

DEVICE FOR TEMPERATURE CONTROL OF A ROOM

The invention relates to a device and a method for the temperature control of a room according to the preambles of claims 1 and 27.

So-called concrete core activation systems are known from the prior art for the air conditioning of rooms having concrete ceilings or concrete walls. In these systems pipes carrying heating or cooling media are mounted in, below or on the concrete ceiling or the concrete wall. By storing the heating or cooling energy in the concrete mass of the ceiling or the walls and a time-delayed delivery of the stored heating or cooling energy, an energy-efficient air conditioning of the rooms can be achieved. Thus, for example, at night a cooling fluid (for example, water) is cooled and passed through the pipes in a concrete core activated ceiling or wall whereby the ceiling or the wall is slowly cooled. The cooling energy stored in the concrete ceiling or wall can then be released into the room during the day in particular in the warm summer months, to slowly lower the room temperature in the room.

However, the installation of such thermally activatable ceilings or walls is restricted to new buildings. When renovating old buildings, such concrete core activation of the ceilings or walls cannot be installed subsequently. In the case of ceilings or walls with concrete core activation it is furthermore disadvantageous that pipes laid in the concrete ceiling or wall could be unintentionally damaged, for example, by the drilling of holes. Repair of damaged pipes is scarcely possible since the pipes embedded in concrete are difficult to access for a repair. The statics and the stability of ceilings or walls provided with pipes also suffer from the pipes embedded in concrete.

Furthermore, the manufacture of such concrete core activation systems is very time consuming and costly. Another disadvantages lies in the inertia of the thermal system which is based on the time-delayed release of the thermal energy stored in the concrete accumulator mass to the room to be temperature controlled.

In order to eliminate these disadvantages, temperature control systems are known from the prior art which can also be provided subsequently on pipe-free ceilings or walls. These temperature control systems usually comprise ceiling or wall elements in which pipes are disposed which can be acted upon with a heating or cooling medium. These ceiling or wall elements are fixed to the ceiling or wall. The thermal energy stored in the heating or cooling medium which is passed through the pipes is diverted via a frame or a lining of the ceiling or wall elements in to the room to be temperature controlled by thermal radiation and free convection. Such a system is described for example in EP 1371915 A1 in which phase change materials are used as thermal accumulators.

These temperature control systems have the disadvantage that the thermal energy from the heating or cooling medium flowing into the pipelines is released directly and instantaneously by thermal radiation and convection into the room. In these temperature control systems the surfaces of the ceilings or the walls are also occupied by the ceiling or wall elements. This has the result that the ceiling or wall surface is thermally separated from the room to be temperature controlled which is why the mass of the ceilings or the walls cannot be used for storage cooling (or heating) in the night.

Starting from this, it is the object of the present invention to provide a device and a method for the temperature control of a room in which the mass of the ceilings or walls can be used as a thermal accumulator without pipes for the passage of a heating or cooling medium for thermal actuation of the accumulator needing to be incorporated in the ceilings or walls. It is furthermore the object of the invention to provide the most energy-efficient temperature control system with short response times. Furthermore, it should be made possible to install these temperature control systems subsequently, including when renovating old buildings.

These objects are solved with a device for the temperature control of a room having the features of claim 1 and by a method having the features of claim 27. Preferred embodiments of the device according to the invention can be deduced from subclaims 2 to 26.

The invention is explained in detail hereinafter by means of exemplary embodiments with reference to the accompanying drawings. In the drawings:

- Figure 1: shows a schematic sectional view of a device according to the invention for temperature control of a room in a first embodiment;
- Figure 2: shows a schematic sectional view of a ceiling or wall element for a temperature control device according to the invention in a second embodiment;
- Figure 3: shows a schematic sectional view of the second embodiment of a temperature control device according to the invention with the ceiling or wall element from Figure 2.

Figure 1 shows a first embodiment of a temperature control device according to the invention. This comprises an element 10 provided on a component 5 made of concrete or brick. The component 5 can comprise a ceiling or a wall or a floor of the room R to be temperature controlled. The component 5 can also be constructed from another conventional building material that is capable of storing heat and/or cold, such as clay or natural stone. The element 10 then accordingly comprises a ceiling, wall or a floor element which is disposed on the surface 11 of the component 5 pointing into the room. As a result of its large mass, the component 5 forms a thermal accumulator in which thermal energy (in the form of heat or cold) can be stored.

The element 10 comprises a panel 1 containing expanded graphite or consisting completely of expanded graphite.

The production of expanded graphite (expanded graphite) is known inter alia from US 3,404,061-A. In order to produce expanded graphite, graphite intercalation compounds or graphite salts such as, for example, graphite hydrogen sulphate or graphite nitrate are heated in a shock manner. The volume of the graphite particles is thereby increased by a factor of about 200 - 400 and at the same time the bulk density decreases to values of 2 - 20 g/l. The expanded graphite thus obtained consists of worm- or concertina-shaped aggregates. If completely expanded graphite is compacted under the directional action of pressure, the layer planes of the graphite are preferably arranged perpendicular to the direction of action of the pressure, where the individual aggregates become entangled. In this way, self-supporting surface structures such as, for example, webs, plates or moulded bodies can be produced from expanded graphite.

In order to stiffen and increase the stability of these graphite panels or moulded bodies, the expanded graphite can be mixed with curing binders such as, for example, resins or plastics, in particular elastomers or duromers. In order to improve the stability of panels made of expanded graphite, it is particularly suitable to mix the expanded graphite with thermoplastic and/or thermosetting plastics which can be introduced into the expanded graphite for example by impregnation or by means of a powder method. After the binder mixed with the expanded graphite has been cured, the graphite moulded bodies or plates made from these mixtures have a sufficient stability for the intended application provided according to the invention. The graphite panels produced in this way are in particular self-supporting and can readily be fixed to components such as ceilings or walls, for example by adhesive bonding or screwing.

Pure expanded graphite, in the same way as mixtures of expanded graphite with binders, has a very good thermal conductivity. The thermal conductivity of a mixture of expanded graphite with a binder is still very high with a 50 wt.% binder fraction according to the type of binder used. Insofar as graphite panels are mentioned in the following, these are understood as panels which either consist of pure expanded graphite or a mixture of expanded graphite with a binder.

It is also possible to manufacture graphite panels from mixtures of expanded graphite with phase-change materials (PCM, phase change materials). For this purpose, common phase-change materials, for example based on paraffin, wax or salt can be added during the manufacture of the graphite panels. Such a graphite panel with a phase-change material can be used in the temperature control systems according to the invention

as additional thermal accumulators (latent heat accumulator) along with the component 5 acting as a thermal accumulator.

Pipes 9 are embedded in the graphite panel 1 shown in Figure 1. The pipes 9 are preferably arranged in a serpentine shape in the interior of the panel 1. Other laying patterns of the pipes such as, for example, a spiral-shaped, grid-shaped or meander-shaped arrangement or an arrangement only in the edge zones of the panel 1 is feasible. The ends of the pipes 9 running in the panel 1 are connected to a conveying device for passing a heating or cooling medium (such as, for example, hot or cold water) through the pipes 9. In order to provide the entire surface 11 of the component 5 pointing into the room R with elements 10, a plurality of such elements 10 can be arranged behind one another or adjacent to one another and fixed on the surface 11. The ends of the pipes 9 of each element 10 are then connected to the associated ends of the adjacent elements 10 to form a pipe circuit and the pipe circuit is coupled to the conveying device for passage of the heating or cooling medium.

The fixing of the elements 10 is preferably accomplished by a thermally conducting adhesive 4, by which means one principal surface 12 of the panel 1 is adhesively bonded to the surface 11 of the component 5. As a result of the adhesive bonding, the principal surface 12 of the panel 1 is in flat thermal contact with the surface 11 of the thermal accumulator formed by the component 5, preferably over the entire principal surface 12.

The other principal surface 13 of the panel 1 can be provided with a stiffening layer 6 as in the exemplary embodiment shown in Figure 1. The stiffening layer 6

can for example comprise a plaster layer or a glued-on hard cardboard or plasterboard layer. Combinations of plaster layers and textile materials embedded therein such as, for example, nets, woven fabrics, knitted fabrics, crocheted fabrics or the like, are also possible. As a result of the stiffening layer 6, on the one hand the stability of the graphite panel 1 can be increased and on the other hand the principal surface 13 of the panel 1 pointing into the room R can be clad in a visually attractive manner. The application of a stiffening layer 6 is particularly appropriate for panels 1 made of pure expanded graphite (without added binder).

The pipes 9 running in the panel 1 can be incorporated during the manufacture of the graphite panel 1. The pipes 9 preferably comprise pipes made of metal, for example copper, or plastic pipes, for example made of polypropylene or cross-linked polyethylene. However pipes made of metal are to be preferred because of the better heat transfer. As shown in the exemplary embodiment in Figure 1, The pipes 9 can be completely embedded in the panel 1. However, it is also possible to arrange the pipes 9 so that they end flush with a principal surface 12 or 13 of the panel 1.

For embedding the pipes 9 in the panel 1, during manufacture of the panel, the pipes 9 can be laid in the filling of worm- or concertina-shaped aggregates and this combination can be pressed in a known manner by action of pressure (for example by means of rollers or pressure plates) to form a dimensionally-stable graphite panel 1. In order to increase the stability of the panels, one of the aforementioned binders can be added during the production process. The graphite panels 1 thus produced with pipes 9 embedded therein typically have thicknesses between 8 and 50 mm. The

density of the graphite panels 1 is usually in the range of 0.01 to 0.5 g/cm³ (depending on the fraction of added binder). The graphite panels 1 have a thermal conductivity of 3 to 6 W/mK.

As a result of the good thermal conductivity of the graphite panel 1, a certain proportion of the thermal energy stored in a heating or cooling medium passed through the pipes 9 can initially be passed by heat conduction from the pipes 9 to the free principal surface 13 of the panel 1 and released from there by thermal radiation and free convection to the room R to be temperature controlled. This release of heat (or release of cold when a cooling medium is passed through the pipes) takes place very rapidly with the result that the room can be heated (or cooled) very rapidly. Another portion of the thermal energy stored in the heating or cooling medium is transferred by heat conduction from the pipes 9 via the heat conducting panel 1 to the thermal accumulator formed by the component 5. By this means, the thermal accumulator is heated (or cooled when a cooling medium is passed through the pipes). The thermal accumulator can then release the thus intermediately stored thermal energy in a time-delayed manner to the room, where the good thermal conductivity of the panel 1 ensures that this is accomplished largely free from losses. The heating (or cooling) of the room R accomplished in this manner takes place on a longer time scale (of a few hours). The temperature control system according to the invention is therefore able to bring the room R to be temperature controlled to a desired room temperature both rapidly and also slowly using the thermal accumulator. Thus for example, at night in summer the thermal accumulator can be cooled by passing a cooling medium (for example cold water) through the pipes 9. During the day the thermal accumulator can then be used

for cooling the room by means of a time-delayed release of cold to the room.

In a corresponding manner, in winter during the day the temperature control system according to the invention can firstly be heated for instantaneous heating of the room by passing a heating medium through the pipes. At the same time the thermal accumulator is loaded with heat. At night the flow of the heating medium can be stopped since the time-delayed release of heat from the loaded thermal accumulator is sufficient to keep the room at a (lower) room temperature at night.

Figures 2 and 3 show another exemplary embodiment of a temperature control system according to the invention. The same or corresponding parts in Figures 2 and 3 are provided with the same reference numbers as in Figure 1.

In the exemplary embodiment of a device according to the invention for the temperature control of a room R shown in Figure 3, a ceiling element 10 is fixed to a component 5 formed as a concrete ceiling. The component 5 forms a thermal accumulator with the concrete mass of the ceiling as accumulator mass. The ceiling element 10 has a frame 2 which is fixed to the surface 11 of the component 5 pointing into the room R, in particular is screwed thereon. The frame 2 is configured as a cassette which is open on one side (i.e. its upper side). The frame 2 is preferably made of a thermally conductive material such as, for example a metal sheet. The frame 2 has a base plate 2a and four side walls 2b disposed thereon or formed integrally with the base plate 2a. At least the base plate 2a (and optionally also the side walls 2b) is formed from a perforated sheet (i.e. a metal sheet with a perforation). A graphite panel 1 is inserted in the frame 2. The

composition of the graphite panel 1 corresponds to the panel 1 of the exemplary embodiment from Figure 1. As in this exemplary embodiment pipes 9 are also embedded in the graphite panel 1 and run there in a serpentine, grid, spiral or meander shape. The graphite panel 1 is preferably adhesively bonded flat on the surface 11 of the component 5 by means of a thermally conductive adhesive 4. The principal surface 12 of the graphite plate 1 is therefore expediently in thermal contact with the surface 11 of the component 5 over its entire surface. The adhesive layer 4 can however also be omitted (see below).

A non-woven fabric 3 and a graphite film 15 are preferably disposed between the base plate 2a of the frame 2 and the graphite panel 1. The non-woven fabric 3 can for example comprise a glass fibre or a carbon fibre non-woven. In combination with the perforation of the base plate 2, the non-woven fabric 3 ensures good sound absorption of the ceiling element 10. The graphite film 15 comprises a thin film of expanded graphite. The thickness of the graphite film 15 is preferably between 0.05 mm and 3 mm, in particular between 0.2 and 3 mm.

The non-woven fabric 3 and the graphite film 15 disposed thereon preferably comprises a non-detachable composite which can be produced for example by calendering. Such a composite can particularly expediently be produced from a carbon fibre non-woven and a graphite film 15 of expanded graphite. When calendering a thin film of expanded graphite with a carbon fibre non-woven, the carbon particles of the non-woven surface and the surface of the graphite film become entangled with one another so that a firm and non-detachable composite is formed between the carbon fibre non-woven 3 and the graphite film 15. It is

particularly appropriate to use a perforated graphite film 15. Perforation of the graphite film specifically increases its flexibility and thereby facilitates the handling of the film. Since graphite comprises a brittle material, there is the risk of the film tearing or breaking when handling thin films of expanded graphite. This risk can be reduced significantly by perforation of the graphite film 15.

Figure 2 shows a sectional view of a ceiling element 10 such as can be used in the exemplary embodiment of the temperature control device according to the invention shown in Figure 3. As can be seen from Figure 2, the upper principal surface 12 of the graphite panel 1 projects over the upper edge 2c of the side walls 2b of the frame 2. When using such a ceiling element 10, the adhesive bonding of the graphite panel 1 to the surface 11 of the component 5 can be omitted. For fixing the ceiling element 10 to the component 5, the frame is specifically screwed onto the component 5. When screwing the frame 2 to the surface 11 of the component 5, the graphite panel 1 is compressed until the principal surface 12 of the panel 1 ends flush with the upper edge 2c of the side walls 2b of the frame. The compression of the graphite panel 1 is made possible by the deformability of the expanded graphite. The graphite material of the panel 1 compressed in the perpendicular direction to the surface 11 is expediently in thermal contact with the surface 11 over the entire principal surface 12 after fixing the ceiling element 10 to the component 5. As a result of the good deformability of the graphite material of the panel 1, unevennesses and protrusions in the surface 11 of the component 5 can also be compensated.

The arrangement of the ceiling element 10 or plurality of adjacent ceiling elements on the surface 11 of the

component 5 corresponds to the exemplary embodiment of Figure 1 described above. The mode of operation of the temperature control device of Figure 3 is the same as in the exemplary embodiment of Figure 1.

CLAIMS

1. A device for the temperature control of a room, wherein the device comprises at least one component (5) which forms a thermal accumulator and has a surface (11) pointing into the room, as well as pipes (9) thermally coupled to the component (5) which can be acted upon by means of a heating or cooling medium,
characterised in that
the pipes (9) are embedded in a panel (1) which contains expanded graphite or consists of expanded graphite and the panel (1) is in flat thermal contact with the surface (11) of the component pointing into the room.
the panel (1) is disposed in a frame (2) fixed to the component (5),
the frame is configured as a cassette (2) which is open at one side, and
the panel (1) disposed in the cassette (2) projects over a frame edge (2c) thereof on the open side of the cassette before the cassette (2) is fixed to the component (5).
2. The device according to claim 1, characterised in that the panel (1) made of expanded graphite is fixed to the surface (11) of the component (5) by means of a thermally conducting adhesive layer (4).
3. The device according to claim 1 or 2, characterised in that the pipes (9) run in a serpentine manner, in a grid shape, in a spiral shape or in a meandering pattern in the panel (1).

4. The device according to any one of claims 1 to 3, characterised in that the panel (1) is in heat-conducting contact with the surface (11) of the component (5) over its entire principal surface (12) facing the surface (11).
5. The device according to any one of claims 1 to 4, characterised in that the density of the panel (1) lies between 0.04 and 0.10 g/cm³.
6. The device according to any one of claims 1 to 5, characterised in that the panel (1) has a thermal conductivity of more than 2 W/mK.
7. The device according to any one of claims 1 to 6, characterised in that the panel (1) is made of a mixture of expanded graphite and a binder, in particular a resin or a plastic.
8. The device according to claim 7, characterised in that the fraction of the binder is 5 to 50 wt.% and preferably lies between 8 to 12 wt.%.
9. The device according to any one of claims 1 to 6, characterised in that the panel (1) is made of a mixture of expanded graphite and a latent heat storage material (PCM), in particular based on salt, wax or paraffin.
10. The device according to any one of claims 1 to 9, characterised in that the component (5) comprises a concrete ceiling or concrete wall.

11. The device according to any one of claims 1 to 10, characterised in that a plurality of panels (1) with pipes (9) embedded therein are fixed adjacent to one another on the surface (11) of the component (5).
12. The device according to claim 11, characterised in that the pipes (9) of adjacent panels (1) are interconnected to form a pipe circuit and that the pipe circuit is coupled to a conveying device for passing a heating or cooling medium through the pipes (9).
13. The device according to any one of claims 1 to 12, characterised in that a stiffening layer (6) is applied to the surface (13) of the panel (1) facing away from the component (5).
14. The device according to any one of claims 1 to 13, characterised in that a stiffening layer (6) is applied to both surfaces (12, 13) of the panel(1).
15. The device according to claim 1, characterised in that the frame (2) is made of a thermally conductive material, in particular of a metal sheet.
16. The device according to claim 1 or 15, characterised in that the panel (1) is glued in the frame (2).
17. The device according to claim 1, 15 or 16, characterised in that the frame (2) is configured as a cassette with a perforated base plate (2a).

18. The device according to claim 17, characterised in that a non-woven fabric (3) and a perforated graphite film (15) are disposed between the base plate (2a) of the frame (2) and the panel (1).
19. The device according to claim 17 or 18, characterised in that the graphite film (15) comprises a film made of expanded graphite with a perforation.
20. The device according to any one of claims 17 to 19, characterised in that the perforated graphite film (15) is firmly connected to the non-woven fabric (3).
21. The device according to any one of claims 17 to 20, characterised in that the non-woven fabric (3) comprises a glass fibre non-woven or a carbon fibre non-woven.
22. The device according to any one of claims 17 to 21, characterised in that the non-woven fabric (3) comprises a carbon fibre non-woven which is connected to the perforated graphite film (15) by calendaring.
23. The device according to any one of claims 1 to 22, characterised in that the panel (1) with the pipes (9) embedded therein is self-supporting.
24. Method for temperature control of a room bounded at least on one side by a component (5), wherein the component (5) has a surface (11) pointing into the room and the mass of the component (5) forms a thermal accumulator which is thermally coupled to pipes (9) through which a heating or cooling medium is passed,

characterised in that

the pipes (9) are embedded in a thermally conducting panel (1) containing expanded graphite or consisting of expanded graphite and the panel (1) is in flat thermal contact with the surface (11) of the component (5) pointing into the room, in this case, the panel (1) is disposed in a frame (2) fixed to the component (5), the frame is configured as a cassette (2) which is open at one side, and the panel (1) disposed in the cassette (2) projects over a frame edge (2c) thereof on the open side of the cassette before the cassette (2) is fixed to the component (5), so that at least a part of the thermal energy stored in the heating or cooling medium is transferred by heat conduction from the pipes (9) via the thermally conducting panel (1) to the thermal accumulator for intermediate storage and from there is delivered to the room in a time-delayed manner.