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(54) **INERTIAL ENERGY STORAGE DEVICE**

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(57) **ABSTRACT**

The invention concerns a device wherein the coil tube **(12)** forming the condenser of a first heat pump assembly and the coil **(13)** which forms a second assembly are each fixed on vertical grids **(28, 29)**. Said grids are arranged parallel to each other and are embedded in the concrete block **(3)** which forms one of the energy storage units incorporated in the system. The grids consist of concrete iron bars welded together into a network with square and rectangular meshes. The means fixing the tubes at certain intersetions of the grid are clamps of a particular type. The grids, the tubes and the clamps are embedded in the concrete block **(3)**.

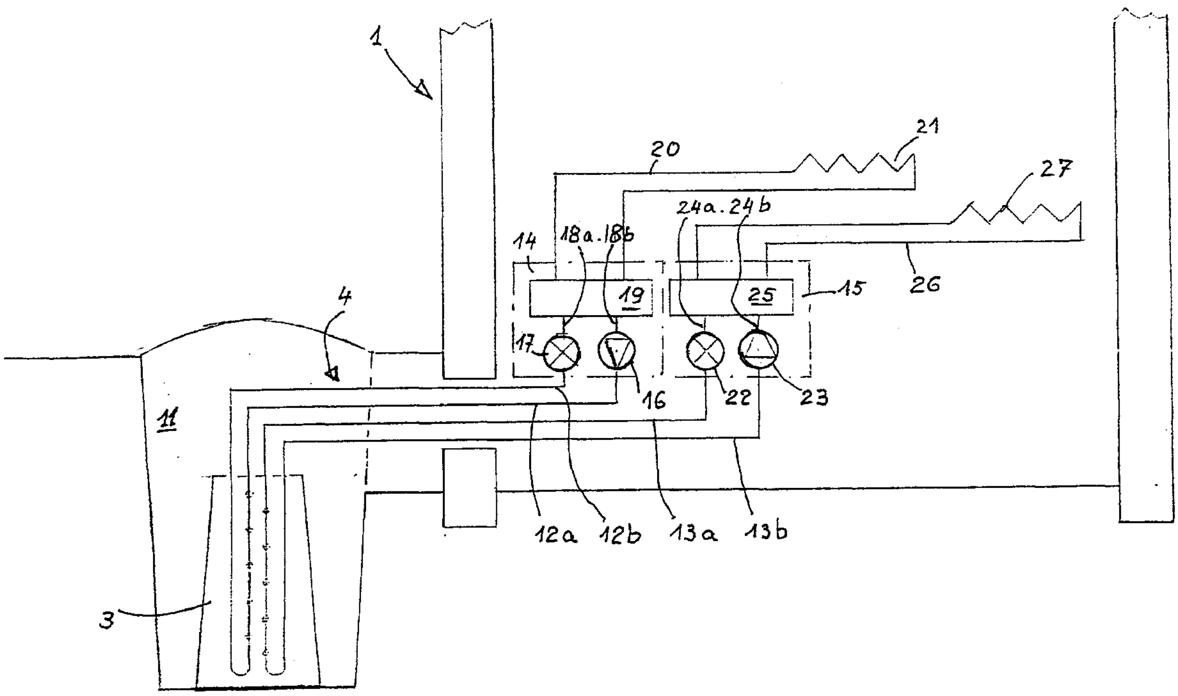
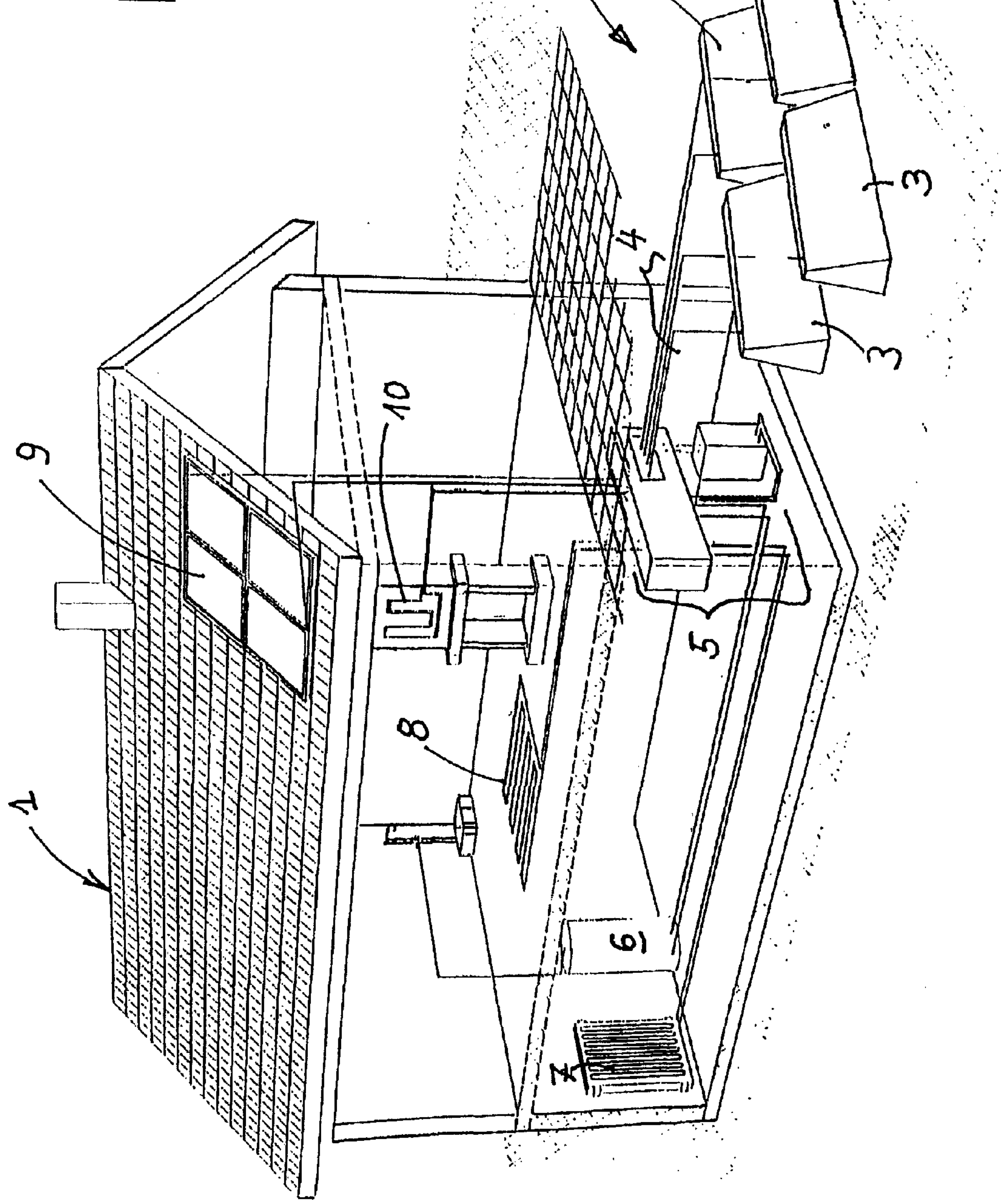
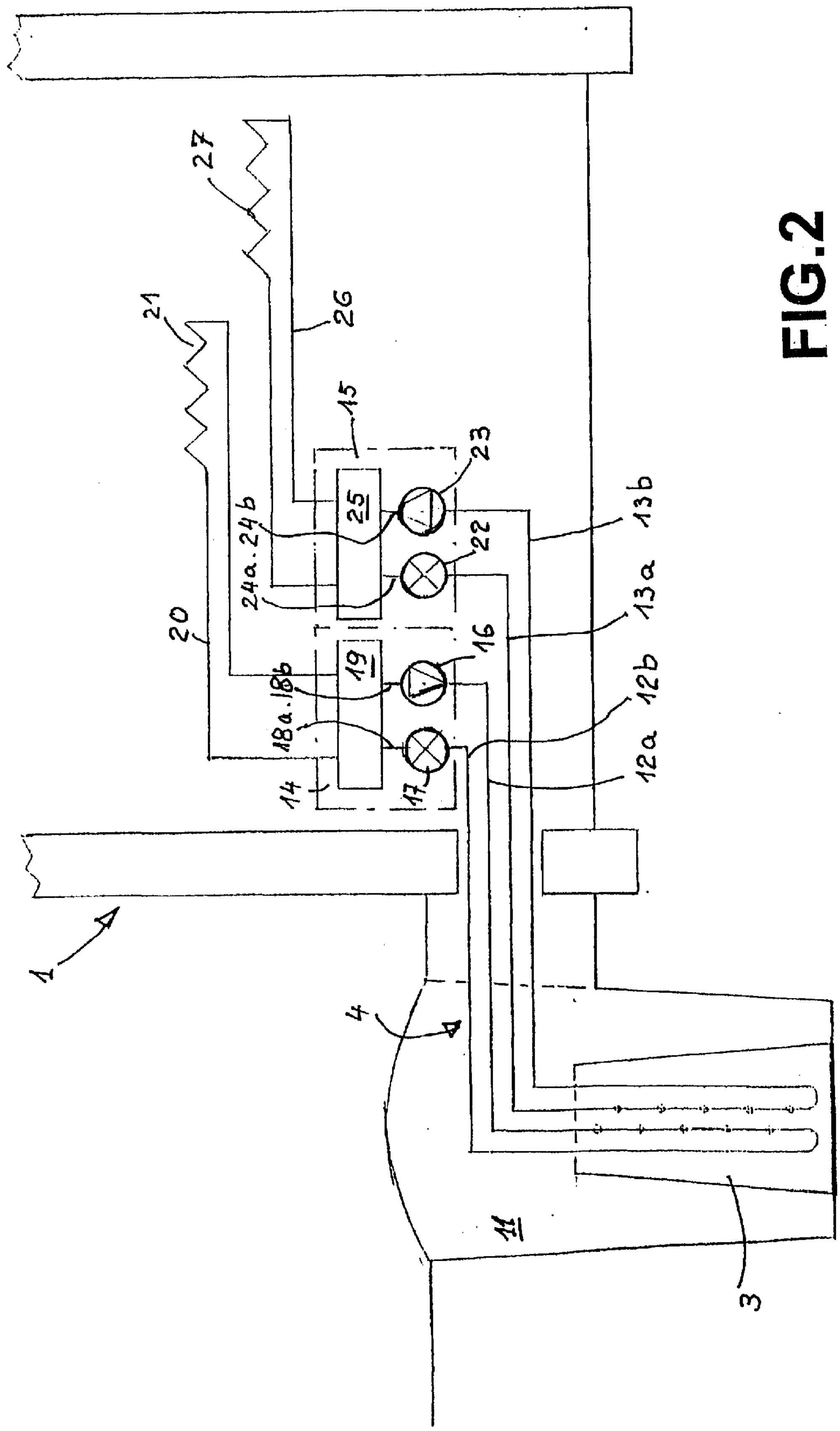


FIG.1

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21
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25
24a.24b
22
13b
13a
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16
18a.18b
12b
12a
14
17
1
4
11
3

FIG.2

FIG.3

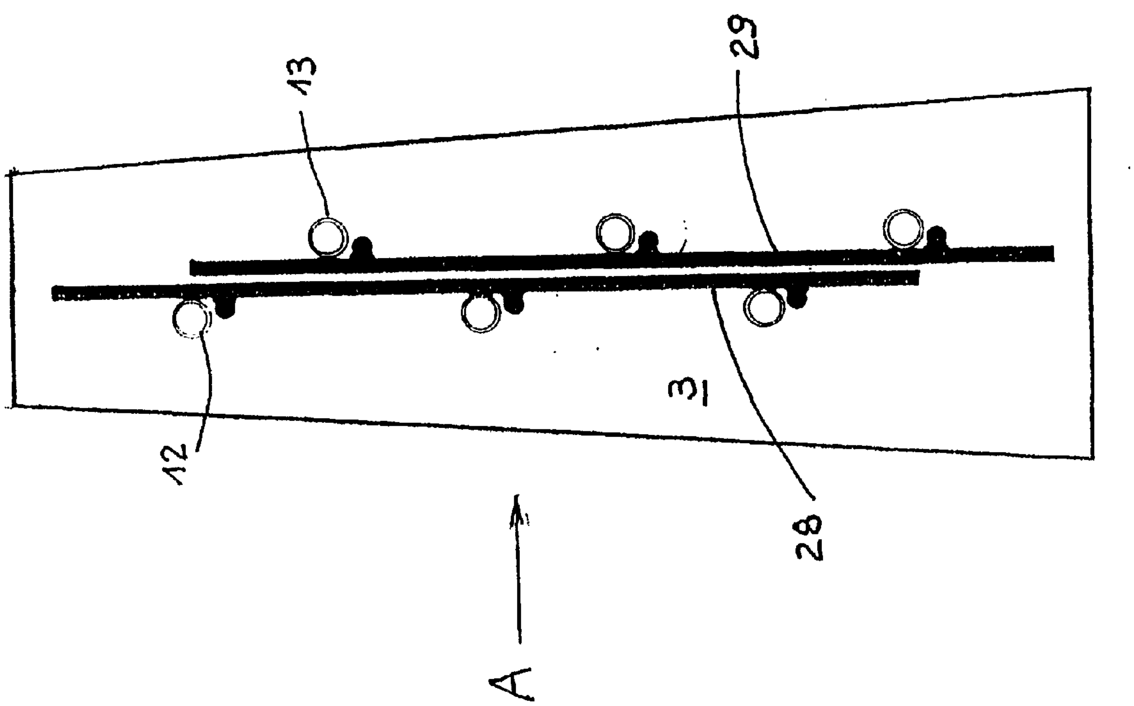


FIG.4

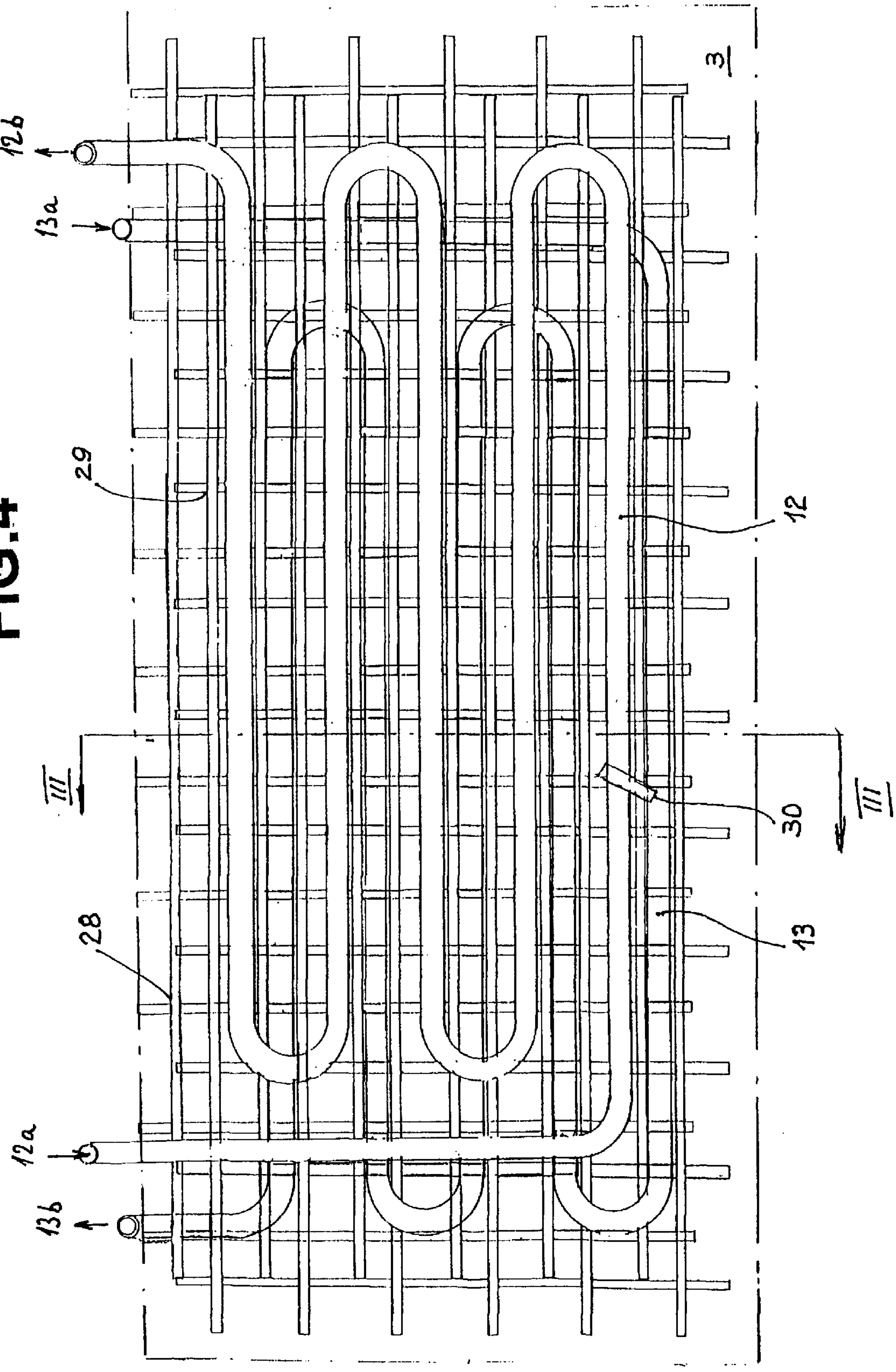


FIG.6

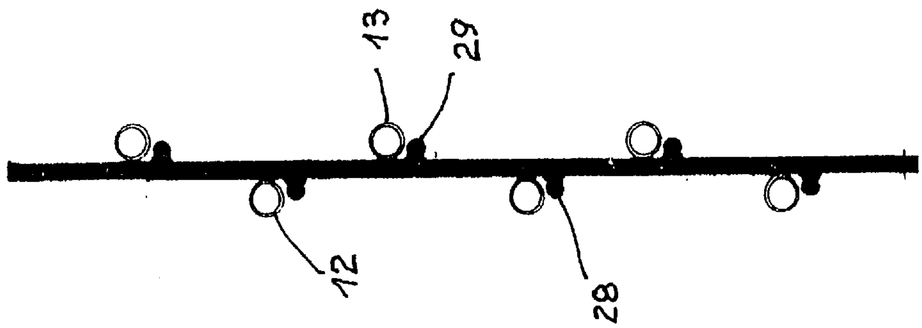


FIG.5

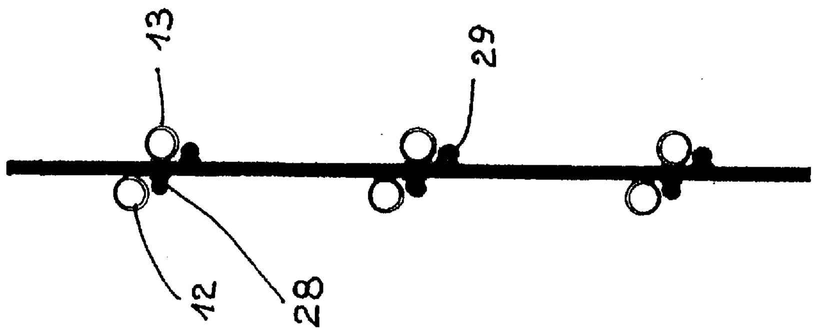


FIG.8

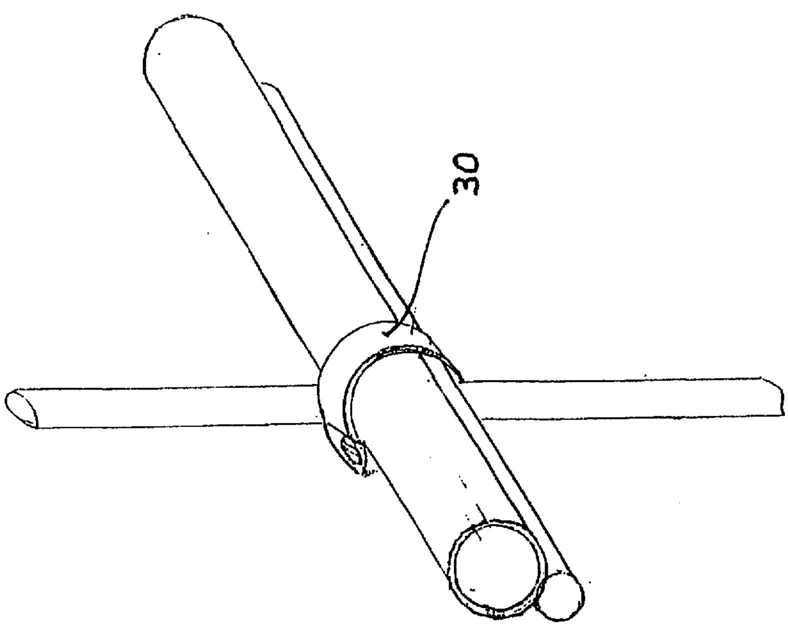
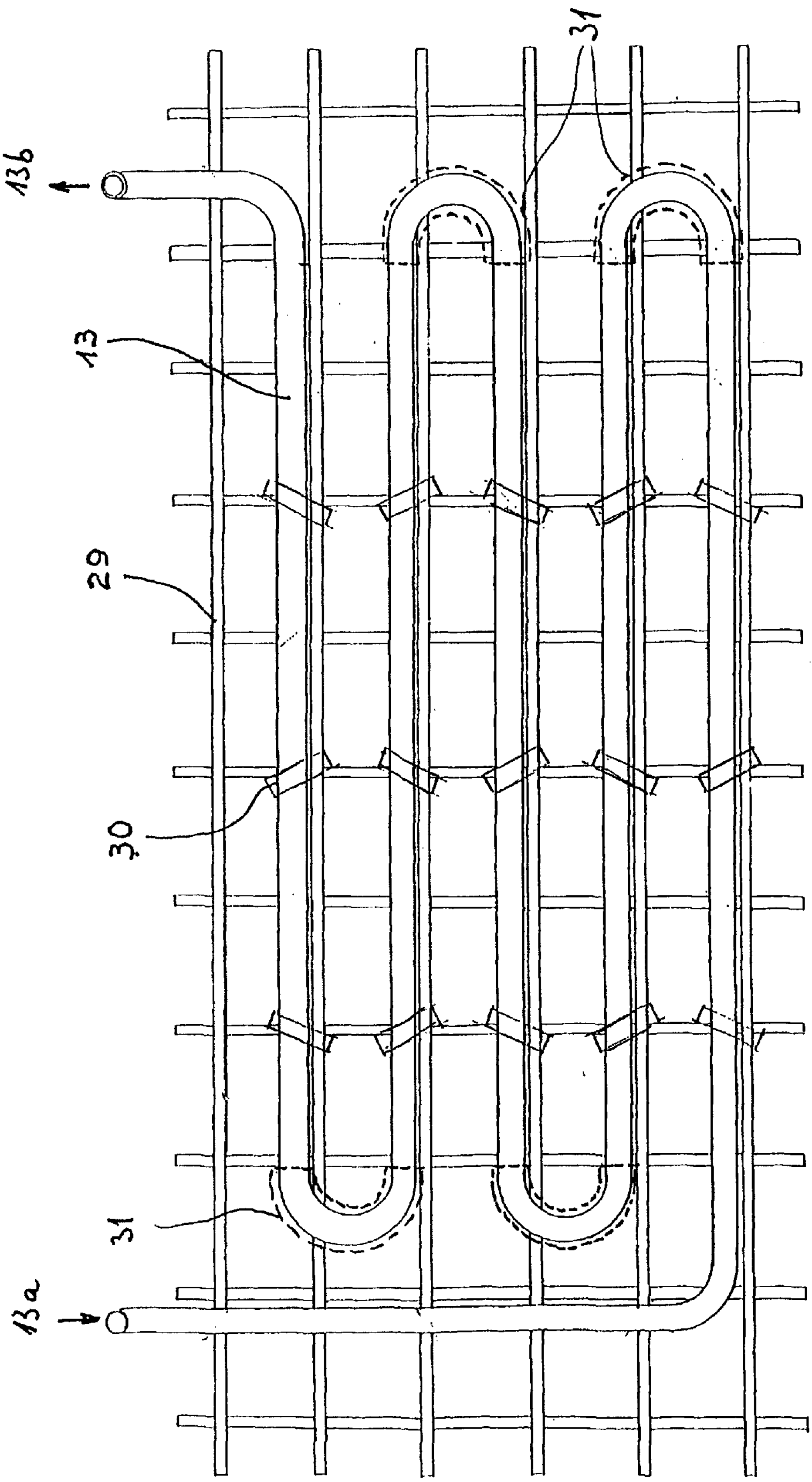


FIG.7



INERTIAL ENERGY STORAGE DEVICE

[**0001**] The present invention concerns in general terms heating and air conditioning systems for premises using renewable energy forms, in particular by means of heat pumps.

[**0002**] It has already been proposed in this field to use heat accumulators comprising solid blocks in which there are embedded one or more circuits formed from metallic tubes through which, when the system is in service, there runs a heat-transfer fluid which may be liquid or gaseous. Patent application WO 96/28703, for example, describes an accumulator of this type, one of the particularities of which is that it is made from concrete, a material which has several advantages.

[**0003**] Recent experiments showed that the storage of heat energy in rigid blocks could have practical advantages which are extremely remarkable with regard to the rationalisation of the installation works, the cost, the reliability of the service, the efficiency and the service life, provided that certain provisions were complied with precisely.

[**0004**] The aim of the present invention is therefore to provide the advantages able to be obtained, by producing economically an energy accumulation device of the inertia type comprising certain particularities which are the object of the invention and which are defined in the accompanying claims 1 to 12.

[**0005**] A description will be given below, by way of example, of an embodiment and a few variants of the device according to the invention, referring to the accompanying drawing, where:

[**0006**] **FIG. 1** is a general schematic view in perspective showing a dwelling house equipped with a heating and air conditioning system with an energy accumulation device of the inertia type according to one embodiment of the invention,

[**0007**] **FIG. 2** is a diagram showing a preferred embodiment of the energy accumulation device of the inertia type according to the invention,

[**0008**] **FIGS. 3 and 4** are views respectively in transverse section and in front elevation in the direction of the arrow A in **FIG. 3**, showing a block with two assemblies formed by a grille and a heat-transfer fluid circuit, according to the preferred embodiment,

[**0009**] **FIGS. 5 and 6** are views in section similar to **FIG. 3** showing two variant arrangements for the grilles,

[**0010**] **FIG. 7** is a view in front elevation of a circuit mounted on a grille, showing the anchoring of the coil at the points where the bars cross, and

[**0011**] **FIG. 8** is a schematic perspective view to a larger scale showing an anchoring flange in place on a pipe and on an intersection of the bars of the carrier grille.

[**0012**] In **FIG. 1**, there can be seen a villa **1** equipped with a heating system comprising an energy accumulation device of the inertia type **2** comprising four accumulation blocks **3** embedded in the ground close to the building and means for conducting as required the latent heat contained in the blocks. The latter are connected, by a set of fluid-circuit elements designated overall **4**, to a heat generator **5** from which various secondary circuits start, supplying normal ancillary equipment such as domestic hot water **6**, room radiators **7** and underfloor heating circuit **8**. The generating unit **5** is symbolised in **FIG. 1** by two superimposed cubicles. Its structure is specified in the diagram in **FIG. 2**. It is also connected by secondary circuits to a solar panel with water circuit **9** and to a recuperator **10** for excess heat liable to be produced by a living room flue.

[**0013**] It will be understood that this enumeration of auxiliary equipment is given solely by way of example and in is no way exhausted. As will be seen again later, it also encompasses, for example, the case of a swimming pool and that of a high-temperature solar furnace. It shows simply the great variety of applications which can be envisaged in any problem of heating and air conditioning premises. The energy accumulation device of the inertia type which will be described now satisfies, by standard and rational means, each particular case which may be predicted.

[**0014**] **FIG. 2** shows the walls of the dwelling house **1** and one of the energy accumulation blocks **3** of the inertia type. This block is placed in an excavation **11** dug close to the building **1** and filled with earth. It has the form of a prism with a large rectangular base placed horizontally and a top face narrower than the base and parallel to the latter. The blocks **3** are made from concrete. Their dimensions will be standardised: for example 2.5×1.7×0.5/0.3 m. The dimensions of the excavation **11** and the position of each block in its excavation will be determined on a case by case basis according to the quantities of energy to be stored and the duration of the periods of reversal of flows, as will be seen below.

[**0015**] The connection between the blocks **3** and the generator unit **5**, designated **4** in **FIG. 1**, is made in fact for each block by manifolds forming two circuits **12** and **13** each with an inlet **12***a*, **13***a* and an outlet **12***b*, **13***b*. The active parts of the manifolds **12**, **13** are embedded in the concrete of the block **3** and, as from the inlet segments **12***a*, **13***a*, are angled in coils in a layer so that the contact surfaces are as large as possible and facilitate heat exchanged between the heat-transfer fluid circulating in the circuits and the concrete.

[**0016**] The heat-generating unit **5** consists in the embodiment described of two entirely separate sets of heat pumps **14** and **15**. Each set comprises a complete heat-transfer fluid loop of the phase change type with: an upstream circuit element and a downstream circuit element, between the two elements a compressor and a pressure reduction valve, on one of the elements a heat exchanger, and a secondary circuit with one or more radiating components.

[**0017**] For the assembly **14**, the compressor and the pressure reduction valve are designated **16** and **17**, the upstream circuit is the circuit **12**, embedded in the block **3** and functioning as a condenser by supplying heat to the block. The downstream circuit is then the evaporator designated **18***a*, **18***b*. The fluid passes into the exchanger **19**, absorbing the heat supplied by the secondary circuit **20** and picked up in the refrigerating circuit **21**. It will be understood that this assembly can keep a cold room running or constitute an air conditioner intended to function in summer. It could also fulfil other functions as will be seen below.

[**0018**] The assembly **15** consists of similar elements but functioning in the opposite direction. There can be seen in

FIG. 2 the pressure reduction valve **22**, the compressor **23** and the upstream circuit **24***a*, **24***b* functioning as a condenser and supplying, through the exchanger **25**, the heat picked up in the downstream circuit **13** to the secondary circuit **26** supplying the radiator **27**. The latter corresponds to the element **7** or to the element **8** in **FIG. 1**. The water heater **6** will also be connected to the circuit **26**.

[**0019**] Thus in each block **3** there are embedded two circuit elements **12**, **13** each incorporated in one of the units **14** or **15** in the group **5** and constituting in one case the condenser **12** of the cold-production unit **14** and the other the evaporator **13** of the heat-production unit **15**. This arrangement gives very great flexibility in the management of the system described. **FIGS. 3 and 4** show once again the block **3** with the heat-transfer fluid circuits **12** and **13** embedded in the concrete. Each of these circuits is formed from a segment of tube of sufficient length, angled in a coil. The tubes can be made from stainless steel or copper, with for example a diameter of 10 mm and a wall thickness of 0.5 mm. They can also be produced from synthetic material, for example from polyethylene, or from composite materials. Each circuit **12**, **13** is mounted on a grille **28**, **29**. This grille can be formed from metallic bars, in particular concrete-reinforcement bars, for example 6 mm in diameter and welded at right angles to one another so as to form a lattice with square or rectangular meshes, having for example a side measuring approximately 15 cm. The grille can also be produced from synthetic material, for example polyethylene, with welded or bonded bars, or moulded at one go. The grilles **28**, **29** constitute support structures for the circuit elements, particularly useful for transporting and installing the circuit before pouring the concrete. Where the accumulator units are prefabricated, use ill preferably be made of grilles formed from concrete reinforcement bars, the grilles then also having the function of providing the cohesion of the concrete. The operation of bending the tubes and fitting the coils exactly with respect to the intersections of the grille may be performed in a rational manner by means of a support having the form of a plate having grooves in which the bars of the grille are placed. The plate will be equipped with grippers fixing the tube with respect to the support and with respect to the grille at the location where a bend in the coil must be produced. The technique of mounting the coils on the grilles will be returned to later.

[**0020**] Although these operations of mounting the coils on the grilles can be performed on the site, in order to allow optimum control of the quality of manufacture and to reduce the working time on site to the maximum possible extent, these operations will preferably be performed in the factory, the grille/coil assemblies being transported to the site already assembled, so as to be able to be fitted directly with formwork, or directly inside a trench in the ground, the sides and bottom of the trench serving as formwork, after which the concrete can be poured. The inlet and outlet segments **12***a*, **12***b*, **13***a*, **13***b* of the circuit elements will be designed so as to be sufficiently long to allow subsequent connections. With the dimensions indicated, each grille/coil assembly has a weight of 50 to 100 kg, making it easy to handle. The site therefore does not require any access means arranged for particularly heavy machinery. However, if the equipment so permits, the blocks **3** can also be manufactured entirely in the factory and transported to the site as products ready for installation.

[**0021**] As can be seen in **FIG. 3**, the two grilles **28**, **29** are placed in a vertical position at a short distance from each other at the centre of the block. Each coil circuit **12**, **13** is fixed against the grille, which carries it on the outside. The grilles and the branches of the coils are offset in height in one of the assemblies with respect to the other by half the pitch of the grille. This arrangement ensures optimum thermal use of the properties of the concrete and of the iron bars of the grilles. The latter fulfil the role of thermal bridges and promote the diffusion of heat.

[**0022**] The blocks can be used as heat reservoirs, either in accumulation, or in "draining", that is to say only one of the two circuits, the condenser circuit **12** or the evaporator circuit **13**, is in operation. However, the functioning sequences can be variable, for example daily or seasonal. It is therefore possible to conceive of cases where the two circuits are functioning at the same time, the energy merely transiting through the block. Such a configuration is particularly useful for hotels and hospitals, where air conditioning and the production of domestic hot water simultaneously and continuously are necessary. The close arrangement of the two assemblies **12-28**, **13-29** then has the advantage that the differences in temperature are very small. However, in this case, the grilles **28** and **29** will be disposed at a substantially greater distance from each other than those shown in **FIG. 3**, generally at a distance of between 5 and 10 cm, so as to allow good diffusion of the energy around the tube. If the temperature difference between the heat source and the heat diffuser is itself small, then the coefficient of performance (COP) of the sets is particularly high. This will be the case for example when, off season, it is wished to use the heat energy from the water of a swimming pool in order to warm inhabited rooms, or conversely, when an air-conditioning effect or the picking up of the solar heat by the panel **9** are used to heat the water in the swimming pool. Because the pumps are reversible, the two circuits can also be used simultaneously, either as an accumulator or for draining. **FIGS. 5 and 6** are sections similar to that in **FIG. 3** and show two variants of the arrangement of the assemblies **12/28**, **13/29** which, in some cases, result in even better performance than that of the preferential execution described up till now. In these two figures, the vertical bars of two grilles **28**, **29** are situated in the same plane, the horizontal bars can be placed as close to each other as possible (**FIG. 5**) or, preferably, offset, for example by a half-pitch (**FIG. 6**).

[**0023**] **FIG. 7** shows the anchoring of the heat-transfer fluid tubes to the grilles. It shows a view of the assemblies **12/28**, **13/29** in the opposite direction to the arrow A in **FIG. 3**. A grille portion **29** is depicted in elevation with a portion of a heat-transfer fluid tube **13** bent in a coil. Although only six horizontal branches and four bends at 180° have been shown, it is obvious that this number is not determinant and that, in practice, it will be higher. The horizontal branches of the coil **13** are fixed to junction points of the grille **9** by fasteners **30** formed by metallic or synthetic bands such as Colson collars. In the example in **FIG. 7**, each collar is attached to a junction point on the grille and holds the horizontal branch of the tube **13** against a horizontal bar of the grille. **FIG. 8** also illustrates the arrangement. According to one variant, the collars are attached not to a junction point of the grille but along a horizontal bar of the grille. The number of collars and their alternating arrangement on each horizontal branch of the coil will be chosen on a case by case basis. It should be noted that this anchoring method provides an elastic pressure of the tubes against the bars of their support grille, which enables the assembly to withstand different grille/tube expansions or contractions during temperature variations. Moreover, the angled portions of the tube for making up the coil can be provided with a device allowing differentiated expansion/contraction of the tube with respect to the concrete. Such a device can be produced for example in the form of sleeves **31** (shown schematically in **FIG. 7**) made from compressible polyurethane foam (preferably with closed cells) which are disposed around the angled parts of the tube forming the coil.

[**0024**] The system described is particularly advantageous for several reasons: it makes it possible to take advantage of the picking up of energy coming from ancillary sources, such as a swimming pool or a water-circulation solar panel with a high coefficient of performance (COP), or for example a heat recuperator in a flue or one in a high-temperature solar furnace. The accumulation of heat in the blocks can be extended, during seasonal periods, to the surrounding ground, which functions both as an insulator and as a receiver. Thus the water tubes coming from the solar panels could be directly integrated in the blocks **3** or in some of the blocks, which avoids the interposing of a heat exchanger. Finally, it is obvious that the cases where the blocks **3** and the surrounding ground directly pick up the ambient heat during the summer and only the circuits **13** and the set **15** are provided, also represent an application of the present invention.

[**0025**] Thus the energy accumulation device of the inertia type according to the invention can serve equally well as a heat energy accumulator, a temperature equaliser, a temperature exchanger or a temperature regulator, the whole being reversible.

[**0026**] The accumulation blocks depicted in **FIGS. 1 and 3** have a cross-section in the shape of a triangular or trapezoidal prism with a top base with a size less than that of the bottom base. However, naturally, the blocks **3** can be produced in any other shape, such as for example in the shape of a T, so as to prevent the block from sinking into the ground, or also rectangular in shape.

[**0027**] Although the device according to the invention has been described with three concrete blocks **3**, the said blocks can also be produced from other solid or semi-solid materials, such as for example with bentonite or other similar gels.

[**0028**] A description has not been given here of the means which will be provided for allowing effective management of the whole of the system, such as valves with several ways for controlling the flows, devices for draining and, where necessary, cleaning the tubes, and measurement and monitoring apparatus. These means will naturally be provided according to requirements. Although a system has been described with two separate sets of heat pumps functioning one as a heat producer and the other as a cold producer, it is also possible to provide only one set.

[**0029**] In addition, the possible applications of the storage device described are obviously not limited to the heating and air conditioning of villas, but equally relate to any building where the rooms must be warmed or cooled.

1. An energy accumulation device of the inertia type, in particular for a heating and/or air conditioning system for premises, comprising at least one block **(3)** of solid or semi-solid material, and at least one heat-transfer fluid circuit **(12, 13)** embedded in each block, characterised in that at least one grille **(28, 29)** is embedded in each block **(3)** and in that each of the said circuits consists of a continuous circuit, curved in a coil, mounted on one of the grilles so as to allow differential expansion/contraction of the pipes with respect to the grille.

2. A device according to claim 1, characterised in that at least one circuit is integrated in a heat-transfer fluid loop with phase change of a heat pump **(14, 15)**.

3. A device according to claim 1 or claim 2, characterised in that each block **(3)** has two assemblies **(12, 28; 13, 29)** of a grille and a circuit, the grilles being plane and placed parallel in the block.

4. A device according to claim 1, characterised in that the block **(3)** has the shape of a polyhedron whose base is rectangular and placed horizontally and which has a top face which is also plane and parallel to the base, the grille or grilles **(28, 29)** being vertical.

5. A device according to claim 2, in which the two circuits **(12, 13)** of a block are integrated in different heat exchange loops, characterised in that the device is associated with two sets of heat pumps **(14, 15)**, one of the said circuits functioning as an evaporator and the other as a condenser.

6. A device according to any one of the preceding claims, characterised in that the block or blocks **(3)** are in the shape of a prism with a triangular vertical section.

7. A device according to one of claims 1 to 5, characterised in that the block or blocks **(3)** are in a T shape.

8. A device according to any one of the preceding claims, characterised in that the material of the block or blocks is concrete.

9. A device according to any one of claims 1 to 7, characterised in that the material of the block or blocks is a gel.

10. A device according to any one of claims 4 to 9, characterised in that the block or blocks are embedded in the soil, their faces being directly in contact with the ground.

11. A device according to any one of the preceding claims, characterised in that a circuit, in at least one block, is connected to an ancillary heat source without connection with a heat pump, the ancillary heat source being a solar panel **(9)**, a recuperator for the heat in a flue **(10)**, a high-temperature solar furnace, etc.

12. A device according to one of the preceding claims, characterised in that the grille is formed from metallic bars connected together at junction points.

13. A device according to one of claims 1 to 11, characterised in that the grille is made from synthetic material.

14. A device according to one of the preceding claims, characterised in that the pipes are metallic tubes.

15. A device according to one of claims 1 to 13, characterised in that the pipes are tubes made from synthetic material.

16. A device according to one of the preceding claims, characterised in that the angled portions of conduit forming the coil are provided with a device allowing differential expansion/contraction of the pipe with respect to the concrete.

17. A device according to claim 16, characterised in that the angled portions of the conduit are provided with sleeves **(31)** made from compressible polyurethane foam.

18. An assembly formed by at least one grille and comprising at least one continuous pipe bent in a coil, anchored to the said grille, as part of the device according to one of the preceding claims.

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