operates from the heat-conveying fluid towards the material of storage along the whole pipe **51**. The temperature T**5**L of the heat-conveying fluid at the cold end **54** is lower than temperature T**5**H but higher or equal to T**2**.

[0065] In a more general way, the heat exchanger is defined as a device made up of an arbitrary number of pipes buried in the ground, each pipe being defined by a geometry and a material that are specific to this pipe, these pipes being connected arbitrarily among them, the resulting system of piping presenting two ends, a “hot” end **53** and one “cold” end **54**, several heat exchanger being possibly inserted in the same borehole.

[0066] In the considered applications, a energy storage unit consists of at least 10 such exchangers of heat **5**. The various exchangers of the energy storage unit can be laid out at different depths and to have or not sheaths **55** in common.

[0067] The hydronic system **100** according to the invention is represented in a diagrammatic way on FIG. **2**. The hydronic system **100** interfaces any type of storage unit of energy **30**, with any type of source of heat or cold consumer **10**, defined as one or more elements supplying heat to the system via a heat-conveying fluid, and with any type of source of cold or heat consumer **20**, defined as one or more elements absorbing heat from the system via a heat-conveying fluid. In what follows, the source of heat or cold consumer **10** is called “hot source” or simply “source”, the consumer of heat or source of cold **20** is called “cold source” or simply “consumer”.

[0068] The hydronic system **100** allows to uncouple the production by hot source **10** of a calorific energy, counted positively by the hydronic system **100**, from the consumption by a cold source **20** of calorific energy, counted negatively by the hydronic system **100**, while storing, by means of the energy storage unit **30**, thermal energy (heat or cold) in a storage zone **31** defined in the ground. It is pointed out that the term of ground must be understood in the broad sense and covers as well an original ground such as a volume of ground, a layer of rock, an artificial ground such as the subsoil of a building or the subsoil of a parking space, the foundations of a building and their geological environment, elements and assemblies of elements of structure of a building (walls, flagstones . . .), or the equivalent. The storage zone **31** corresponds to the zone heated or cooled by the set of heat exchangers. It should be noticed that, if one stores energy in a continuous material, for example ground, the storage zone is not physically delimited. One can then try to define its geometric envelope by considering that it corresponds to the volume of ground that surrounds, at an arbitrary distance L, the exchangers of heat **5** buried at the periphery of the field of heat exchangers. The length L can for example be a characterized by the thermal diffusion properties in the material of storage.

[0069] The storage zone can be a heat storage zone; it is in this case characterized by an average temperature which is higher than the natural temperature of the ground. The storage zone can also be a storage zone of cold thermal energy, called cryo-energy. It is then characterized by an average temperature lower than the natural temperature of the ground.

[0070] Alternatively, a same storage zone can be used successively as a heat storage zone and as a cryo-energy storage zone. In this case, it is characterized by a level of temperature which evolves during a complete cycle of load/discharge between two extreme values, one higher than the natural temperature of the ground, and the other lower than this same natural temperature of the ground.

[0071] In still another alternative, the storage zone can be subdivided in one or more domains of heat storage juxtaposed with one or more domains of storage of cryo-energy, each domain being defined by its own envelope.

[0072] The hydronic system **100** controls the circulation of at least one heat-conveying fluid to carry out heat transfers. As seen from hot source **10**, a heat-conveying fluid, activated by pump **15** with a mass flow Q**10**, leaves the hydronic system **100** through outlet **207** (flow direction indicated by the white arrow) at a low temperature T**10**L, receives heat on behalf of source **10** thanks for example to an exchanger of heat **14** (see direction of the black arrow), then enters the hydronic system **100** through inlet **208**, at a high temperature T**10**H.

[0073] As seen from consumer **20**, a heat-conveying fluid, activated by pump **25** with a mass flow Q**20**, leaves the hydronic system **100** through outlet **209**, at a high temperature T**20**H, loses heat while circulating in consumer **20** thanks for example to an exchanger of heat **24** (see direction of the black arrow), then enters the hydronic system **100** through inlet **210**, at a low temperature T**20**L.

[0074] At every time, hot source **10** is characterized by the fluid flow Q**10** measured by flow sensor **18**, and two levels of temperature T**10**L "low" and T**10**H "high" measured by temperature gauges **17**, and the cold source **20** is characterized by the fluid flow Q**20** measured by flow sensor **28**, and two levels of temperature T**20**L "low" and T**20**H "high" measured by temperature gauges **27**.

[0075] The hydronic system **100** according to the mode of realization currently preferred comprises an upper part known as subsystem of pumping **200**, an intermediate part known as flow control subsystem **300** and a lower part known as connection subsystem **400**. The hydronic system also comprises a control system **500**.

[0076] The subsystem of pumping **200** allows controlling heat-conveying fluid flows associated with thermal exchange at the levels of the hot source **10**, the cold source **20** and the energy storage unit **30**. The subsystem of pumping **200** can carry out the following operational modes:

[0077] Injection of the whole of the heat produced by hot source **10** in the storage unit **30**;

[0078] Injection of part of the heat produced by hot source **10** in the storage unit **30** and direct transfer of the remaining part of the heat produced by hot source **10** to consumer **20**;

[0079] Feed consumer **20** by extraction from the storage unit **30** of the entirety of heat required by consumer;

[0080] Feed consumer **20** partly by direct transfer of the heat produced by hot source **10** and partly with heat extracted from the storage unit **30**.

[0081] Injection of heat produced by hot source **10** in certain sectors of the storage unit **30** and, simultaneously, feed consumer **20** with heat extracted from other sectors of this same storage unit **30**.

[0082] Internal displacement of heat by extraction of heat from certain sectors of storage unit **30** and re-injection of this heat in other sectors of the storage unit **30**.

[0083] Referring to FIG. 3, the subsystem of pumping **200** comprises two circulating pumps **201** and **202**, equipped with variable speed electric motors, eight ON/OFF gate valves **221**,**222**,**223**,**224**,**231**,**232**,**233** and **234**, and two hydraulic separators (or bottle or balloon) **220** and **230**, both connected to the same expansion tank **240**, thus forming the neutral point of the hydraulic system.

[0084] It must be noticed that in this invention, hydraulic separators are not necessarily used for their aptitude to store a buffered volume of fluid. In the subsystem of pumping **200**, the hydraulic separators are also used for their two following properties: on the one hand, they allow the advantageous calorific transfer of energy between two hydraulic loops in which flows can be different, without fluid temperature undergoing a variation during the passage from one loop to the other, as that would be the case if plate heat exchangers were used; and, in addition, their built in bottles constitute, between their inlet and outlet canalization, a quasi-null hydraulic resistance which authorizes the parallelized branch, between these canalizations, of several hydraulic loops having each one its own pumping means.

[0085] On the left of FIG. 3, the heat-conveying fluid can circulate in a loop comprising hot source **10** and/or in a loop of the storage unit **30** for the extraction of energy.

[0086] When the gate valves **221** and **222** are open, bottle **220** is connected to the outlet **207** and the inlet **208** to form a fluid circulation loop in the hot source **10**. The heat-conveying fluid, moved thanks to pump **15**, leaves hydraulic separator **220** at a temperature T**10**L. It flows through node A, then through node B by passing open valve **222**, towards item **207**. The fluid circulates then in the hot source **10** where it receives heat. It returns with a temperature T**10**H in the subsystem of pumping **200** through inlet **208**, then circulates through node C, then through node D by passing open valve **221**, and finally returns in balloon **220**.

[0087] The heat-conveying fluid can also circulate in a loop allowing the extraction of heat accumulated in material of storage. Pump **201** carries out circulation of the fluid. The fluid leaves bottle **220** at a temperature T**5**L-A up to the node A, and is then directed towards the outlet **203** of the subsystem of pumping **200**. As that will be described hereafter in relation to FIGS. **5**,**6** and **7**, between points **203** and **204**, the fluid may circulate in parallel through one or more elementary loops respectively comprising a heat exchanger **5** or one group Gi of heat exchangers **5** or a series Si of groups of heat exchangers **5**, where it receives heat on behalf of the material of storage. The fluid re-enters the subsystem of pumping **200** through inlet **204** at an higher temperature T**5**H-A. The fluid returns finally in balloon **220** by passing through node D.

[0088] On the right of FIG. **3**, the heat-conveying fluid can circulate in a loop comprising consumer **20** and/or in a loop of the storage unit **30** for the injection of energy.

[0089] Bottle **220** is connected to the inlet **210** and the outlet **209** to form a loop of circulation of fluid in consumer **20**. The fluid, leaving balloon **220**, is moved by pump **25**, circulates up to the node E then up to the outlet **209** with a temperature T**20**H. Outside the subsystem of pumping **200**, the fluid circulates in the consumer **20** where it yields heat. It re-enters in the subsystem of pumping **200** through inlet **210** with a lower temperature T**20**L. It circulates up to the node G then up to balloon **220**.

[0090] When the gate valves **223** and **224** are open, the fluid may also circulate from balloon **220**, in a loop allowing the injection of heat in material of storage. In heat storage mode, the fluid is moved by pump **202**. It leaves hydraulic separator **220** at a temperature T**5**H-B up to the node E. The gate valve **223** being opened in this case, the fluid circulates towards the node F, then towards the outlet **205**. As that will be described hereafter in relation to FIGS. **5**,**6** and **7**, outside the subsystem of pumping **200**, between points **205** and **206**, the fluid may circulate in parallel in one or more elementary loops respectively comprising an heat exchanger **5** or one group Gi of heat exchangers S or a series Si of groups of heat exchangers **5**, where it yields heat to material of storage. The fluid re-enters subsystem of pumping through inlet **206** with a lower temperature T**5**L-B, then circulates up to the node H. The gate valve **224** being opened in this case, the fluid circulates up to the node G, and then returns in balloon **220**.

[0091] To allow the simultaneous use of the subsystem of pumping **200** for both accumulating heat coming from hot source **10** and extracting energy from the ground to feed the consumer **20**, the loops described above are slightly modified in the way indicated hereafter.

[0092] The subsystem of pumping **200** comprises a second hydraulic separator **230**, which is then used thanks to a hydraulic connection between the loop of circulation of the fluid in source **10** and the loop used to accumulate heat in material of storage. First hydraulic separator **220** preserves in this case its function of means of hydraulic connection between the loop aiming at extracting the heat accumulated in the material of storage and the loop of circulation of the fluid in consumer **20**. In this functional mode, the gate valves **222**,**221**,**223**,**224** are maintained closed, whereas valves **232**, **231**,**233**,**234** are open.

[0093] Left side of FIG. **3**, bottle **230** is then connected to the nodes B and C to form the loop of circulation of fluid in source **10**. When valve **232** is opened, the heat-conveying fluid, moved thanks to pump **15**, leaves balloon **230** at a temperature T**10**L, and flows up to the connection node B, then towards outlet **207**. The fluid circulates in the source **10** where it receives heat. It returns with a temperature T**10**H in the subsystem of pumping **200** through inlet **208**. The fluid can return to the balloon **230** through connection node C and through valve **231**, this one being open.

[0094] On the right part of FIG. **3**, the balloon **230** is then connected to connection nodes F and H to form a loop allowing the accumulation of heat in the material of storage. When valve **233** is opened, the heat-conveying fluid, moved by means of pump **202**, leaves balloon **230** at a temperature T**5**H-B, circulates up to the connection node F, then towards the outlet **205**. The heat-conveying fluid can circulate through the material of storage, where it yields heat. The fluid returns through the inlet **206** with a lower temperature T**5**L-B, through to the node H, and returns finally in balloon **230** through valve **234**, this one being open.

[0095] On FIGS. **4** A to D are presented four examples of use of the subsystem of pumping **200**. The canalizations in which the heat-conveying fluid moves are indicated by continuous lines, the gate valves in open position are indicated in black, and the flow direction of the fluid in these canalizations is indicated by arrows. In return, the gate valves in closed position are indicated in white and the canalizations in which the fluid does not circulate are indicated by dotted lines.

[0096] The FIG. **4**A represents the subsystem of pumping **200** in a functional mode allowing at the same time the extraction of heat from the round and the accumulation of heat in the ground. Such a use allows redistributing heat within the storage zone. When this mode is selected, valves **221**,**222** are closed, valves **223** and **224** are open. Valves **231** to **234** are all closed, thus isolating balloon **230** from the circuit. The hydraulic separator **220** forms a hydraulic connection between the loop allowing the extraction of heat comprising pump **201**, and the loop allowing the accumulation of heat comprising pump **202**.

[0097] The FIG. **4**B represents the subsystem of pumping **200** in a functional mode allowing simultaneously the injection of heat coming from hot source **10** and the extraction of heat toward consumer **20**. In this state, valves **221** to **224** are closed, while valves **231** to **234** are open. The hydraulic separator **220** hydraulically connects the loop allowing the extraction of heat comprising pump **201**, and the loop of circulation of the fluid towards consumer **20** comprising pump **25**. Hydraulic separator **230** allows to connect hydraulically the loop of circulation of the fluid in source **10** comprising pump **15** and the loop allowing the accumulation of heat comprising pump **202**.

[0098] The FIG. **4**C represents the subsystem of pumping **200** in a functional mode allowing simultaneously the partial extraction of heat and the circulation in the loop comprising hot source **10**, this to produce the whole of the heat delivered to the cold source **20**. In this mode of use, valves **221**,**222** are opened and valves **223** and **224** are closed. Valves **231** to **234** are also closed, thus isolating balloon **230** from the circuit. The hydraulic separator **220** has then as a function to connect in one hand the loop of circulation of the fluid in the hot source **10** comprising pump **15** and the loop allowing the extraction of heat comprising pump **201**, and, on the other hand, the loop allowing the circulation of heat in the cold source **20** comprising pump **25**. The absence of production of heat by hot source **10** constitutes a particular case of this functional mode. In this case, the heat delivered to the cold source **20** is integrally extracted from the storage unit **30** by the extraction loop comprising pump **201**.

[0099] Finally FIG. **4**D represents the subsystem of pumping **200** in a functional mode allowing simultaneously the partial accumulation of heat produced by hot source **10** in the volume of storage **30** and the transfer of the remaining part of this heat to feed the cold source **20**. In this functional mode, valves **221** to **224** are open. Valves **231** to **234** are closed, thus isolating balloon **230** from the circuit. The hydraulic separator **220** allows connecting on the one hand the loop of circulation of the fluid in hot source comprising pump **15**, and on the other hand the loop allowing the accumulation of heat comprising pump **202** and the loop allowing the circulation of heat in the cold source **20** comprising pump **25**. The absence of consumption of heat by the cold source **20** constitutes a particular case of this functional mode. In this case, the heat produced by hot source **10** is integrally injected into the storage unit **30** to be stored there.

[0100] While referring to FIG. **5**, the subsystem of control of flow **300**, allowing the selective circulation of the heat-conveying fluid between subsystem of pumping **200** and the storage unit **30**, and the subsystem of connection **400**, allowing conferring a particular architecture to the storage unit **30**, will now be described in detail.

[0101] The subsystem of connection **400** constitutes an interface allowing connecting a set of exchangers of calorific energy **5**, buried in the ground, with the subsystem of control of flow **300**. Although the invention could make it possible to control individually each exchanger of heat **5**, it is advantageous, for reasons of cost and facility of realization, to associate a certain number of exchangers of heat **5** within an exchange unit. An exchange unit, comprising at least one exchanger, then constitutes the finest unit which one can control individually. Thus, for example, the device of storage **30** of FIG. **5** is organized so as to comprise for example M groups Gi of exchangers (index i ranging between 1 and M). The elementary exchange unit of the storage unit **30** is then made up, instead of a single exchanger **5**, by a group G of exchangers. This is particularly interesting for the large installations aimed by the invention.

[0102] At the level of the subsystem of connection **400** is organized the architecture in various groups Gi (1<=i<=M) of the whole of the exchangers of heat. As that is represented on FIG. **5**, the hot ends **53** of each exchanger of heat **5** of the same group Gi (1<=i<=M) are connected between them to a "hot" manifold Ui,**1** of the group Gi, and the cold ends **54** of each exchanger **5** of the group Gi are connected together to the "cold" manifold Ui,**2** of the group Gi. Thus, in this mode of realization, between the hot manifold Ui,**1** and the cold manifold Ui,**2**, various exchangers of heat **5** of the group Gi are assembled in parallel from/to each other. The hot manifold Ui,**1** is connected to the subsystem of control of flow **300** via a hot canalization **37***i*. The cold collector Ui,**2** is connected to the subsystem of control of flow **300** via a cold canalization **38***i*.

[0103] The subsystem of control of flow **300** can be divided into a part of injection of heat **300**B (left right FIG. **5**) and a part intended for the extraction of heat referred by identifier **300**A (left part of FIG. **5**).

[0104] One supposes that the storage unit **30** includes M hydraulic loops of heat exchange, each one of these loops consisting of a group of exchangers Gi (i varying of 1 to M).

[0105] The part of injection **300**B is connected to subsystem of pumping **200** at point **205** and point **206**. From the point of view of the physical system that the part of injection **300**B constitutes, point **205** allows the input of the "hot" heat-conveying fluid and point **206** allows the output of the "cold" heat-conveying fluid.

[0106] Input **205** is hydraulically connected to a branch **301**-B. The branch **301**-B comprises M downward canalization **31***i*-B (1<=i<=M).

[0107] Each downward canalization **31***i*-B is respectively connected downstream, via node Ki, then via the canalization **37***i*, to the hot manifold Ui,**1** of associated group Gi.

[0108] The cold manifold Ui,**2** of the group Gi (1<=i<=M) is connected to a branch **302**-B, via the canalization **38***i*, then via a dedicated ascending canalization **35***i*-B passing by the node Li. Branch **302**-B is connected to output **206**.

[0109] One sees thus that between input **205** and output **206**, M hydraulic loops of extraction of heat, each comprising a group of exchanger Gi (1<=i<=M), are laid out in parallels.

[0110] The branches **301**-B and **302**-B are equipped with a differential pressure sensor **303**-B. The downward canalizations **31***i*-B (1<=i<=M) are respectively equipped with a flow sensor **32***i*-B, a valve of regulation **33***i*-B, making it possible to regulate the flow in the corresponding loop, and of a ON/OFF gate valve **34***i*-B. It should be noticed that the two valves **33***i*-B and **34***i*-B are laid out in series and that the gate valve **34'**-B makes it possible to actually block any circulation in the canalization which it equips; a valve of regulation, such as the valve **33***i*-B, being never completely tight.

[0111] Each ascending canalization **35***i*-B is provided with a ON/OFF gate valve **361**-B.

[0112] In a similar way, in the heat extraction part **300**A, the "cold" fluid is injected into the subsystem of control of flow **300** by the input **203**. This input **203** is connected to a branch **301**-A. From branch **301**-A, M downward canalizations **31***i*-A (1<=i<=M) are respectively connected to the cold manifold Ui,**2** of the group of exchangers Gi via the node Li. The hot manifold Ui,**1** of each group Gi (1<=i<=M) is connected to a branch **302**-A, via a dedicated ascending drain **35***i*-A passing by node Ki. This branch **302**-A itself is connected to the output point **204**. Branch **302**-A allows a return of the "hot" heat-conveying fluid towards the subsystem of pumping **200**, via the output point **204**.

[0113] Thus, between branches **301**-A and **302**-A, M hydraulic loops of extraction of heat are laid out in parallel from each other, each one allowing supplying the associated group of exchanger Gi with heat-conveying fluid.

The branches **301**-A and **302**-A are equipped with a differential pressure sensor **303**-A. The downward canalizations **31***i*-A (1<=i<=M) are respectively equipped with a flow sensor **32***i*-A, a valve of regulation **33***i*-A making it possible to regulate the flow in the corresponding loop and with a ON/OFF gate valve **34***i*-A making it possible to stop completely the circulation of the heat-conveying fluid in the associated loop.

[0114] Each ascending canalization **35***i*-A is provided with a ON/OFF gate valve **36***i*-A.

[0115] It will be noticed that for reasons of saving and facility of assembly and maintenance, the downward canalizations **31***i*-B (1<=i<=M) and the ascending canalizations **35***i*-A which leads both to the same hot manifold Ui,**1** advantageously has a common section **37***i*, from the hot manifold Ui,**1** to the node Ki. Similarly, the downward canalization **31***i*-A and the ascending canalization **351**-B connected to the same cold collector Ui,**2** share advantageously a common section **38***i*, from the cold manifold Ui,**2** to the node Li.

[0116] A loop including a group of exchangers Gi (1<=i<=M) is then either activated in injection of heat, this loop being then connected to the branches **301**-B and **302**-B, or activated in extraction of heat, this loop being then connected to the branches **301**-A and **302**-A, or inactive, this loop being then isolated hydraulically from the circuit.

[0117] The flow in each loop activated in injection of heat is individually regulated by the adjustment of the pressure loss created by the corresponding valve of regulation **33***i*-B (1<=i<=M). The measure of flow associated with this regulation is ensured by the sensor of flow **32***i*-B. In order for the various flow regulators to work together, the adjustment of the flow in any of the loops activated in injection should not have any influence on the flow in the other loops also activated in injection. In other words, the M flows in the downward canalizations **31***i*-B (1<=i<=M) must be independent from each other. That is carried out by the keeping of a constant difference of hydraulic pressure, independent of the total flow of fluid, between the branch **301**-B and the branch **302**-B. To that end, the circulating pump **202** of the subsystem of pumping **200** is driven by an electrical motor equipped with a variable speed control device, functioning in differential pressure regulation mode: the speed of pump **202** is controlled to maintain the differential pressure between the two branches **301**-B and **302**-B at a preset set point, the loop of measure of this regulation being ensured by the differential pressure sensor **303**-B. The difference in pressure between the branches **301**-B and **302**-B being maintained constant, each of the M flows in canalizations **31***i*-B (1<=i<=M) can be controlled in an independent way.

[0118] It will be noticed that on the side of branch **302**-B, the fluid runs out up to bottle **220** through the gate valve **224**, or up to bottle **230** through the gate valve **234**, according to the selected functional mode. In both cases, branch **302**-B is hydraulically connected to the neutral point of the circuit only by the means of a gate valve in opened position, representing a very weak pressure loss. The pressure at the level of this branch **302**-B can be regarded as independent of the total flow of fluid, which confers a great stability to the regulation of differential pressure between the branches **301**-B and **302**-B.

[0119] In the same way, the flow in each loop activated in the extraction of heat is controlled with its individual value by the adjustment of the pressure loss created by the valve of regulation **33***i*-A (1<=i<=M). The measure of flow associated with this regulation is ensured by the sensor of flow **32***i*-A. The M flows in the downward canalizations **311**-A (1<=i<=M) must be independent from each other. That is carried out by maintains of a constant difference in water pressure independent of the total flow of fluid, between the branches **301**-A and **302**-A. To that end, the circulating pump **201** of the subsystem of pumping **200** is also driven by electrical motor equipped with a variable speed control device, functioning in differential pressure regulation mode: the speed of pump **201** is controlled to maintain the differential pressure between the two connections **301**-A and **302**-A at a preset set point, the loop of measure of this regulation being ensured by the differential pressure sensor **303**-A. The difference in pressure between the connections **301**-A and **302**-A being maintained constant, each M flows in the canalizations **31***i*-A (1<=i<=M) can be controlled in an independent way.

[0120] It will be noticed that on the side of branch **302**-A, the fluid runs out directly to balloon **220**. Branch **302**-A is thus hydraulically connected to the neutral point of the circuit, so that the pressure at the level of this connection is independent of the total flow of fluid, which confers a great stability to the regulation of differential pressure between the branches **301**-A and **302**-A.

[0121] On the FIG. **6**A, the subsystem of control of flow **300** is represented in an functional mode for the injection of energy using a loop of heat transfer including the group of exchangers Gi (i<=i<=M). The canalizations in which the heat-conveying fluid is moving are indicated by continuous lines, the open gate valves in position are indicated in black, and the direction of flow of the fluid in these canalizations is indicated by arrows.

[0122] In this functional mode, one wishes to inject heat in the ground, for example starting from hot source **10**. Consequently, the fluid at a temperature T**5**H-B is introduced by input **205** at the level of branch **301**-B When the gate valve **34***i*-B corresponding to the Gi group is actuated to be in the open state and the gate valve **36***i*-A is simultaneously actuated to be in the closed state, the fluid under pressure is conveyed via the canalizations **31***i*-B and **37***i* towards the hot manifold Ui,**1** where it is distributed among the various exchangers of heat **5** of the Gi group. The temperature of the heat-conveying fluid T**5**H-B is higher than the average temperature T**2** of the medium. Consequently, the heat of the heat-conveying fluid is transferred towards material of storage. At the output of each exchanger **5**, the heat-conveying fluid is collected by the manifold Ui,**2**, then conveyed via the canalizations **38***i* and **35***i*-B towards branch **302**-B, the gate valve **36***i*-E**3** being actuated to be in the open state and the gate valve **34***i*-A being simultaneously actuated to be in the closed state. Finally, the heat-conveying fluid, having a temperature T**5**L-B, is conveyed at the output point **206**. The flow of the fluid in the loop which has just been described is controlled by the valve **33***i*-B.

[0123] On the FIG. **6**B, the subsystem of pumping **300** is represented in an functional mode for the extraction of heat using a loop of heat transfer including the group of exchangers Gi (1<=i<=M). By opening the valves **34***i*-A and **36***i*-A while closing the valves **34***i*-B and **36***i*-B, a loop is activated which includes the downward canalization **31***i*-A, the common canalization **38***i*, the group of exchangers Gi equipped with its two cold Ui,**2** and hot Ui,**1** manifolds, the common canalization **37***i*, and the ascending canalization **35***i*-A.

[0124] A description equivalent to the one done above for the injection could be made for the functional mode in extraction using part **300**A to describe how the heat-conveying fluid introduced at point **203** at a temperature T**5**L-A runs out at the level of point **204** at temperature T**5**H-A.

[0125] Finally a functional mode of subsystem of control of flow **300**, in which the loop comprising the group of exchangers Gi (1<=i<=M) is maintained inactive, is obtained by closing the valves **34***i*-A, **36***i*-A, **36***i*-B and **34***i*-B.

[0126] While referring to FIG. **7**, for a certain number of applications aimed by the invention, functioning in injection and/or extraction requires an important variation of temperature between the entering fluid and the outgoing fluid of the storage unit. To satisfy this functioning, it is often necessary to connect in series several groups of exchangers.

[0127] In this case, during its passage through the storage unit **30**, the heat-conveying fluid does not cross only one exchanger (a group of exchanger consisting of exchangers in parallel), but also several exchangers in series (each one belonging to one of the groups connected in series). Thus the quantity of heat exchanged with the material of storage and the temperature variation undergone by the fluid are increased. However, because of the variations of flows and temperatures of the fluid at the entry of the system and the need to precisely being able to control the physical zones of injection and extraction of heat, it is advantageous that series of exchangers can be configured in order to decide number of groups used in a series and position of the resulting series.

[0128] In order to limit the costs induced by the combinative aspect, it is proposed the following compromise, represented on FIG. **7**. For a particular realization of the invention, it is decided, before the realization, to have a fixed number S of series of exchangers Si (1<=i<=S) inside the means of storage **30**. Each series Si comprises a fixed number Mi of groups of exchangers Gi,j, J (1<=j<=Mi) ordered from 1 to Mi. The system contains means allowing configuring, at any time, a branch of variable position and length as a subseries of a maximum series SiMax made up of all the groups of exchangers Gi connected in series.

[0129] More precisely, it is at the level of the subsystem of connection **400'** that the serialization of the groups of exchangers is organized. FIG. **7** is a diagrammatic representation in mode of injection of heat, of part of the subsystem of control of flow **300'** and of the subsystem of connection **400'** when the activated loop does not comprise one single group of exchangers but a branch of the series Si. Subsystem of connection **400'** organizes the storage unit **30** so that the cold inputs of exchangers belonging to a group of heat exchangers of Gi,j and the hot inputs of exchangers of heat of the following group Gi,j+1 are connected to the same manifold Ui,j, except for the first manifold Ui,**1** which is only connected to the hot entries of the first group Gi,**1** of the series Si, and the last manifold Ui,Mi+1 which is connected only to the cold entries of the last group Gi,Mi of the series Si. There are thus Mi+1 manifolds.

[0130] The principle implemented in the subsystem of control of flow **300'** to activate the loop comprising a branch of the series Si (1<=i<=S) and to control the flow of heat-conveying fluid in this loop is identical to what was described previously in the case of the activation of a group of exchangers. The difference lies in the fact that, for any series of groups of exchanger Si (1<=i<=S), the hot canalization **37***i* of the subsystem of control of flow **300'** is equipped with a flow switch **310***i* and the cold canalization **38***i* is equipped with a flow switch **320***i*.

[0131] A flow switch is a bidirectional device hydraulically connecting a primary canalization to an arbitrary number of secondary canalizations equipped each with a bidirectional ON/OFF valve. By opening a valve while keeping closed all the others, the flow switch connects the primary canalization to only one secondary canalization, thus opening a path for the heat-conveying fluid.

[0132] For any series Si (1<=i<=S), the switch of flow **310***i* comprises Mi+1 secondary canalizations respectively equipped with a bidirectional controlled valve **31***ji* (1<=c=Mi+1) and connected via node Vi,j to Mi+1 manifolds Ui,j (1<=j<=Mi+1). The switch of flow **320***i* comprises Mi+1 secondary canalizations respectively equipped with a bidirectional controlled valve **321***i* (1<=j<=Mi+1) and connected via node Vi,j to the manifold Ui,j (1<=j<=Mi+1).

[0133] Being given two indexes p and q (1<=p<=Mi, 1<=q<=Mi), the valve of index p (noted **31***pi*) of the switch of flow **310***i*, associated with the secondary canalization connected to manifold Ui,p, as well as the valve of index q+1 (noted **32** (q+1) l) of the switch of flow **320***i*, associated with the secondary canalization connected to the collector Ui,q+1, are both actuated to be in the open state. The heat-conveying fluid, coming from the branch **301**-B at temperature T**5**H-B, is then directed by the switch of flow **310***i* towards the collector Ui,p. It enters the Si series by the group of exchangers Gi,p, circulates successively in all the groups of exchangers of the series Si ranging between Gi,p and Gi,q included, where it exchanges heat with the material of storage. It leaves the Si series through the manifold Ui,q+1 at a temperature T**5**L-B lower than T**5**H-B. It is then directed towards the branch **302**-B through the switch of flow **320***i*. Thus the circulation of the heat-conveying fluid is restricted to the only branch of the series Si located between the groups Gi,p and Gi,q. It will be noted that, when p=q, only the group Gi,p is traversed. Moreover, the system makes it possible to reverse the direction of circulation in the branch by simple permutation of the indexes p and q.

[0134] A similar description could be made in mode of extraction of energy.

[0135] The possibility of selecting, inside a series Si (1<=i<=S) activated in injection or extraction, the branch which will be in adequacy with the targeted functioning, in particular with requested values of temperature of the fluid entering and outgoing the storage section, and of restricting the circulation of the fluid to this only branch, in an arbitrary direction, allows thus limiting and localizing the phenomenon of thermal diffusion in the whole of the storage section. Moreover, the adequate branch having been selected and having been activated, the regulation of the flow of heat-conveying fluid circulating in this branch makes it possible to adjust the temperature of the fluid at the output of the branch and thus to adapt it to the value requested by the source in mode of injection of heat or by the consumer in mode of extraction of heat.

[0136] In a more general way, the system of connection can be seen as a fixed unit making it possible to gather exchangers **5** in parallel or series. The system of connection may undergo the addition (and more rarely the withdrawal) of certain groups of exchangers, in order to adapt the total power of injection and/or extraction of heat to the needs for the application. Except in these exceptional operations, the system of connection is fixed and does not undergo any variation in structure. Moreover, the system of connection is specific to each application since the total architecture of the storage unit **30**, in particular the number and the localization of exchangers **5**, their association in groups and the possible connection of certain groups in series, will be the result of a study undertaken on a case-by-case basis for each application, and will depend on various parameters such as the quantity of energy to store, the characteristics of the source and the consumer, the power of injection/extraction necessary, the thermal characteristics of material of storage, or the coefficients of infiltration or underground water circulation through the storage unit **30**.

[0137] The subsystem of control of flow allows selecting with the finest possible granularity, the domain of the adequate storage zone for the extraction or the injection of calorific energy. The activation of an exchanger, of a group of exchangers or whole or part of a series of groups of exchangers makes it possible to control the thermal power injected or extracted in the domain corresponding to storage zone.

[0138] While referring again to FIG. **2**, the hydronic system **100** according to the invention comprises a loop of control allowing the automatic actuation of the various valves used to activate one or more exchangers according to the selected functional mode.

[0139] To that end the hydronic system **100** and the storage unit **30** are equipped with a set of temperature gauges. They are temperature gauges **6** laid out in the ground or the heat exchanger's sheath **55**, and possibly of temperature gauges **17** and **27** laid out in various points of the hydronic system to know the temperature of the heat-conveying fluid. Sensors **6**, **17** and **27** allow a local measure of the temperature. Other types of sensors can be used. During the description of FIG. **5**, one introduced sensors **32***i*-A and **32***i*-B which allows obtaining information about flow. The loop on the source side and the loop on the consumer side can also be equipped with sensors of flow **18** and **28** in order to know at any time the thermal power (product flow by the difference of the temperatures of the heat-conveying fluid in the input and output canalizations) supplied by source **10** and the thermal power used by consumer **20**. More generally, the hydronic system **100** and the storage unit **30** can comprise a plurality of sensors and actuator making it possible to act physically on the system, as well as programmable automation devices allowing remote input/output operations, carrying out successions of remote operations and generating operating condition state variables. The output signals of hydronic system **100** and storage unit **30** thus include all the signals coming from the sensors, from the actuators and from the automation. The input signals of hydronic system **100** and storage unit **30** include all the signals addressed to the actuators and to the automats.

The output signals of hydronic system **100** and storage unit **30** are conveyed in the form of electrical signals towards a calculating unit **500**.

[0140] The calculating unit **500** comprises means of memorizing and means of calculation. The instructions of a program are memorized in the means of memorizing and are carried out by the means of calculation. The calculating unit **500** comprises an interface input-output ready to receive in entry the hydronic output signals of the system **100** and storage unit **30** and to emit at exit the entry signals of the system hydronic **100** and storage unit **30** allowing the actuation of the various ordered valves and controls of regulation of the subsystem of pumping **200** and/or the subsystem of control of flow **300**.

[0141] In function of the signals coming from the source and the consumer, amongst other things the instantaneous thermal power provided by source **10** and the instantaneous thermal power required by consumer **20**, as well as hydronic output signals of the system **100** and storage unit **30** defining the actual position and the current configuration of the zone, the calculating unit **500** is ready to determine the composition of the loops of the storage unit which must be configured and activated by the system hydronic **100**.

[0142] To this end, the calculating unit **500** determines, for each active loop, if the activation of the loop must be done in injection or extraction of heat. In mode of injection of heat, the group Gi (1<=i<=M) (or series of groups Si (1<=i<=S)) will be connected to branches **301**-B and **302**-B by opening the two gate valves **34***i*-B and **36***i*-B. In mode of extraction of heat, the group Gi (1<=i<=M) (or series of groups Si (1<=i<=S)) will be connected to branches **301**-A and **302**-A by opening the two gate valves **34***i*-A and **36***i*-A.

[0143] Unit **500** also calculates the flow of the calorific fluid which must traverse this loop. This flow circulating in the group Gi (1<=i<=M) (or series of groups Si (1<=i<=S)) will then be controlled with the calculated value using the valve of regulation **33***i*-B in mode of injection of heat, and using the valve of regulation **33***i*-A in mode of extraction of heat.

[0144] In the alternative of realization described above with respect to FIG. **7**, during the activation of a series of exchangers Si (1<=i<=S), the calculating unit **500** defines also the topology of the branch of this series Si which will be traversed by the heat-conveying fluid by defining the value of the indices p and q. The corresponding groups Gi,p and Gi,q will be activated using the associated switches of flows **310***i* and **320***i*.

[0145] A mode of realization making allowing the designation of active loops in function of the output signals of the hydronic system **100** and the storage unit **30** now will be described in detail.

[0146] Prior studies of the storage unit **30** and its realization in a particular geological site allow, among others, to define a plurality of successive optimal states of the storage section. Each optimal state thus defined can be represented by a map in three dimensions giving the temperature in any point of the storage section to a given date. For example, in the case of a storage unit of heat supplied with solar collectors, the successive optimal maps could be determined for every summer month with as criterion to maintain of a weak temperature gradient at the level of the envelope of the storage zone, i.e to maintain a weak flow of calorific energy through this envelope; then, at the end of the cycle of load, the optimal maps could be determined with as another criterion the maximum filling of the volume of storage. Other types of optimal states, represented by their associated optimal chart, can be given with other criteria by the user. For example, for the same storage unit **30**, one can want to establish a map for summer and a map for autumn. The map of summer defines several sectors corresponding to storages at different levels of temperature in summer: thus the storage zone can comprise a sector dedicated to the accumulation of heat produced by solar panels for a production of winter heat and a sector of storage dedicated to an application of air-conditioning during summer. The objective here is to allow the system to accumulate heat for the next winter, while supporting a sector adapted to an application of air-conditioning, in order to increase energy efficiency. The map for autumn can then be defined so as to remove, in the storage unit **30**, this air-conditioning dedicated sector and now store there heat coming from the solar panels, in order for the storage unit **30** to present a spectrum of temperatures of storage allowing the production of winter heat to function with an optimum energetic efficiency.

[0147] More generally, a map indicates any means making it possible to obtain information on the total state of the storage unit **30** at a given date; the global state of the storage unit being characterized by knowledge, possibly approximate, of the temperature in each point of the storage unit **30**.

[0148] During the use of the storage system, one of the optimal maps is loaded in the means of memorizing of the calculating unit **500**. This optimal map is then regarded as an objective to reach during time. For example, in the case of a storage unit of heat supplied with solar collectors, the user will load the map optimal at the end of the cycle if it wishes the storage zone to contain a maximum of calorific energy for example in October, right before the arrival of the winter months which are months of strong energy consumption, during which one knows that the heat source will produce only little energy.

[0149] The calculating unit **500**, allows at every time, according to the temperature measurements sampled by various sensors **6**, to carry out an instantaneous three-dimensional map of the temperature in the storage zone. This map gives the instantaneous state of the storage zone.

[0150] Given the instantaneous map, the optimal map fixing the objectives to be reached and the information concerning the instantaneous state of the source and the consumer (flows and temperatures), the calculating unit **500** emits signals of actuation so that at every moment the functional mode of the hydronic system **100** meets the needs of the consumer and the source, but also the final objective to reach.

[0151] For example, the calculating unit **500** locally evaluates the differences between the temperature given by the optimal chart and the temperature given by the instantaneous chart. If the thermal power produced by the source is higher than the one required by the consumer, unit **500** selects the functional mode of partial injection of energy and activates in injection of heat the exchangers located in a cold part of the storage zone, whose temperature levels are adapted to the contributions of the source and which presents a deficit in temperature compared to the targeted map. If on the contrary the thermal power produced by the source is not sufficient to feed the consumer, unit **500** selects the functional mode of partial extraction of energy and activates in extraction of heat the exchangers located in a hot part of the storage zone, whose temperature levels are adapted to the needs of the consumer and which presents an excess of temperature compared to the targeted map. This way the distribution of temperature inside the zone converges in time towards the optimal state.

[0152] The calculating unit **500** can present a user interface allowing an operator to completely define, at every time, the configuration of hydronic system **100**: in this case, it is the operator himself who defines the input signals of the hydronic system **100** and of the storage unit **30** in order to control the evolution of the storage unit **30**.

[0153] The calculating unit **500** can comprise a process of regulation or a predictive control used to calculate the input signals of the hydronic system **100** and the storage unit **30** in order to control the evolution of the storage unit **30**: in this case, the calculating unit **500** is based on a method of optimization that determines the input signals of the hydronic system **100** and storage unit **30** to satisfy the objective of transition between the current state of the storage unit **30** corresponding to the instantaneous map, and a desired state corresponding to an optimum map.

[0154] In the immediately preceding case, the method of optimization can take into account a set of constraints represented by a cost function (optimization under constraints), so that the constraints are satisfied when the cost function is optimum. In this case, the purpose of the method of optimization under constraints is to determine the input signals of the hydronic system **100** and the storage unit **30** to satisfy the objective of transition between the current state of the storage unit **30** corresponding to the instantaneous map, and a desired state corresponding to an optimum map, the transition taking an optimum way as seen from the cost function, thus satisfying optimally the constraints.

[0155] Thus, from what precedes immediately, the control of the evolution of the storage unit can be carried out by taking into account constraints related to the global efficiency of an energy system using the invention. In particular, the constraints can be strongly related to the level of energy efficiency and/or the cost of exploitation of the sources and/or the consumers. Constraints resulting from weather forecasting can also be taken into account, in order to adapt as well as possible to the coming needs from the consumers, and/or with the coming production from the producers, in particular if they use renewable energies.

[0156] Lastly, the constraints related to the schedule of the heat production of a producer and/or the consumption of heat by a consumer can also be taken into account.

[0157] FIGS. **8**A to **8**D represent a simple example of optimal maps at associated to a given depth of a heat storage unit. The FIGS. **3**B, **8**C and **8**D represent the distribution of temperature one looks for at three different and successive moments during a cycle of injection of heat in the storage section, The temperature of each isothermal curve is indicated in Celsius degrees. In this example, the storage zone contains 42 exchangers **5** regularly laid out and noted Eij (1<=i<=7, 1<=j<=6). The represented system is based on a grouping of the exchangers in 14 series of three exchangers (each series being able to generate sub-series according to the present invention), numbered S**1** to S**14**, defined as (without taking account of the direction of circulation of the fluid): S**1**=E**11**, E**12**, E**13**; S**2**=E**14**, E**15**, E**16**; S**3**=E**21**, E**22**, E**23**; S**4**=E**24**, E**25**, E**26**; S**5**=E**31**, E**32**, E**33**; S**6**=E**34**, E**35**, E**36**; S**7**=E**41**, E**42**, E**43**; S**8**=E**44**, E**45**, E**46**; S**9**=E**51**, E**52**, E**53**; S**10**=E**54**, E**55**, E**56**; S**11**=E**61**, E**62**, E**63**; S**12**=E**64**, E**65**, E**66**; S**13**=E**71**, E**72**, E**73**; S**14**=E**74**, E**75**, E**76**. The storage zone comprises moreover temperature gauges which are not represented on the FIG. **8**A.

[0158] In the initial state, the temperature of the storage section is equal to the outside temperature of the ground, that is approximately 15° C. Then, one seeks to constantly inject heat so that one can, at any time of the cycle of charge, have access to the greatest quantity of directly exploitable thermal energy, i.e. a temperature from approximately 40 to 50° C. Moreover, one seeks to create gradients at the edge of storage section which allow to limit losses during the cycle of injection.

[0159] One decides to inject thermal energy according to 3 distinct phases in the cycle of charge, which are respectively represented by FIGS. **8**B, **8**C and **8**D. The procedure consists in forming then increasing a central zone having a temperature from 45 to 50° C. so that, at the end of the injection, the envelope of the storage section is as close as possible to the topology of the storage unit to maximize the recuperation of energy during the phase of extraction. In this example, the storage zone comprises a single domain defined by a temperature of 45 in 50° C., but the storage zone could comprise various domains each having a particular range of temperature.

[0160] One has access to a hot source producing water as a heat-conveying fluid with a temperature of 60° C. for a flow of 10 kg/s. In the first phase, in order to fill the objective presented on the FIG. **8**B, the series S**5**, S**6**, S**7**, S**8**, S**9** and S**10** are selected, and the branches S'**5**=E**33**; S'**6**=E**34**; S'**7**=E**43**; S'**8**=E**44**; S'**9**=E**53**; S'**10**=E**54** are configured. The fluid is injected in parallel in the branches S'S to S'**10** until the temperature of the storage section is as close as possible to what is represented in FIG. **8**B.

[0161] When this first phase is reached, the system configures (by taking into account the direction of flow of the fluid) the following branches: S"**3**=E**23**, E**22**; S"**4**=E**24**, E**25**;

S"**5**=E**33**, E**32**; S"**6**=E**34**, E**35**; S"**7**=E**43**, E**42**; S"**8**=E**44**, E**45**; S"**9**=E**53**, E**52**; S"**10**=E**54**, E**55**; S"**11**=E**63**, E**62**; S"**12**=E**64**, E**65**. Then it carries out the injection in parallel in the branches S"**3** to S"**12** until the temperature of the storage section is as close as possible to what is represented on the FIG. **5**C.

[0162] When this second phase is reached, the system configures (by taking account of the direction of flow of the fluid) finally the following branches: S'"=E**13**, E**12**, E**11**; S'"**2**=E**14**, E**15**, E**16**; S'"**3**=E**23**, E**22**, E**21**; S'"**4**=E**24**, E**25**, E**26**; S'"**5**=E**33**, E**32**, E**31**; S'"**6**=E**34**, E**35**, E**36**; S'"**7**=E**43**, E**42**, E**41**; S'"**8**=E**44**, E**45**, E**46**; S'"**9**=E**53**, E**52**, E**51**; S'"**10**=E**54**, E**55**, E**56**; S'"**11**=E**63**, E**62**, E**61**; S'"**12**=E**64**, E**65**, E**66**; S'"**13**=E**73**, E**72**, E**71**; S'"**14**=E**74**, E**75**, E**76**. The injection is carried out then in parallel in the branches S'"**1** to S'"**14** until obtaining the final state of the section storage presented on the FIG. **8**D.

[0163] In function of input and output temperatures of injection imposed by the source or extraction imposed by the consumer, it is possible to work out several scenarios of injection or extraction implying series or groups of exchangers and, possibly, various domains in the storage zone having different average temperatures and to anticipate the impact of each scenario on the global efficiency of the installation. The system can then rely on combinatorial optimization processes in order to lead the cycle of load/discharge while optimizing the output of the unit.

[0164] Thus, the calculating unit **500** ensures the optimal control of the distribution of temperature in the storage zone **30** throughout load/discharge cycles.

Thus, the hydronic system **100** according to the invention allows:

- **[0165]** to control the thermal storage unit **30** according to three functional modes: injection of heat, the extraction of heat, injection and the extraction simultaneous,
- **[0166]** to actively control throughout the cycle of load/discharge the distribution of temperatures inside the storage zone in order to minimize the quantity of energy lost at frontiers during a complete cycle, while optimizing the volume of material of storage,
- **[0167]** to ensure the optimal control of the processes of injection and extraction of heat in the device of thermal storage **30**, in order to limit the phenomena of diffusion in the material of storage which is at the origin of the thermal losses, in particular by restricting the circulation of fluid to the only zones which would have been selected for the injection or the extraction, in adequacy with the requested functioning, in particular with the necessary values of temperature of the fluid entering and outgoing the storage section.

[0168] to ensure the optimal control of the processes of injection and extraction of heat in the device of thermal storage **30**, in order to split the thermal device of storage **30** into one or more different thermal zones with the aim of presenting to the producers and to the consumers ranges of temperature and quantities of heat adapted to their applications, in particular by restricting the circulation of fluid to the only zones which would have been selected for the injection or the extraction, in adequacy with requested functioning, in particular with the necessary values of temperature of the fluid entering and outgoing the storage zone.

- **[0169]** to ensure the optimal control of the processes of injection and extraction of heat in the device of thermal storage **30**, according to one of the functionality previously described, while satisfying arbitrary constraints, in particular those related to the global efficiency of the power system, including the sources and/or the consumers.
- **[0170]** to allow to fight against the effects of the transverse hydrogeologic infiltrations, as far as possible, while transferring heat between various zones of the same thermal buffer **30**.

[0171] Although the invention was described in reference to a particular mode of realization, it is by no means limited to this mode of realization. It includes all the technical equivalents of the described means as well as their combinations entering within the framework of the invention.

1. Process of control of a unit of thermal energy storage in the ground comprising a plurality of exchangers of heat buried in the ground, each one of the aforesaid exchangers allowing a calorific energy exchange between a heat-conveying fluid traversing it and the ground, the aforementioned energy storage unit being laid out at the interface between a source and a calorific consumer of energy to store thermal energy, characterized in that one measures the temperature in various points of the ground by means of buried temperature gauges, the temperatures and flow of a heat-conveying fluid in input and output of the source to determine the thermal power provided by the source, and temperatures and flow of a heat-conveying fluid in input and output of the consumer to determine the thermal power to provide to the consumer, and in that one optimizes the storage of thermal energy in the aforementioned storage unit by selecting active exchangers among the aforementioned plurality of exchangers according to temperature measurements, flow measurements and thermal power measurements.

2. Process according to claim **1**, characterized in that it comprises the stages consisting in:

determining beforehand an optimal map of the temperatures in the ground;

determining an instantaneous map of the temperatures in the ground by the means of the aforesaid temperature measurements taken in various points of the ground;

selecting active exchangers among the aforementioned set of exchangers in function of the local variations of temperature between the aforementioned instantaneous map and the aforementioned optimal map, of the temperatures and flow of the heat-conveying fluid in input and output of the source, and the temperatures and flow of the heat-conveying fluid in input and output of the consumer, in order to drive the transition of the storage unit from the current state corresponding to the instantaneous map towards the state corresponding to the optimum map, the transition taking an path which is either arbitrary or imposed by a set of constraints.

3. Process according to claim **1**, characterized in that one moves of heat inside the storage unit by circulation of the heat-conveying fluid between a loop comprising at least one exchanger activated in extraction and a loop comprising at least one exchanger activated in injection.

4. Process according to claim **1**, characterized in that it comprises an additional stage consisting in:

When the thermal power provided by the source is adapted to the thermal power used by the consumer, not activating any the exchangers and making circulate the heat-conveying fluid between a loop comprising the source and a loop comprising the consumer;

When the thermal power provided by the source is not usable by the consumer, making circulate the heat-conveying fluid between a loop comprising the source and a loop comprising some exchangers activated in injection, and making circulate simultaneously the heat-conveying fluid between a loop comprising the consumer and a loop comprising some exchangers activated in extraction;

When the thermal power provided by the source is higher than the thermal power used by the consumer, making circulate the heat-conveying fluid on the one hand in a loop comprising the source and on the other hand in a loop comprising the consumer and a loop comprising some exchangers activated in injection;

When the thermal power used by the consumer is null, totally injecting the thermal power provided by the source in the storage unit;

When the thermal power provided by the source is lower than the thermal power used by the consumer, making circulate the heat-conveying fluid on the one hand in a loop comprising the consumer and on the other hand in a loop comprising the source and a loop comprising some exchangers activated in extraction;

When the thermal power provided by the source is null, completely extracting the thermal power used by the consumer from the storage unit.

5. Hydronic system of control of a unit of thermal energy storage in the ground comprising a plurality of exchangers of heat buried in the ground, each one of the aforesaid exchangers allowing a calorific energy exchange between a heat-conveying fluid traversing it and the ground, the aforementioned hydronic system being intended to be laid out between a calorific energy source, a consumer of calorific energy and the aforementioned storage unit, characterized in that it comprises:

a plurality of temperature gauges buried in the ground;

flow and temperature gauges to measure a thermal power provided by the source and a thermal power used by the consumer;

means of regrouping to group the aforementioned exchangers in a plurality of elementary exchange units, an exchange unit comprising at least one exchanger; and,

means of activation to activate the aforementioned elementary exchange units selectively.

6. System according to claim **5**, characterized in that, an exchanger comprising a hot end and a cold end, the means of regrouping allow to form groups of exchangers, known as exchange unit, the various hot ends of the aforesaid exchangers of the same group being connected to a hot manifold and the cold ends of these same exchangers being connected to a cold manifold, various exchangers of the said group being in parallel from each other.

7. System according to claim **6**, characterized in that the aforementioned means of regrouping allow to form series of exchangers as an exchange unit, a series of exchangers (S) comprising a number (nS) of groups of exchangers (Gi), the cold collector of one of the aforesaid groups (Gi) of a series being connected to the hot manifold of the following group (Gi+1) of the aforesaid series, so that the aforementioned groups of the same series of exchangers are laid out in series between an initial group (G**1**) and a final group (Gn).

8. System according to claim **7**, characterized in that the aforementioned means of regrouping comprise first and second switches, each switch having a principal canalization and secondary canalization, the hot manifold of a group of exchangers being connected to the said first switch via one of its secondary canalizations equipped with a gate valve, and the cold manifold of the said group being connected to the said second switch via one of its secondary canalizations equipped with a gate valve, so that the means of regrouping make it possible to select arbitrarily, at a given time and according to the position of the valves of the first and second switches, a first group of exchangers (Gp) and the last group of exchanger (Gq), to form between the latter a sub-series of exchangers (S') used as an exchange unit.

9. System according to claim **5**, characterized in that the means of activation comprise means of activation in injection suited to form a hydraulic loop of injection comprising at least one exchange unit for the injection of energy, and of the means of activation in extraction suited to form a hydraulic loop of extraction comprising at least one exchange unit for the extraction of energy; in what the aforementioned means of activation in injection comprise an input branch of injection and an output branch of injection, each exchange unit being connected by its hot end to the said input branch of injection and by its cold end to the said output branch of injection to form a connection of injection between the input and output branches of injection, the various exchange units being then in parallel from each other between the aforementioned input and output branches of injection, each connection of injection thus defined being equipped with means of regulation of flow in injection, so that the flow circulating in the aforementioned connection of injection can be arbitrarily fixed during an injection, and in what the aforementioned means of activation in extraction comprise an input branch of extraction and an output branch of extraction, the aforementioned exchange units being respectively connected by their cold end to the said input branch of extraction and by their hot end to the said output branch of extraction, to form a connection of extraction between the input and output branches of extraction, various exchange units being then in parallel from each other between the aforementioned input and output branches of extraction, each connection of extraction thus defined being equipped with means of regulation of flow in extraction, so that the flow circulating in the aforementioned connection of extraction can be arbitrarily fixed during an extraction.

10. System according to claim **9**, characterized in that a differential pressure sensor is connected between the aforementioned input and output branches, in that a canalization supplying the input branch comprises a pump controlled in differential pressure according to the measure taken by the aforementioned sensor, so that the flow in any of the connections in parallel between the input and output branches can be controlled individually.

11. System according to claim **5**, characterized in that it is provided with means of pumping comprising the pumps suited to make circulate the heat-conveying fluid in a loop of injection comprising at least one exchange unit functioning in injection of energy and a loop of extraction comprising at least one exchange unit functioning in extraction of energy, and with means of connection allowing at least one connection among:

the connection of a loop of circulation in the source with the loop of injection;

the connection of the loop of circulation in the consumer with the loop of extraction;

the connection of the loop of circulation in the source with the loop of injection, and simultaneously, the connection of the loop of circulation in the consumer with the loop of extraction;

the connection of the loop of extraction with the loop of injection;

the connection of the loop of circulation in the source with the loop of circulation in the consumer;

the connection of the loop of extraction with the loop of injection, and simultaneously, the connection of the loop of circulation in the source with the loop of circulation in the consumer.

12. System according to claim **11**, characterized in that the aforementioned means of connection allow moreover:

the connection of a loop of circulation in the consumer with a loop of extraction and the loop of circulation in the source; and,

the connection of a loop of circulation in the source with a loop of injection and the loop of circulation in the consumer.

13. System according to claim **11**, characterized in that the aforementioned means of connection comprise:

a first hydraulic separator, connected to an expansion tank forming the neutral point of the said hydraulic system, the aforementioned first hydraulic separator being connected to the aforementioned loop of extraction on the one hand and the aforementioned loop of circulation in the consumer on the other hand;

a first pair of gate valves whose state allows to connect the aforementioned loop of circulation in the source to the aforementioned first hydraulic separator;

a second pair of gate valves whose state allows to connect the loop of injection to the aforementioned first hydraulic separator.

14. System according to claim **13**, characterized in that the aforementioned means of connection comprise moreover:

a second hydraulic separator connected to the said expansion tank forming the neutral point of the said hydraulic system;

a third pair of gate valves whose state allows, in relation with the state of the aforesaid the first pair of valves, to connect the aforementioned loop of circulation in the source to the aforementioned second hydraulic separator, the loop in extraction being connected to the aforementioned first hydraulic separator;

a fourth pair of gate valves whose state allows, in relation with the state of the second pair of valves, to connect the aforementioned loop of injection to the aforementioned second hydraulic separator, the loop of circulation in the consumer being connected to the aforementioned first hydraulic separator.

15. System according to claim **5**, characterized in that, the aforementioned means of activation, connection, and pumping being actionable automatically, the system comprises a calculating unit able to receive the signals of measure emitted by the various sensors and to emit a control signal towards the aforementioned means of activation, connection, and pumping, the aforementioned calculating unit executing the instructions of a program stored in means of memorizing of the aforesaid calculating unit to implement a process comprising steps of:

measuring temperature in various points of the ground by means of buried temperature gauges, the temperatures and flow of a heat-conveying fluid in input and output of the source to determine the thermal power provided by the source, and temperatures and flow of a heat-conveying fluid in input and output of the consumer to determine the thermal power to provide to the consumer; and

optimizing the storage of thermal energy in the storage unit by selecting active exchangers among the plurality of exchangers according to temperature measurements, flow measurements and thermal power measurements.

16. Storage system of calorific energy in the ground, characterized in that it comprises a hydronic system according to claim **5** and one storage unit of energy comprising at least ten exchangers.

17. Process according to claim **2**, characterized in that one moves of heat inside the storage unit by circulation of the heat-conveying fluid between a loop comprising at least one exchanger activated in extraction and a loop comprising at least one exchanger activated in injection.

18. Process according to claim **2**, characterized in that it comprises an additional stage consisting in:

When the thermal power provided by the source is adapted to the thermal power used by the consumer, not activating any the exchangers and making circulate the heat-conveying fluid between a loop comprising the source and a loop comprising the consumer;

When the thermal power provided by the source is not usable by the consumer, making circulate the heat-conveying fluid between a loop comprising the source and a loop comprising some exchangers activated in injection, and making circulate simultaneously the heat-conveying fluid between a loop comprising the consumer and a loop comprising some exchangers activated in extraction;

When the thermal power provided by the source is higher than the thermal power used by the consumer, making circulate the heat-conveying fluid on the one hand in a loop comprising the source and on the other hand in a loop comprising the consumer and a loop comprising some exchangers activated in injection;

When the thermal power used by the consumer is null, totally injecting the thermal power provided by the source in the storage unit;

When the thermal power provided by the source is lower than the thermal power used by the consumer, making circulate the heat-conveying fluid on the one hand in a loop comprising the consumer and on the other hand in a loop comprising the source and a loop comprising some exchangers activated in extraction;

When the thermal power provided by the source is null, completely extracting the thermal power used by the consumer from the storage unit.

19. Process according to claim **3**, characterized in that it comprises an additional stage consisting in:

When the thermal power provided by the source is adapted to the thermal power used by the consumer, not activating any the exchangers and making circulate the heat-conveying fluid between a loop comprising the source and a loop comprising the consumer;

When the thermal power provided by the source is not usable by the consumer, making circulate the heat-conveying fluid between a loop comprising the source and a loop comprising some exchangers activated in injection, and making circulate simultaneously the heat-conveying fluid between a loop comprising the consumer and a loop comprising some exchangers activated in extraction;

When the thermal power provided by the source is higher than the thermal power used by the consumer, making circulate the heat-conveying fluid on the one hand in a loop comprising the source and on the other hand in a loop comprising the consumer and a loop comprising some exchangers activated in injection;

When the thermal power used by the consumer is null, totally injecting the thermal power provided by the source in the storage unit;

When the thermal power provided by the source is lower than the thermal power used by the consumer, making circulate the heat-conveying fluid on the one hand in a loop comprising the consumer and on the other hand in a loop comprising the source and a loop comprising some exchangers activated in extraction;

When the thermal power provided by the source is null, completely extracting the thermal power used by the consumer from the storage unit.

20. System according to claim **8**, characterized in that the means of activation comprise means of activation in injection suited to form a hydraulic loop of injection comprising at least one exchange unit for the injection of energy, and of the means of activation in extraction suited to form a hydraulic loop of extraction comprising at least one exchange unit for the extraction of energy; in what the aforementioned means of activation in injection comprise an input branch of injection and an output branch of injection, each exchange unit being connected by its hot end to the said input branch of injection and by its cold end to the said output branch of injection to form a connection of injection between the input and output branches of injection, the various exchange units being then in parallel from each other between the aforementioned input and output branches of injection, each connection of injection thus defined being equipped with means of regulation of flow in injection, so that the flow circulating in the aforementioned connection of injection can be arbitrarily fixed during an injection, and in what the aforementioned means of activation in extraction comprise an input branch of extraction and an output branch of extraction, the aforementioned exchange units being respectively connected by their cold end to the said input branch of extraction and by their hot end to the said output branch of extraction, to form a connection of extraction between the input and output branches of extraction, various exchange units being then in parallel from each other between the aforementioned input and output branches of extraction, each connection of extraction thus defined being equipped with means of regulation of flow in extraction, so that the flow circulating in the aforementioned connection of extraction can be arbitrarily fixed during an extraction.

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